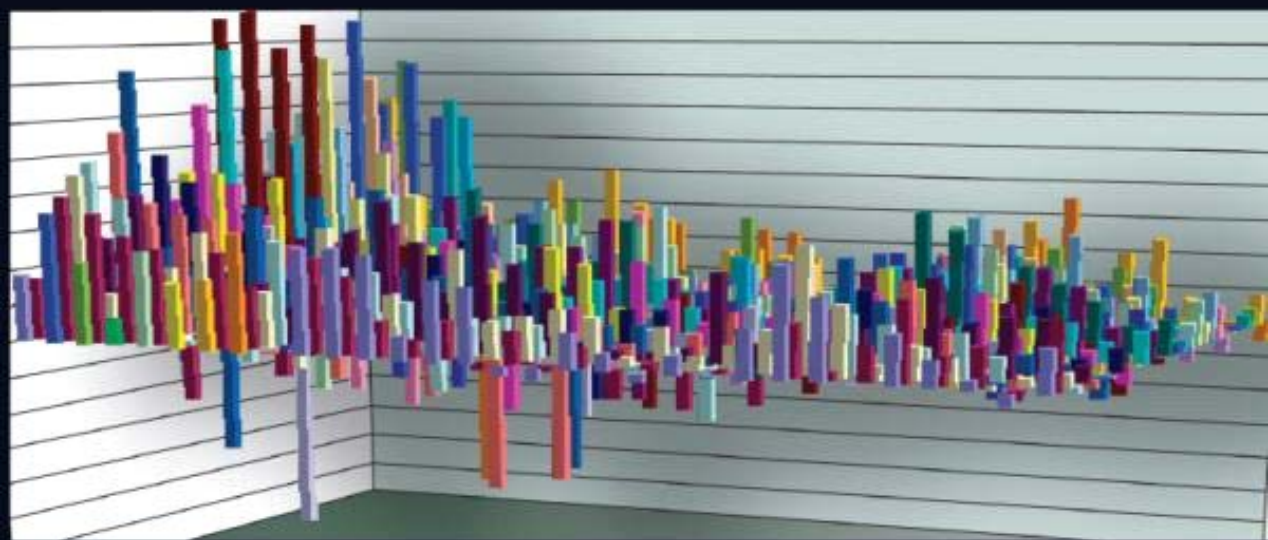


Accelerating New Food Product Design and Development



EDITORS

**Jacqueline H. Beckley, M. Michele Foley,
Elizabeth J. Topp, J. C. Huang, Witoon Prinyawiwatkul**



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DEDICATION

To current and future product developers who seek knowledge from those who learn their lessons by doing the work they talk about. To the Product Development and Marketing & Management Divisions of IFT for their support of our programs for the members of the Institute of Food Technologists.

Titles in the *IFT Press* series

- *Accelerating New Food Product Design and Development* (Jacqueline H. Beckley, Elizabeth J. Topp, M. Michele Foley, J. C. Huang, and Witoon Prinyawiwatkul)
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PREFACE

Innovation today goes beyond new products. To be successful, organizations need to innovate to reinvent every area of the business—systems, processes, technologies, strategies, and business models. This book addresses innovation in developing new products with a focus on challenging the status quo, changing how we think about our work, and adapting to meet the business needs. The authors provide unique perspectives based on their personal experiences to the challenging world of new product development. If you want to innovate faster, it's worth taking the time to read through these chapters—you're sure to find a valuable nugget that will change the way you think about your work. Today and tomorrow.

How to read this book:

Part I is titled understanding product development in Today's Food Industry. The content in this chapter has strategic implications from a historical, organizational, relational, and philosophical perspective.

Part II is titled Accelerating Food Product Design and Development. The content relates to many aspects of implementation of current thinking in food product design from brand, market, process, people, package, and management orientation.

Part III, titled Optimizing Food Product Design and Development, provides the reader with more tactical approaches to product design and development. The tactics are made tangible through very specific examples of high level quantification methods used regularly in the implementation phase of product development.

Each part had an editor of its own (Part I – Topp, Part II – Foley, Part III – Huang and Prinyawiwatkul) who has brought forward the authors' voices. Please enjoy our book.

Chapter 1

INTRODUCTION

*Jacqueline H. Beckley, M. Michele Foley, Elizabeth J. Topp,
J. C. Huang, and Witoon Prinyawiwatkul*

“It is hard to fail, but it is worse never to have tried to succeed.”

—Theodore Roosevelt, 26th president of the United States

This book is about change. It is based on three extremely popular symposia conducted at the Institute of Food Technologists’ annual meetings in the summers of 2004 and 2005. The symposia were developed for the Product Development and Marketing and Management Divisions and were designed to provide some clarity about the past life of food scientists and what tools and thinking these individuals might provide for the future. Parts 1 and 2 are geared toward management and strategy of business people and scientists. Part 3 provides more “hands-on” orientation to quantitative methods that the previous two parts assume is in place. This book fits well within a series of books that Blackwell has published over the last several years. The book has been designed with food industry professionals in mind. In editing the presentations, the authors were thinking of the following individuals as potential readers:

- Director, vice president, or chief technology officer of a product-development group
- Bench scientist who works to make the product successful
- Professor who teaches students to be successful business leaders
- Quality assurance technicians who are responsible for the certification of safe products in a manufacturing facility
- Marketing manager
- Research insights manager

- Project technician
- Food industry consultant
- Sensory scientist
- And many more

Why this very broad definition of an executive? Today, big and small companies struggle to maintain relevance with the consumer. Their work is sometimes unacknowledged and unappreciated; yet it all is part of this industry. The food industry has a long classic tradition, yet needs to move into the experience-based world of today.

This book seeks to begin to address some of the comments made to the editors during its preparation:

“Most companies are more interested in spending money ‘safely’ without results, than finding the results to save them yet needing to spend money in unconventional ways.” (Read chapter 5.)

“Following the process is more important than finding the solutions.” (Read chapter 2.)

“What bothers me as an action oriented young professional? People in middle to upper management who are unable to make decisions. They fear making the wrong decision or taking a chance, so instead they make no decision at all. This makes the speed at which business takes place very slow, which around here usually results in our missing big opportunities in the marketplace.” (Read chapter 7.)

“When companies are in trouble, their decision making goes from smart to stupid, from rational to irrational.” (Read chapter 11.)

“I strongly believe that in a system of 25 employees, all working on the same project (launch for example) that only 8 of these people are connected well enough to make things happen. The rest of the 25 are the ones who are constantly looking for help on how to do things, or whom to see to get certain job specific duties completed. They always end up at the desk of one of these 8 ‘connected’ people, who then have to direct them as to whom to see in order to get this done; which more times than not is one of the other 8 ‘doers.’ So wasteful!”
Comments by a young packaging engineer at a highly successful and profitable consumer package goods company. (Read chapter 12.)

At the time of the symposia, given during two IFT technical meetings, many of the writers of these chapters were speakers. They were very

specially selected for their range of expertise in the field and for their capability to speak authoritatively on their subjects. It is very rare to get this type of person to write a book chapter. They just won't take the time. But they did for this book. And for you. So we hope you enjoy the unique perspective that each of these writers takes on his or her storytelling journey, which provides you with insight into:

Accelerating new food product development:

To compete in today's marketplace, food product development is under pressure to create innovative new products at a time when there are pressures to cut back on development costs, labor, and other problem-solving tools. R&D groups are in a constant mode of development and improvement over the last successes they achieved. Additionally, companies must balance the needs of consumers, customers, the company and its position in the world, timetables, and resources. Consumers today want choices, but they hate too many choices. They want intelligent marketing but it has to be shorter than a 15-second TV spot. They want uniqueness, but not too different. They want luxury and upscale qualities, but prefer to buy value. Companies need profitability and news, but they need to have it without cost. Research departments have put in new product development processes and encourage their staffs to innovate, yet have reduced the number of suppliers and require that those suppliers provide discounts. Universities have well-trained professors who are under budget constraints. The university programs are good yet lack much grounding in today's business and product development environment. We know that packaging can drive innovation, but we cannot afford the time it takes to get that new film or the mold. What are product developers to do? The trade-offs they face today are tremendous. Chapter authors present perspectives of why we are accelerating and why the speed seems so exhausting, in addition to some approaches that have worked in their business lives with specific food product development examples.

Optimizing new food product development:

Food scientists are often faced with developing new products such as functional foods marketed toward health-conscious people to meet growing consumer trends. The parameters of the product being developed need to be analyzed in each stage by either instrumental or sensory data to ensure that development goals are met. Statistical tools are often improperly utilized when trying to determine factors

that contribute to product quality, consumer acceptance, and purchase decisions. Also, an inappropriate experimental design or data analysis will not help the developer identify and simplify parameters in formulation consideration. The process of developing new products is often time consuming and costly when all factors are taken into consideration. First, scientists have to identify the important factors and responses to minimize the number of factors (ingredients, temperature, etc.) and responses (instrumental and sensory data) for pilot plant tests; then they have to continuously minimize and optimize for the production test. Appropriate experimental designs in food product development start in the early stages and often can reduce unnecessary tasks at later stages. Factors that may influence product quality can be funneled to a few that have significant effects as well as interaction effects that can be detected by the experimental design. Thus, an effort to facilitate the new product-development process, various experimental designs, and data-analysis methods can be used in each step to shorten the timeline and optimize the formulation more efficiently. This book lays out a clear picture of new product-development process along with appropriate design and analysis methods. Authors use a conceptual/intuitive approach to convey experimental design and data analysis to the reader. Authors also demonstrate a series of data-analysis techniques performed to identify sensory attributes critical to consumers' purchase decisions and to attain an optimal product-formulation range. This will enable food scientists not only to make sound scientific conclusions but also to succeed in new product development or new technology because the conclusions and results are made based on parameters representing the true population.

The presentations that these chapters represent are *conversations* that industry professionals who are engaged everyday in work for the food industry would have with you, if they had the time. We have stripped away the clutter that often bogs us down at work (bureaucracy, processes that cost a lot to be implemented and still don't work, and politics of business) to present a summary of thinking at the beginning of a new century.

Please enjoy the book.

Part I

Understanding Product Development in Today's Food Industry

Chapter 2

HOW DID THE FOOD INDUSTRY GET (FROM THERE) TO HERE?

Diane Toops

Why Read This Chapter?

Diane Toops provides you with a wonderful overview of the key benchmarks in the history of the food industry and gives you a rapid way to see that innovation is not new—but a path the food industry has been on for years and years.

This chapter discusses the events, technological innovations, trends, and consumer needs that led the food industry from “there” in the late nineteenth century to “here” in the twenty-first century. It also touches on the challenges and opportunities for product developers.

I track trends looking to the future, but looking back over the past 115 years has been quite an education and surprising as well. Some things never change; the overriding trends have been, and continue to be, convenience and good health.

A '50s child, I remember that my mom wore a dress and high heels while preparing dinner. She spent her entire day going to the butcher and grocer to buy fresh ingredients, cook them from scratch, and have a balanced meal ready precisely at 6:00 p.m., when my father arrived home from work. Fortunately, feeding my family is a great deal more convenient today.

We know the food industry does not lead trends, it responds to world events and consumer needs by developing innovative technologies and

foods that solve problems and deliver what the consumer wants. That is as it should be.

Turn of the Century

Before the turn of the twentieth century, America was a rural, farm-based economy. Seventy percent of the population, some 60 million Americans, farmed the land and most of them ate the vegetables they grew and livestock they raised (Food for Thought, 1998, pp. 1–8).

Today, almost 294 million Americans (USDA, 2004) can purchase an incredible variety of inexpensive foods at their local supermarket. Food processors, retailers, and a sophisticated distribution chain make that possible. In fact, American families last year spent just 10 percent of their disposable income on food (USDA, 2004). That's probably the lowest percentage in the world.

Looking in the Fridge

Let's compare the contents of the fridge today to those in 1918 (Frigidaire, 2003). Redefining home convenience, Frigidaire introduced the refrigerator in 1918. A peek inside shows everything is fresh, home-made, and nutritious and will quickly spoil (table 2.1). Today's mom has options; foods have a longer shelf life and are more conveniently

Table 2.1. Found in "the fridge."

| 1918 | 2003 |
|-------------------------|-----------------------------|
| Bottle of milk (fresh) | Gallons of homogenized milk |
| Eggs | Eggs |
| Lard | Fat-free margarine |
| Cream | Flavored, nondairy creamer |
| Churned butter | Sports drinks |
| Homemade lemonade | Squeezable yogurt |
| Homemade cottage cheese | Colored ketchup |
| Apple butter | Salad in a bag |
| Homemade jelly | Ice cream |
| Fresh meat | Frozen TV dinners |

Source: Frigidaire (2003).

packaged, and many foods no longer have to be refrigerated. Eggs are in both refrigerators, but today they might be organic, free-range, brown or white, pesticide-free, or enhanced with omega-3s. Certainly, they will not spoil as quickly.

American food professionals should pat themselves on the back. Through their innovations, products have extended shelf life, and foods are safer, more affordable, and available to people all over the world. That said, let's go back for a quick study of how we got from "there to here."

1889 to 1899—New Options for Mom

In the late 1890s, millions of immigrants poured in from western and eastern Europe, bringing new cuisines and recipes. The first transcontinental railroad transportation system was completed. To accommodate the needs of a growing population, manufacturing plants proliferated. As more people spent their day at work, entrepreneurs realized there was an opportunity to feed them, first from horse-drawn lunch wagons and later from restaurants and general stores. Convenience was the driving need.

Food technology was the vehicle. Mechanical refrigeration became possible because of a machine that liquefies air (Matranga, 1997). Canning improved when Campbell Preserve Co. invented a way to condense liquefied foods. Southern Oil Co. chemist David Wesson developed a new method for deodorizing cottonseed oil. "Wesson Oil" revolutionized the cooking oil industry (Bellis, 2004). Processed foods with longer shelf life began to appear in specialty grocery stores, and consumers enthusiastically embraced them.

As consumers sought reliability and quality from prepared foods, branding became important. National Biscuit Co. was formed, and the Uneeda Biscuit, the first branded cracker, was introduced. Campbell's canned soups debuted with striking red and white labels, in honor of the uniform colors used by the Cornell football team. Lawyers B. F. Thomas and J. B. Whitehead persuaded Atlanta pharmacist Asa Chandler to let them bottle his Coca-Cola fountain beverage in a uniquely shaped bottle (Food for Thought, 1998). Meanwhile, Caleb Bradham put together his secret ingredients for Pepsi-Cola. The Kellogg brothers used direct-mail marketing to sell their "healthy" corn flakes and Entenmann's delivered

10 *Understanding Product Development in Today's Food Industry*

baked goods directly to a customer's door. In a nutshell, mom wants convenience, technology solves the problem. She is satisfied with the brand and becomes a repeat customer.

1900 to 1910—Optimism and Prosperity

In fast-expanding cities, commercial food manufacturing and restaurant openings boomed. Eating abundantly meant you were prosperous, and the middle class beefed up on beef, chicken, and desserts.

As often happens, there was a reaction to this perceived gluttony. The Kellogg brothers and C. W. Post began a pure foods movement, saying that protein was not healthy and whole grains were the secret to mental and physical well-being.

In early 1900, William Fletcher, a doctor, and Sir Frederick Gowland Hopkins, a biochemist, separately discovered that certain foods were important to health and a lack of nutrients can make you sick.

British chemist William Normann developed the hydrogenation process for oil (Bellis, 2004). Hydrogenation converts mono- and polyunsaturated fatty acids from their fluid state to a harder fat, which raises the melting temperature and slows rancidity, resulting in foods with a longer shelf life.

Convenience drove innovation. Drip coffeemakers debuted, Hills Brothers began packing roasted coffee in vacuum tins, and instant coffee was invented. Canned tuna was first packed in San Pedro, California; Milton Hershey introduced the innovative Hershey bar; and Jell-O, everyone's favorite dessert, was available to all.

We leave 1910 with mom's desire for convenience still the main driver, technology that provides longer shelf life, and the awareness that the foods you eat affect your health.

1911 to 1920—Gearing Up

Two of the first home refrigerators appeared in Fort Wayne, Indiana, where in 1911, General Electric Co. introduced a refrigerator invented by a French monk (History of the Refrigerator, 2004). The first "Guardian" refrigerator—a predecessor of the Frigidaire—was manufactured in 1916 by the Guardian Refrigerator Co., which was acquired by General

Motors Corp. in 1919, giving it the capital to grow (Frigidaire History, 2004). The introduction of refrigerators for the home meant that mom did not have to shop for food every day. By 1928, more than one million households owned a refrigerator.

Continuous cooking and cooling equipment was developed (Food for Thought, 1998). Process cheese in tins was produced by J. L. Kraft & Bros. Co. in their first cheese factory. Polish scientist Cashmir Funk named the special nutritional parts of food as “vitamine” after *vita*, meaning life, and “*amine*” from compounds found in the thiamine he isolated from rice husks.

With the outbreak of World War I in 1914, food manufacturers changed gears and focused less attention on convenience for mom. They were busy increasing production to feed the troops. New awareness of proper nutrition for soldiers led to the fortification of foods.

Immigration was at an all-time high, bringing new flavors to the kitchen—ethnic infusions of Italian, German, Jewish, Chinese, and eastern European foods and flavors. Old El Paso began canning Mexican foods. LaChoy Food Products started manufacturing Chinese foods in Detroit.

Hobart Manufacturing patented the first electric mixing machine. The modern timer pop-up toaster was invented in 1919.

All the new technologies were eventually used to make new processed foods for mom. Procter & Gamble gambled that Crisco, the first solidified shortening product made entirely of hydrogenated vegetable oil, would be a hit. They were correct. The shortening stayed solid year-round, regardless of temperature.

But the food industry needed a place to showcase these new foods. Memphis-based Piggly-Wiggly became the first supermarket chain.

The war and changing demographics were the driving needs of this decade. Technology made it possible to feed the troops with portable, healthy foods, and later helped mom fill her refrigerator and cupboard with convenient food products that were innovative in their time.

1921 to 1930—Shaken But Not Stirred

Conspicuous consumption was the mantra during the 1920s. The war was over and the stock market was up. Consumers had money to spend on

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refrigerators, gas stoves, the new electric stove, and gadgets. The decade also began the lifelong love affair with America's coffee cup—along with soda pop—the result of Prohibition. The ban on public drinking didn't dampen enthusiasm for alcohol; instead, consumption increased. Most of the drinks we know today, such as the martini, were concocted in speakeasies (Oliver, 2004).

Convenience took center stage. Clarence Birdseye and Charles Seabrook developed a process for flash-freezing cooked foods under pressure. Frozen foods in packages were introduced with trade name Birds Eye Frosted Foods, Dupont's waterproof cellophane permitted prepackaging of meat, potato-peeling machines made mass production of potato chips possible, and Clapp's Vegetable Soup, the first commercial baby food, hit the market. KOOL-Aid powdered fruit drink, Jiffy biscuit mix, Hostess Twinkies, and Kraft VELVEETA process cheese were introduced. Continental Baking Co.'s Wonder presliced bread was a boon for mom.

During this decade, technology flourished to satisfy the continuing need for convenience, mass production, and expanded shelf life. But the stock market crash of 1929 and subsequent Great Depression made mom tighten her wallet, influencing new product development for the food industry.

1931 to 1940—Less Is More

Mom was cooking from scratch to save money, and she used inexpensive ingredients to prepare one-pot meals, such as macaroni and cheese, chili, and meat loaf stretched with filler. Easing her duties were the electric blender, the first automated kitchen appliance, by Waring Co. and the first pressure cooker by National Presto Industries Inc. Dupont debuted Teflon for easier pan cleanup and Cryovac invented the deep-freezing process (Matranga, 1997).

Kraft introduced Miracle Whip salad dressing at the 1933 Chicago World's Fair. Kraft Macaroni and Cheese Dinner was introduced with the advertising slogan of "Make a meal for 4 in 9 minutes." Instant coffee was marketed commercially by Nescafé in 1938.

On the health front, Pet Milk Co. introduced the first evaporated milk products fortified with vitamin D, using the irradiation process. Meanwhile, in Germany, Rudolph Wild founded Wild Flavors. His goal

was to produce beverages entirely from natural ingredients. And General Mills made the decision to officially listen to mom. Betty Crocker was introduced to respond to consumer inquiries and to create the brand. Her appearance may have changed over the years, but her task remains the same.

One could sum up the 1930s with this slogan: Use it up, wear it out, make do, or do without (Matranga, 1997). Convenience and health were important for mom during this decade, but the most important innovation of the '30's was Dumont Co.'s television for the home—it changed our lives forever.

1941 to 1950—Out of the Kitchen, into the Fire

World War II brought great advances in the food industry. As men marched off to Europe and the South Pacific, women marched out of kitchens and into factories. At home, most foods were rationed, so rather than cooking, civilians began to regularly eat out in restaurants.

The food industry was hard at work innovating to feed the troops. It produced dehydrated potatoes, converted rice, Minute Rice, and Spam, the staple with a shelf life of seven years. Frozen foods took off as manufacturers sought alternatives to metal cans during the war years. New frozen products were introduced, including puff pastries, hors d'oeuvres, soups, entrees, french fries, Mexican cuisine, whipped topping, meat pies, seafood, and pizza.

When the war was over in 1945, America was poised to use its production power and forge the greatest period of growth in its history. After years of rationing, consumption of meat, poultry, and dairy products soared to record levels. So did consumption of baked goods—many prepared with cake mixes developed by General Mills and Pillsbury. Reynolds Metals Co. used surplus aluminum from World War II to make Reynolds Wrap aluminum foil. Tupperware resealable food containers were invented by Earl W. Tupper. Polyethylene terephthalate (PET) plastic was patented in the UK, and it changed the packaging of both food and beverages.

Refrigeration and the rise of suburbia are responsible for the creation of supermarkets, where all food stuff can be found under one roof. New food products were introduced: Nestlé instant tea, and Reddi-Whip

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the first major U.S. aerosol food product. Foil was used to package frozen foods. The process of condensing and freezing orange juice was developed.

Nutrition concerns spurred Congress to begin the National School Lunch Program, mandating minimum nutrition standards. Manufacturers brought Italian, Asian, Mediterranean, and Hispanic products to market in response to America's exposure to international cuisines, and sales of spices skyrocketed.

In 1945, Percy LaBaron Spencer at the Raytheon Co. accidentally discovered that food could be cooked by microwaves, when radar waves melted a candy bar in his pocket. His observations led to development of the microwave oven. Raytheon patented the microwave cooking process and sold the first commercial oven in 1947. Raytheon licensed its technology to the Tappan Stove Company, which led to an unsuccessful 1955 marketing attempt for the home, a large wall unit microwave priced at \$1,295 (Microwave Oven, 2004).

Watching television became the leisure activity of choice, and a remote control device, appropriately called Lazy Bones, was invented by Zenith. Consumers spent more time in front of the television and less time in the kitchen.

Convenient on-the-run foods for the troops were the driver for the food industry in the early '40s, and the industry used those innovative technologies to develop convenient foods for mom, who still wore her high heels in the kitchen.

1951 to 1960—Burger in Every Hand

The 1950s brought renewed vigor and money flowed. The building of the national highway system brought about better distribution of food products and the rise of fast food chains. Ray Kroc purchased the franchise rights from Richard and Maurice McDonald, setting his dream of feeding millions at McDonald's restaurants in motion.

Mom had been out of the house for the duration of the war, and she found it difficult to go back to the kitchen. Advertising for appliances and prepared foods promising to "free her from the kitchen" proliferated. Tuna noodle casserole, sloppy joes, and frozen fish sticks were popular fare. Lever Bros. debuted Imperial Margarine, which had a longer shelf life than butter, Tropicana Products produced the first



Figure 2.1. Life was good in the '50s. (From *Food Processing* magazine)

chilled, pasteurized fruit juices. Powdered nondairy coffee cream was developed. Kraft introduced the first commercially packaged sliced process cheese and Cheez Whiz pasteurized process cheese spread. Weber Kettle Grill began to take its place in everyone's backyard, giving dad the first opportunity to don his toque.

In 1953, Swanson's introduced the first TV dinner packaged in an aluminum tray (Bellis, 2004). The shift away from traditional family dinners (fig. 2.1) continued and today, more than 66 percent of American families eat meals while watching television. The airline industry started to use frozen foods.

At the end of the '50s, jet travel came in, and Paris was suddenly only seven hours away. Container ships proliferated, bringing intriguing foreign goods to our dinner tables (Trager, 1992).

On the R&D front, work was beginning on calorie restriction, more the result of a sugar shortage than health concerns. Sweet 'n Low saccharin was introduced. But when sugar became plentiful again, consumers went back to it; they forgot it had calories.

The most notable innovations were in packaging. Modified atmosphere packaging (MAP) increased shelf life; milk was sold in plastic milk containers; and Seabrook Farms' boil-in meal bags appeared

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(Kevin, 2004). Commercial use of aluminum cans for food and beverages started, bringing new portability.

So the '50s brought us international flavors, more convenient on-the-go packaging, and a less-active population.

1961 to 1970—Sizzling '60s

John Fitzgerald Kennedy was in the White House, and First Lady Jackie hired a French chef to preside in the kitchen, bringing international flair and glamour to her dinner parties. Young housewives were enthralled and rushed out to buy Julia Child's cookbook, *Mastering the Art of French Cooking* (Child et al., 1961), and their first Cuisinart.

But in the average home, the desire for convenience foods and shorter preparation time for meals continued. Frozen pie crust was introduced. Convenience products, such as Shake 'n Bake and Cool Whip nondairy whipped topping from General Foods Corp., were on mom's shopping list (Johnson, 2004). General Mills' Hamburger Helper stretched a pound of hamburger for a family of five. Kellogg introduced Pop Tarts, starting a snack foods boom across the United States.

On the research and development front, high-fructose corn syrup, a substitute for sugar, was developed by Clinton Corn Processing Co. It is easy to transport; it is just piped into tanker trucks. This translated into lower costs for food producers. Pull-tab openers for cans, patented by Ermal Cleon Frazee, revolutionized the beverage industry. Resealable plastic bags were introduced.

Two of the things the food industry does best are to make the supply chain more efficient and create products and technologies that cost less. Then it uses its marketing expertise to show consumers the added value of the product.

The Immigration Act of 1965 opened our doors to millions of Asians. Exotic restaurants sprang up in even the most homogenized neighborhoods. The first were Szechuan, known for hot and spicy cuisine.

The late '60s brought social unrest, growing tension over the Vietnam War, and hippies with an unquenchable hunger for unprocessed, proletarian food made from scratch. The late '60s also brought the introduction of the first popular home model microwave, the Radarange by Amana, at a price of \$495 (Microwave Oven, 2004).

As we leave the '60s, convenience and bottom-line constraints for manufacturers lead the way. Couch potatoes are getting more comfortable sitting and eating in front of the television, but a new age of communication is on the horizon.

1971 to 1980—Dawn of Enlightenment

Hungry for more spice and flavor, Americans feasted on Hunan and Vietnamese specialties. Many experts say that's when America's love affair with heat began. The American palate had finally been unleashed. Happily, mom was unleashed too—from wearing heels in the kitchen. In fact, she was free to stay out of the kitchen all day by using her Rival Crock-Pot slow cooker.

From her famous Berkeley, California, restaurant, Chez Panisse, Chef Alice Waters fueled a revolution. She reintroduced the idea of cooking with natural, seasonal ingredients, an almost forgotten concept because of the prepackaged-food boom. Mom's new mantra was fresh food, simply prepared.

It was the beginning of the natural/organic category, one of the fastest growing segments in the mid-twentieth century. Baker/Beech-Nut introduced "natural" baby foods, herbal teas began to appear, and Perrier bottled mineral water flowed into the United States.

Americans spent more time in front of the television and gained weight. The industry responded with the "lite" movement, including Slim Fast meal replacement powder and Miller Lite beer. Meanwhile, USDA developed the first standard nutrition label.

The first supermarket scanner was introduced at Marsh Supermarket in Troy, Ohio, and Universal Product Codes, or UPCs, were developed for all supermarket products. Eventually manufacturers could track what, where, how many, and how often mom was buying.

The Apple computer came into the marketplace in 1976, heralding the beginning of a new technology phase. By the late 1970s, purchase of microwave ovens started to grow due to improved technology, which lowered prices. In 1978, the microwave oven was added to the consumer price index sample.

In the '70s, health and disease prevention caught up to convenience, tracking consumer purchase behavior became commonplace, and the

computer technology revolution began and would soon impact every facet of manufacturing and consumers' lives.

1981 to 1990—Shape-Up Time

Nouvelle Cuisine, small amounts of food with a high price tag and served on a large plate, became the cuisine du jour of food aficionados. Actually, eating smaller portions was a great idea, but on October 19, 1987, the stock market plummeted 508 points.

As with the crash of 1929, restaurant spending skidded to a halt and Americans ran for cover. Simple comfort food such as chicken-fried steak, mashed potatoes, meat loaf, and pasta became the new rage. Boston Market (then Boston Chicken) started up in Massachusetts. General Mills introduced Pop Secret, the first microwave popcorn to accompany homebound television viewers. Extra pounds settled around collective midribs from all that comforting food and the sedentary lifestyle of couch potatoes.

The food industry was ready. Monsanto Corp.'s NutraSweet division introduced Simplese fat substitute, and soft drink makers replaced sucrose with NutraSweet sugar substitute to lower calories. Joining the fat revolution were Yoplait Breakfast Style Yogurt, Stouffer's Lean Cuisine low-fat frozen entrees (Johnson, 2004), and ConAgra's low-fat, low-salt, and low-cholesterol Healthy Choice line of frozen entrees.

Consumers also felt they deserved a little luxury. Howard Schultz bought and expanded Starbucks coffee shop chain nationwide. Small affordable luxuries in a comfortable, stylish setting caught on.

The mid and late 1980s saw the end of beef tallow for use in frying by McDonald's and Burger King. These fast food companies began to provide nutrition and ingredient information. Snapple hit the market with bottled iced tea opening the market to ready-to-drink tea beverages. Oscar Mayer introduced Lunchables.

By the end of the 1980s, microwave ovens were in almost every home, and the industry responded with a tremendous variety of frozen meals in plastic containers designed for microwave cooking. Today it is estimated that nearly 95 percent of households own a microwave oven, with some models available for less than \$100.

Health and obesity concerns and response by industry to bring low-calorie products to consumers in a convenient way sums up the decade.

1991 to 2000—We Know Better

The '90s brought change to the workplace. More women than ever joined the workforce, with close to 60 percent of married women working, as compared with 46 percent in 1973.

Microwave ovens became a primary technology; other technologies adapted to perform with microwave applications. Packaging was designed to simulate conventional ovens for slow-cooking and browning. Browned surfaces and crispy crusts on baked goods were achieved through packages designed with shielded layers of metal foil to concentrate and direct microwave energy.

The federal government decided they would do a better job planning our diets. The USDA introduced the first Food Guide Pyramid in 1992 to guide food consumption (fig. 2.2). In 1994, Congress approved a standard nutrition label, which outlined for the first time label claims including low fat, low sodium, and light. FDA dietary guidelines endorsed vegetarian meals and moderate alcohol consumption.

Food companies rolled out nutraceutical and functional food products, energy bars, fortified drinks, and such. Two new cholesterol-lowering margarines were approved by the U.S. Food and Drug Administration as “foods”: Benecol (McNeil Consumer Health Care) and Take Control (Unilever) (Apgar, 1999).

Food companies also found ways to make everything fat free, low fat, or reduced fat. Nabisco debuted its Snackwell line of reduced-fat and fat-free baked goods. But try as we might, most of us didn't lose weight. We fooled ourselves into believing that because we were eating fat-free and low-fat foods, we could guiltlessly binge. We forgot to count total calories. Procter & Gamble's fat substitute Olestra was approved in snacks, but it was too late. Consumers had given up on fat-free and gobbled up their Ben & Jerry's Cherry Garcia ice cream once more.

As consumers had less and less time to spend in the kitchen, a new category began to emerge at the end of the decade. The new industry buzzword became Home Meal Replacement (HMR), meals that were precooked, partially cooked, or ready-to-eat (R-T-E), and sold from restaurant and grocery outlets. Sales for HMR meals hit sales of \$89 billion in 1998, according to Packaged Facts, the New York-based market research firm. Mom could now pick up a fully cooked meal on the way home from work.

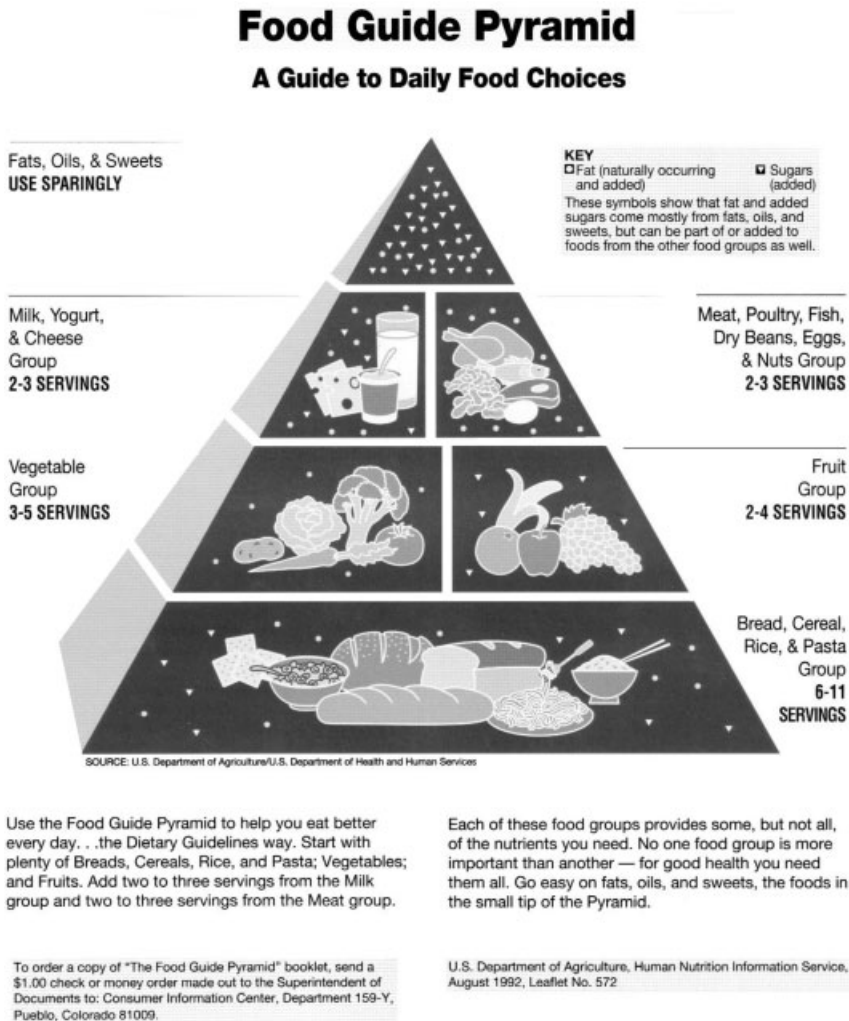


Figure 2.2. Pyramid power unleashed in 1992. (From U.S. Department of Agriculture and the U.S. Department of Health and Human Services)

2001 to 2005—Tragedy Makes Us Rethink Our Options

When terrorists attacked the World Trade Center on September 11, 2001, America was forced to rethink its isolationist politics. Violence was on our doorstep, changing us forever. Would we ever feel safe again? We began to cocoon, spending more time at home. We again craved

comfort foods, as if those meal choices would make everything all right again.

Boston Market debuted Home Style Meals in the frozen food aisle. Nestle's Slow Fire Classics and ConAgra's Home Style Bakes became the new comfort foods. But as obesity concerns intensified, Americans flocked to the Atkins and South Beach low-carb diets. In fact, in 2001, some 352 low-carb products debuted. Sales of fresh bread, particularly white bread, plummeted. Low-carb product introductions peaked in 2004 (there were 1900 new low-carb products between April and September) and began to slow and lose their luster in 2005.

Mad cow disease appeared in 2003 in Canada, but Americans seemed unconcerned. We continued our love affair with meat. The \$44.5 billion red meat market posted an 18 percent increase between 2002 and 2004, reports market research and analysis firm Mintel. Today, 9 of 10 Americans continue to eat beef. In fact, as of July 2005, only 22 percent of Americans worry about mad cow disease, according to the New York City-based NPD Group. We became obsessed with the big squeeze—with products such as Yoplait's Go-Gurt yogurt squeeze product, ConAgra's Squeeze 'n Go Portable Pudding, and Skippy Squeez 'It. Convenience, especially portability for eating anywhere, continued to be in the forefront of new product development. Campbell's Soup at Hand and Snapple's Snapple-A-Day meal replacement were perfect products for on-the-go consumers.

Americans were ready to have some fun and food manufacturers responded. Procter & Gamble introduced Pringles Prints, an innovative snack that features a unique, fun design printed on every crisp, Snicker's Popables bite-sized treats, and Ritz Chips, combining toasted crunch with a taste reminiscent of Ritz crackers.

The slow cooker, an icon of the 1970s, was reintroduced with retail product offerings that featured super convenience—ConAgra's Banquet Crock-Pot Classics—frozen components including meat or poultry in a stand-up pouch that cook all day in the slow cooker—and General Mills' Slow Cooker Helper—just add water and meat. Jennie-O-Turkey Store revolutionized turkey preparation with Oven Ready Whole Turkey. Cleaned and preseasoned, the turkey is packaged in a proprietary Fool-Proof oven roasting bag and goes directly from freezer to oven.

On the health front, Minute Maid introduced Heart Wise, cholesterol-reducing orange juice containing plant sterols. Dreyer's Grand Ice

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Cream launched Dreyers/Edy's Slow Churned Grand Light, using its proprietary technology that reduces fat by 50 percent. In 2005, Nabisco rolled out 100 Calorie Packs, portion-controlled snacks. Cocoa Via, from Mars, debuted after 15 years of research. Just two servings a day of this chocolate can reduce LDL cholesterol and promote healthy circulation to maintain heart health.

The new Food Guide Pyramid, an interactive pyramid with a more individualized approach to improving diet and lifestyle, debuted on April 19, 2005. It emphasizes whole grains, variety, moderation, and physical activity. Unfortunately, many consumers find it unwieldy.

The government's emphasis on increased consumption of whole grains has spurred new products from food manufacturers. Lean Cuisine debuted Whole Grain Spa Cuisine, with added fiber; Unilever's Knorr Lipton introduced dry whole-grain side dishes, as did Uncle Ben's; General Mills debuted whole grain Cheerios; and Sara Lee launched Sara Lee Soft & Smooth, whole-grain bread with the look, aroma, and texture of regular white bread. In Q4 2004 to Q1 2005, the number of whole-wheat prepared foods grew a whopping 168 percent, whole-grain pasta stirred up gains of 27.4 percent, whole-grain cereal snapped up 8.3 percent, and bread and baked goods rose 7.4 percent. Whole grains are the latest buzz, and it can be anticipated the trend of new whole-grain products will keep food-product development scientists busy for the foreseeable future. Also on the front burner are products containing zero grams of trans fats.

Challenges for the Future

On the regulatory front, the industry can expect continued influence from the USDA's Food Guide Pyramid and changes in dietary guidelines. It is anticipated that labeling standards will be developed for low-carbohydrate and organic products as well as for food supplements and herbal ingredients.

Food companies are facing economic realities for competition in the global marketplace. Consolidation within the food industry continues within the food manufacturing and supplier companies, through acquisitions and mergers and consequent downsizing, which affects new product development (table 2.2).

Table 2.2. Food business mergers and acquisitions: 1997–2003.

| Full year | 2003 | 2002 | 2001 | 2000 | 1999 | 1998 | 1997 |
|-----------------------------|------|------|------|------|------|------|------|
| Food processors | 104 | 98 | 146 | 172 | 229 | 230 | 186 |
| Raw product suppliers | 3 | 3 | 10 | 16 | 28 | 44 | 31 |
| Retailers: | 42 | 27 | 45 | 53 | 66 | 67 | 54 |
| Acquisitions of U.S. firms: | | | | | | | |
| Canadian | 13 | 10 | 10 | 13 | 7 | 15 | 18 |
| Foreign | 23 | 13 | 40 | 50 | 34 | 39 | 36 |

Source: Food Institute (2004).

It is notable that most mergers and acquisitions occurred from 1998 through 2001. Many of those acquired were functional food companies. Pepsi bought SoBe and Quaker, Cadbury acquired Snapple, Kraft bought Balance Bar and Boca Burger, General Mills bought Small Planet Foods, and Kellogg acquired Worthington Foods. Retailers continue to merge. In 2003, there was a flurry of acquisitions of U.S. firms by Canadian and other foreign-owned companies (Food Institute, 2004).

Fewer dollars are being spent on R&D, and consolidation means fewer employees must do more work. At the same time, there is a push to get new products to market sooner, resulting in shorter product-development timelines. A new product is expected to achieve market success immediately; there is no time to build brands, and companies have less advertising and marketing money available. Shareholder demand for increased bottom-line profits adds to the pressure. Meanwhile, brands are under fire from less expensive, private-label brands.

Consumers face new economic realities as well. They have less disposable income to try new products and less time to shop. Multitasking moms are more likely to buy the same products over and over. In fact, the average supermarket carries 40,000 SKUs, while an average family gets 80 percent of its needs from just the same 150. That means they ignore 39,850 items in the store. Some 10,000 new products are introduced in the United States every year, but more than 90 percent fail. How do you get consumers to try your new products? Differentiating products and services is the key, and knowing your consumer, according to marketer Jack Trout (Trout, 2000).

Opportunities for the Future

New opportunities for the food industry include:

- tailoring products for America's new immigrants from Mexico and Asia
- marketing products to fit the obesity paradox (healthy vs. indulgent)
- organic, whole-grain and natural products
- nutraceutical/functional products with value-added attributes
- foods marketed to generational niches
- foods that solve the needs of an aging population
- portion-size packaging
- foodservice foods

Today, aging Americans may watch what they eat to improve their health, but let's not forget they also suffer from dietary schizophrenia. Give them healthy, but give them indulgent products as well—conveniently, if you please.

Mom's needs haven't changed much in 115 years—health and convenience are at the forefront. But the one big change is instant communication around the world. Yes, consumers and technology may lead trends, but computers and cell phones allow food companies to respond almost immediately. Kraft, Unilever, and General Foods had low-carbohydrate foods introduced into the market faster than one can pronounce carbohydrate.

The food industry, even with all the constraints, is still a great industry to participate within. Even pharmaceutical companies want to have products that are food related. The food industry continues to innovate with convenience, longer shelf life, food safety, and improved textures and flavors. New types of refrigerated product offerings present new opportunities as well as challenges for food-development scientists and new convenience for consumers. Developing food products with healthier value-added attributes will keep food labs busy.

Consumers want products that say what they do, and do what they promise. Mom not only wants foods that cook themselves in 15 minutes or less, she wants healthy foods that make her and her family look good, feel great, and live to a ripe old age.

As always, the most important attribute of a food product is good taste. Taste is No. 1; everything else falls far behind. If it doesn't taste

good, dad will complain and spit it out, junior will dump it in the trash, and mom won't buy it a second time.

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Chapter 3

DEVELOPING PARTNERSHIPS: USING OUTSIDE RESOURCES FOR PRODUCT DEVELOPMENT

Kathleen N. Feicht

Why Read This Chapter?

Large and small companies augment their knowledge base through the use of active partnerships with companies and individuals who have specific expertise in how to effectively manufacture foods for today's marketplace. Through the extensive use of examples, Dr. Feicht illustrates various ways to utilize outside resources.

Introduction

It is generally accepted that if your business is not investing in new products and growing market share, it is falling behind, will decline in market presence, and may eventually fail. How does a business develop new products and extend existing product lines when faced with finite resources? This chapter illustrates numerous ways in which a variety of food companies have utilized outside resources to expand their range and reach of product offerings. While there are still a few companies operating with the luxury of full research and development departments, many companies now elect to use outside expertise to assist in some or most of the new product development process. This chapter will provide

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specific examples of when and why companies elect to use independent contractors for product development. The examples are drawn from real-life experiences that our firm has collected over our more than 20 years of business as a contract product development firm. The examples are grouped into two categories:

1. White space opportunities—we want to do this, but we don't know how (given our time frame)
 - a. No internal research and development department
 - b. Lack of experience in food product development
 - c. Lack of specific technical expertise
 - d. Adapting technologies from other markets
2. Choice opportunities—we want to do this, but we are making a choice to outsource (given our time frame)
 - a. Shortage of internal resources for a specific project
 - b. Outsourcing activities outside a core competency
 - c. A fresh perspective
 - d. Commercializing a concept or recipe and acting as a liaison to the manufacturer

In the complex world of making products that are relevant to consumers *today*, food businesses apply a high level of pragmatism, which provides them with far more ways in which to get a business built or a product launched. Select examples below are designed to illustrate these situations.

White Space Opportunities—We Want to Do This, But We Don't Know How (Given Our Time Frame)

Henry Ford did not invent the automobile (as some may think); rather his big contribution was the development of a superior method of manufacture, the mass-production assembly line, which brought cost into line with what the average American could afford. In the past few decades, great wealth has been amassed by inventing great processes. Dell, Toyota, and Wal-Mart have risen to the top of their industries with efficient ways of manufacturing or selling less-expensive products than their rivals. We can all think of food companies that have streamlined

production and distribution (Tyson, Nabisco, Frito-Lay) making it impossible for small players to compete on price.

A firm may elect to run production with operations and quality control departments only. It could be a temporary situation during a business downturn or a regular condition to keep overhead costs low by using outside research and development services on an as-needed basis. It can provide the opportunity for brand building while not tying up resources that may be expensive and unnecessary for day-to-day business or may be outside of the scope of the business owner.

No Internal Research and Development Department

Many years ago we began taking on special projects for a company when a technical problem was beyond the expertise of the technical staff or a special product development need arose. This relationship has continued for over a decade, expanding to generate both entirely new product lines as well as simple line extensions.

One of the challenges to a company working with automated, high-speed lines is that a new product must deliver enough volume to fit the scale of the operation. An opportunity arose to market a line of southwestern flavored burritos to a large national retailer. The required product volumes fit the business model; however, without a research and development (R&D) department, and with an anxious customer, a time-crunch for development existed. Working with new and existing vendors, our company developed a line of four burritos and two chimichangas that were introduced for nationwide sale in a matter of months. The food company continues to prosper, doing what it does best, producing good-tasting products for a very reasonable price.

Leveraging contract product development on an as-needed basis keeps overhead costs low, which can be especially critical in a low-margin business.

The messages illustrated by this example:

- External R&D companies can generate new products or line extensions quickly and without drawing on internal resources.
- A manufacturer can decrease fixed overhead costs by using an outside contractor for new product development on an as-needed basis.

Lack of Experience in Food Product Development

In the late 1990s, a company approached us with an interesting cross-cultural project. This company had expertise in traditional Chinese medicine and the marketing and sales of these products. They indicated that although it is common for the Chinese to prepare infusions by grinding a root, bark, or herb into a powder and preparing a broth or tea to drink for its healing properties, the average American consumer found this a foreign concept. To address the preparation issue, the company developed tinctures of healing blends to be sold in small bottles. A dose would be delivered by a dropper into a cup of tea or other beverage as a more user-friendly product. Although the company was able to solve part of the acceptance problem, the bitter, sour, and astringent tastes remained, thus impacting acceptability.

At this point, the company had an effective product line, but the problem remained of how to take it from a century's old medical practice of tinctures and infusions to a format that the American consumer would find easy to use, understandable, and, of course, good tasting.

In addition to retail sales of the tinctures and other products, the company started a small retail bar, preparing and selling "teas" made with hot water, fruit juices, and the medicinal tinctures. The bar was a tremendous success and management saw an opportunity to market the product to food-service venues across the nation, if preparation could be simplified.

Unfortunately, the company knew nothing about food technology and how to make a shelf-stable product containing the traditional Chinese herb blends and fruit juices in an all-natural product. They engaged our company to provide the technical expertise.

The first challenge was to develop formulations that would be stable at room temperature and could be dispensed from a bottle with a pump similar to the flavored syrups used at coffee and tea shops today. The second challenge would be to make it taste good with all natural ingredients, remembering that we have concentrated medicinal ingredients (which have bitter, sour, and astringent properties).

A line of six concentrates based upon fruit juices and containing the traditional Chinese medicinal ingredients were developed. Today these products are sold at retail in a 12-ounce bottle and in a 32-ounce pump bottle for food service. Instructions are provided for preparation as a hot tea or iced for a refreshing beverage.

The product line has had steady growth since its inception. Being based on traditional Chinese medicine and with high concentrations of active ingredients (enough to provide the intended effect), the products attracted the attention of a large Chinese firm specializing in traditional Chinese medicine, and a new partnership was born. As Asia becomes westernized and the pace of life accelerates, youth in China no longer have an interest in brewing traditional herbal medicines and want the convenience and good taste offered in these American products.

The role our firm facilitated in this case was the creation of products that were stable for the food-service market and the creation of extended uses that provided interesting and tasty product solutions. The messages illustrated by this example include:

- Medical and functional ingredient companies utilize contract product development firms to move into the food industry.
- Expertise in food technology allows the creation of products that are safe, stable, and good tasting, and that meet regulatory requirements.

Lack of Specific Technical Expertise

Many small, frequently family-owned firms contemplate manufacturing and selling family recipes. Often someone tastes the product and says, “You should make this and sell it,” encouraging these entrepreneurs to manufacture and market their special foods. Although made as their families have for generations, these foods are usually produced with little or no scientifically based proof that they are safe for consumption and stable to the conditions of storage and distribution to which they are subjected. The need to assure not only safety and stability, but also compliance with federal and state regulations soon becomes obvious, unfortunately sometimes after a food-related illness has occurred.

As small companies strive to expand the market of their products, extended shelf life also becomes important. These firms have never thought of having research and development departments and by virtue of their size require outside expertise only on an as-needed basis to find answers to specific, usually technical, questions.

Candy and dessert products are found in every culture. Traditional Japanese sweets made from sweetened bean pastes and rice flour include Uguisu, Inaka, An Mochi, and Kochi An (fig. 3.1). These sweets



Figure 3.1. Japanese pastries. (Printed with permission of Kathleen N. Feicht)

are traditionally sold at room temperature for up to three days from the date of manufacture. But are they stable using the sound scientific information available today? Our company worked with one such company to decrease the water activity of these traditional desserts to prevent growth of pathogens and to extend the products' shelf life.

Candy, cookies, and other baked goods are examples of traditional U.S. businesses that have a low barrier to entry for an entrepreneur. Unfortunately, these companies soon encounter technical challenges as their products are shipped across the nation or internationally. Caramels and nougats can become hard and dehydrated. Chocolate blooms or melts as temperatures fluctuate. Cakes and cookies dry out and become hard or crumbly. These technical challenges are coupled with the need to increase shelf life as the distribution area grows and the product transitions from being consumed within a few days to possibly weeks or even months after manufacture. Small entrepreneurial companies need technical expertise to reformulate their products and provide packaging recommendations for extended shelf life.

Sushi is a good example of a food that has moved beyond traditional sushi bars where it is prepared in front of us by individuals who are believed to be experts in understanding and handling fresh fish (fig. 3.2).



Figure 3.2. Sushi. (Printed with permission of Kathleen N. Feicht)

Is the sushi we now see sold refrigerated in our local supermarkets free of pathogens? Is it free of spoilage microorganisms up to, and beyond, the printed “use by” date? A company interested in marketing and distributing sushi requires internal resources or access to an outside firm for the technical expertise to document stability and extend shelf life of its product lines.

The messages illustrated by these examples include:

- Small and entrepreneurial firms need to acquire technical expertise to ensure product safety and regulatory compliance.
- Specific technical expertise allows firms to improve products and extend product shelf life.

Occasionally, a project comes along that is truly innovative and technically challenging. A company selling cake decorating supplies had the idea to sell computer software programs for cake decorations, edible inks, and edible paper on which to print the images. With these supplies, a baker could print and apply a limitless number of decorations to the top of a cake or cookie, for example a child’s photograph. Our company was approached for assistance in formulating and manufacturing an edible paper. This paper needed to adhere to a backing sheet, be flexible, be easily removed from the backing sheet, not bleed colors into the icing, and taste good. The project was well over a year in initial development and required additional optimization as the paper sheets were shipped to national and international destinations with hot, humid climates requiring greater product tolerance. While the cake decorating supply company knew it had a grand idea, understanding

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the complexity of the base formulation, stability, and consistency issues were beyond its scope of knowledge.

The message illustrated by this example is:

- Outside resources provide an understanding of ingredients and their functionality as technical expertise is provided to entrepreneurial firms.

Adapting Technologies from Other Markets

There are valuable lessons to be learned from successful foreign operations. Because needs and norms differ around the world, technology sometimes advances faster in one location than another. For example, the now common aseptic Tetra Brik package was an outgrowth of solving the problem of limited refrigeration space available in most European homes. While aseptically packaged cow's milk has yet to replace the refrigerated table-top container or large plastic gallon containers in the United States, we do see juices, soy milk, soups, and other products in this type of shelf-stable container. We have seen an explosion of aseptic package shapes and sizes utilizing technical expertise from Europe. Successfully adapting the foreign product or technology from the foreign market into the domestic market requires understanding the local consumer's needs and expectations.

From manufacturing to ingredients, packaging and processing equipment, foreign markets may be vastly different from those found in the United States. Regulatory requirements are often very different as well. Likewise, processes and equipment from foreign companies may be available to solve a specific technical problem, or may be significantly advanced over what is available domestically.

Our firm has worked with companies that package foods and beverages aseptically with the objective of utilizing this technology to offer products targeting a specific consumer. In one instance, a company desired to develop an individual serving of dip that could be sold next to chips on the retail shelf in a small, easy-to-use, and easy-to-discard container. Aseptic packaging was the ideal solution. A second example packed soy-based smoothies aseptically for individual servings of a quick lunch or snack that could be stored in a desk drawer or in the pantry.

The message illustrated by this example is:

- Outside expertise allows a company to tap into technologies originating in foreign markets.

Choice Opportunities—We Want to Do This, But We Are Making a Choice to Outsource (Given Our Time Frame)

Shortage of Internal Resources for a Specific Project

Often, a large company with a top-notch in-house R&D staff wants to evaluate a business opportunity without diverting resources away from its core business. This happened with a well-known, multinational restaurant company approximately ten years ago, when the company was in the early stages of evaluating its entry into the school lunch business. In test markets with a few local high schools, several restaurant companies had partnered to provide some of their most popular items on the school menu. These items were to be prepared in a shared school kitchen. The school food-service staff would be trained in the preparation of these products, which included (as could be guessed) hamburgers, french fries, pizza, tacos, and burritos. This arrangement was essentially equivalent to setting up a small unit of each restaurant in the school and serving a similar, although limited, menu.

The restaurant company had a large and capable R&D staff that was fully engaged in supporting ongoing sales and new product development for the regular restaurant business. For the school lunch project, the company elected to go outside and hire an independent company to work with suppliers and develop menu items that had the quality associated with a freshly prepared, restaurant product, but could be sold frozen to school food service nationwide. If successful, this project would bring the restaurant's name to schools everywhere, provide a branding opportunity, and offer good-tasting, easy-to-prepare menu items to school foodservice with good price value.

Several menu items were developed, some targeted to meet the standards and cost parameters acceptable for funding under the national school lunch program, and others were developed to be more upscale. All items were packaged in an ovenable film that could go from the manufacturing facility, through frozen distribution, thaw and bake in a convection oven, and be held hot in a warming unit so as to be available for sale in a short, 45-minute lunch period.

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Our company was contracted to develop the products, scale-up for manufacturing, and oversee production for test markets. We partnered with the restaurant company's in-house marketing, quality control, and market research departments to form a cross-functional team. Upon completion of successful test markets, the company allocated internal R&D resources to expand the products into national test markets and eventual roll out.

The message illustrated by this example is:

- Utilization of outside resources can be the best use of capital to evaluate a new business opportunity.

Outsourcing Activities Outside a Core Competency

Most of us are familiar with companies outsourcing internal functions such as payroll, accounting, auditing, janitorial service, and more. Some companies do this with what a food technologist would consider product development. Ingredient suppliers are a good example. The ingredient company's internal R&D department has expertise in producing the basic product line—starches, corn syrup, spices, or flavors. But how do suppliers communicate to the customer how the product would be used? Development of recipes might be outsourced to a chef or home economist. Development of application formulas for use in food manufacturing would be outsourced to a product development firm.

We have worked with many companies in this capacity. An interesting example is a Mexican firm that had planted fields of agave in arid regions of Mexico, and with inexpensive labor had a reasonably priced crop. From this crop they developed an efficient method of manufacture of agave syrup. Syrup from the blue agave has traditionally commanded a high price since it is the only source of agave allowed in production of tequila. The opportunity this company pursued was to use agave syrup in place of high fructose corn syrup, especially where a premium could be obtained from the cachet of wild agave. This company needed application formulas for beverages, baked goods, and confectionery, providing usage level recommendations, starting formulations, and tips on how the syrup functions compared to traditional sweetener options such as sugar, corn syrup, and high fructose corn syrup.

Increasingly, we are seeing that functional ingredient manufacturers are utilizing independent product development companies for preparation of specification sheets, recommendations on how to use the ingredient, application formulations, and insight into problems that might be encountered when incorporating the ingredient into a food or beverage.

The message illustrated by these examples is:

- Contract product development companies can provide application expertise to ingredient suppliers.

A Fresh Perspective

The size of the company doesn't matter—there are occasions when it is necessary to bring in others for a fresh perspective. Sometimes the in-house development or engineering staff becomes tied to obsolete processes or existing manufacturing equipment. Their mindset about a product may be narrowed by their intimate knowledge of the process or a senior manager's perspective.

Outside consultants usually have a broader exposure to new technologies, new equipment, and new product ideas since they typically are involved in a much wider variety of projects than any one individual company.

An outside consultant may be better able to suggest unique opportunities that can take advantage of a company's core competencies. In this way, consultants can challenge management and staff to look beyond the obvious and evaluate emerging technologies and trends. This challenge may provide the next business opportunity for the firm.

We have worked with companies to expand product lines by entering the low calorie, low fat, or low carbohydrate market with existing dry mix businesses such as cake, muffin, pancake, and beverages. A bodybuilding company expanded its weight gain and muscle building line of dry mixes to include "lean builders" for women. Many years ago we helped a local baker to utilize an existing rotary die cookie line to make a low-fat product that has enjoyed long success as a satisfying low-calorie snack. A multinational snack food manufacturer expanded into the ethnic market by building upon existing production lines and distribution systems.

The messages illustrated by these examples are:

- An outside consultant brings a fresh perspective and can recommend novel utilization of existing product platforms and processing equipment.
- Creativity can be enhanced and participants engaged to look beyond a company's current product mix for new business opportunities.

Commercializing a Concept or Recipe and Acting as a Liaison with the Manufacturer

When an entrepreneur wants to develop and market Uncle Charlie's famous barbecue sauce or Mom's "world's best" salad dressing, he or she normally requires an independent product development firm to commercialize the recipe into a manufacturing formula with quality control parameters, identify a copacker, and provide the required labeling information. Over the years, our company has worked with many entrepreneurs aspiring to take a favorite family recipe, their restaurant's sauce or salad dressing, cookies, cakes, and numerous other products and bring them to market. Many of these entrepreneurs have gone on to make a comfortable living from the sale of their products.

An interesting project came to us from a book publisher. The author had written a book reviewing five-star restaurants across the nation including recipes and beautiful photographs of the restaurants and surrounding areas. She desired to market a few products from a particular restaurant. We worked with the owner-chef to commercialize the recipes and source ingredients. A manufacturer was identified, unique packaging acquired, and the products packed for sale with the book. The gourmet food products augmented and increased book sales.

Sometimes an entrepreneur has a good idea but needs outside expertise to reduce it to practice. In another instance, we were able to assist two individuals with their fun idea—colored refrigerated dough that children play with, like Play-Doh, to make artwork. Later these small treasures can be baked and eaten as cookies!

The message illustrated by these examples is:

- Contract product development companies provide entrepreneurs with technical expertise and supplier and manufacturing resources for product commercialization.

Conclusion

Outside resources can help a business develop new products, solve technical problems, comply with government regulations, ensure food safety, and move an idea from concept to reality. Even large companies with in-house research and development staffs can benefit from the specific expertise that external resources can provide. Companies can compete and find cost savings by outsourcing their entire R&D efforts to contractors. Entrepreneurs can bring new, innovative, and safe products to market. In today's global economy, leveraging the expertise of outside resources is the smart way to do business.

Chapter 4

BUILDING SUPERIOR R&D ORGANIZATIONS

Elizabeth Topp (Inspired by presentation by Paula Manoski)

Why Read This Chapter?

Research and Development (R&D) organizations are under pressure to complete more development projects with less people resources. The business climate requires R&D personnel to bring more to their jobs than traditional technical knowledge. Elizabeth Topp provides insight on the broad spectrum of skills and capabilities within the R&D organization necessary for companies to compete successfully with limited resource.

There are many times when a company seeks assistance from external sources to resolve project issues. Often, however, a company needs to rely on its internal resources to tackle the issues and identify a satisfactory resolution. The question is, how can you ensure that your internal resources have the capabilities to resolve project issues? This chapter discusses skills that are critical for R&D organizations to maximize the opportunity for the successful outcome of projects.

The Challenge

The climate in the twenty-first century food industry is more demanding than it was 25 or even 10 years ago. The competitive front today is global in nature not just country specific. Changes in the marketplace are more

rapid resulting in timeline pressure to launch products sooner with compressed development schedules. Customers are more demanding and more engaged in the development process. Consumers are constantly seeking something new and exciting. The regulatory climate demands an awareness of laws and regulations to ensure products and labels are in compliance.

The focus on achieving shareholder expectations has intensified. Companies have re-structured because of profit pressures and mergers, resulting in reduction of personnel and greater demands on the people remaining in the organization. Tighter raw material cost allowances and restricted supplier lists further contribute toward a challenging development environment.

The challenge for R&D organizations today is to make sure that the people in the organization have the skills and capabilities to deliver project objectives. The skills required today are more than technical competence. More than ever, R&D professionals are working closely with marketing, sales, finance supply chain, and other business areas on cross-functional teams. Working effectively on teams and within the corporate environment places demand on skills that may not be well developed within R&D personnel, such as communication skills, financial knowledge, and understanding of the company's business system.

The Game Plan

Development of these skills has similarities to playing a video game. If one is playing a video game for the first time, a basic understanding of the rules and game technique develops as one plays and some points are scored, but relatively quickly the game is over. In the next game one plays, one is more astute in technique and scores higher points, but the buzzer signals the game is over too soon. Then one starts observing others playing the game and the next game is longer and a decent score is obtained. Finally, one starts asking other players for tips on how to play and learns that they have strategies on how to win. A better understanding of the game results and one starts feeling like a winner too, achieving a high score during a long game.

As in playing a video game, R&D professionals need to understand the strategy of their organization and improve their existing skills or learn new skills to successfully perform their jobs. Skill development is acquired over time through stages and leads to a new level of

performance. The rest of this chapter will focus on these stages of skill development.

R&D Skills: Level 1—Technical Basics, Required Skills

To perform in an R&D position, one needs to have basic technical skills, gained through education and or experience. This is a prerequisite to get into R&D organizations. If one lacks basic technical skills, such as science and math knowledge and the ability to put information together and solve problems, then one won't qualify for the position. Typically, the individual's specific education or experience qualifies him or her to function in various technical positions, such as a product development scientist, a process engineer, or a packaging engineer, perhaps even a flavor chemist or chef. The basic skills one brings to the company result from the individual's education, general knowledge, and all his or her experiences, work related or otherwise.

In addition to education and experience, companies today typically seek individuals who demonstrate good communication skills, are team players, have leadership potential, and are results oriented. They expect the individual to have reasonably developed problem-solving skills utilizing a scientific approach—the objective, a plan, a method, the execution, results, and conclusion. Basic computer skills are also a prerequisite.

Regarding communication skills, individuals are expected to have an ability to write reports and other documents in a clear, concise style with acceptable grammar and spelling. Because e-mail communications are a key part of business communications, this form of written communication needs to follow these same rules. Individuals should be able to articulate their thoughts and demonstrate acceptable verbal skills. Often R&D professionals need to present their project work and other information to management or to customers, so presentation skills are important.

R&D Skills: Level 2—Team Player

The work environment in the food industry, similar to other industries, has moved toward a team approach for major projects. Teams can be

cross-functional, composed of team members representing marketing, sales, purchasing, manufacturing, quality assurance, research and development, and possibly other areas of the company. An R&D team could be populated with individuals representing different disciplines within the R&D organization, such as microbiology, analytical science, and product development. A team could be customer focused with team members from sales, marketing, and research and development. A customer team could also include customer representatives. Team membership is dependent on the objective the team will be focused on. Working on teams has become a standard practice in most companies today.

With such a focus on team participation, it becomes important that individuals within the R&D organization develop skills that will contribute toward successful accomplishment of team objectives. Often, development of team skills originates during school years through participation on sports teams and in other groups where cooperative interaction is necessary. Again, communication is an important skill, in this case effective interpersonal skills are required. Interpersonal skills are important in the workplace and particularly in a team-oriented work environment. Teams require cooperation, commitment, and action by team members to achieve success on project objectives.

Competent interpersonal skills include an awareness and acceptance of individual differences among people, active listening, clear communication, understanding nonverbal communication, and effective conflict resolution. Skilled interpersonal abilities result in improved communication and harmonious work relationships, which lead to creative and effective approaches to solving problems and getting work done. To build a superior R&D organization that works well within the cross-functional teamwork environment, emphasis needs to be placed on developing competent interpersonal skills capabilities.

Teams are often engaged in resolving problems. Developing or improving problem-solving abilities within the R&D organization leads toward a superior R&D department. Creative problem solving is a skill one develops starting in childhood. For technical people, problem solving is a significant aspect of the job. Individuals can improve this skill by learning techniques that organize the thinking process to lead to creative and imaginative solutions. Innovative products often result from this process.

The Level 2 R&D professional needs to have the financial acuity to prepare formulation costing spreadsheets and understand the implications of raw material costs on profit margin and ultimately the company's profit and loss statement.

Other characteristics, not skills per se, that contribute toward a superior R&D group and would be expected from someone at Level 2, are found in an individual who demonstrates personal commitment toward getting the job done: no matter the amount of time required or how tedious the task, he or she stays with the task. Similarly, an individual's personal integrity contributes to the strength of an organization. These characteristics are innate qualities an individual possesses. In today's work climate of change, higher value is placed on the individual who demonstrates these qualities and contributes to their survival in the organization.

Within the R&D organization, a Level 2 individual is typically responsible for leading R&D activities for projects, or perhaps the entire project. Project management becomes a skill that needs to be developed. Numerous books have been written about project management. Universities teach this subject as part of their curriculum for technology and business management. Consultants make a living providing training in this subject as well as managing a company's projects. Some companies have internal courses on this subject. So, the question arises, why is there such a shortage of project management skills apparent in most corporations?

Skillful project management is a process. Various tasks to meet project objectives must be executed in sequence and in parallel within specific timelines for the project to succeed. The tasks are multifunctional, typically requiring all areas of the business to contribute toward a successful result. The responsibility to manage the complete project could fall within any of the functional disciplines, however, typically marketing or R&D assumes this role.

For R&D professionals, managing projects is a natural progression as technical and corporate experience increases. It pulls into use all the skills previously discussed and requires sharpening these skills as well as understanding the project management process, which may include company specific aspects. It is critical for successful R&D organizations to ensure they have people resources with the skill base required to manage projects.

R&D Skills: Level 3—Business Partner

Successful companies place a high priority on ensuring that all personnel are cognizant of the corporate strategy and objectives so they can focus their limited resources on the right priorities for the company. Superior R&D organizations are run by management that makes sure R&D professionals understand how their company operates and the role R&D has in making the company successful. The R&D personnel understand the company's project priorities and are empowered to question projects that don't meet the criteria.

At Level 3, the R&D individual is a business partner with other functional areas of the company, contributing equally on business decisions. He or she has a clear understanding of the company's strategy, business objectives, and priorities. Technical issues are presented with a business perspective, because Level 3 individuals understand all aspects of the company's operation such as finance, manufacturing, and quality control. They are proactive and influence project objectives and timetables.

It has been said that finance is the language of business. To influence business decisions, R&D needs to be able to speak the language of business and frame R&D information in the appropriate financial context. The Level 3 R&D individual is adept at translating technology benefits, issues, and risk into financial and business terms to facilitate decision making by the company's management.

Most decisions to move forward or kill a project are made based on financial matters. The viability of a product launch is usually determined by the projected profit margin, which is based on projected sales volume, target retail price, manufacturing cost, raw material cost (ingredients, packaging, etc.), capital expenditure, and return on investment. Through understanding the criteria for financial success of a project, R&D can proactively identify and resolve issues to move a project forward. Equally important, with better financial knowledge, R&D can ascertain project paths or projects unlikely to be financially successful and advocate an alternative project direction or an alternate project with a better opportunity for success.

Consumer and or customer knowledge is important to ensure that products are on target. Consumers are looking for solutions to make their lives easier. Life seems to move faster today, with greater demands on consumers' lives. Consumers seek solutions to make their lives easier

and fit into their lifestyle—which changes over time. This creates an interesting dilemma for development teams: Provide consumers with a unique product solution that meets their current lifestyle need, yet the product also needs to meet the company's profit requirements.

Superior R&D organizations encourage personnel to better understand their target consumer. Test methodology is developed to maximize consumer input throughout the development process. Testing is conducted to correlate how product attributes influence product acceptability and how well the product meets the concept.

At Level 3, R&D professionals work closely with their marketing colleagues, brainstorming together on product ideas to meet consumer needs, collaborating on product concepts, and working to ensure the developed product fits with the concept. They have a sound understanding of consumer testing methodology that will drive the development effort forward.

Consumers, however, may not be the only focus for a company. The customer carries significant clout. Who is the customer? For consumer branded good companies, the customer is the retail purchasing management in supermarkets and other retail channels that sell merchandise. For ingredient, packaging, and other “supplier” oriented companies, the customer is purchasing management and research and development personnel in either a branded good company or a food service company. Level 3 R&D personnel work closely with the sales group to identify customer needs and potential issues that could influence customer acceptance of their product. Sometimes R&D personnel accompany their sales colleagues on customer visits to gain a better perspective of how to satisfy the customer's needs.

R&D personnel work closely with supply chain colleagues during the product development process and particularly during manufacturing scale-up. Level 3 personnel have well-developed expertise in commercializing product formulations and understand how to work efficiently with manufacturing personnel to achieve their objectives. Superior R&D organizations develop a system for standardizing the approach to commercial scale-up and team together experienced (Level 3) and novice (Level 1) R&D personnel to facilitate the learning curve for the less-experienced personnel.

Proactive awareness of the regulatory environment and changes that could affect existing or pending products is standard operating procedure for a Level 3 R&D professional, which builds a superior

R&D organization. During the development process, R&D personnel interact with regulatory colleagues to ensure their ingredients, formulations, and processes adhere to current government regulations. At Level 3, the R&D professional sometimes collaborates with the regulatory group to petition the government on regulations that affect their products.

Skill and Capability Assessment

To improve the skills and capabilities within an R&D organization, one first should determine what the organization needs in terms of knowledge, skills, and ability of the personnel, which may be further defined by discipline, such as process engineer, analytical scientist, or product developer. Then an assessment process can be done to identify gaps between existing knowledge, skills, and ability of the current R&D organization versus what was identified as needed for the organization to be successful.

Where to Start

The R&D organization needs to identify the levels of R&D professionals within its company. This chapter presents three job levels based on overall skills, knowledge, and abilities, however each R&D organization is different and the job levels can be adjusted to reflect the organization's structure and needs. An organization could, for example, have five levels of skill requirements, which could include a skill level for R&D management.

For each job level, the R&D organization needs to identify the required skills, knowledge, and abilities needed to perform the work at that job level. The skill level could be further defined by the job discipline, for example, engineer, microbiologist, or product developer. The degree of mastery for the skill is defined for each level. For example, basic, advanced, and expert could be terms used to define level of mastery of the skill. Or a numeric value based on a five-point scale could be used. See table 4.1 for example definitions of skill levels.

For identifying required skills, knowledge, and abilities, a brainstorming session with individuals within the organization will provide a good starting point. There are many sources to investigate for assistance in

Table 4.1. Skill level definition.

| Level | Definition |
|----------|--|
| Novice | Absent or minimal level of skill |
| Basic | Beginner level, basic understanding, demonstrate skill |
| Advanced | Competent level of skill |
| Expert | High level of competency of skill |

identifying skills, knowledge, and abilities. A search on the Internet for job-skill assessment will result in a wealth of information, including consultants and companies who specialize in this area. The important criterion is to define what is required for each skill, which should be a transferable ability that can be measured by demonstrated capabilities. Examples of skills that may be considered are listed in table 4.2.

R&D organizations are typically a group of individuals with different disciplines and job responsibilities. Each job category, for example, process engineer or microbiologist, should have a skill assessment profile developed to reflect the skills, knowledge, and abilities for the discipline.

Table 4.2. Examples of skills with definition.

| Skill | Definition |
|----------------|---|
| Communication | Written and oral communication is professional, clear, and persuasive |
| Presentation | Demonstrates ability to present data and ideas in oral presentation or graphic format that is readily understood |
| Team member | Communicates technical issues in terms other team members can understand |
| Problem | Effective assessment of a problem /issue; gathers data and analyzes objectively; uses logic and reasoning to assess alternative solutions; determines actions to resolve the problem and acts toward resolution |
| Consumer focus | Ability to translate consumer needs into products utilizing consumer test methodology, collecting and interpreting data, and through direct consumer interaction |
| Job knowledge | Understands and applies technical knowledge to get the job done |
| Financial | Assesses relative costs and understands financial impact |

It can be expected that there will be specific skills required for a job category, and general skills, such as communication, will be the same for each job category. A determination should be made on the level of mastery expected for these skills for each skill level. Table 4.3 presents an example of expected levels of mastery for three job levels. Once this has been determined, individuals can be assessed and the results tabulated for each job category. Upon completion of skill assessment for the entire R&D organization, the skill gaps can be determined.

Skill Gaps and Next Steps

A determination should be made on what the needed skill composition should be for the R&D organization. For example, if the Process Engineer job category comprises 12 individuals, how many need to have expert skills in project management? If there are 250 people in the R&D organization, how many need to have advanced project management skills to lead projects? When the needed skill composition is determined, a comparison can be made to the actual skill levels present, based on the skill assessment summary for the R&D organization.

To build the skill levels of individuals so the entire R&D organization meets the overall skill requirement needed to conduct and lead project activities, a training program can be implemented. It can be internal, external, or online training that is focused on teaching the techniques need to improve the targeted skill. For example, if it were determined that improvement is needed in problem solving, a training course in creative thinking would be beneficial.

Besides formalized training in various subjects, coaching by the supervisor/manager on targeted skills will benefit the individual. An individual could be assigned a specific project that will provide experience to help develop specific skills. Assigning a mentor for an individual who is new in the job level provides an informal exchange with someone who is experienced at the job and can share their learning about the job, as well as the performance expectation from the organization. The mentor can serve as a sounding board for the individual on ways to improve job skills.

Experience is a highly effective path to the development of cross-functional skills. While most R&D professionals are engaged in cross-functional activities and develop skills over time, this activity can be accelerated by the planned movement of R&D professionals

Table 4.3. Example of skill assessment.

| Project Management | Applying Project Management Principles and Techniques to Achieve the Project Objective on Time and Within Budget | | |
|---|--|----------|----------|
| | Level 1 | Level 2 | Level 3 |
| Define the Project | | | |
| Agreement on project deliverables and success criteria | Basic | Advanced | Expert |
| Identify end user expectations | Basic | Expert | Expert |
| Define overall project strategy | Novice | Advanced | Expert |
| Design and Plan the Project | | | |
| Identify key phases of project | Novice | Advanced | Expert |
| Develop technical project strategy | Novice | Expert | Expert |
| Identify critical path, milestones, targets, and interim deliverables | Novice | Advanced | Expert |
| Prepare project schedule | Novice | Expert | Expert |
| Organize required resources | Novice | Advanced | Advanced |
| Monitor and control project budget | Novice | Basic | Expert |
| Manage the Project Team | | | |
| Identify appropriate people and skill level, type, and number | Novice | Basic | Advanced |
| Clarify team member responsibilities | Novice | Advanced | Expert |
| Provide project leadership | Novice | Advanced | Expert |
| Motivate and build team morale | Novice | Basic | Expert |
| Resolve team problems/conflicts | Novice | Basic | Expert |
| Monitor team performance | Novice | Basic | Expert |
| Control and Deliver Project | | | |
| Measure performance against plan | Basic | Advanced | Expert |
| Drive project deliverables and deadlines | Novice | Advanced | Expert |
| Conduct project milestone reviews | Novice | Advanced | Expert |
| Ensure effective project communication | Basic | Advanced | Expert |
| Flag potential changes | Basic | Advanced | Expert |
| Prepare and deliver implementation plan | Novice | Advanced | Expert |
| Project Accounting | | | |
| Determine economic/financial viability | Novice | Advanced | Expert |
| Estimate project implementation cost and construct project budget | Novice | Basic | Advanced |
| Review actual project costs and communicate variances | Basic | Advanced | Expert |
| Provide all project documentation | Novice | Advanced | Expert |
| Perform post project review | Novice | Basic | Advanced |

into other functional areas of the company, such as assignments in manufacturing, marketing, sales, and quality assurance. These assignments build a first-hand understanding of the role other disciplines have within the company and provide a greater understanding of the business overall. Through a different work experience, current skills are improved and new skills are developed. The overall R&D organization will benefit from having R&D individuals who have had work exposure within different functional areas of the company, because of enhanced skill development and greater appreciation of the contribution other disciplines bring to projects.

The final solution to build the skills needed for the R&D organization is to hire new individuals with the skills, knowledge, and abilities that are missing. Conducting a structured interview with a perspective employee, which seeks to ascertain the true skills and capabilities of the individual, is worth the effort to ensure the new hire fulfills skill gaps within the current R&D organization.

Building an R&D organization with capabilities to meet the needs of the business is a continuing process, because companies continue to evolve and introduce new products to compete in the marketplace. Companies have the ever present challenge to grow shareholder value. This business environment places a premium on the value contribution of the R&D organization, which is composed of limited human resources to "get the job done."

To build and maintain a superior R&D organization, a regular assessment of the organization's skills and capabilities should be conducted. The present state of skills should be compared to the R&D skills needed to meet current and future business opportunities. A plan for skill development should be implemented to ensure the R&D organization has the capabilities needed. Adhering to this type program places the R&D organization in a position to meet the challenges of the twenty-first century food industry and maximizes the opportunity for the successful outcome of projects.

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Chapter 5

A SUPPLIER PERSPECTIVE: SUPERIOR SERVICES AND PRODUCTS HELP CHANGE HAPPEN

Victoria de la Huerga and Elizabeth Topp

Why Read This Chapter?

Understand the perspective of the supplier in this chapter, which provides a straightforward and explicit description of the fine dance that exists today between customers and suppliers.

Introduction

This chapter presents the role of a supplier at the beginning of the new millennium. The perspective I am sharing is from a product development standpoint of a supplier. As a supplier, we (WILD Flavors) work with big companies, small companies, and start-up companies. And we see all types of challenges out there. But there are a lot of common themes—convenience, leveraging outside resources—and issues related to partnerships. I will focus on what a supplier sees and what some of the challenges are, and how a client company might be able to further leverage suppliers to help get to the endgame of successful products and their launches faster.

In an analysis of supplier integration practices, many companies reported that getting the suppliers involved earlier in the product development cycle is of paramount importance (Ragatz et al., 1997). The study

identifies supplier membership on the product development project team as the greatest differentiator between most and least successful integration efforts.

Basic Product Development Process Flow

I will start off first with a very basic product development process flow. When a new product project is initiated, the steps entail defining the product concept, identifying consumer needs and product benefits, and determining the target consumer demographics. Finally, a key objective of the project is to make the business case for the product “can the company make money on the product?” These steps define the product, the consumer, and all the key elements that should make a product that consumers want and that will make money for your company (fig. 5.1).

After these steps are defined, developing the product is initiated. Key steps in developing the product are figuring out how to make it on a commercial scale, identifying product and microbiological issues, and any regulatory concerns. Once an acceptable prototype product is developed, the process is scaled up from bench-top to pilot plant and then to the manufacturing location to confirm production feasibility and potential scale-up effects on the product. Gearing up for production and product launch, one needs to prepare all the technical documents that identify the product formulation, ingredients, packaging, and manufacturing process. During this stage, the rest of the organization is working on finalizing the business plan. The marketing and sales groups finalize the launch plans including launch regions, target customers, advertising, and the action standard for success. The manufacturing group is

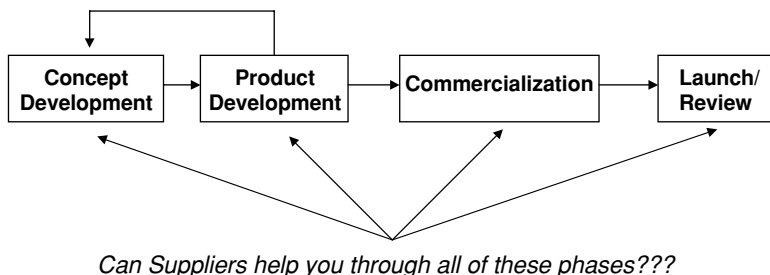


Figure 5.1. The product creation process.

reviewing process equipment needs and other issues related to start-up of a new product.

Following launch, review begins on the product performance. Were purchase rates achieved? What is the repeat purchase rate? What are the consumer complaints? Is the product meeting the expected shelf life?

While this may be a simplistic perspective of the product development process, it approximates the process for many companies.

For some companies, this process can take a very short period of time. I have observed some companies that complete the development process in as little as three months. I know of companies that have taken two years to develop and launch a product. A two-year timeline is becoming rare, because most companies are working to quickly grow top and bottom line performance through speed to market with innovative and differentiated products. Most companies want products that meet changing consumer needs when the opportunity is fresh and there are limited products available that address this new consumer need.

The question that arises is, can suppliers help you through this whole cycle? Can they really help you at every stage of this cycle? I say the answer is yes. First, though, I present a review of situations that slow the product development process, impacting project timelines.

Changing, Creeping, or Unclear Objectives for the Product

The project is initiated and you begin developing the product based on consumer input, and you think the product is on the right path. Then, what happens? Your company's management gets involved in the project and changes the development direction. Sometimes the product needs to be changed so much to address the management input that it's like going back to square one. The entire project may need to be reworked, taking time to get it right.

Creeping objectives arise in situations such as when your customer tells you, "I want you to do this," and then later they add, "But I need you to do this as well." This can lead to another round of refocus and change in the project plan, and in some cases, the need to redo some work or start again from the beginning.

Unclear objectives can slow down the development process. This can be problematic if members of your team aren't marching down the same path toward the same objective. Clearly stated project objectives

and timelines agreed to by all team members can alleviate this problem.

Changing Timelines

Most people in product development have experienced an occasion when marketing told the project team they committed to management that the product would be launched earlier than the timeline the development team was working against. The team scrambles to figure out how to take time out of the development process and achieve the new launch date. When launch dates change and teams regroup, sometimes additional precious project time is lost, because team members need time to investigate how they can speed up their area of responsibility.

Large Teams

Suppliers observe the impact of large development teams at their customers, which is more typical for big food companies than smaller food companies. On a project team with many team members, it seems it takes longer for things to get done, to get all the team members together for meetings, to agree to work on the same objectives, and to reach agreement on issues. Teams are an effective approach to develop products today. To maximize the benefit teams bring to the development process, teams should be sized as small as needed to include members that represent the key business areas that are engaged in the decision process. All team members need to understand their role and should agree on project objectives and timelines.

Changing Team Members

As a supplier to food companies, my company has worked with all kinds of customer organizations. We observe that people on teams change all the time. Changes with marketing representatives appear to happen more than with R&D people. Whenever a new person joins the team, inevitably the person brings new ideas, which sometimes strengthen what the team is doing, and sometimes disrupts previous actions the team has already completed. The time it takes for the new team member to become fully on-board with the rest of the team can have a costly impact on the project timeline. Forming teams with individuals who

remain team members throughout the project duration benefits the project continuity, decreases potential time delays and can lead to a smoother path for the project.

Communication, Communication, Communication

Poor communication contributes to delay in projects. Effective teams demonstrate good communication among team members on the issues and decisions that impact the project. Regular team meetings to exchange progress and discuss project issues guide the team to make necessary adjustments in project direction and to modify the timeline if required. Team meetings also provide a forum for flagging significant project issues and delays that can be communicated to higher levels of management.

Getting Agreement

The issue of getting agreement, again, is more of an issue at the larger food companies than the smaller food companies. The project team leader has to present the team's decision to senior management and make sure management is aware of the team's actions and that they're aligned with the risk the team might be taking on. Reaching agreement on risks and other issues adds time to the project. At this point, one can begin to understand why smaller companies can move more quickly and capitalize on opportunities suppliers may provide.

Lack of Risk Taking

In some companies, you may hear the term "paralyzed by perfection." Ensuring food safety is the responsibility of every food company, so it is important to make sure the company's procedures are adhered to in order to avoid risk of a food safety issue in the marketplace. But some food companies focus on small technical issues unrelated to safety, which the consumer is unlikely to be concerned about. When a company focuses on details that have low impact on the consumer, taking time to dot every "i" and cross every "t" before the product can be launched into the market, the company could lose its lead position. Market advantage is lost when a company is second or third

bringing its product to market. With a late entry to the market, not only has the customer lost out with decreased sales and profit potential, but its suppliers are impacted as well with reduced sales of their components.

Inappropriate Action Standards or Misleading Consumer Information

Suppliers often observe the use of inappropriate action standards by their customers. Branded goods companies that conduct a lot of consumer research testing develop “norms” that serve as guidelines for product success and they may apply these norms to new product categories, where the norms may not apply. This can result in a company becoming unable to make a decision.

A similar situation has been observed from consumer research guidance testing, during product optimization. Results from a designed consumer test may indicate the consumer wants the product to be a little less sweet, or perhaps the consumer wants the beverage to be a little more carbonated, yet consumers rate the product highly acceptable. The question is, how do you make this product better? The product developer adjusts the product formulation to address the consumer input. Then the revised product is tested again. Well, guess what? The consumer rating of the product may actually go down. Because while they're telling you they want it less sweet, consumers really liked the sweetness. Interpreting consumer feedback on tested products is difficult. Understanding how to use the feedback to modify or not to modify the product formula is important, because one doesn't want to slow the project down unnecessarily.

In summary, changing or unclear objectives, timeline changes, team size, team member changes, poor communication, senior management agreement, risk aversion, and misinterpretation of consumer data can all contribute to slowing the product development effort. And these issues can lead to the difference between becoming the leading company in a new market or being second or third to market. The market leader is often perceived as the innovator while the others are seen as market followers.

With all of these issues facing product development teams, working with suppliers can add another issue to deal with and a new set of challenges. It can sometimes add to the project time to have suppliers

work on project activities, but if the team manages it right, it won't take more time and will often reduce project time.

The Product Creation Process—Barriers to Using Suppliers, Are They Real or Perceived?

Capability

Do you understand your supplier's capabilities? Where can they help you? What skills and expertise does the supplier organization have that your company does not have? If you know your suppliers well, working with them will not be an impediment to moving along the product development cycle faster.

In-House Expertise

Many companies want to own everything. And while a lot of outsourcing is going on, some branded goods companies still want to make sure they own the technology. Companies often believe they have sufficient expertise in-house and enough time to develop the new technology. The reality often facing companies is aggressive project timelines often don't allow sufficient time to develop the technology within the time frame using only in-house resources.

Confidentiality

Companies are often concerned about the confidentiality of their projects. They ask themselves, "will the supplier tell my competition what our company is doing?" Suppliers survive by being confidential about customer projects. If they don't work confidentially, they lose business. To address this concern, formal confidentiality agreements are signed between companies and suppliers. A supplier will gladly sign a confidentiality agreement with a packaged goods company to alleviate any concern about confidentiality. A supplier is not motivated to breach the confidentiality agreement because they want a successful product launch for their customer. The supplier's success is tied to the success of their customer; they win when the company wins.

Time Schedule

As long as you clearly communicate with suppliers about your project timetable and what is needed from the supplier, this should not be an impediment to moving through your product development cycle. Supplier companies are organized to respond quickly to customer requests. If you don't inform the supplier about your timing requirement and the supplier responds later than your deadline, that's your fault for not communicating. Keep your supplier company informed about your project schedule and what you need from them, by a specific date.

The "Not Invented Here" Syndrome

This was previously discussed in chapter 3 by Dr. Feicht. What we find is that it's hard for people to take somebody else's technical know-how and leverage it within their own company to get to the results faster. However, this is changing quite a bit these days in terms of further leveraging suppliers and their expertise on how they can get you to market faster. The companies who do not work with their suppliers leveraging their technology will lose out and take longer to get their product to market.

Understanding the Marketplace

Does the supplier really understand the marketplace in which you're competing? Well, suppliers these days have become very savvy in what is going on in the marketplace. Suppliers often investigate new trends that are going on around the world, within a country, and with consumers—their needs and behaviors. They do understand the marketplace, and they can help you understand the marketplace and the competitive environment.

What If There's a Problem Down the Line with a Technology Solution?

Will the supplier help me out? This is related to a concern about losing control of technology, especially if a problem occurs and the company needs to rely on the supplier to step in and resolve the technical issue. Suppliers are very responsive and readily assist with issues that arise.

The supplier's business is on the line, and it wants to ensure your product success so its company can be successful as well.

Job Insecurity

This is linked with the “not invented here” syndrome. Internal product developers become concerned about their role when a supplier is perceived as having more knowledge and expertise. If development activities can be outsourced, what is the role of the branded goods company product developer? Well, the reality becomes that the role of the developer becomes one of managing the supplier. Developers are engaged in their company's process for developing and launching products. They understand the internal issues, concerns, politics, and timeline. Their role is to provide the supplier with information needed to drive them in the right direction for completing the project. Often the developer works together with the supplier company and is intimately involved with evaluating the progress of the product, providing input and direction. It becomes a collaborative exchange of knowledge, expertise, and technology that leads to a faster end result.

Does the Supplier Understand Your Company

Suppliers often hear conversations from their customer that may be something like, “Well, you don't understand what it is like in my company, one has to have every ‘i’ dotted and every ‘t’ crossed. Internal politics drive decision making. How could you really understand that?” It can be difficult to understand the internal work process and expectations within a customer company. However, communication can help solve this issue to a great extent. When working with a supplier, as long as the customer company identifies what it needs, what is acceptable for a result, when it is needed, as well as its overall expectations from the supplier, the supplier will work as hard as it can to achieve the result.

A Shift in the Paradigm

The business world today is global. Many companies have evolved from their original business to larger multibusiness organizations to compete in the global economy. An example is the communications industry.

Originally the communications industry was only made up of land line phones and the U.S. Postal system's snail mail. In time, fax machines, pagers, and cell phones were introduced. Then came the new wireless communications world of extended cell phone functions and computers that allow you to be connected to anything to anywhere in the world. Today, it is possible to run the phone, computer, and television from the same cable connection. The question becomes, what defines a phone company, or a cell phone provider, or a cable company? Sometimes they are all one and the same.

The food industry reflects a paradigm shift in the relationship between suppliers and customers. I will illustrate from a supplier's perspective the evolution of change over the years creating a paradigm shift (fig. 5.2).

In the 1980s, suppliers received requests from customers to submit their ingredient. The typical request was "I'm developing a product, I need these three flavors" or "I need an ingredient to help stabilize something." Rarely would the supplier hear from the customer about the type of product the flavors or other ingredients were used for. The chance of success at this time was often 50:50: the supplier got lucky because it happened to submit the right ingredient, which the customer actually liked and used in their application.

In the early 1990s, we observed companies becoming more open with suppliers about what they were doing and there was more team collaboration. Suppliers started to become savvier and began conducting more extensive application work to demonstrate their ingredients more effec-

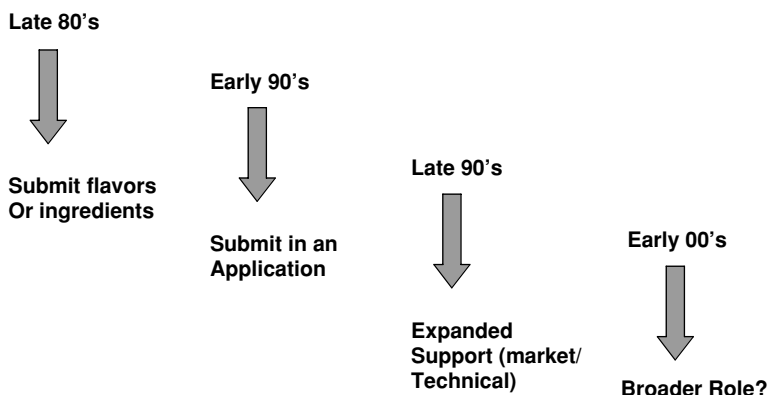


Figure 5.2. Paradigm shifts.

tively for customers. While suppliers often did not know all the specifics of the customer's application, they could provide the ingredient to them in a product form the customer could easily evaluate and determine if the ingredient met their need.

Throughout the 1990s, suppliers experienced an expanded role with their customers beyond just providing traditional technical and application information about their ingredient. The phenomenon of downsizing had started and branded good companies needed someone with expertise to work on the project, which their supplier could provide. The food industry experienced the intersection of a soft economy (companies were restructuring and jobs were eliminated), strong demand for innovative products, and faster product launches, which created "the perfect storm" for suppliers. This resulted in suppliers becoming more involved with customer projects and taking on activities that had been the domain of product developers in packaged goods companies.

Today in the 2000s, suppliers are experiencing a broader role with customers that sometimes includes the supplier as a member of the company's business team. Oberoi and Khamba (2005) report several key reasons why suppliers are becoming more important to packaged goods companies. Packaged goods companies are focusing on their core competencies and have come to rely on suppliers to support non-core-competency project requirements. Suppliers can support a company's effort to innovate in critical areas of product and process technology by filling the competency gaps.

By developing effective supply chain strategies, the package good company also counters competitive forces. As these companies continue to seek performance improvements, they consolidate their suppliers and manage suppliers as an extension of their business system.

Challenges in Today's Environment

Figure 5.3 indicates the challenges faced in today's customer-supplier relationship. There are both positive and negative implications from this new situation.

The first challenge is *speed*—everybody hears this all the time. We need to launch new products faster with fewer resources. Package good companies are getting very good at managing projects, figuring out how to multitask to get everything done. And companies that are leveraging

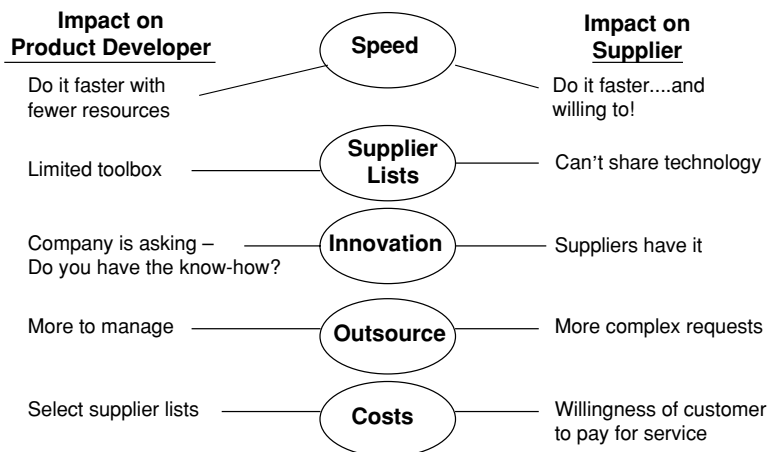


Figure 5.3. Challenges in today's environment.

suppliers find that suppliers are willing and able to move faster and to take on risk alongside them. Suppliers want to see your company be successful and grow because their company will benefit and grow as well.

The next challenge is the *select suppliers list*, which is a growing occurrence in the industry. A supplier list is generated by packaged goods companies to focus purchasing among selected suppliers. Typically, ingredients and other product components are consolidated into categories. Supplier lists reduce complexity and are leveraged to save money on raw material costs. Select supplier lists impact the product developer in the package good company by limiting the toolbox. If the developer is allowed to work with only a handful of suppliers, it limits options to access only the ingredients and technology provided by the select suppliers. From a supplier perspective, if they are on the supplier list, they have the opportunity to work on projects and supply their ingredients, technology, and service to the packaged goods company. If a supplier is not on the list, they are typically not invited to present their ingredients and technology. The unlisted supplier may have the right ingredient or technology to solve a development issue in the packaged goods company, but the product developer will never know this supplier could help with the technical challenge. Benefits of supplier lists are mixed, both positive and negative to both parties.

The third challenge is *innovation*. All companies say they need innovative products but may not know how to get there. Does your company

know how to create innovative products using novel technology to provide a new product for the consumer and satisfy unmet needs in the market? Suppliers have much to offer companies in developing on trend innovative products that consumers want. When suppliers communicate their capabilities and have a good relationship with their customers, they are often asked to collaborate with the company to develop product innovations.

Outsourcing job functions is the fourth challenge in the industry. Some companies outsource a small number of activities, while other companies outsource development of the complete product. Today, one can observe supplier organizations that are used like an external resource to develop products. Outsourcing project activities impacts the role of the package good company's internal product development staff. The product developer's role becomes more of a management function as they manage a supplier's activities to keep them on track and keep internal team members and management informed. When there is strong communication with the supplier, this is not a major problem, however, when communication is not so good, it becomes more difficult for the product developer.

From a supplier's perspective, we are more than willing to take on project requests as an outsourced resource. We have observed that outsource requests have become much more technologically complex. A project is not just a simple request, such as creating a carbonated soft drink for the company and then the project is done. Now project requests are more complex sometimes requiring a new technology be developed or extended to a new area. Suppliers need to have a good understanding of government regulations and an awareness of consumer trends. For example, a project request for a functional beverage may use amino acids, vitamins, minerals, and herbal ingredients to deliver a functional benefit. The supplier needs to know how to formulate with these types of ingredients to deliver a functional benefit and eliminate the bitter off-taste these types of ingredients typically have, as well as to be knowledgeable about usage regulations. In addition, the supplier may need to develop a new process to make the beverage.

Cost is a challenge that always factors into consideration. Finding ways to improve the bottom line is everyone's goal. The customer company wants to maximize its profit margin potential and unfortunately its approach may impact the profit margin potential for the supplier.

Companies with select supplier lists in place work with the supplier to negotiate the best deal possible on raw materials they purchase. In addition, these companies also expect the supplier organization to step to the plate as an external resource (outsource replacement). It can become difficult for a supplier to make a reasonable profit, when the supplier is squeezed to provide a low price to retain business with the customer and needs to utilize significant internal resources to work on customer outsourced projects. With their net profit potential in mind, a supplier has to probe to understand the business potential and chance of success before agreeing to take on a customer project.

How Best to Utilize a Supplier Today

The best way to consider suppliers today is as willing team members or extensions of the company's development teams. Suppliers have a wide range of expertise and personnel who can augment the skills in the packaged goods company's organization. Suppliers can provide value to large and small companies throughout the product creation, development, and implementation phases.

Conceptual Stage

Use suppliers as a sounding board and a place to get ideas. Most supplier companies have a market research department; ask your supplier to provide your company with consumer insight and trend information that can assist your project, especially when you are on a tight timetable. Invite suppliers to participate in your brainstorm sessions for your company's projects to develop new product ideas or to develop creative ways to solve a problem. Sometimes suppliers with international offices can assist your company in obtaining product samples through their multinational locations that would be difficult to otherwise obtain.

Scoping and Definition Stage

Suppliers can provide your company with conceptual samples for use in qualitative work a company conducts during the product definition phase. Helping their customer bring a concept to life demonstrates

the supplier's capabilities and illustrates to a customer company an opportunity to reduce project time. Suppliers have a broad spectrum of knowledge about ingredients and product systems and can provide good input during prototype development when package good companies consult with them. Suppliers can be particularly valuable assisting in identifying issues that should be addressed during the early stages of development, of which the company's development staff is sometimes unaware. Suppliers can help bring a reality check to product concepts and provide suggestions for broadening the appeal of the concept or reining it in. Suppliers can prove to be a valuable, objective third party during early development.

Product Development and Refinement Stage

During the development stage, many suppliers can provide product developers in a packaged goods company with formulation guidance including the complete product system, not just recommended levels for the ingredient they supply. Preliminary assistance in developing product formulations can help a company get a faster start on the project than starting from scratch with a trial and error method. Leveraging a supplier's expertise can lead toward earlier knowledge of project information, such as the nutrition data for a label—fat, carbohydrate, protein, and calories—or the ingredient list. Availability of such information allows companies to make earlier formula modifications to meet target parameters.

Commercialization and Launch

Product commercialization and launch sometimes run into glitches. Some suppliers can provide assistance during the commercialization stage to augment a company's product development and engineering staff. Companies should consider tapping their suppliers as a resource composed of knowledgeable and capable technical personnel who could provide assistance with troubleshooting during production start-up or when issues occur during ongoing production. Suppliers sometimes provide assistance with identifying a copacker to manufacture the final product. They can also recommend quality assurance and auditing procedures and recommend quality control checks during product manufacturing.

Choosing the Right Supplier for the Right Reasons

Choosing the right supplier for a particular project is critical. You need to determine your supplier's capabilities including their area of expertise, their core competencies, and then determine how they can assist with the project. Usually one supplier cannot solve every development issue a packaged goods company has nor can one supplier provide all the ingredients needed to make a food or beverage product.

When selecting a supplier, the packaged goods company product developer needs to determine the quality of service that will satisfy the project need and how the supplier's service will be used—is it to provide bench-top formulations as a starting point, or is it more full service, working side by side with the developer throughout the project including the manufacturing stage?

Part of the supplier selection process is based on the ingredients the supplier has to sell and an understanding by the developer of project constraints that influence this choice. If the product to be developed has a target raw material cost guideline, communicate this to the supplier and they will work with the developer to meet the target cost. Sometimes a packaged goods company developer is trying to develop a product as cheaply as possible and is seeking a good deal—cheap ingredients, the cheaper the better—they should communicate this with the supplier and reconsider how much service they should expect from the supplier. When a supplier gets pushed on price, they are likely to pull away from providing multiple services because it is not cost effective, cutting into their profit margin.

The packaged goods company product developer should understand the priority of the project within the company and share this information with the selected supplier to increase success with the supplier. Suppliers get bombarded with multiple project requests from all of their customers, and they prioritize all the projects for effective use of their resource and expertise. Sometimes a supplier does not provide the service or focus the customer is seeking, perhaps because of poor communication or low priority status. This should be an indication to the product developer to better communicate needs, timing, and priority with the supplier or perhaps to seek another supplier. Through selective choice of suppliers for a project, a package good company can get its product launched faster into the marketplace.

The packaged goods company should determine its need to have a confidentiality agreement with its supplier. If a company is concerned about information leaking and potentially ending up with a competitor, a confidentiality agreement should be signed with the supplier. While suppliers maintain confidentiality about their customer products and projects as a business practice, a signed agreement is the legal approach for a company to ensure confidentiality from a supplier. The more information a package good company can share with its supplier, the better and faster the supplier can meet requirements. A supplier-packaged goods company partnership sealed with a confidentiality agreement leads to seamless collaboration on projects, shared information, and open discussion on issues.

As indicated earlier, communication is important, particularly regarding the overall project timeline as well as timing for completion of various activities within the project timeline. When the supplier is aware of what its customer needs and the related timing, it will work hard to deliver on the request. Effective communication can be accomplished through phone calls and e-mail messages. E-mail communication is becoming a convenient means of keeping people informed. An e-mail message can be forwarded to other people in an organization to keep them informed or to alert them that their assistance is needed.

Things to Think About Today with Respect to Suppliers

Suppliers can help speed up the product development process in packaged goods companies. Suppliers are organized to assist their customers in getting their products launched to market quickly. Suppliers have a broad range of expertise and depth of knowledge in multiple food categories. Suppliers can provide valuable perspective based on their experience working with many different types of food and beverage products. Suppliers can provide insight to avoid technical issues, project pitfalls, and delays during the product development process.

Suppliers will work closely with the developer to help develop a cost-effective formulation that keeps the product within the target cost parameter. Suppliers can provide a project resource, which is especially valuable for packaged goods companies that have been downsized.

Suppliers will work hard for their customers to meet project criteria and deliver product expectations. Suppliers help the packaged goods

company win in the marketplace. When their customer has a successful product, the supplier enjoys success and also wins.

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Chapter 6

ONE COMPANY'S PERSPECTIVE ON INNOVATION—STARBUCKS COFFEE

Lawrence Wu, Jr.

Why Read This Chapter?

Starbucks is often acknowledged to be one of those companies that has managed to stay ahead of the curve of profitability and meeting consumer demand. Larry Wu, who was a director of product development for Starbucks, was asked to provide his unique intimate perspective on how and why that has happened.

Introduction

Most executives and employees of companies both private and public have an interest in innovation and innovative companies. We all want to work for innovative companies. There is a culture of excitement, opportunity, freshness, and success that these companies exude. Innovation can set a company apart from its competition and enhance the value of the company if it is publicly held, and the halo that the innovation concept provides tends to continue to increase the gap in public perceptions about the company. However, very few of us ever get the opportunity to be aboard an innovation driven and lead company.

Innovative leadership is a requirement for building long-term strategies for market success. Starbucks Coffee Company is known for both its innovative culture and leadership, and many of us are interested in gleaning insights and secrets from that company. Starbucks Coffee

Company has a reputation for innovation, changing the way consumers viewed coffee and adding values like indulgence, harmony, and escape into their lifestyles. In this chapter, you will be able to see into one aspect of innovation present at Starbucks and learn a few principles that this company uses to drive growth in a crowded product category. You will learn that there is no “secret sauce,” and that the principles, while unsexy in the radical thought department, are quite effective in establishing patterns for innovative thought. I have attempted to relate aspects of the innovation culture that I have lived at Starbucks, so that you may be able to look at your business culture and understand your innovation strategy.

Innovation Defined

Innovation can mean many different things to many different individuals. To someone in the high-tech world, it can be purely about the newest inventions and discoveries. In other areas, it can be about revolutionizing thoughts and processes to create new business opportunities for companies.

It is the easy way out, but a dictionary's purpose has always been to define words. The definitions found in that reference can bring unanticipated insights that clarify thoughts and provide inspiration. The word “innovation” is one of those words. In the *American Heritage Dictionary*, we find the following definition for the word “innovation”: To begin or introduce (something new) for, or **as if** for the first time.

For Starbucks Coffee Company, it is that second half of the definition that provides the insight and inspiration. Coffee consumption has continued uninterrupted since it was first recorded in Ethiopia over 1000 years ago (Pendergrast, 1999). The coffee trading market is one of the largest and oldest markets in the world. Coffee drinking, brewing, and trading are not new. What *is new* is the ability to charge premium prices and bring people together in a culture built on great coffee. By introducing high quality, specialty coffees and indulgent drinks based on coffee to a larger, mainstream audience, Starbucks appeared to be reintroducing the world to coffee. Restated, innovation is an extraordinary view of an ordinary thing, like coffee (table 6.1).

So, breathing new life into old existing businesses can be defined as innovation.

Table 6.1. Ordinary and extraordinary views.

Ordinary view

Coffee is a commodity
\$0.10 cup of coffee
Coffee is not a destination beverage
Cream and sugar, what more does anyone need?
Coffee is coffee

Extraordinary view

Coffee as a premium brand
Coffee at a premium price
Coffee house as a community
Coffee customization
Coffee as a growth strategy

- What other opportunities like this exist in your business?
- How can you think differently and more innovatively about how your clients and customers interact with your brand and products?

Key Principles and Applications

Here are four principles and the key application thoughts on innovation that Starbucks Coffee Company uses to help identify ways to increase the gap between themselves and the fast-growing population of competitors in the specialty coffee segment.

1. Establish your company profile for innovation.
2. Maintain relevance to your customer.
3. “Target” the possibilities by building an adjacency map.
4. Don’t focus on the enormity of the goal.

Establish Your Company Profile

It is critical to understand who you are as a company in relation to how comfortable you are with the levels of innovation. Defining your company’s innovation profile helps define the parameters for the acceptable “playing ground” for innovation. Indeed, there are limits to innovation for companies. However, it is very possible to be innovative in any space.

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A very conservative company with little interest in being cutting edge can find success at innovation if it understands the space in which it will innovate. It will not be successful if it tries to apply innovation principles that are outside of its boundaries of comfort. It is important to know where those boundaries are. Through a series of questions and answers, the parameters and innovation space can be better defined.

- What is your innovation comfort level? Which stage of the innovation cycle are you most comfortable in? Bleeding edge? Leading edge? Mainstream?
- What is your innovation investment level? How great is your investment in innovation? Do you hire innovative thinkers? How do you measure growth and your innovation returns?
- What are your core competencies? What do you do right? What do your customers say you are good at? What do your competitors say that you do right?

Innovation Comfort Level

Some companies want to be the first to market with a new gizmo, and are willing to invest in order to have that leadership. Other companies are more comfortable waiting for the market leader to launch and quickly launching with a similar product with similar features while helping to grow the category. Others are more comfortable knocking off the market leaders and living on a smaller share. While Starbucks is quick to begin following new trends to start to understand drivers of consumer behavior, Starbucks is most effective (and comfortable) in the role of expanding the market and growing the category by following new trends that show promise of longevity.

Innovation Investment

Bleeding- and leading-edge companies invest heavily in being first to market. First to market is an important strategy for these companies. Heavy investment for establishing a market is worth it. Other companies may not have the resources for development, but may have supply chain competencies to quickly follow as a competitor, while many others may have economies of scale to compete on price. All are legitimate strategies.

Many in the industry may view Starbucks as a leading-edge innovator, striving to be first to market with innovative offerings. However, Starbucks has achieved that reputation and success through identifying early on what trends and products will have momentum in the consumer's mind (indulgent coffee-based drinks), and changing the offering slightly to bring their brand flair (artisan caramel sauce, for example). As the 800-pound gorilla in the space, Starbucks has the supply chain and retail muscle to follow the newest trends quickly and with such great scale as to appear to be bringing fresh ideas to the consumer.

Core Competency Defines Your Current Strengths

However the market changes, triggers to that market require you to view your competencies from that fresh perspective. As transportation shifted from horse and carriage to horseless carriage, which companies evolved and which became extinct? Do you believe Starbucks to be simply another coffee brand? The brand focus has shifted over the years from a single product (roasted, whole bean coffee) to a brand based on the consumer value of "personalization." This helps explain why the company offerings can move easily to food, tea products, music and entertainment, and chocolate. Changing with the market, and more importantly with the customer, without sacrificing the integrity and hallmarks of the brand creates an opportunity to build a legacy.

Too many consultants offer too many companies a single innovation product. It is as if a hat maker offered only one hat in one size. If you tried on that hat and by luck it fit, you would continue to wear it. However, if that hat did not fit, you would not use it, no matter how beautiful and stylish it was. Innovation can be like a hat. If you bought it and it fit, you wore it, but if it didn't fit, you gave up on it. Sometimes the first hat you come across isn't the right one for you. Profiling helps find the right hat by helping to define the head that the hat will wear. If you bought a hat that didn't fit your head, but you insisted on wearing it anyway, you would have to change the shape and size of your head to fit that hat! It can be time-consuming and painful, and in the end it might go out of fashion before you can wear it.

The "hat size" of the company is the one constant, but the style and function of the hat can change. Starbucks understands where its comfort

zone for innovative thinking and investing lies. That is the size of their hat. The style, design, and function of the hat allows them to employ a variety of innovation techniques.

Be smart, understand what kind of company you are. Knowing your profile will help innovation take root and grow. It will feel natural. Be comfortable with what you find, or be willing to radically alter your culture, which can be very painful. Starbucks realizes it cannot be a “bleeding edge” company, it is not resourced and structured to endure more failure than success. It is, however structured and staffed to put proven products out quickly and at a large scale.

Maintaining Relevance with Your Consumer

There are four principles that Starbucks uses to help gauge the connection the brand has with the consumer. Each of these areas can be measured either qualitatively or quantitatively to help set expectations for growth in innovation. Starbucks uses a combination of these techniques to establish its brand relevance. It is important to review your brand values and hallmarks with your consumers frequently enough to detect shifts and opportunities. Is it annually, semiannually, or once in a decade? This will depend on the market you play in. An annual “Customer Loyalty Study” is how Starbucks helps gauge its consumer connection.

Understand Your Company and What It Sells

- Are you peddling a trademark or growing a brand?
- Are your marketing approaches product (functional) or consumer-needs (emotional) focused?

Most of us believe we work for major brands, but in reality many of the brands we represent are merely trademarks. Trademarks are product focused, leveraging the functionality and performance of the products the brand represents. Brands, on the other hand, leverage the emotional connection with the customer. Take, for example, two pairs of running shoes. One pair is from Wal-Mart, highly functional, a great value, and well-designed. The other pair is the latest trail running shoe from Nike. Both sets of shoes function equally well for your feet and your running

style. There is a big difference in the brands that represent the products placed in front of you. The Wal-Mart customer is buying a pair of shoes to *run* in, while the Nike customer is buying a pair of shoes to *win* in. Nike as a brand has convinced us that we are winners when we wear the brand! Do you believe Starbucks is simply a coffee trademark? It isn't about the flavor, the roasting, or even the brewing. It is about the personal attention, customization, and the escape we desperately need and deserve.

Understand Your Customers and What They Are Buying from You

- How have they defined your company and its product lines?
- Where will they grant you “permission” to venture?
- Where can you lead them?

This principle reflects upon how a trademark becomes a brand—that is, through the evolution of what the customers are buying from you. It starts with a product and evolves into a relationship. Starbucks started as a trademark, with its hallmark of quality sourced and roasted whole bean coffees. You couldn't get them ground let alone brewed. It was about a commodity product with quality features. As customers create a relationship and bond around your products, they become receptive to evolution, and allow you to enter into other aspects of their lives. Roasted whole bean coffee becomes well-brewed and served coffee. Well-brewed high quality coffee becomes food pairings, which morphs to café experience and the beginning of a Third Place. Third Place *is not* about coffee (or the “badge”) but human connection, and nobody does this better than the *barista*. This personalized service and attention of course can be applied to the beverages and customization and a language for this new community, and culture evolves into being. As much as you talk to and measure your customers, they cannot lead your company in the right direction; that is still *your* job. You must be able to feel the winds of change, and that is reflected in the way the customer talks about your product, your service, and ultimately your brand. The language and tone will change. The appearance of values like “community,” “connection,” and indulgence, which normally are not associated with coffee, help you determine when the consumers are ready for you to lead them in a deeper relationship with your company and brand.

Understand How Consumers' Needs Are Changing

All right, you know your customers have changed their view of what they are actually buying from you, and you have helped guide them along based upon listening for the change in tone, measuring their loyalty and affinity through their purchasing and visitation habits. In fact, you can now define a Super Fan (visits more than 15 times per month spending an average of X per visit) from a casual user (less than 5 visits per month, spending an average of Y per visit). Now you have to be able to factor in how the market is changing to maintain relevance. How do you decipher how low carb diets will affect your customer and consequently your business? More important, how do you craft a position and strategy to tell your customer where you sit on these issues? How is the government changing your marketplace? Understand the outside influencers and craft a strategy that doesn't waver.

Find the "Sweet Spot"—Evolution Without Changing the Experience

Tactical evolution is the key to maintaining relevance. You know from the data that your consumer is changing, or that there is something changing in your market that affects their interaction with your brand. How do you evolve to that changing consumer without changing the basic emotional connection with him or her? You make sure you carry the same emotional connections through to any new product or category opportunity. You want to sell music CDs in the store? Make sure they are *barista* selections and represent their eclectic tastes. Knowing how you are emotionally connected will help you expand your product portfolio, and the customers will feel it is a natural extension of your brand because they can find the original values in your new offering.

Target the Possibilities: Map Your Product Adjacencies

So, what do you offer new to your eagerly awaiting and growing customer base? Without an Adjacency Map, it could be hit or miss (fig. 6.1). Adjacency mapping helps you and anyone coming after you to understand what spaces consumers will allow you to bring them to within the brand framework of your company. While it is critical to understand what your brand stands for, it is also important to understand what

Mapping the Adjacencies



Figure 6.1. Mapping adjacencies.

product is at the core of your consumer's mind. For example, for Starbucks the corporation, roasted whole beans are at the core of the brand. It is in the name, the history of the company, and the core of its supply chain. However, in the consumer's mind, the core product offering is coffee in other forms: either brewed or espresso. While whole bean coffee has iconic meaning for them, their connection to the brand appears as a different entity—it is the product they consume. The connection consumers make with your brand is based on their interpretation of the message you are creating for them in helping them discover your brand.

Once the center of the map is identified, and its connection to the consumer understood, then the adjacency mapping can begin to be populated. Existing products can be classified by broad classes of consumer/brand interaction, and the adjacencies can be identified. For current coffee-based products offered by Starbucks, the following adjacencies exist:

Foundational products (espresso, brewed coffee): The bull's-eye of the target.

Personalized beverages: The "10" ring.

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In-store experiential products (frappuccino blended beverages): The next circle out.

Out-of-store experiential products (liqueurs, ice cream, whole bean grocery business): the next circle out.

Nonexperiential (instant coffee): Off the target.

The key to adjacencies is to drive incremental business by tapping larger and larger bases of consumers. Each adjacency space is larger than the previous space in numbers of consumers and size of opportunity. By definition, foundational products are those that are central to the brand core. For Starbucks, it is the closest you can get to whole bean without it being whole bean—espresso and brewed coffee. Personalized beverages are still mainly about the romance of coffee and the central theme of the brand, but begin to let consumers control the experience. In-store experiential products are those that create brand value and equity, but are less about the central theme (coffee) and more about need state (refreshment, indulgence). Out-of-store experiential products are those that build brand value and equity, but in avenues outside of the Starbucks store environment, like consumer packaged goods. The last adjacent space is nonexperiential. This is defined as products that do not build the value or equity of the brand, but contain coffee. This space would only be explored if additional coffee sales would be necessary for the survival of the company. A good example is instant coffee. While a good outlet for coffee beans, instant coffee would not add value to the Starbucks brand, and would be a product of last resort. That is why this area is off target and not considered as a viable adjacency space.

It is important to understand how your consumer uses your foundational products and then to define the consumer connection to the adjacent spaces. Innovation in product offerings can move in toward the central core or out toward the edges based on the white space. In the Starbucks adjacency map, there was an opportunity to drive consumers back to the foundation of espresso and espresso-based coffee-centric products like cappuccino or premium brewed coffee. However, the real market value is driven by pushing consumers into the adjacent spaces away from the foundation. Remember, consumers cannot tell you what to offer, but they can tell you when they are ready to move into the next adjacent space and consider whether or not the products you offer will fit their lifestyle. Once you successfully fill a space, a company can begin to test adjacent offerings in adjacent spaces. Coffee liqueur is

only a testable, winnable proposition when in-store experiential is well understood and accepted by the Starbucks' consumer. This is the key to winning at innovation—maintaining your relevance to your consumer while broadening the category of products that they are willing to accept from you.

Can an adjacent space be skipped? It is very possible through acquisition, but generally it will make more sense to your consumer when you don't.

And finally. . . .

Don't Focus on the Enormity of the Goal

Most corporations I have worked with want staggering growth targets hit for their long-term strategies. I don't think your companies are exceptions to that observation. In order to provide returns for shareholders and other stakeholders, our corporate leadership sets growth numbers that are hard to focus on. It was the same in the early day of Starbucks. Not long ago, 1993, Starbucks Corporation put its first growth numbers up for analyst reaction. By 2003, the corporation would have over 5000 stores with 77,000 partners (table 6.2). For those original 80 partners with 18 stores, those numbers were staggering. It is scary to think about that kind of growth around an unproven business. If you only focus on the end goal in your strategy sessions, you can become crippled just by the magnitude and size of the goal. When you look at where you are today against where you need or want to be in ten years, does it scare you? It should! You can't see the resources around you that will make that ten-year goal a reality, you can't see the products in the pipeline

Table 6.2. Growth from 1992 to 2003.

| | 1992 | 2003 |
|-----------------------|---------------|----------------|
| Number of stores open | 165 | 7,225 |
| Partners (employees) | 1,800 | 78,000+ |
| Number of countries | 2 | 32 |
| Customers/week | 600,000 | 25 million |
| Revenue | \$92 million | \$4.7 billion |
| Market cap | \$400 million | \$11.6 billion |
| Menu items | 10 | 32 |

that will deliver what the business needs. The actual 2003 numbers for stores opened and partners hired are much larger than the goals the company originally reported to the analysts and investors. I can only imagine Howard Schultz and Orin Smith and the small staff in 1992 setting these goals—they didn't have 75,200 other partners waiting outside their doors to go to work, they had to find them. The key was focusing on what the 1,800 existing partners did best.

As the president, Jim Donald (who wasn't there to set the original targets), says so eloquently, "We don't serve 25 million customers a week, we serve one customer 25 million times." Starbucks is good at serving one great cup of coffee at a time. It is good at building one store at a time. It is great at hiring one partner at a time—it just does it a lot of times!

So the lesson here is to focus on executing what you are good at doing, and do it a bunch of times. How do you eat an elephant? You can't swallow one whole. You eat it one bite at a time.

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Part II

Accelerating Food Product Design and Development

Chapter 7

BRANDS: A DISCUSSION ON THE DIFFERENCE BETWEEN CREATING GOOD BRANDS AND MEANINGFUL BRANDS

Johannes Hartmann

Why Read This Chapter?

Supporting business development in new parts of the world provided the author a first-hand opportunity to truly understand the important elements of meaningful brands.

Introduction

Over the last six years, my company has given me the very great and ultimately quite educational opportunity to work in Asia, helping a number of company teams build new foods businesses in the region, virtually from scratch. Though the image of a “Western guy comes to the East and then finds out that the world there is not the same” seems to be quite stereotypical, the effect that Asia had on my paradigm of developing brands was enormous, and worth sharing with the reader in this book on products. I knew that brands in general had a huge impact on peoples’ lives. Surprisingly, however, I was blind to the power that brands can be given ascribed “facts” by their users. I discovered that the idea of “branding” is not necessarily limited to the commercial part of

our lives. You and I, as people, are brands. We mean something to people around us in our daily life. We can determine what we mean to people, once we are aware of how we are seen and how we fit into perceptions of our environment. This type of information, from the viewpoint of the marketer and market research, can be quite transformative.

A brand is a kind of mental representation (Ries, 1981) supported by products and by differentiated communication including where the brand is sold. From the very beginning of my endeavor in the business world, I wanted to understand the difference between a brand that “does well” and then suddenly vanishes versus those brands that develop their emotional bonds and continuously renew their relevance. In my own food industry environment, I had the chance to work with strong brands, though most of them were strong only in their immediate geographical environment. I discovered and was quite surprised that only a few brands could successfully travel across borders—being universal for people and independent of cultural circumstances. Before I worked in Asia, I thought that a number of well-defined universal human related themes like “caring,” “creating potency,” “protecting,” etc. were brand themes that could travel without any problems (Callebaut et al., 1996). The work a good marketer had to do with these brand themes was to just translate the category adequately into a given cultural context (Norton, 2003).

Unfortunately, the foregoing strategy of finding brand themes works when the competitors do not have the “brand key.” Once the competition awakens and discovers our strategy, they then improve upon it. They find a better design, creating new features into products and communication. The real goal is to find that subtle difference between “good” and “great,” between brands that can be copied and brands that appear to last forever.

The “Meaningful” Brand, One Key to the Puzzle

Great brands are able to strengthen existing human desire and with it, human ego. For example, a consumer can say to himself, “I can become a more attractive person by using brand X” (Tolle, 2006). However, meaningful brands are able to transcend the human ego behind the brand concept. Meaningful brands have two goals: first they aim to make people feel better about themselves and they aim to make the world a better place.

A story will reveal why there is a place in the world for the meaningful brand. We begin with the idea that brands are everywhere, and indeed can be construed as part of a person.

The Lady from Hanoi

During my time in Asia, I listened to at least 200 qualitative interviews in different countries. In addition, my impressions were influenced by many observations and interactions with people in these countries. Almost everyone I spoke with would first and foremost proclaim that their country and people were very special and had some fundamental requirements, characteristics, needs, or endowments that differentiated it from other countries and peoples. Unfortunately, such prejudices don't leave a lot of space to create marketing systems that travel well across national and cultural boundaries. Indeed, such vehement statements that one's country, culture, people are different maintains chaos, even in the face of data and corporate marching orders. We found that month after month, meeting after meeting descended almost predictably into the discussion of how everything is different in country A versus county B. Workshops didn't help at all.

Our goal at the time was to develop a fact-based information system about how local cuisine and cooking styles related to female motivations. It is not hard to understand that we found very different answers per country. The fractious nature of the investigation eventually brought us to the point that we decided that our objective couldn't be achieved and we implicitly developed arguments to defend that negative position.

A fortunate turn of events provided the opportunity to listen to an interview with a woman from Hanoi in Vietnam. This interview was the starting point to change my view dramatically. It transformed my paradigm about brands and marketing.

Let us give a convenient name to the woman who was doing the talking. We will call our respondent Thuy, but Thuy really represents many people. Thuy was a working woman who lived with her husband and in-laws and a six-year-old son. She worked eight hours a day in a governmental department in Hanoi. In Vietnam, a lot of women work full time, and are also responsible for the cooking and all household chores.

You can imagine that Thuy had a very busy life. Thuy, however, was living with one big problem—she wasn't a good cook. In Vietnam, this

is perhaps the biggest disaster for a woman, because in Vietnam, her status is almost completely determined by her ability to cook authentic and delicious Vietnamese dishes. As one might expect, Thuy's in-laws didn't like her cooking, and to make things even more difficult, they perennially asked for different food than Thuy prepared for the rest of her family. Her mother-in-law gave Thuy a hard time, telling her that she wasn't good enough for her son. The father-in-law tried to ameliorate this mother-in-law vs. daughter-in-law tension, but his efforts made the situation even more pitiful for Thuy. Thuy's husband seemed to be a much better cook, but didn't help her a lot. Looking at the family interaction, it appeared that the biggest problem (and perhaps the biggest opportunity) was Thuy's son who appeared simply not to like anything Thuy cooked. Her son's rejection generated in Thuy's mind a daily dose of very unpleasant guilt.

Thuy was confronted with "not being a good Vietnamese woman" on a daily basis and as might be expected, suffered accordingly. She couldn't develop personal status in the family and she saw herself as a failure, trying to compensate for the lack of worth with her work and the little salary she earned.

One day, Thuy saw her best friend make a very simple dish. This observation, coupled with modern food distribution, would be a turning point for Thuy. She decided to replicate the food at her home. Thuy bought some chicken wings at the "wet market" in the early morning. Before she went to work, Thuy marinated the wings with a new branded product just being stocked at her local supermarket. Thuy put the marinated chicken wings into the refrigerator, and proceeded to her office. When she came back in the evening she took the plate with the chicken wings out of the fridge. During the day, the new product had sucked a lot of water out of the meat and had given the meat a yellowish crust. Undaunted, Thuy took the wok in hand, added some oil, and put in the soggy chicken wings. The aromatic impact of the water/oil combination was immediate, recognizable, almost intoxicating in its quality. Thuy added some of the watery solution from the plate into the oily wok, now laden with the wings. When the aroma wafted through the house, her husband, in-laws, and child came, one after the other, into the kitchen, asking her what she was doing because the aroma was delightful. Thuy was, as you might expect, quite flattered. During the meal, everyone ate without complaining. She fed her child, not taking one piece for herself, and he ate with gusto. After all the wings were devoured, Thuy was

again complimented on her cooking. Of course, Thuy would use the same recipe regularly—replicating the same cooking effects that gave her so much more gratification, and restoring her idea of self-worth. Thuy tried to experiment with the new product in many different ways with other sorts of meat, desiring to mix variety with competence. She had finally discovered something that gave her the status and worth she was seeking.

Where Good and Great Brands Might Arrive and Where Meaningful Brands Start

Thuy implicitly related her success to the product/brand she was using, but perhaps not in the way we would think. She still thought that she was in the driver's seat—she was the cook. But she realized somewhere deep in her subconscious that she had a lot of help that made her feel so much better about herself. She also knew the brand name of the product that helped her. Thuy implicitly ascribed to the brand her feeling of gained self-worth and her ability to be able to cook. At the same time, Thuy allowed herself some explicit gratification about her own abilities, an ascription that she would not give to the brand. Surfacing a direct connection between success and the brand would reduce the emotional and psychological benefits that she enjoyed. The ascription and thus the connection had to be implicit.

“Good and even great brands are the psychological entities that guide the human journey from an existing self to a point that is called the idealized self. They strive to make us better human beings—inside ourselves and outside” (Fouroboros, 2004). This statement is the first fundamental insight for brand equity building and certainly recognized by the majority of marketers. It is based on recognizing the needs of the person's ego, the desire to nourish, strengthen, and grow personal self-worth, as well as the ever-present imagery and status in any given life context.

Within the requirements and constraints of a business environment, we can identify three areas that “drive” good brands, and even perhaps create them. The following structure is inspired by Stephen Covey's *The 8th Habit* (2005).

- *Function*: Every brand needs function. Function means that the brand does something physically to the person who uses it, preferably so that

there is a positive, immediate effect on the user. Function can range from relatively simple sensory aspects (e.g., the aroma of coffee) to the complexity experienced when using the I-Pod. In our story of Thuy, the function is the particular sensory effect the product had on the dish. In addition to that function, however, the brand experience required personal involvement, some skills, and minor effort. That is, function may require other elements beyond the product features, perhaps an interaction with the product. Thuy could still believe that she was cooking.

- *Knowledge*: A brand needs adequate and relevant knowledge that contributes in a meaningful way to the daily life of the prospect. Knowledge involves the competence that a brand gains in the mind of the consumer. Cooking brands often use recipes and chefs as endorsement for the degree and quality of knowledge they want to express. In Thuy's case, her friend was the endorser of knowledge. Mouth-to-mouth advertising is a very important element. Such "buzz" advertising factually transfers the idea of the brand's competence from one to another. Nothing can be more believable. Some philosophies about hypes are built on this notion (e.g., Malcolm Gladwell's notion of the "tipping point" [2000]).
- *Emotional intelligence* (Goleman, 1995): The brand "understands human emotions," or at least accounts for them, dealing with these emotions in a respectful and positive manner. The brand shows empathy and compassion for the individual in his/her specific culture. The brand connects to the inner and outer life of a consumer. In Thuy's case, the brand connected with emotions of feeling adequate, empowered, strong, and in turn conveyed a sense of status. The result is that Thuy and others using the product gain influence on their environment.

In its most ideal state, the brand creates a psychological (also iconic) entity that transcends the three individual items listed above. It delivers, instead, a total "gestalt"—a mental representation of the "positive developmental act, "that is, a representation of what a person could become through growth" (Ries, 1981). This representation stands in direct relation to an internal idealized self.

Beside the three "whats" of good brands, it is crucial to emphasize basics about four "hows"—how good brand experiences can be described.

1. *Coherence*—A brand story must make sense.
2. *Relevance*—The brand applies to what we do (i.e., have a connection).
3. *Resonance*—The brand must be meaningful enough that we don't forget it during our daily lives, or at least when the situation arises when we need it.
4. *Internalization*—The brand must be sufficiently powerful to point out and crystallize what we already think. It makes us “damn proud” in the words of some practitioners. The brand should feel right, because it is already “us.” It moves people because they are ready to, and can handle, the moving (Fourboros, 2004).

Companies often try to build brands on function and knowledge alone, despite the fact that function and knowledge are connected to the most dynamic and least reassuring areas in our brain—the left hemisphere. This left hemisphere hosts logic, rational thinking, and decision making using facts. The left hemisphere is the youngest part of our brain that continually looks for good stories surrounding behavior so that we don't embarrass ourselves, and don't experience negative feelings.

One outcome is that brands built principally on logic alone don't survive very long nor fight particularly well against a determined, powerful competitor. The reason for this is that the left part of the brain simply reacts to the “dance” of the older and deeper brain structures. If we don't listen to the real music, we won't understand the dance. The left part of the brain responds to *real politik*, always weighing alternatives, never really driving for a commitment (Knox, 2003). Brands that compete on rationality and competence alone need better competence stories than their competitors in order to find and maintain some connection with the brain. But, it's a difficult task. The battle in the laundry powder business shows how difficult it is to win this kind of war. Every story about “I am able to wash whiter than anybody else because I have a new technology xyz” can be fought easily by a different and better-sounding ingredient story. Billions of dollars are spent in this area, causing consumer confusion day in and day out.

The need for, and thus focus on, competence stories may be why parts of the IT and communication industries face problems maintaining their brands. The thinking is that these companies try to build brands primarily via logic and competence, rather than linking more emotionally with their customers. And to be fair, who would argue with them when life

cycles of brands in these areas are becoming shorter and shorter. There are those IT and communication companies that dominate by sheer power of size. That supporters label competitors who gain momentum against the big conglomerates as “rebels” and “Robin Hoods” shows the strength of emotion, and perhaps even suggests that emotions might topple big robotlike organizations.

To build emotional connection with their customers, brands need to accept to whom they are talking, and choose their language and message accordingly. Basic human emotions like those we discussed earlier are screened in the oldest part of the brain, the limbic system. After 16 years working in marketing, I believe strongly that in advertising and product delivery, as well as interpersonal relations, it is impossible to “fake-out” this area in the human brain. In whatever way, it discovers everything and is able to sense the difference between honest advice and fake kindness. If an emotional story is nonsense, then this part of the brain will recognize it. If the story isn’t genuine, then it will tell you. If we put personal projections, fake imitations, negative unresolved counter-transference, or desire for over-simplification into place to build brands, we won’t find the necessary attraction nor will we discover emotional resonance, at least not in the long term.

Let’s go into the issue a bit further as we explore the limbic system and branding. Our limbic systems are hard-wired and very simplistic, though hidden by all the educational and cultural stuff that makes us function day-to-day. Once you reach the limbic system with genuine and well-meant effort and the brain allows you to pass the gate, you will have made a fundamental step into becoming a great brand for your audience. If you live up to the trust given to you, you get the chance to become an established and essentially “not-up-for-discussion” entity in the prospect’s life.

In contrast to the more emotional left hemisphere that was described earlier, the right hemisphere works on an abstract level—in metaphors. It makes the connection between the left-brain and the limbic system (Knox, 2003). The right hemisphere determines internal working models (paradigms); in Thuy’s case, for example, a symbolic translation of the relations between the aroma of the cooking product and the emotional gratification. The right brain-hemisphere combines image-cognition (symbolic/sensory experience) and the feeling states, creating a metaphorical translation. Once established, the right hemisphere recognizes the symbol as a roadmap for behavior.

If a brand developer is sufficiently savvy, then he or she magnifies this effect by creating external symbols to summon up the emotional reaction (e.g., Nike's swoosh). After a time of repetition and conditioning, the external symbols can represent the overall brand story because they trigger the right hemisphere paradigms. To summarize these starting ideas about building good and great brands:

The human self needs a place to reside. In our brain the most secure place is the limbic brain (the oldest brain part). Therefore a brand must be composed of character traits, which build shelter for the consumers' journey. These can be care, trust, sex, bravery, whimsy, sobriety, generosity, beauty, wisdom, faith and compassion. Following on these aspects; brand is not a product, not a price. Not approachability, nor attitude. Brand is not a persona. It is the self, a quieter, hopeful, original part of a person, place or thing that can't be neatly tagged yet fit naturally and effortlessly. And it grows along with its admirers. Better still, it helps them grow. In this way, brands mirror the ambition of a human being and reveal themselves as a tool for the journey of becoming the idealized self. (Fourbos, 2004)

Here we have the best definition of good and great brands: they are a "vehicle on the journey of becoming the idealized self." In reality, the idealized self is a reflection of the values of our societies. Her environment builds Thuy's guilt. If Thuy were strong within herself, she would not mind what her family tells her. But people aren't in general enlightened and good brands can fill the gap to maintain human sanity.

In some cases, the idealized self isn't objectively something to reach out to, or worse, the way it is done by companies is morally doubtful. I heard an example where laundry powder contained added grayish ingredients to make the water that was used for rinsing dark, giving women the idea of efficacy. I believe that the given example crosses the line.

From Great Brands to Meaningful Brands

It would be arrogant and counterproductive to say that brands reaching the aforementioned level of emotional resonance didn't do a good enough a job. In fact, many brands never even come close to doing this

job. They survive anyway delivering their companies good revenues. The topic was written about extensively by Al Ries, one of the most important gurus on brands and positioning. In Ries and Ries's book *The Origin of Brands* (2004), he describes how competitive environment forces brands to make a difference in the brain of consumers in order to survive. Most of these brands face an intensely competitive environment. We often hear talk about the pure "Darwinism" or so-called Darwinian competition that forms the landscape of brands in our society. Brand developers should be aware that, just as in ecosystems, there is a lot of competition in branded marketing and a lot of change going on as well. This playground allows only the best-fitted brands to survive.

Let's return to our study of foods, food habits, brands, and how in Asia the consumer deals with brands in their own ecosystem. In our Asian work, we were quite happy to discover several of these emotion-laden, positively oriented mind positions for our brands. In some cases, we were even able to translate the positions from one country to another, albeit with a fair amount of effort. A lot of the effort was within the company, not across countries. We didn't come to the point that a brand idea was able to travel between geographies and racial related belief systems and at the same time be independent of individual or collective egos inside and outside the companies.

The reader would ask why it is necessary to search for it, if brands are successful anyway. To explain the need for it, I have to talk about another interview that took place in Jakarta, Indonesia, on a very hot July afternoon. My team and I had been listening for several days to different women telling us about their lives and problems. We wanted to understand what kind of values and beliefs the Indonesian women had. Our goal was to develop the right tonality for advertisements. We were exhausted. I was joined by a group of local colleagues, all of them women, making me, the author, the sole male in the group. My female colleagues were listening to their fellow countrywomen and they were sometimes embarrassed when reminded of their own family situations.

We were listening to Ira, a woman in her 40s with four children. Ira's husband was a taxi driver. His average monthly income was around 400,000 rupiah (equals 40 dollars). The couple lived in a small, rather impoverished hut close to the freeway. Ira recounted the details of her life married to a man her mother had chosen for her. Her parents were too poor to give her a better education that would have guaranteed a job for her. Ira had to marry to escape the poverty of her family, only to

create another poor family. Now she found herself in the same kind of situation her mother was in 20 years ago. There was not enough money to send two of her four children to schools. She was thinking about her younger daughter, how good she was at school. However, there was no way to maintain the situation; that daughter would have to marry and leave the family in order to better herself, and to relieve Ira's financial burden.

Ira wasn't complaining about her situation, quite the contrary. Ira was speaking with grace and humility about her life, and her deep-felt desire to change something of what she perceived to be her daughter's destiny. When her first tear fell, my colleagues behind the screen could not hold theirs anymore. We were sitting there crying for Ira and though we came from different parts of the planet, we knew that we wanted to change Ira's life, or better, we wanted to change the lives of all of Iras around Asia, who live in the grip of poverty and dependency from parent to children, from generation to generation.

Once Ira was gone, the group of marketers sat around, looked into each other's eyes, and recognized that we had just witnessed a brand-based transformation. We promised ourselves that we would make a difference through our brands. We had just experienced one of the powers of the brand to which we had been previous blind. Suddenly one of the local (i.e., Asian) colleagues began to talk about how the company's local brands could be used via activation to collect money for consumers such as Ira's daughters, giving them the opportunity to go to school. The brand we had in mind could build up a fund to collect and share money with those families in need. Another colleague began to talk about spending one of her weekends to tutor the girls. At this point, the brand leader suggested we could bring our emotion-based responses into reality, and indeed we might motivate the whole company to do volunteer work on a regular basis.

Not so much about the specific ideas, the aforementioned moment was one where everybody in the room saw the same thing. We all wanted the same goal, stated in a different way. We decided to leverage a commercial entity on a platform where it could better humankind. We saw the power of this concept at our next regional meeting, where we discussed it with our colleagues from other geographies. They all were touched by the idea. The advertising agency involved immediately knew how the new branded idea could be captured in and enhanced by a "holistic" communication program, involving different media, different talents,

and different executions, all toward the same objective. Creativity unfolded everywhere and, on a personal basis, I had never before seen any commitment like this in any group of people. From that day on, everyone involved in the brand development process knew the reason for going to work every morning. They felt the urge to do something meaningful by giving meaning to a brand. It transcended the initial notion of “everything is different in our country,” and developed energy to help each other find approaches that would be successful. Vision and energy guided us into one direction. Individuals “volunteered” their skills beyond the call of the project, as the true meaning of the work was felt by all. There is no need to talk about the huge commercial success the project engendered; such commercial success was simply a by-product for us at that point in time.

In addition to the three dimensions of good brands that I discussed earlier, the foregoing story suggests one more factor that leads us to meaningful brand development: social intelligence (Covey, 2005)—the brand and all people involved in its development want to touch universal human truth. The brand and its people seek to grow humanity inside and outside the company. Individual ego becomes secondary. These “meaningful” brands transcend ego and defining universal human meaning; they want to make this world a better place.

It is difficult to instantly discover meaningful platforms for brands, no matter how strong the marketing directive and corporate desire may be. The theme or specific nature of social intelligence needs to stand in relation to function, knowledge, and emotional intelligence of a given brand. It will sound artificial to the limbic brain unless the brand has the desired meaning in its genetic code. A brand for condoms can obviously make an effort to stride against HIV. A computer company or a software developer could think about computer literacy in the third world and develop products and activities that help children in the third world to reduce the gap with the more developed world. In any event, the mission of the brand comes out of the context in which it operates. The exact nature of that mission will necessarily be related to the brand’s origin.

Pragmatics—How to Discover Meaning for a Brand

The stories I told about Thuy and Ira are real stories. However, I am sure that although they could have occurred in any given research situation,

they might not have made the impact to another group of people in the way they did to us. This brings us to pragmatics, the actions that the group might follow to bring out the meaningfulness of brands.

The team was looking for something they couldn't describe yet. The individuals were, as separate people, traveling on personal journeys, trying to find meaning in their lives (Frankl, 1959). This situation does not always occur, and when it occurs it may not be recognized for what it is. Only in hindsight, perhaps, can the opportunity be recognized. We were members of the same team for an extended period, and so were able to look at research and insights, over time, each person growing with the insight. Over this period, we all began to realize that with every piece of research and with every personal talk we had with our consumers, we were looking in the face of humanity. The group and the individuals felt the need to gain understanding, for some higher purpose. Some individuals felt the need to bring a higher awareness to the corporation; others felt that the information we gathered and insights we discovered provided new appreciation about their relationships with their partners and parents.

The most important feature was the recognition of coming into contact with something higher, despite the factor that we were dealing with a food product. By achieving that degree of awareness, team members discovered how they were projecting their own past realities, rather than facing today's truth. This was indeed something they didn't want to accept anymore. Something in them was moving ahead to illuminate simple human truth. This inside-out process of everyone involved in the development process was an absolute prerequisite to find genuine meaning for a brand.

The following guidelines can help a team that is interested to reach the required degree of maturity.

1. Build a diverse team. Though this may constitute a barrier at the start of the journey, different viewpoints, different cultures, different beliefs, and different value systems are very helpful building blocks to jump-start awareness. Awareness will then begin to grow, as long as the diversity is maintained.
2. Believe in the collective genius (Surowiecki, 2004). Great insights coming from only one single person are the exception, not the rule, in business. In most cases, when business miracles occur, a group of people have been involved who were able to inspire each other's

thinking and believing. The collective genius is always much more efficient and effective than the individual genius.

3. Work with humility (Collins, 2001). I had the chance to work in an area where even the highest boss found it important to join into difficult team meetings to sweat out an idea or to work through a difficult piece of analysis. We were all equal.
4. Role-model desired behavior. Leadership has to demonstrate explicitly that the company believes in the endeavor. Our bosses showed that they were involved and role-modeled desired behavior. Companies “adopted” orphanages. The whole Asian leadership went into tsunami-hit areas to rebuild small shops, schools, and other buildings. We spoke with people in the areas to revive the “lost spirit,” and to give encouragement by being there. The experiences of our people during these times translated back into their daily work.
5. Trust the process and have patience. The transformation of a brand development group doesn’t happen overnight. Every participant follows his/her own path at his/her own pace. In some cases, this group behavior might be a bit frustrating, because the slowest individual in the group determines the pace of the whole team. Therefore, the team needs to create moments of self-reflection and moments of consumer connection where the process can be intensified and accelerated. The team has to continually review where it is in the process, act as a group, yet allow individuals to develop at their own specific pace.
6. Stay involved in the research methodology. The way consumer research is sold to companies today has not dramatically changed during the last decades, despite some of the better technologies. This lack of progress in method might not be the biggest problem, except that a lot of methods are sold like medicine. “If you have a problem I give you tool XYZ and your problem will be solved. Once we go through 3–6 weeks of good research I give you a nice presentation and you are cured, your problem goes away.” Reality is so much different. Good methodology always combines content and process and allows that the team members develop their outcomes. A final presentation of research that comes without personal involvement of team members is a waste because it doesn’t allow everyone to internalize and own the findings. The main principle is that you can only believe and do things if you feel them. Finally, everyone should be aware that the insights may not come as planned. There may be specific, unexpected moments that finally made the difference. If teams go

their journey and are continually stimulated in a positive manner by process and methodology, it will happen to them. There is something like synchronicity involved. Deeper analysis needs to be summarized to create real insights for companies to define the meaning of their brands. To summarize the above: Meaningful brands can only be an outcome of process led by a mature group of people going through a personal discovery journey that is designed to connect them at some level with the greater humanity. The journey requires the desire of everyone involved to illuminate universal human truth, and to not settle for anything less.

What About the Money?

This is a chapter in a business book, not a book on ethics. Some might say that this goal and approach sound quite nice, but how does it really move the business ahead? Where is the money? Or the picture of money doesn't fit in all of the nice talk. Let's see the connection between this approach and money. Again, the connection doesn't come from preaching as much as from relating experiences.

When my company launched a new product on the Dutch market, its realization required the installation of a new production line. I remember that day because I was invited to join the first run. The new team that was hired was very excited and you could sense their pride in the company. Twenty new people had to be hired to handle the line, most of them with families. The money that was created went to jobs, to profits, to growth, all fueled by positive development.

It gives deep satisfaction when my company grows, thus guaranteeing wealth to the people that are the company. Growth is a necessity, but companies are always able to choose the path they take to generate that growth. The effort to build meaningful brands doesn't only deliver immediate business success for the company. The effort will make money. The effort will make a company strong and make it very difficult for the company's brands to be defeated by competitors.

The development and maintenance of meaningful brands though allows a company to go through its corporate life in a graceful, successful, and rewarding fashion. The company can choose this and make the world a better place by building trust, pride, and admiration inside and outside the company. In the end, such a meaningful path does not create a

conflict with making money, but rather produces a synergy that may last far longer than any momentary boost in brand performance obtained by other means. Meaningfulness in brands may, along with innovation, constitute a true new competitive advantage.

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Chapter 8

MARKET FORCES: THE PUSH-PULL OF MARKETING AND ADVERTISING IN THE NEW PRODUCT BUSINESS

Jeffrey Ewald and Howard R. Moskowitz

Why Read This Chapter?

Both marketers and product developers will have a better understanding of their partnership in driving successful new product development in today's marketplace after reading this chapter.

Introduction

In this chapter, we examine the interrelationship between a product and its brand, and posit that the product itself can be an integral element of the marketing communications mix. The product represents the “push,” that which is going to market and is pushed into the distribution channel, while the brand is the “pull,” that which creates the consumer interest. The role of the product is particularly critical, itself a marketing communication element. The physical product contributes both to the development of consumer expectations (i.e., trial) and to the delivery of fulfillment against those expectations (i.e., repeat). Unacceptable physical products promise almost nothing but disaster; acceptable physical products may or may not create a market success. This is clearly a shift in the paradigm between marketing, advertising, and product development.

New product environments are characterized by significant hyper-competition on the one hand and increasing introduction costs on the other, both followed by high failure rates, which can literally waste the invested monies. When the estimated cost of a new product launch is between \$20 million and \$50 million, and the chances of success about one in five (Kotler, 2000), it's clear that developing a better understanding of how consumers choose a product and what they expect when they try a new product can have a significant impact on the ROI of new product efforts.

What Is a Brand?

The traditional definition of a brand has its roots in the Old West's practice of placing a particular ranch's brand on its cattle. For modern practice, the American Marketing Association has adopted the following definition for the term "brand": "a name, term, sign, symbol, or design, or a combination of them intended to identify the goods and services of one seller or group of sellers and to differentiate them from those of competition" (Keller, 1998). This definition, "brand as stimulus," conceives of a brand as a set of visible signals that are controlled by the brand manager: names, logos, colors, packages, advertising, and so on. Implicit in this notion is that a brand's components, its symbols, can actively be manipulated in order to achieve the marketing objectives of the moment.

An alternative definition of brand emerges from taking a consumer perspective. In this view, "a brand name represents a collection of concepts that consumers learn to associate with a particular product" (Nagle, 1979). Over time, and with repeated exposure to both the symbols and the product, this internally held collection of notions congeals into a deeply held set of beliefs or impressions, which can act as a time-stable reference. Kapferer argues that these impressions create a cognitive filter; dissonant attributes are discounted and reinforcing attributes are retained so as to create an illusion of permanence and coherence within a brand's perceptual space (Kapferer, 1997). This alternative perspective for the definition of a brand is a consumer's perspective and can be summarized as "brand as a memorized response." We see this difference most strongly in figure 8.1. On the left is what a manufacturer might perceive to be the brand—note that the manufacturer perceives

What is a Brand?

| | |
|-----------------------------------|--|
| Manufacturer's Perspective | Consumer's Perspective |
| Name Logo Colors Symbols | Memories Experiences Stabilizing Influence |
| Stimuli | Responses |

Figure 8.1. What is a brand?

the brand as something to be acted on. The right, as noted above, comprises the consumer's perspective, which involves responses to brand stimuli.

Why Product Developers Should Understand the Inner Working of Brands

Consumers choose brands because they expect that brand to perform in accordance with the set of perceptual attributes they hold in their memory, that is, the mind-print of the brand. Furthermore, today, an era awash in product proliferation with enormous customer choice, consumers are increasingly demonstrating a cowardly preference for the familiar (Travis, 2000)—for brands that consistently deliver against expectations. The brands that consistently deliver are remembered. Knowing how to deliver the sensory characteristics among others is one of the keys to brand success. By framing expectations, a brand (as defined by consumer perceptions) shapes the future of its products. The successful product developer must therefore first develop a thorough understanding of the target audience's expectations for the product—not only in the context of the category, but also in the context of the consumer memory and meaning of the brand.

Through the set of accumulated associations over a lifetime or even during a relatively short period of days and weeks, brands convey a

rich set of meanings. Although the leading experts in branding and brand equity use differing nomenclature and differ somewhat in subtle variations of brand aspects (e.g., Aaker, 1996; Kapferer, 1997; Keller, 1998; Aaker and Joachimsthaler, 2000), there is substantial agreement and common thought at the higher levels of abstraction as to how brands convey meaning to consumers. In general, brands create meaning in four major aspects: (1) functional, (2) situational, (3) symbolic, and (4) price and quality.

Functional Meaning

Functional meanings usually involve those key product-related attributes that are intrinsic to the category itself. For food products, these meanings are often linked to basic physiological attributes. For example, Hershey means chocolate, and Weight Watchers means lower calorie dishes. Brands can also carry finer-grained meanings. Try this test: *Which of the following four candy bars has the most peanuts: Milky Way, Baby Ruth, Snickers, or Payday?*

Without opening a wrapper, tasting the product, or even seeing a picture, most people can extract the correct answer (i.e., Payday) from their memories. The brands have functional meaning on the “amount of peanuts” attribute.

Situational Meaning

The situations (places, moments, social contexts) with which brand use is associated can be characteristic of a specific brand (Franzen, 1999). These associations have personal, intrinsic meaning as compared to the more extrinsic symbolic meaning of the above-mentioned “badge brands.” For example, Betty Crocker evokes childhood memories of Mom baking in a warm kitchen, the smell of anticipation wafting through the air—memories that shape desired characteristics for products that use the name Betty Crocker.

Symbolic Meaning

Symbolic meanings usually correspond to non-product-related attributes, especially user imagery. A brand with symbolic meaning may relate to an underlying need for social approval or personal expression

(Keller, 1998). Symbolic brands are often known as “badge brands,” where consumers believe that brand usage signals some information about themselves to others. The beverage industry has many examples of “badge brands.” Good examples of these are Samuel Adams in the beer category or Bombay Sapphire in the gin category.

Price and Quality Meaning

Price is a particularly important attribute because consumers often hold strong beliefs about the price and value of a brand, and may classify the way they organize their knowledge about a product category in terms of the price tiers of different brands (Blattberg and Wisniewski, 1989). At the extreme, many consumers perceive store brand products to be a lower price and a step lower in quality than their name-brand counterparts. Haagen Dazs ice cream represents a premium priced brand that carries a higher quality perception than do other brands such as Sealtest. This price/quality position carries along with it an unstated, internal meaning, which helps to define the range of acceptable new products for the Haagen Dazs brand. Haagen Dazs flavors must be rich, creamy, and chock-full of the highest quality particulates.

Brands as Frames of Reference

To a social psychologist, “frames of reference” have to do with *any* context that exerts a demonstrable influence upon the individual’s perceptions, judgments, feelings, or actions (Allport, 1940). Marketers are most interested in identifying influences on purchase behaviors.

We noted earlier that brands can take on a variety of meanings based on attributes and associations that a given consumer attaches to the brand. How these attributes and associations impact *choice* (the selection of a preferred alternative) (Random House, 1999), depends on one’s mental frame of reference.

Emery (2003) observed, “The meanings we make of a fact may be determined *more* by our frame of reference than by the fact itself.” This observation suggests that the specific associations and attributes that consumers attach to a brand are less important than the comparison of those associations and attributes relative to other brands that are also held in memory. It is the comparison, the relative position on various

dimensions in the consumer's mind, which makes all the difference—which defines the brand.

As frames of reference, brands help to define the competitive set. They therefore serve as enablers that allow consumers to make relative evaluations between offerings. To use an earlier example, “Payday has more peanuts than other candy bars (relative comparison) and I like peanuts . . . therefore I will choose Payday.” It is this relative meaning of a brand that helps drive choice.

The Relation Between the Brand and the Product

So far, we have established the concept of brand as a mental construct that helps to establish a frame of reference that drives choice. Given this “mental nature” of the brand, if a brand is to succeed, the product must truly deliver on those key attributes that formed the basis for that particular brand's selection, that is, the attributes that differentiate the brand from its competitors. In other words, products are key to the brand, and in turn, as one might expect, the sensory characteristics are key to the product.

The notion of a “virtuous circle” (fig. 8.2) can help us better understand the interplay between a brand, as it frames and shapes choice, and the product itself, as it supports and builds the brand's associations and reinforces points of competitive differentiation.

Products with attribute profiles that amplify those particular brand differentiators considered to be critical in a consumer's memory are those key brands that, by definition, continually reinforce the brand's “choice drivers.” In turn, these drivers of brand choice create a frame of reference that focuses attention on certain product attributes and filters out those product attributes that are not core brand drivers. It is this

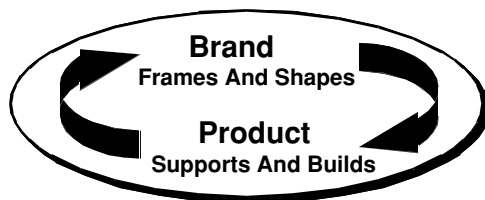


Figure 8.2. Alignment of brand and product is critical to achieve virtuous circle.

alignment between brand and product, which to a great degree, albeit not completely, determines market success. If the foregoing statement appears to be circular, that is, key brands are those that have and reinforce the attributes that belong to the key brands, it is meant to be. We have here a system where the power of the brand is continually reinforced by the experience with the product. In a sense “the branded product experience” reinforces that one has “experienced the brand.”

Because consumers buy the product and the brand together as a unit, product development can no longer be done in a vacuum. Brand has to be part of the initial thinking, the initial product development. One 20-year old case where a brand clearly shaped the expectations of the product involved Coca-Cola. Blind taste testing had demonstrated that the new formula was clearly superior to the original formula. The brand was introduced with unexpected backlash; and the classic formula was eventually reintroduced and the new formula disappeared (New Coke—A lesson in brand loyalty).

Another concept, silver bullet, is the notion that a product can be used strategically to change brand perceptions (Aaker, 1996). The Goodyear Aquatread story represents this idea. When this product was introduced, the value of the Goodyear brand was declining and, although the company had introduced a few minor product improvements, they had produced no distinct innovations. For the Aquatread concept, no product prototypes were developed until the concept and positioning strategies were completely designed. The communication of the product highlighted the characteristics developed in the concept work. Although the deeply grooved aqua-channels contributed only a minor functional benefit from a pure product delivery standpoint, the unique tread pattern, name, and iconic demonstration of the grooves in action (Goodyear introduced the Aquatred with a memorable television commercial featuring a tire rolling over a glass-plate so that the viewer could see water being pushed away from the tire itself) clearly communicated a unique and important end-benefit: better traction on a the wet surface. The product’s compounding and chemical composition actually delivered most of the functional benefits, but those aspects could not be communicated as effectively as vividly demonstrating the grooves gripping the roadway. Once you know what the benefits are, product development can be used to build brand value.

These examples demonstrate that satisfying consumer wants and needs is no longer sufficient. Kotler revolutionized marketing thought

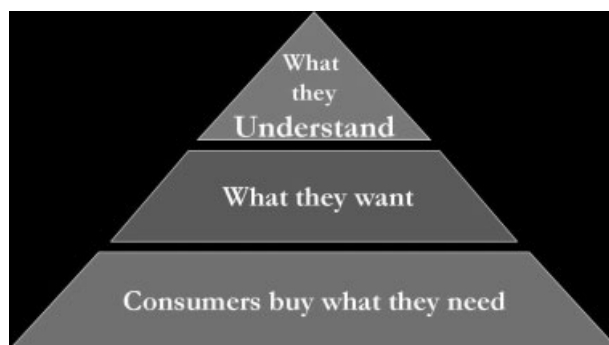


Figure 8.3. In today's marketplace, consumers buy what they understand; needs and wants are necessary but not sufficient.

in the 1950s and '60s through the notion that consumers buy what they need and want. In today's marketplace, consumers buy what they understand; needs and wants are necessary but not sufficient (fig. 8.3). When confronted with choices, consumers need to understand why products exist. Products that communicate those features and benefits tend to be differentiated, as well. As shown in this equation, $S = f(F/E)$, satisfaction (S) is a function of fulfillment (F) over expectations (E). If a product overdelivers against expectations, satisfaction is high and consumers are more likely to purchase that product again. Fulfillment is the primary role of the product; expectations are set by the brand and marketing communication.

How Can Marketing and Product Development Teams Ensure They Are Achieving Alignment Between the Brand and the Potential New Product?

Research to understand the core brand associations has traditionally relied on qualitative techniques—some of them quite sophisticated and insightful. A leading brand consultancy uses a unique process to uncover key associations that define the brand as it exists today, turn each association into a continuum of attributes and benefits, and then use combinations from the extended attributes and benefits to create new product concepts for subsequent testing and validation (Prophet, 2005).

Another innovative approach for understanding how consumers view brands is the Zaltman Metaphor Elicitation Technique (ZMET; Keller,

1998). Gerald Zaltman and Robin Higie Coulter designed the ZMET toolset to let nonverbal communication reveal the mental models that drive consumer thinking and behavior in order to better understand how brand memories and perceptions influence choice. ZMET probes beneath the surface to reveal “what people don’t know they know”—the underlying motivations that influence a person’s decision to buy a product or form an opinion. Because approximately 95% of all thought occurs in the unconscious, most of these factors are missed by traditional research methods (Olson Zaltman Associates).

These approaches, and others involving the use of projective or other psychiatric interview techniques, require experts skilled at interview, analytical, AND interpretative methods. The approaches uncover what a brand means and establish clear goals for the product development efforts so that these efforts best align with the intrinsic brand meaning.

Conjoint measurement refers to a class of research and analytic procedures whose objective is to estimate the contribution of components in a mixture (e.g., concept, advertisement, actual physical product) from measuring reactions to the combination (Green and Srinivasan, 1990). Conjoint measurement becomes one of the critical measurement tools to utilize when blending the complexity of product, brand, marketing, messaging, and advertising together.

The following is an illustration of conjoint measurement that we use to help make sense of the discussion we have had thus far. In a set of 20 conjoint analysis studies, making up part of the 2001 Crave It! databases, respondents evaluated concepts comprising product features, brand names, emotional statements, and the like. Each of the 20 studies, one study per food or beverage product, comprised 36 elements or phrases that were mixed and matched in the various test concepts that were evaluated. Nine of these 36 elements in each study were product descriptions and 9 elements represented brands or other communication benefits (Moskowitz, 2006).

Looking at the top ten ranked utilities from high to low in table 8.1, we see rather quickly that it is not brand but rather the product description and sensory promise that carry the day, driving consumer acceptance. These results leave us with the sense that more must be going on—that brand names by themselves don’t have the impact that one might think based upon marketing theory. They do not enter into the most acceptable messages; those are taken up by popular indulgent foods. Nor do

Table 8.1. Utility values for the best performing and worst performing elements from the 2001 Crave It! database.

| Food | Element in concept study | Utility |
|------------------|---|---------|
| WINNING ELEMENTS | | |
| Nuts | Fresh mixed nuts like pecans and cashews, not a peanut anywhere | 26 |
| Nuts | Large cashews, brazil nuts, pecans . . . With just the right amount of salt | 24 |
| Tortilla chips | With all the flavors and sides you want . . . cheddar, nacho, ranch, lime . . . refried beans, melted cheese, salsa, and jalapenos . . . whatever | 23 |
| Steak | Thick cut T-bone steak grilled to perfection using grilling salts | 21 |
| Steak | Juicy filet mignon cooked medium rare to melt in your mouth | 20 |
| Chicken | Plump, juicy chicken breast, marinated in a special sauce and cooked over an open fire for a smoky grilled taste | 20 |
| Tacos | Homemade soft taco shells wrapped around warm simmered meat and topped with chunks of tomato and shreds of lettuce and cheese | 20 |
| Cheesecake | Cheesecake with swirls of raspberry, chunks of white chocolate, baked in a crunchy crust and garnished with pecans | 19 |
| Ice cream | Sundae with scoops of ice cream, thick sauce, chopped nuts, real whipped cream, and a bright red cherry | 19 |
| Cinnamon rolls | Big 3-inch spiraled rounds of dense chewy pastry like a donut with sweet cinnamon inside, covered with sweet icing | 18 |
| Cheesecake | Dense cheesecake swirled together with ribbons of chocolate chips in a chocolate crust . . . served with a raspberry sauce drizzled across your plate | 18 |
| BBQ ribs | Slow simmered for an award winning smoky flavor . . . hickory, western, or mesquite . . . or that rich, meaty flavor you love . . . whatever | 18 |
| Cheese | Chunks of white Vermont cheddar cheese aged to perfection | 18 |
| LOSING ELEMENTS | | |
| Peanut butter | Scoops of peanut butter with ribbons of marshmallow throughout | –15 |
| Olives | Olive paste with lots of chopped olives | –15 |

Table 8.1. (Continued)

| Food | Element in concept study | Utility |
|-----------------|---|---------|
| Peanut butter | Peanut butter blended with ribbons of jelly . . . Tasty and so convenient | –16 |
| Hamburger | At Jack-in-the Box | –16 |
| Chocolate candy | With fruit fillings in any flavor you want | –17 |
| Cola | Diet cola with a slice of lemon . . . the world's most perfect drink! | –18 |
| Coffee | Decaffeinated whole bean coffee for those who want all the taste and none of the caffeine | –19 |
| Olives | Small dark wrinkled olives marinated with hot pepper flakes | –19 |
| Cola | From Shasta | –20 |
| Cola | From Tab | –22 |

Source: Data with permission from It! Ventures, LLC.

brands appear as the least acceptable messages, except for some soft drinks (Tab and Shasta). It is the product description that does well, nothing else, not even messages of product quality. But the product description itself must be conjoined with a product, because otherwise it is meaningless.

Brands as Added Value—Interactions and Scenarios

Because brands by themselves do not appear to add much does not, however, mean that brands are irrelevant. It may well be that brands act in *other ways* to drive consumer responses, and that the conventional method of experimental design and “linear analysis” fails to reveal these alternative effects. Discovering these “other ways” always interests, and usually disappoints, because the precise way that brands impact choice is never as exciting as their promise.

If we rid ourselves of marketing melodramatics, and think in a more prosaic and yet possibly poetic fashion, we might liken brands to multipliers. The notion of “motivation” as a multiplier of “habit” is well respected (Klitzner and Anderson, 1977) and certainly not dismissed as a flight of fancy. Experimental psychologists empirically tested this hypothesis—by operationally defining some behavior, imposing a

motivational situation on an animal, and observing the magnitude of behavioral shifts. The resulting magnitude of shift was more in line with a multiplication than a simple addition.

Brands Act as Multipliers

By themselves, brands may not drive acceptance, as we saw in table 8.1. However, in concepts, brands may *synergize* with specific elements so that the combination is much greater than would be expected from treating the brand and other message as independent. To understand how brands act as multipliers, we have to discover pair-wise “interactions” (synergies, suppressions) in a conjoint analysis task. We look for evidence to show that the particular combination of brand name and message is far more potent or far less potent than would be expected on the basis of treating brand and specific communication as entirely separate entities, and just adding their individual utilities. That is, if we are able to measure pair-wise interactions between brand and concept element, are these interactions significant, and are they relatively strong?

Brand as Director—Brands Direct Responses of Other Elements in a Concept

When a respondent sees a brand, he or she expects certain things and these expectations may vary by brand. If there is a set of specific expectations dictated by each brand, then treating the brands and the other elements as independent variables in one large regression model may not work. We may learn more by analyzing in detail limited sets of concepts comprising only one single brand name, to discover what particular elements work with that brand name, and whether there is a unique pattern, brand-specific, of what “works.”

Some Empirical Data—Results of a Study to Understand What “Brand” Really Does

The study we will use as an educational device to understand brand was run to identify the mind-set of the consumer for big issues of today—health versus taste, effect of messaging, effect of store venue. This

study was designed using inputs from three much larger conjoint studies related to craving, health, and convenience (over 90 conjoint studies with more than 13,000 consumer responses in aggregate—Moskowitz et al., 2005).

For the specific purposes of this study, comprising four silos of nine elements each, we created a basic design structure comprising 60 combinations. The respondent was told that the study would deal with “what is IMPORTANT to you with respect to the choices you make in foods and other activities related to food.” That is, the respondent knew that this study would be about the intersection of food and lifestyle/values.

What “Simple Ideas” Win in the Consumer’s Mind?

In table 8.2, the highest and lowest utilities tell the story, revealing the mind of the respondent. Similar to other studies, the highest scoring utilities were descriptions of the specific nutritional and/or sensory benefits, and the lowest scoring elements were brands. The individual brand elements show a fairly wide range in utility, from +4 (From Kraft and From Campbell’s) to −7 (From Trader Joe’s and From Wal-Mart). Brands from manufacturers show higher interest than shopping venues, which were all negative. Attaching the venue name to a food product in this study’s context, will lose 2–7% of the interested respondents.

Brands as Multipliers

We’ve just seen that brands (product brand, manufacturer, and store) do not do much. So, we’ve reaffirmed the original finding that brand by itself is not a strong player. Yet, marketing wisdom tells us again and again that the brand is critical, and perhaps the brand is far more than the product.

What’s wrong with this picture? If brand is so important, why doesn’t it show up as a driver of importance or interest in the concept? Brands may be important, but they may act in a different way, an indirect way. They may multiply the impact of an element.

We can test for this different, that is, “multiplicative” way that brands act, by looking again at our large data set. When we partial out the effects of the 36 elements, what remains are the interactions between pairs of elements. Of the 486 different pairs of elements, there were

Table 8.2. Top scoring elements and utility values for the linear model.

| Silo | Element | Utility |
|---|---|---------|
| Top Scoring Elements | | |
| A—Specific nutritional and sensory benefits | A6—One pot. One step to a meal. Start it in the morning, and have it in the evening just as you walk in the door | 11 |
| A—Specific nutritional and sensory benefits | A8—Prepared just to your liking . . . just the way your mom or someone special made it . . . so close to homemade you can almost smell the meal | 9 |
| A—Specific nutritional and sensory benefits | A7—Fresh juicy slices, slow roasted for added flavor, hot off the rack | 7 |
| A—Specific nutritional and sensory benefits | A2—This food includes calcium and other nutrients that give you bright teeth, shinier hair, and smoother skin | 7 |
| A—Specific nutritional and sensory benefits | A3—Food that contains 20% of your daily requirement for fiber . . . important for reducing your risk of chronic diseases like heart disease | 7 |
| B—More general health and quality benefits | B3—Provides essential vitamins and minerals your body needs including potassium, magnesium, and zinc | 6 |
| B—More general health and quality benefits | B2—Contains essential omega-3 fatty acids, which may reduce your risk of heart disease | 5 |
| Lowest Scoring Elements | | |
| D—Brands, stores | D8—From Whole Foods | −2 |
| D—Brands, stores | D2—From Newman's Own | −3 |
| D—Brands, stores | D7—From Trader Joe's | −7 |
| D—Brands, stores | D9—From Wal-Mart | −7 |

Source: Elements courtesy of the Understanding and Insight Group, LLC.

15 combinations that had significant pair-wise interactions (about 3% of the terms). Of those, brands do act as multipliers in 9 of these 15 combinations (table 8.3). The interactions can be positive and negative, even for the same concept element, such as Betty Crocker: for example, the combination *Tastes like it was prepared by someone who cared*

Table 8.3. Significant pairwise interactions containing brand.

| Element (utility) | + Brand (utility) | Pairwise Utility |
|--|-------------------------|------------------|
| B9—Tastes like it was prepared by someone who cared about you (+2) | From Betty Crocker (+2) | 13 |
| A6—One pot. One step to a meal. Start it in the morning, and have it in the evening just as you walk in the door (+11) | From Whole Foods (−2) | 12 |
| A8—Prepared just to your liking . . . just the way your mom or someone special made it . . . so close to homemade you can almost smell the meal (+9) | From Quaker Oats (+3) | 12 |
| A1—As part of a lowfat diet, this food may reduce the risk of some types of cancers (+5) | From Whole Foods (−2) | 11 |
| A5—Meals that require NO preparation. Just heat and eat! (+6) | From Whole Foods (−2) | 10 |
| C9—So irresistible, just thinking about it makes your mouth water . . . (+2) | From Trader Joe's (−7) | −10 |
| C1—Calms you . . . (−1) | From Kraft Foods (+4) | −11 |
| A5—Meals that require NO preparation. Just heat and eat! (+6) | From Quaker Oats (+3) | −13 |
| C1—Calms you . . . (−1) | From Betty Crocker (+2) | −14 |

about you + *From Betty Crocker* has a strong positive utility value of +12, substantially higher than the two components separately, which each have utility values of +2. In contrast, the combination *Calms you* + *From Betty Crocker* has a utility value of −14, the largest negative utility, even though the components have utility values of −1 and +2. It appears to be impossible to predict which combinations will show interactions, the direction of the interaction (synergy, suppression) or

Table 8.4. Utilities of concept elements for scenarios based upon strata in Silo D (Brand, Outlet).

| | Overall utility | Quaker Oats | Newman's Own | Kellogg's | Kraft Foods | Betty Crocker | Campbell's | Trader Joe's | Whole Foods | Wal-Mart |
|--|-----------------|-------------|--------------|-----------|-------------|---------------|------------|--------------|-------------|----------|
| Overall utility | | 3 | -3 | 1 | 4 | 2 | 4 | -7 | -2 | -7 |
| As part of a lowfat diet, this food may reduce the risk of some types of cancers | 5 | 4 | 8 | -2 | 2 | -1 | 0 | 8 | 13 | 10 |
| This food includes calcium and other nutrients that give you bright teeth, shinier hair, and smoother skin | 7 | 2 | 7 | 5 | 4 | 13 | 4 | 15 | 7 | 12 |
| Food that contains 20% of your daily requirement for fiber ... important for reducing your risk of chronic diseases like heart disease | 7 | 12 | 7 | 5 | 12 | 3 | 10 | 11 | 8 | 7 |
| Meals that require NO preparation. Just heat and eat! | 6 | -4 | 9 | 6 | 10 | 5 | 4 | 3 | 16 | 11 |
| One pot. One step to a meal. Start it in the morning, and have it in the evening just as you walk in the door | 11 | 7 | 13 | 9 | 8 | 16 | 7 | 16 | 20 | 4 |
| Fresh juicy slices, slow roasted for added flavor, hot off the rack | 7 | 3 | 11 | 8 | 11 | 8 | 5 | 11 | 3 | 6 |

| | | | | | | | | | | |
|--|---|----|----|----|----|----|----|----|----|----|
| Prepared just to your liking... just the way your mom or someone special made it... so close to homemade you can almost smell the meal | 9 | 19 | 17 | 4 | 3 | 8 | 8 | 12 | 6 | 13 |
| Luscious, creamy texture. So rich, so moist... dotted with juicy jewels of fruit, Just one serving provides important cancer protective benefits | 3 | 1 | 11 | 5 | 1 | 5 | -4 | 5 | 1 | 7 |
| Contains essential omega-3 fatty acids, which may reduce your risk of heart disease | 3 | -1 | 11 | 6 | 0 | 3 | 0 | 6 | 15 | 4 |
| Provides essential vitamins and minerals your body needs including potassium, magnesium, and zinc | 5 | 10 | 5 | 0 | 2 | 6 | 5 | 4 | 5 | 9 |
| Tastes like it was prepared by someone who cared about you | 6 | 3 | 4 | 7 | 1 | 5 | 0 | 12 | 2 | -1 |
| Feeling good about feeding your family.... | 2 | 1 | 3 | -2 | -4 | 15 | 6 | 3 | 0 | 0 |
| Looks great, smells great, tastes delicious.... | 4 | 5 | 9 | 1 | -1 | 5 | 11 | 7 | 0 | 6 |
| A joy for your senses... seeing, smelling, tasting | 4 | 0 | 11 | 1 | 2 | 3 | 2 | 2 | 3 | -2 |
| | 3 | -1 | 4 | 10 | -2 | 6 | 4 | 1 | 2 | -3 |

Note: Each column is a different element in Silo D, corresponding to a brand or an outlet.

the magnitude of the interaction, just from knowing the performance of the concept elements alone.

Brands as “Directors”

An alternative to brands as multipliers (directly measuring pair-wise interactions) comes from rethinking the nature of the concept. What if the brand is a director? That is, if we change the brand, then do other elements change their utility values? If we can establish this “directorship” of brands, we may be able to determine how brands affect responses to messages. It may well turn out that the same message does well in the presence of one brand but poorly in the presence of the other brand. The brand is, in effect, directing the element.

By looking at the darkened boxes in table 8.4, which shows the utilities under each of the scenarios dictated by Silo D (brand, venue), we see that many more of the utilities are above an arbitrary cutoff of 10 (10 is a nice number, which separates strong performing elements from weak performing elements). The utilities for the same element often show differences by “director” (i.e., by brand or outlet). The reader just needs to find any element, and look across at the range of utilities for the same element in the presence of the different “directors.” Sometimes the effects are large, sometimes small, and sometimes in opposite directions.

Focusing in on the top element overall (A6—One Pot. One step to a meal) reveals the effect on interest under different directors. The utility scores increase under the direction of Newman’s Own, Betty Crocker, Trader Joe’s, and Whole Foods and decreases under the direction of Quaker Oats, Kellogg’s, Kraft Foods, Campbell’s, and Wal-Mart. This probably represents that the meal occasion is more consistent with some brands than others. From a marketing standpoint, creating one-pot products under some brands will be a potential consumer disconnect.

Implications for New Products

Brands and products have strategic interactions. Brands frame the product choice, and therefore the usage evaluations and products can frame or reframe the brand name. Different brands will support different types

of product characteristics, and therefore the alignment between the two is what's really critical. There is empirical evidence that's available to help us assess these alternatives. A systematic approach to concept development, using principles of experimental design, provides the ability to identify product characteristics that align best with the brand. This enables the fulfillment of expectations leading to higher satisfaction and increased repeat purchases.

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Chapter 9

APPLYING PROCESSES THAT ACCELERATE NEW PRODUCT DEVELOPMENT

Hollis Ashman

Why Read This Chapter?

For those product developers who currently feel stifled by systems, this chapter provides an overview of how disciplined integrated processes accelerate product development.

Introduction

The use of product development processes is wide spread and there are many professional organizations dedicated to these processes. A well-known example is the Product Development and Management Association (PDMA). Founded in 1976, the PDMA is a volunteer-driven, not-for-profit organization with the mission to improve the effectiveness of individuals and organizations in product development and management. Processes are utilized by most companies to provide more consistent, common practices for creating new products. In fact, according to the PDMA innovation survey of 2004, 79% of all companies surveyed use a formal, cross-functional product development process, while only 6% are not using any process at all (Adams and Boike, 2004). This formalized product development process ensures that the right procedures, tests, and analyses are done at the appropriate time so they mesh together

into one coherent set of data to make go-forward decisions. Manufacturing decisions are clarified closer to the end of the product development cycle and business development/ideation decisions are made closer to the beginning of the product development process.

One of the issues we face, since we, as an industry, have this process inculcated within our organizations, is dealing with complex data sources. From every corner of the business—quality systems, consumer complaint lines, SAP systems, sales, procurement, marketing, development, manufacturing—different types of information in a variety of formats are available for informing and inspiring. Looking at all the data streams is very complex and can be overwhelming for a product development team. Even if teams utilize experts and knowledge databases to provide a framework for what data are important, what makes someone an expert in one field does not necessarily give him or her expertise in another field. Then multiple experts are leveraged to deal with this difference in knowledge base. The product development process is then used to ensure that we focus on four fundamental concepts: target, speed, accuracy, and money. Utilizing these concepts will allow us to focus on moving products to market.

Target

Target refers to the strategy, not just the consumer target. The target addresses several key strategic questions:

1. What is the key focus for the project?
2. Where am I now?
3. Where do I want to go?
4. How do I get there?
5. Who is my competitor?

Demand Economy

A demand economy is one of abundant choice for the consumer (Kash, 2002). Consumers have an ability to meet their needs in a variety of ways. If they want something indulgent, they can purchase a chocolate bar, drive to Starbucks and get a “latte,” or purchase a pair of sandals. Their ability to meet their needs is no longer restricted to a very few

choices, but instead can be met via a larger number of choices. The demand economy is driven by the fact that there is more competition from low cost economies using new technologies, skilled people, and mobile capital. New economies can be anywhere from India to China to South America. Innovative products, processes, and services are spreading rapidly around the globe, and electronic commerce has radically changed the way business meets consumers' demands. Just consider your own response difference to an e-mail versus a letter. Science and knowledge underpin these new technologies. All of these together drive a perfect storm whereby consumers can get their needs met from a variety of sources and expect to do so at a great value.

Providing a high-quality good and a differentiating strategy based on quality of manufacturing no longer provides enough differentiation today. Private Label products are as good as or better than branded. Information is critical in dealing with this new world. But let's look at information in an example.

The pasta market was forecasted to grow around 2% per year from 2001 to 2006 from a market size of \$6.0 billion to \$6.75 billion in 2006 (table 9.1). But consumers had different choices in consumption and the low carb diets reframed what consumers considered healthy foods, and impacted pastas and competitors. Retail pasta consumption declined 5–6% in 2004 and the market for pasta hit \$5.5 billion in 2005, much lower than forecasted (Webster, 2005). How were the pasta companies to know? And more importantly, how were they going to deal with the new product space in which consumers had placed them? A once low cost, healthy meal that could be stretched to feed a large family was now a nonhealthy meal with limited consumer appeal. Were the forecasts

Table 9.1. Forecast of U.S. FDM sales of pasta and pasta-based meals (June 2002).

| Year | Sales (million\$) | % change |
|------|-------------------|----------|
| 2001 | \$6,027 | |
| 2002 | \$6,185 | 2.6 |
| 2003 | \$6,340 | 2.5 |
| 2004 | \$6,488 | 2.3 |
| 2005 | \$6,623 | 2.1 |
| 2006 | \$6,755 | 2.0 |

Source: IRI (2000).



Figure 9.1. A typical knowledge map.

wrong? Forecasts are built on historical data with models that project forward into the future. They assume there will not be major shifts in consumer perceptions. If the pasta industry utilized experts, they might only see one concern with the marketplace at one time.

In *The New Law of Demand and Supply*, Rick Kash (2002) argues that to succeed in today's market, companies must first determine existing demand and then predict emerging needs of their existing market. A method that works well and has been utilized by many industries is to create organic strategy, strategy that is created from the knowledge base of a wide variety of experts and stakeholders. These strategies can be overwhelming and difficult to manage. The first step is to create a "knowledge map" from sound bites of data that integrate knowledge that is both tacit (resides in various peoples heads) and explicit (resides in reports) in a graphical, pictorial representation (fig. 9.1). By generating this knowledge map in a short period of time (typically a day), the wide array of complex information can be included, discussed, and vetted, and an overall strategy can be created from common knowledge. By making the knowledge common, the team moves together from the same starting point, integrating the various knowledge streams. They become aware of what they do know (many times companies repeat the same research because people move on or previous research is not known or readily

available), leverage that knowledge, and identify the gaps on which to focus to drive the strategy forward.

Lots of new products fail. The numbers vary but PDMA suggests that, overall, 40% of new products fail. IRI has at times put the number at 52%. The key message is that creating new products is a gamble. Recognizing that new products fail A LOT means understanding that the processes that a company builds around creating them should be fast and accurate. Most important, they should not leave a company with a level of financial investment in an idea, such that if it fails, it will have a significant impact on the company's ability to invest in more and alternate ideas.

Speed

Most companies have internalized improvements in the product development process. The improvements have been stepwise and moved from first implementing a formal product development process and then doing some stages in parallel. Now improvements in cycle time or speed to market require some serious thinking. The implication of the drive to reduce cycle times has been risk reduction behavior (fig. 9.2). Projects

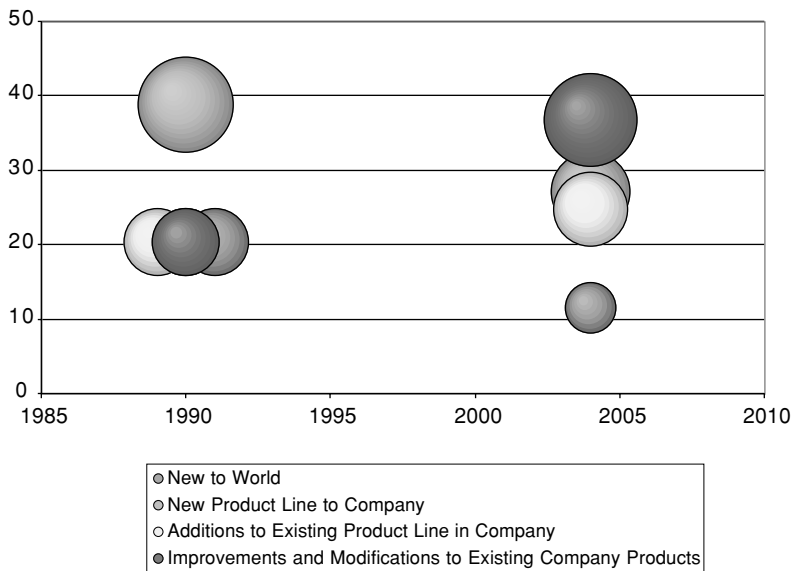


Figure 9.2. Implications of risk reduction behavior in terms of development project type. (From Adams and Boike, 2004a, b; for mid-1990s data, see Griffin, 2004)

that are more complex and have higher risk associated with them, typically new to the world, have decreased by 43%, and projects that are simpler and easier to do, with less risk (typically improvement and modifications to an existing product) have increased by 80% over the time frame of 1990 to 2005 (Adams and Boike, 2004). While our strong focus on speed has reduced cycle times and time to market, reducing the risk with new products has left money on the table. Products that enter the market first have a greater than 70% chance of succeeding and a potential rating of 6.3. In contrast, products that enter the market second have a success chance of 63% and a potential profit rating of 5.7 (Cooper, 2001, 2002).

Accuracy

Robert Cooper (2001, 2002), in his studies of the product development process, has found that companies cite three key reasons for new product failure: marketing analysis, product problems or defects, and not enough marketing efforts. When you dig deeper, it is more a mindset issue than a general marketing analysis or product problem. When we look at the types of consumer understanding tools reported as being used, they range from alpha testing and concept tests to lead users and ethnography, to focus groups and trade-off analysis. We find that the companies that are doing the best are spending more time on research that generates understanding and not on research that confirms what is known (fig. 9.3). Ethnographic research is focused more on understanding and less on confirmation. A focus group is focused more on confirmation and less on understanding. This is not a plug for ethnographic research, but instead a recommendation to focus the research on learning, not on confirmation in the early stages of the product development process, and then focus on confirmation research in the later stages. The learning should focus on a few key ideas:

- Is the new benefit/product valuable to consumers?
- Do consumers even notice?
- Does the benefit/product fit the concept or promise made?
- And finally, will consumers actually integrate this new product into their lives?

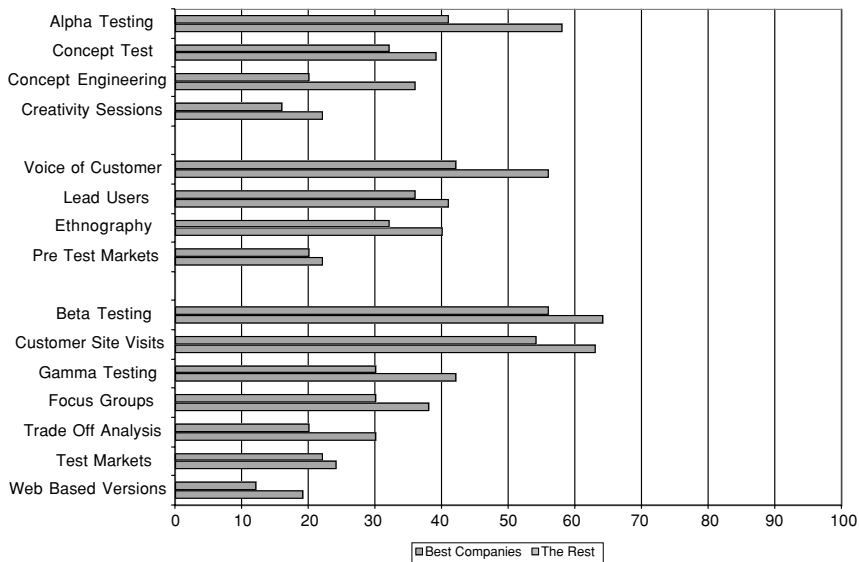


Figure 9.3. Market research tools utilized by “the best” and “the rest” by % of time. (From PDMA Foundation New Product Development Report of Initial Findings, Summary of Responses from 2004 CPAS)

By answering these questions, we are more likely to be more accurate measuring the true financial impact on profit margins.

We have all heard the idea of creating an experience for consumers. Joseph Pine and James Gilmore, in their 1999 book *The Experience Economy*, talked at great length of the importance of doing this, but the real question is how to do it. Creating an experience requires a company to use a variety of research techniques to understand how an experience works from the consumer’s perspective. Traditional market research has focused on listening, using words and language to understand consumers. We need to integrate images, usage, and emotional connections to this language-based understanding in order to gain a clearer understanding (fig. 9.4). Through the use of metaphors to clarify consumer visualization, in context/ethnographic to get to observable function and usage of products, and person-to-person interviewing techniques to get to emotional connections, we gain true understanding. Using a methodology that allows the consumer to lead the interview, rather than the traditional style of interrogating the consumer, provides the basis for gaining this knowledge quickly and accurately. We want to be able to observe what it is about the product attributes that drives their behavior

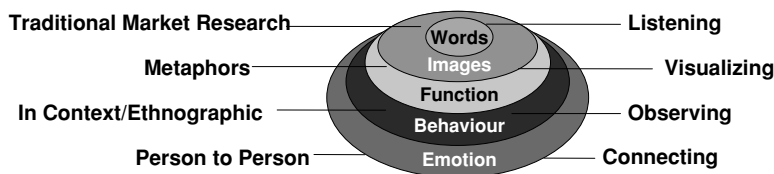


Figure 9.4. Creating an experience requires integration of a variety of research methods.

and enables their emotional response, and to map this out so we know how the choices we make as product designers impact these pathways. The brand itself is a short cut for consumers to move from product attribute to emotional responses, because they know that the behaviors will be elicited. We as product developers want to make sure there are no unintended barriers to these pathways.

One of the issues with the product development process that few people speak to is the assumption that there will be perfect access to technology. Most people in industry are goal-oriented people who do what they know they can do. They tend to focus on what is known and available in technology—because why would they do something they can't since they don't know it will not bring failure? Searching for the technology that will provide a competitive advantage requires that the product developer have some idea of what the future holds. Given a series of choices, what type of trade-offs would consumers make and do they change in the context of health, indulgence, or convenience? With this understanding, the product developer can make a better judgment about the technology on which to focus and where to find it.

Money

For any company, creating new products is an investment, and beyond just the costs, there are opportunity costs of not doing an alternative project with the same resources. But failure is not typically an option, it's just too expensive. So one way to deal with this is to iteratively integrate the product development, consumers' understanding, and market development together, so the team focuses on learning and less on confirmation as it moves through the product development process. This is supposed to be happening at the gates of the product development

process, but by separating much of this research, we are not seeing the world through the consumers' eyes. They integrate the brand, the product, the package, and the message. We must reflect this integration in our research. By iteratively integrating this knowledge, the steps are shorter, tend to be more affordable, and can keep the costs down.

By focusing on four key areas, we can get products to market faster: (1) target—make sure we are working on the right things; (2) speed—utilize processes that move the process faster but do not leave higher risk projects behind; (3) accuracy—focus on learning rather than confirming to drive a higher level of understanding; and (4) money—ensure we are focused on iterative integrated learning to keep costs contained.

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Chapter 10

FIVE YEARS LATER—LOOKING AT HOW THE UNIVERSITY PREPARES SOMEONE FOR A CAREER IN FOOD SCIENCE

Carol McCall, Chow Ming Lee, and Soo-Yeun Lee

Why Read This Chapter?

McCall, Lee, and Lee present a valuable overview about what needs to happen for students to be more prepared for the current business situation in the food industry. Their research suggests areas of alignment between industry and academia. Their discussion should be of interest to anyone who teaches students or hires and manages the newest members of our community.

Introduction

Today's job market has become increasingly competitive, and the food industry is no exception. With each passing year, there seem to be fewer open positions and more qualified candidates. Students struggle to stand out among their peers when applying for jobs. On top of that, today's work environment is changing at a rapid pace and looks very different than it did even 10 years ago. Food science professionals are faced with the challenge of doing more with less time and resources. Because of this new environment, recruits are expected to make immediate contributions to their new organization, which means they need more than just their academic qualifications (Schofield, 2000). With

that said, what are universities doing to prepare students for a career in food science—whether as a product developer in the food industry or as a professional in academia? Are today's students adequately prepared for what lies ahead? Have they had the proper coaching, guidance, and experiences that will allow them to move seamlessly into their new roles?

The answer to many of these questions is “Yes”—students rely on their scientific foundation and the principles they learned in school every day. However, there are vast differences between professional and student timelines, priorities, and missions. Understanding these differences and being practiced in these newly needed skills is critical to success. This chapter will discuss qualities or experiences successful new hires most often possess. It is written from two perspectives: one from product developer and one from academic professional. Although differences exist in these two professional worlds in terms of environment, focus, activities, and personalities, for the most part, the training happens in the same place—the university.

In fact, the two coauthors Carol McCall and Soo-Yeun Lee began their careers together, studying food science as lab mates at the University of California, Davis. While Dr. Lee pursued teaching and research as her main career focus, Dr. McCall chose a career in product development. They studied the same materials, began their research in the same field, and were taught by the same professors; however, five years later, Lee is now an assistant professor at the University of Illinois and McCall is doing product development at Frito-Lay. This chapter will explore how the university prepares students for either career path. Two studies were conducted to identify and quantify experiences, skills, and personal traits important to the success of new professionals in either product development or academia. Although literature relating to qualifications of new hires sought by employers exists (Henry, 1995; Schofield, 2000; Kitchen, 1994; Lazzareschi, 1989; Marchant, 1999), data specific to this field have yet to be published.

As universities evaluate and evolve their programs, it is critical they partner with professionals in the field to understand both opportunities for improvement as well as program strengths. Data and discussions in this chapter will highlight such areas. In addition to benefiting students, this information will provide “food for thought” to instigate the critical dialogue that must take place between the university and industry to secure the future of the field.

Study Methodology

Conjoint analysis was used as an exploratory/screening tool to determine “what really matters” in terms of preparing students for professional careers in food science. This method was chosen to reveal how people respond to complex combinations of alternatives for the concept of a successful professional in the food industry vs. academia, which results in a hierarchy of attributes, ranked in the order of importance (IntelliQuest, 1992; Moskowitz et al., 2005).

Originally, the study was created to explore elements related to the area of product development only; therefore, the elements selected are more closely associated with those pursuing a career in industry. The elements were chosen after conducting 10 one-on-one in-depth interviews with product developers who have been working in industry for two to five years immediately upon completion of their graduate work in food science. After the results of this work were presented at the 2005 Institute of Food Technologists’ (IFT) Annual Meeting and Food Expo (Session 23-3, New Orleans, July 2005), collaboration with Dr. Lee began to add to the research, comparing the results from the perspectives of product development vs. academia. In order to compare the results directly, the same elements were used in both studies (understanding the elements selected are not the ideal set for telling the story of the academic perspective).

The conjoint analysis studies were conducted using IdeaMap.Net (i-Novation, Inc., White Plains, NY). A 4×6 design was used including the categories School Experience (classes, graduate work, and research), Graduate Department (characteristics of the department where the student studied), Work Experience and Leadership (including internships, co-ops, leadership roles held), and Personality Traits. A complete list of the 24 elements tested can be found in the results section in table 10.2. On each screen, a concept of a hypothetical candidate was shown for which the respondents were asked if they agreed with the following statements (where 1 = strongly disagree and 7 = strongly agree). For the product development study, the statement read, “This candidate would be a successful new Product Developer”; for the academic professional study, the statement read, “This candidate would be a successful Academic Professional (i.e., faculty, lecturer, post-doc, etc.) in Food Science.”

Following the conjoint portion of the study, classification questions were asked to capture demographics, educational background, and work

experience. These also included rating questions to gauge how respondents' university experiences prepared them for their jobs, and how easy or difficult they felt it was to transition from student to new hire in either product development or academia.

Recruitment of survey respondents took place through word of mouth, traveling through peer networks via e-mail invitations. For the product development study, recruiting reached individuals from top food companies in the nation including Frito-Lay, General Mills, M&M Mars, and IFF. For the academic study, participants were solicited from food science departments across the country through an administrator listserve, IFT listserv, and individual e-mail invitations. The list of all the universities that received an invitation is shown in table 10.1. For each study, a sample size of at least 50 respondents was targeted as a relevant N to achieve meaningful data (Lancaster et al., 2005).

Results

For the product development study, all of the respondents were in an R&D function and 84% either had been or were currently in a product development role. Forty-one percent were working in industry less than six years and could easily look back on their university experiences, and 60% had an advanced degree in food science. In contrast, 92% of the participants in the academic professional study were university professors. Among the academic professionals, 97% of them had worked as either a teaching or research assistant, and 70% or more had teaching experience as a student.

The scores for the elements in each category can be found in table 10.2. Results for classification questions gauging how well students' school experiences prepared them for their respective careers in the food industry or the university and how easy or difficult they found their transitions from student to new hire are found in figures 10.1 and 10.2.

Discussion

For both studies, the base constants for the regression equations were low (0 for industry and 7 for academia), which validates the method

Table 10.1. Universities that received invitations to participate in the academic study.

| | |
|---------------------------------------|-------------------------------------|
| Alabama A&M University | San Jose State University |
| Auburn University | Texas Tech University |
| Brigham Young University | University of Arkansas |
| California State Polytechnic | University of California at Davis |
| University at Pomona | University of Delaware |
| California State Polytechnic | University of Florida |
| University at San Luis Obispo | University of Georgia |
| California State University at Fresno | University of Idaho |
| Clemson University | University of Illinois at |
| Colorado State University | Urbana-Champaign |
| Cornell University | University of Kentucky |
| Delaware Valley College | University of Maine |
| Florida State University | University of Maryland |
| Iowa State University | University of Massachusetts |
| Kansas State University | University of Minnesota |
| Louisiana State University | University of Missouri at Columbia |
| Michigan State University | University of Nebraska |
| Mississippi State University | University of Tennessee |
| North Carolina State University | University of Wisconsin-Madison |
| North Dakota State University | University of Wisconsin-River Falls |
| Ohio State University | Virginia Polytechnic Institute |
| Oregon State University | Washington State University |
| Pennsylvania State University | Wayne State University |
| Purdue University | |
| Rutgers—The State University of | |
| New Jersey | |

because it indicates that with no description, low career success would be achieved. However, when the elements are introduced that bring to life hypothetical people, the interest in the question at hand increases substantially: scores of the elements ranged from -8 to $+36$ for the industry study and -4 to $+40$ for the academic study, driving the total maximum regression scores up near 100.

Industry Study

In the industry study, the strongest elements were related to relevant work experience, leadership, personality, and interest in food and

Table 10.2. Category totals and element scores.

| | Industry | Academia |
|--|----------|----------|
| Base size (N) | 77 | 72 |
| Constant | 0 | 7 |
| <i>Category 1: Work Experience/Leadership—Category Total *</i> | 85 | 63 |
| Gained work experience in the food industry through internships or co-op positions | 36 | 15 |
| Has culinary training or work experiences in the restaurant/food service industry | 15 | 3 |
| Key contributor to the IFT product development team | 14 | 3 |
| Worked in between undergraduate and graduate school | 12 | 10 |
| Held leadership roles in university or community organizations | 10 | 8 |
| Work experience consists of research and teaching (little-to-no product development experience) | −2 | 24 |
| <i>Category 2: Personality Traits—Category Total *</i> | 49 | 30 |
| Outgoing and personable | 17 | 6 |
| A “foodie” with a real passion for good food and drink | 13 | −4 |
| Concentrates on “The Big Picture” more than minor details | 6 | 6 |
| Rigorous and detail oriented | 6 | 10 |
| Aggressive—speaks up and presses his/her point of view | 4 | 8 |
| A good listener | 3 | 4 |
| <i>Category 3: Graduate Department—Category Total *</i> | 36 | 62 |
| Graduate of a program that encourages and provides resources for those pursuing a career in industry | 12 | 3 |
| Frequently exposed to members of Industry through classes, seminars and conferences | 9 | 12 |
| Taught by faculty who previously worked in Industry | 9 | 7 |
| Attended a school where research is more applied | 6 | 11 |
| Came from school with strong IFT involvement | 1 | 6 |
| Graduate of a program focused on basic research | −1 | 23 |
| <i>Category 4: School Experience—Category Total *</i> | 3 | 132 |
| An M.S. with a fundamental understanding of principles in food chemistry, food processing, and food safety | 12 | −1 |
| Possesses a command of research tools, approaches, and methodologies | 7 | 34 |
| A Ph.D. who has conducted years of in-depth research | −2 | 40 |
| Has a high GPA | −2 | 6 |
| Teaching experience gained through TA positions | −4 | 18 |
| Published author of numerous scientific papers | −8 | 35 |

* Additive total for category.

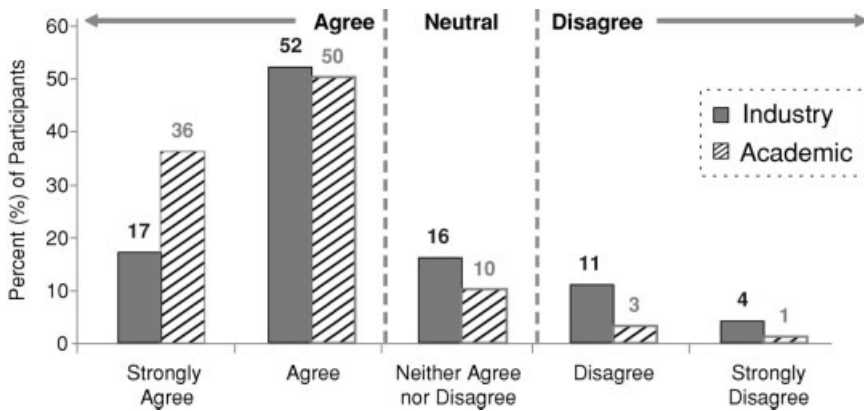


Figure 10.1. School preparation—How much do you agree with the following statement: “Overall, I feel my school experience well prepared me for my career in the food industry*” (5 = strongly agree and 1 = strongly disagree; *Academia replaced the words food industry in study 2).

cooking. Specifically, the top scoring elements were: (1) gained work experience in the food industry through internships or co-op positions, (2) outgoing and personable, (3) has culinary training or work experiences in the restaurant/food service industry, (4) key contributor to the IFT product development team, and (5) a “foodie”—with a real passion for good food and drink. Midscoring elements were associated with

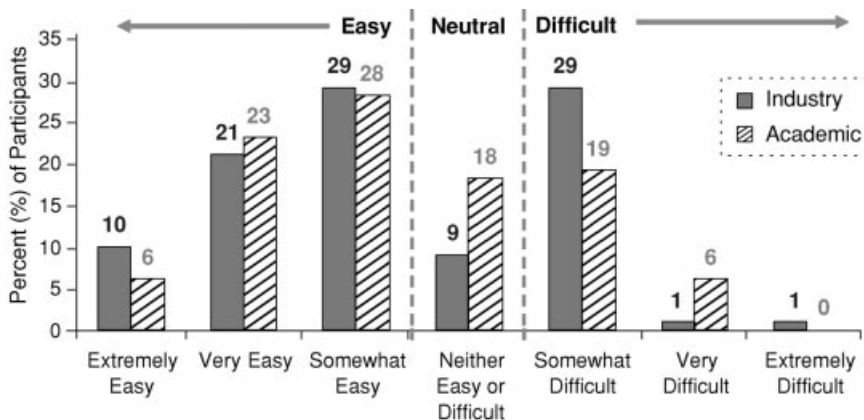


Figure 10.2. Transition from student to new hire—“How easy would you describe your transition from student to new hire?”

the department from which the student graduated, including providing support for those pursuing careers in industry as well as resources and opportunities for developing product development skills. The lowest scoring elements were lack of work experience and descriptions of graduate student roles and activities such as focusing on basic research, authoring papers, and teaching.

These results suggest that having the degree and the academic qualifications, although “must haves,” are no longer enough when it comes to landing and successfully carrying out a product development job. One could propose that at this level of education, intelligence and analytical ability are givens, providing a right-of-entry for consideration, although no guarantee of getting a job. Students who have made it this far in their academic careers, graduating with masters and doctorates from the top schools in food science, have already proven they have what it takes technically. What makes someone stand out from others lies in the area of soft skills, including team-working ability, interpersonal skills, motivation, enthusiasm, flexibility, and customer orientation (Anon., 2001). Because many of today’s candidates lack these professional abilities, successful new hires have created an advantage by making an effort to build the skills they will need through work experience and leadership positions. In support of the results of the conjoint analysis, a theme emerged from the respondents in the open-ended portion of the study: many stated that what prepared them most for their new product development jobs was putting the knowledge they learned in school into practice through internships, co-ops, project-oriented coursework, and extracurricular activities.

Indeed, these interpersonal skills are critical to getting things done in the workplace. A significant part of the product development role involves working with teams, communicating, selling ideas to gain support, and influencing decisions. Many times these interactions occur cross-functionally with groups including marketing, finance, and operations, and being adept in these skills allows for an effective communication of technical information to nontechnical counterparts. Also, in order to gather information and make decisions or recommendations quickly, one has to rely on existing data and past experiences. The most efficient way to tap into this knowledge is to form relationships and build personal networks. Although product developers are technical first and foremost, they are also business people. One respondent in the study

may have said it best: “The Food Industry is not just about food. It is really about an industry that deals with food”.

These findings, although specific to the food industry, are not unique when it comes to what employers are looking for, across many categories and facets of business. A survey of senior executives by staffing organization Select Appointments of North America revealed “today’s workers need soft skills even more than technical expertise” (Marchant, 1999). In addition, the Business Higher-Education Forum and the Collegiate Employment Research Institute at Michigan State University agree that although many students have technical skills, they tend to not necessarily possess these all-important soft skills (Coplin, 2004).

In addition to the importance of soft skills, elements related to good food and cooking were rated important in the industry study. This is not surprising in a world where travel to foreign lands is increasing, ethnic menu items are no longer perceived as exotic, and taking cooking classes or watching the Food Network have become popular forms of entertainment. Consumers have become savvier when it comes to their expectations of food; therefore, it is essential that product developers (considered experts in the field) be knowledgeable and practiced in this area. Food companies are realizing the importance of a culinary knowledge base and are taking action by incorporating such components in their development approaches, training their food scientists in the culinary arts, contracting with chef councils, and even hiring resident chefs in their R&D departments (Baggs, 2004; Cornwell, 2005). The Research Chefs Association (Atlanta, GA) has played a prominent role in the recent years’ Institute of Food Technologists’ (Chicago, IL) Annual Meeting and Food Expo by showcasing product development efforts through demonstrations by chefs, product developers, and students.

Even though gaps exist between what the university offers and what is needed by today’s graduates pursuing careers in industry, the majority of the participants in this study felt their school experience prepared them well for their careers as product developers. They valued the level of quality education they received and felt technically prepared. A number of participants in this study did have some difficulties transitioning from student to new hire, however. What they found to be most difficult as a new hire included not understanding the business, corporate culture, and politics, coping with the speed at which things happen in

industry, and having little self-confidence in their answers and recommendations.

Academic Study

In comparison to the industry study, the academic participants rated the concepts very differently. In fact, many of the lowest scoring elements for a product developer were rated as most important for an academic professional—specifically those related to school experience including focusing on basic research, publishing, and teaching. Top scoring elements were (1) a Ph.D. who has conducted years of in-depth research; (2) published author of numerous scientific papers; (3) possesses a command of research tools, approaches, and methodologies; (4) work experience consists of research and teaching; and (5) graduate of a program focused on basic research. In similar fashion, the most important elements from the industry study scored lowest here, including those related to culinary science (a “foodie” and culinary training), IFT involvement, personality traits (i.e., outgoing and personable), and having an M.S. degree.

These contrasting results are not surprising given that academic and industry professionals have distinctly different objectives and roles. The most important attributes in each study emphasize the qualifications of the job and could easily serve as job descriptions. In the academic study, the highest ranked elements speak directly to the requirements and experiences needed to become a professor. One must have a Ph.D. (along with all knowledge and experiences it stands for), teaching and research experience, and a list of impressive publications in order to even be considered as a candidate for assistant professor, and for future tenure and promotion to associate professor (Zyzanski et al., 1996). These qualities are the essence of the makings of a university faculty member. Potential candidates will lecture, run laboratory classes, and conduct research in their area of emphasis. They will teach courses, advise students in their research area, present research findings at conferences, write grants, and publish papers as they gain respect and expertise in their fields in the pursuit of success in academia.

There were many differences in how the elements ranked between the two studies; yet, there was some agreement on what is important for both jobs. Although the elements related to work experience and ties with industry were not the top scoring elements in the academic study,

they were rated as having some level of importance with ratings between 10 and 15. The university professionals saw the value of relevant work experience and the resulting growth and maturity gained. Maintaining ties to industry and getting a glimpse of this world through internships and co-ops allow students to see how their technical know-how is applied to the real world. In addition, these candidates pursuing careers in academia will potentially teach tomorrow's students working toward industry careers. By having first-hand experience, these future educators can better guide and direct students pursuing product development. Additionally, much of the funding for research comes from industry. The bigger the network and the stronger the relationships with industry members, the more likely it is that the new professor will have easier and earlier success in securing funds.

To further highlight what is important for new hires in academia, participants expressed what they felt were the top three qualities of a successful academic professional in an open-ended portion of this study following the conjoint section. Their responses can be categorized into (1) excellence in research skill, (2) interest in teaching and dedication to students, (3) perseverance, (4) good personality, (5) publications, and (6) experience in teaching and research. In addition, top experiences ranked by the academic professionals as important were research, teaching, internship/industry, postdoctoral positions, quality educational curriculum, and writing.

While participants in the academic study found the transition from student to their respective academic careers easier than that of the product developers, the change was not without hardships. The process of grant writing and obtaining funding ranked first among the most difficult tasks faced by the new hires in academia. Academic professionals were concerned about the teaching burden, time management, and conflicting priorities, and identifying his or her research niche. The academic professionals were most unprepared for the amount of workplace politics, teaching load, competitiveness of funding, and the lack of guidance from the university. In order to provide an environment to foster successful academic professionals once they enter the workplace, significant improvements must be made within the university system. Administrative support in grant submission process, promotion and tenure evaluation process, and teaching and research enhancement training can play a critical role in facilitating a smooth transition from a graduate student status to a successful professional in academia.

It is important to note that some of the responses to the academic study were not initially positive. Because the academic study was established as a direct comparison to the product development study, the authors strived to cover two different careers within the scope of a limited list of elements. Some of the participants in the academic study expressed concerns about using the conjoint analysis methodology as well as the limitations of the study elements (skewed toward industry) as a means to explore what is important for those pursuing a career in academia. Some comments included referring to the study as “flawed” and that conjoint analysis is typically used by “trendy marketing types” rather than by those in academia. Since the major focus of this book chapter was to compare the results from the two parallel studies, this project was conducted with the same elements for the two different demographics (this comparative objective was not revealed to the participants so as to not bias the results). The intent of the study was not to provide an ultimate list for shaping the food science academic programs, but rather to highlight the differences in what is needed to prepare graduate students for a career either in academia or in industry. While conjoint analysis is one of many methods that could be used for this type of exploration, it provides a powerful way to evaluate complicated concepts composed of multivariate characteristics (i.e., people). We believe that some critical findings were unraveled from the two studies presented in this chapter, and we hope that this will lead to future studies related to the important topic of education, building on these results.

Conclusions

Clearly, there are vast differences in what makes someone a successful new hire in industry vs. academia. The traditional university experiences that include coursework, research, and teaching activities for graduate students are strongly geared toward those pursuing an academic career. After all, these students are receiving their training in the best possible environment—the one in which they hope to work. The majority of the participants in the academic study expressed that the university provides good training to produce quality educators with the proper emphasis on teaching and research. While this is reassuring for those pursuing an academic career, this chapter reveals large gaps between

what is needed and what is provided by the university for those pursuing industry careers.

Although the student is ultimately responsible for making sure he or she is adequately prepared for his or her career, the results of these studies demonstrate that the university plays a role as well. Specifically, for those pursuing a job in product development, it is important that universities provide encouragement, make students more aware of the nature of the job, and stress the importance of the skills needed. To help build networks and have a better idea of what product development entails, the university should encourage participation in conferences, classes, seminars, and industry-related activities. It would be ideal if product development coursework were incorporated into the graduate curricula, or at least be available for those who chose that career path. Universities have included product development components into their undergraduate programs, but do not have offerings for graduate students. Because most students from other backgrounds (like chemistry, biology, and engineering) study food science for the first time in their graduate years, they may never be exposed to product development principles and practices, and will be at a disadvantage when it comes time to look for a job. Furthermore, because gaining work experience through internships and co-ops is so important for those pursuing an industry career, the university should make it easier for students to build this component into their graduate studies. Undergraduates have the freedom of summers off to be able to work for several months in industry; however, graduate students do not have this luxury, as they tend to work through the summers and are not able to negotiate time away from their research with their professors, even for these critical experiences.

In closing, the different needs of the food industry and academia ask for customizable guidelines from the current and future educators for the different career paths students are seeking. Rather than a one-for-all recipe, the training for each student should be based on the student's future direction and career goal. This can only be achieved if the realization of the goal is early in the educational program. Knowing the future career path of the student, the curriculum can be mapped to develop the best person for the job. Universities should continue to work closely with the IFT when developing such curricula, as this organization continues to effectively bring together members of industry and academia. Not only does IFT play a key role in establishing standards for curricula in food science, it also provides students with information, guidance,

and opportunities for pursuing careers through its employment committee and career center. The competence of academic institutions is reflected by the success of its graduates, which can be doubly benefited by the alumni contributions these successful graduates may make. With increased competition in today's job market, educational institutions that work to customize their programs, tailoring to the students' career needs, will deliver higher caliber new hires in both industry and academia, helping to secure the future of food science.

Some Organizations Cited in This Chapter

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Institute of Food Technologists, 525 W. Van Buren, Ste. 1000, Chicago, IL 60607

Research Chefs Association, PO Box 420187, Atlanta, GA 30342

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Chapter 11

SPEED BUMP OR OPPORTUNITY: INNOVATIVE PACKAGING AND ITS IMPACT ON ACCELERATED PRODUCT DEVELOPMENT TIME

Pamela Eitmant, Clint Haynes, and Steve DeHoff

Why Read This Chapter?

There are a lot of people who say they do packaging design and implementation. Chapter 11 reveals the “secret” ingredient for all good package design. You cannot pass on reading this if you are developing products for the world today.

Introduction

The demand to get new packages and products to market faster and faster is a growing issue for new products as well as new packaging. Even before the pressure of speed, new packaging development has been wrought with rework issues at least 90% of the time. This has meant delays to market, more cost, and ultimately consumer disappointment. For packaging initiatives, speed adds more problems to a process already complicated by development issues.

The authors posed this question: Is the need for speed in packaging development an opportunity or a speed bump? We propose that it can be an opportunity if we rethink and reshape the package development

process so it eliminates the rework. If done appropriately, companies will develop packaging changes that look good, work better, cost less, and get to market faster.

Packaging Development Has Become a Speed Car Race

The effectiveness of mass media marketing has diminished and is increasingly being driven into a 2.5–10-second interval of time in which the consumer surveys the retail store shelf and selects a product. The term “first moment of truth” is becoming a common descriptor for this dynamic (Berner, 2005). Further, some marketing research dictates that rapid package recognition must occur from as far away as 12–15 feet during this short time interval. The ability of your package to stand out in this crowd and be recognized quickly is becoming essential to sales. This creates a new function for packages that moves way beyond being a vessel that contains the product and provides use and nutritional information (Berry et al., 2005).

Market speed also increases in this environment since Private Label and others copy your package almost as soon as you put it out and try to get consumers to mistake theirs for yours. This means either coming out with changes frequently and rapidly or establishing ownership via design patents that prevent copying. In any event, a trend toward increasingly complex and visually interesting package shapes is in progress as a result of these dynamics.

A Historic Perspective

Historically, package forms followed Bauhaus design concepts where form equals function. These packages typically offered combinations of basic shapes that did not challenge the boundaries of manufacturing technology and know-how. It was common to see combinations of rectangles, cylinders, spheres, and conical segments, and so on. These designs dutifully contained the liquid to be dispensed, but they did not convey any message to the consumer that the package is designed with their convenience or aesthetics in mind. They were not designed for you! They were economically and functionally efficient, however, with regard to cost and manufacturing ease. Even so, statistics show that

even for simple designs, the traditional development process of rapidly making prototypes, testing them, and repeating the process until they work yields significant development rework—about 90% of the time for these traditional basic shapes (Mininni, Brandchannel.com).

Recent years have seen an emerging design trend where aesthetic and functional design elements are being added to enhance consumer recognition and experience. The concept of incorporating unique functionally aesthetic profiles into packages is not new. The pinch-waist dishwashing bottle is an icon in its category and has been around for many years. However, the design elements are simple and the technologies associated with its manufacture are straight-forward. Design elements being incorporated today increasingly challenge the technologies needed to mold and assemble the packages. They are more intricate, complex, ornate, and frequently asymmetrical. The result is more eye-appealing packages with greater shelf presence. This commitment to design is often rewarded with consumers willing to invest more money into their experience with the product in addition to the added ability of the package to stand out on the crowded store shelf.

Today's Challenge—Speed Without Fatal Errors

The problem is that the more complex designs nearly universally translate into the need to use more, and often more expensive, materials. This can be seen broadly in architecture, art, furniture—essentially anywhere complex shapes have been employed. In addition, development time, expense, and risk are increased as well. In general, the more “design” is employed the more difficult the package is to develop and the more money it will cost. A certainty of development of anything is that increased development speed plus increased complexity equals more fatal errors if the development process itself is not changed to accommodate the higher complexity. Yet, management in today's market requires even more speed and even less cost.

The speed to market phenomenon creates an unrealistic environment that causes many companies to “jump the gun.” The pressure to get there fast and first sets a team up for failure. Teams end up focusing in too soon—selecting one solution before they have had a real chance to explore the problem, identify useful hypotheses, and brainstorm solutions that will meet the objectives at hand and can be commercially produced

(no functional failures). In essence, the team ends up running the race backwards: “GO . . . Get Ready . . . Get Set!”

As a result, 90% of current package designs have very meaningful development and market rework issues. Reworks increase costs past budgets and either delay market entry or force product introductions with problematic products. Additionally, adding shape complexity to packages necessarily adds development complexity and risk while we are trying to go even faster than before. It is clear and paramount that something in the development process has to change to accommodate this increased complexity and risk.

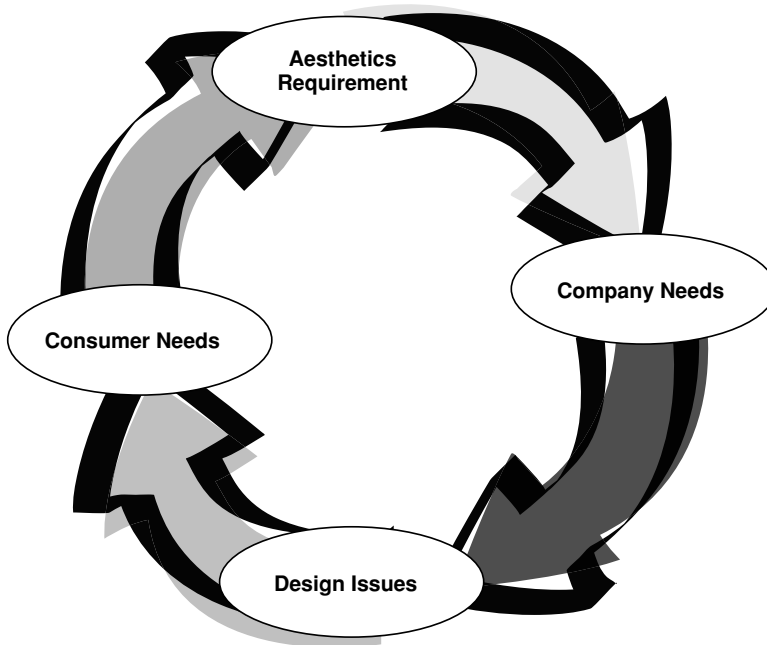
So the question arises, “How can companies quickly create packaging innovations that win?” The answer lies in fixing the process along with utilizing powerful new tools.

Mindful Design—Get Ready! Get Set! Go!

Mindful Design (Eitmant et al., 2005) is a new innovative approach to package development that seamlessly integrates the needs of the consumer with structural design and aesthetic requirements in a closed-loop process very early in the project. Each of these functions feeds critical design information forward to enable developers to conceive new packages that not only better satisfy the needs of the consumer, but also deliver a cost structure that satisfies profit goals in the least amount of time possible (fig. 11.1).

In essence, we find that fastest market speed occurs from a slower project front end. This is reminiscent of the old adage “one must crawl before one walks and walk before one runs.” The speed with which physical parts are in the hand is not a satisfactory definition of being fast. The fastest speed comes from careful planning and doing as much development learning as possible *WITHOUT* making real parts. This makes the front end of projects slower as a result of the careful planning, but the total project time is inevitably much less. The time saved is the enormous, unplanned rework loop time that plagues the traditional development process. The planning process is always much shorter than the rework and problem-extended production start-up process.

To borrow from the car race analogy, Mindful Design is a systematic process—Get Ready! Get Set! Go! The Mindful Design philosophy relies on three basic steps:



Synthesis of needs, aesthetics requirements and design is needed very early in the packaging design process.

Figure 11.1. Synthesis of needs (both company and consumer), aesthetics requirements, and design required for Mindful Design process.

1. Assess the track
2. Design the right engine
3. Do prerace trials

Assess the Track

Today more and more often packaging initiatives are launched to meet one or more of the following objectives:

1. To create “new news” for the brand
2. To reduce costs
3. And (sometimes) to drive incremental sales based on meaningful packaging innovations

However, the need for speed often pressures marketing and development teams into short cutting the needed upfront thinking and

preparation required to be successful (Easley, 1994). The modern racing teams know to win the race, you need a careful review and study of the track. So, marketing and development teams need a careful review of what is known (and almost more important, not known) about consumers and the use of packages they buy.

Take a Day to Identify What You Know and Don't Know

A close and systematic review of what is known (and not known) about what consumers want and need is an essential first step. Several internal and external sources should be reviewed and mapped (Maxwell, 2003).

1. *Past Research*: What do we know about consumers, the packages they use and how they impact their lives? How satisfied are they with current solutions? How are products (packages) used? Are there issues/concerns about the product that could be solved by a package change?
2. *Evolving Trends* (within and outside the category): Have there been recent packaging adjustments within the category that stimulate interest and/or sales? What introductions in other categories might be applied to solve issues/problems of target consumers? Is there new technology available now or in the near future that might be worthy of consideration?
3. *Internal Resource*: Are there suggestions for packaging changes from front-line salespeople? Do marketing and R&D teams have ideas on what packaging improvements might meet stated goals?

In contrast to what you may think, this does not require a lot of time. In fact, a very effective technique for grounding a team has been developed called Knowledge Mapping. In just a half-day or whole-day work session, the team can quickly consolidate and map its information (Moskowitz et al., 2006) (fig. 11.2).

The mapping exercise allows the team to develop useful hypotheses about how specific packaging solutions will fit its objective. Many times historic documents (usually forgotten by some or most) show that a few of the ideas being considered have been tried before—and without success. With that knowledge, the team can redirect its thinking. And importantly, the team can also generate a list of questions that will provide missing information needed to move forward.



Figure 11.2. A knowledge map created during an innovation knowledge work session.

Design the Right Engine

To be a “winner,” the racer needs the right engine. Engines that win are custom engineered and tooled to fit the race, hug the track, and get to the checkered flag first. In the packaging process, this means engineering packaging solutions that meet consumer needs as well as company goals and that integrate needed aesthetics while avoiding technical problems (Easley, 1994). The Mindful Design process makes sure this is done early in the process.

Obtain Consumer Insights Early

Perhaps one of the biggest errors in package development is to rely solely on internal hunches/ideas. While these ideas may be viable, it is very critical to check to see if these changes are meaningful for consumers. By checking in early with consumers, the team can:

1. Eliminate/kill bad ideas early on
2. Confirm at least directionally ingoing hypotheses
3. Identify new ideas that may have even higher success

Two steps can be employed at this early stage to validate hypotheses formed by the team and expand understanding of where packaging adjustments might be effective and meet the objectives of the team.

Ethnographic Interviews

What a better place to learn about packages than to visit consumers actually using products where they do normally—at home, in the car, on the athletic field, at work, at school. Spending time with consumers when and where they normally use products can provide a wide range of insights and clues for new package designs.

1. What elements of the packaging work well when using the products?
2. What elements delight consumers?
3. What things about the packaging cause concerns/issues or irritations?
4. What is observed about the packaging use that may be an opportunity for packaging changes/adjustments?

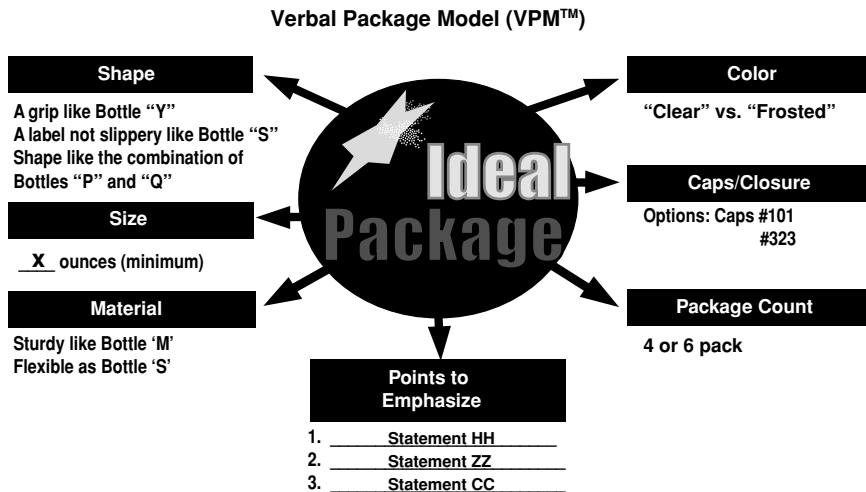
The good thing about ethnographies is that just a few (8–16) will provide directional confirmation of ingoing hypotheses and/or point to new insights about use and packaging improvements. Once the team has a general understanding of packaging issues, it can now drill down to explore specific packaging elements that can be earmarked for improvement/refinement.

Building a Verbal Packaging Model (VPM™)

A verbal packaging model is a “blueprint” (Buzan and Buzan, 1996) of the ideal packaging solution from a consumer’s perspective (fig. 11.3). The process was developed originally to detail what consumers wanted to see, taste, smell, and touch in a new product idea. Its application fits the packaging development process as well.

The VPM™ technique is executed in typical group discussions. These groups are a little smaller than usual—no more than six participants. After focused discussions on the use of packages, consumers are paired to form three teams. The pairs are asked to describe their “ideal” package. A VPM™ Mind Map is provided for guidance (see fig. 11.3).

As you can see in figure 11.3, the teams are asked to brainstorm specific aspects of the package. To spur ideas, examples of many packaging options within and outside the category are also made available. For example, if you’re looking for ideas for packages containing breath mints, examples from existing breath mints are included along with examples from the candy industry and perhaps the medical market. The extended



Note: In actual VPM™ the terms are specific. These done for illustration purposes only.

Figure 11.3. A verbal package model (VPM) mind map.

examples give consumers permission to go outside their usual frame of reference.

Another key success component of these groups is to have members of the R&D and marketing teams come in and work with the consumer teams. Their role is not to add ideas but to listen and urge consumers to be specific and examine all possible avenues. Needless to say, this interaction provides an opportunity for developing conversations directly with consumers.

Each consumer team then shares its "ideal." Common elements across the Mind Maps become clear. Unique ideas from each team can be probed, clarified, and expanded by the members of the entire group. Reactions to these unique ideas usually let the members of the marketing and development teams know which ones are worth pursuing and which are not. Based on these consumer insights, the marketing and development teams are now ready to generate plausible solutions.

Identify Major Technical Needs

Consumer insights and data **DRIVE** the brainstorming of **DESIGN** solutions to move development forward. The key to conducting a successful

brainstorming session is to have the creative and technical staff participate as equals in the brainstorming process. The goal is to establish a synergy between the creative interpretation of the consumer need and the physics of package performance. The goal of this process is to conceive concepts that satisfy the consumer and the performance and profit requirements of the program.

An assessment of the major technical problems of the product and package should be performed very early in the process, preferably before designers generate shapes. The reason for this is to build the opportunity to integrate aesthetics and structure into the design process.

The normal creation process starts with a needs statement, which is given to designers who then generate interesting shapes, graphics, and so on. These aesthetics are then shared with consumers who vote, management gets excited, and the process of making a big mistake is underway. The next step is usually the engineers who are likely to say “but you can’t do that.” Very unpopular guys, those engineers! The structural needs are then imposed on the shape to the angst of the designers or a problem product goes to market.

The better process solicits the engineers first to identify what is known about the major problems and the current body of solutions that are known to work. This information is then conveyed by the engineers to the designers. This process allows the designers to consider these needs up front and to look for aesthetic opportunities in the structural needs when they are usually in ignorance of them. While not a guarantee, this process has shown some regular tendency to generate more interesting aesthetics since the designers are made aware of the general shapes that will be required and their creativity often finds novel ways to use the structure. The process also should include reviews of the concept ideas with the engineers as they evolve and before the consumer test.

In addition to involving the engineers early, virtual modeling at a directional level for different major package concepts can be highly effective in the process of screening or improving concept candidates.

Design the Right Engine

Once a package concept or concepts are identified, most of the difficulties and problematic shortfalls that occur in new package development are related to either asking the wrong questions at the onset of the project

or not anticipating what the key questions should be. The Mindful Design approach adopts a unique approach to early project planning that is focused on drawing the key questions out of the critical functional disciplines. It has been shown that roughly 90% of what will go wrong is visible in the concept drawing and can be avoided if the time is taken to assemble all of the downstream players at the beginning of the design process. Setting up these meetings takes longer than “just go do it” designs involving only a packaging engineer and his favorite supplier. However, the design output is inevitably less rework prone. Another key step, then, in the process of “designing the right engine” is the kickoff meeting.

Technical Kickoff Meeting

The critical goal of the kickoff meeting is to generate a closer to final concept BEFORE the product is finalized with the consumer. To achieve this, all the downstream stakeholders must be represented during the initial planning. This includes marketing, package design, design analysis, logistics, purchasing, molders, mold builders, assembly machine builders, and others. During this intense multiday meeting, the relationship between the requirements for each function are explored to expose where continuity exists and, more important, where conflicts exist. Ultimately, the conflicts represent the early opportunities to forestall future failure. Modifications to shape details and function are explored to generate a final concept that has execution success potential against all success criteria closer to 80–90% than the 0–10% of the traditional process.

This process will also draw out constraints and limitations that cannot be addressed so early in the development process. These issues are documented and kept in play until such time that they can be adequately addressed. This list of development tasks and steps from these discussions guide the critical steps to success and their order—a development plan. Typically, the manner of addressing the issues is also initially determined at this point. Some things must be tested. How, when, and where will we do it? Others are amenable to various kinds of analysis. What are they, what analysis technique will be used, who will do it, etc.?

After the known and known unknowns have been identified and documented, a rational project schedule can be created that reflects a realistic assessment of the package development environment.

In contrast, the conventional development process consists of a series of handoffs where information exchange across those boundaries typically results in rework at each handoff. This dynamic is highly similar to that avoided by Lean Manufacturing. We need to focus on minimal work-in-process inventory and parallel processes. Think of development work done in isolation from downstream development processes as being the same as molding parts, putting them in a box, sending them to the warehouse, and bringing them back a month later to assemble. We find when we open the box a month later, there was something wrong and we have now made a month's worth of bad product that has to be scrapped and started over. The same principle applies to good development strategy and process.

The final critical concept is to solve the critical detail design problems BEFORE the design is consumer tested in take-home trials. What good is a consumer test of a product that can't be made or isn't economical? Yet, companies do this all the time. The inevitable result in the face of the inevitable problems is a conversation that sounds like:

Engineer to Marketing: "It won't work. It breaks."

Marketing to Engineer: "You can't change it. We've already consumer tested and management has bought in. We'd have to delay the project and redo the consumer test. Make it work. Spend what it takes."

Do Prerace Trials

In a recent packaging initiative, the marketing and development teams were considering many options: seven (7) different packaging shapes, five (5) unique closures, six (6) sizes, and three (3) types of materials (fig. 11.4).

With these elements, one could construct a little over 600 different package options. Of course, these packages represent a variety of costs to produce. While consumer input is needed, it was cost prohibitive to make mock-ups of these elements. The internal team had several key questions.

1. Which package option will generate the most interest among target consumers?
2. Do we need to make the most expensive combination? If not, which options would represent a reasonable trade-off?

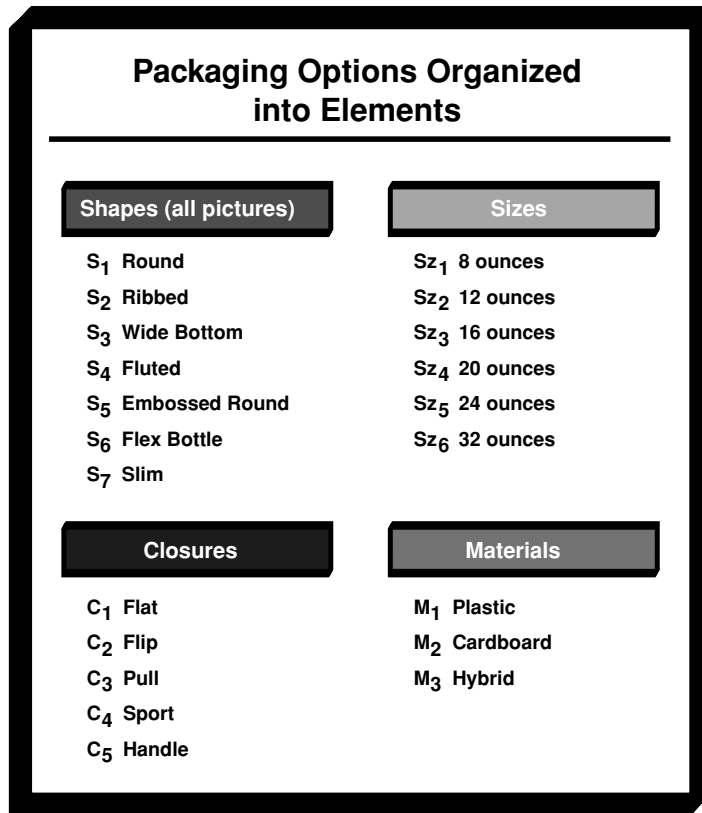
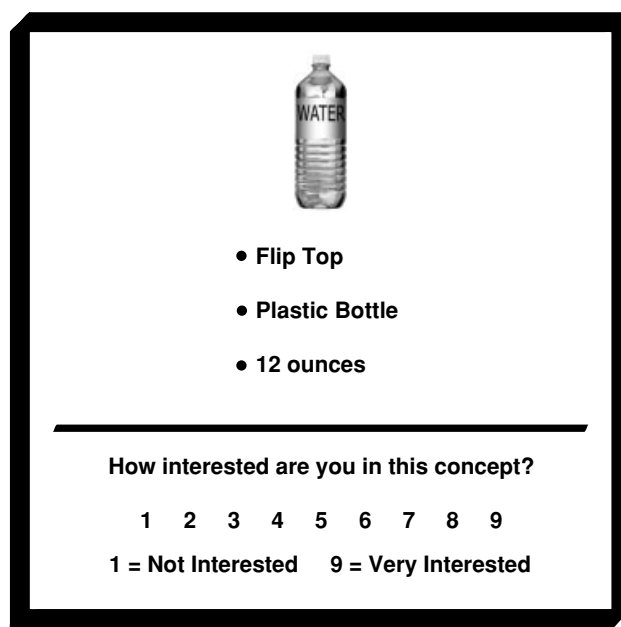



Figure 11.4. Packaging options organized into four elements: shapes, sizes, closures, and materials.

3. If an expensive package option is best liked, will consumers be willing to pay a little more?

Fortunately, the team took advantage of IdeaMap, a testing system developed by Moskowitz Jacobs, Inc., designed to help the team understand consumer preferences as well as identify the best possible options they can consider. IdeaMap was developed from conjoint analysis (Moskowitz et al., 2006).

The system “builds” concepts from a set of real-world stimuli that is selected by the team. The stimuli can be words, copy, video clips, visuals, or sound clips. The experimental design combines elements into test concepts (fig. 11.5).




 • Flip Top
 • Plastic Bottle
 • 12 ounces

How interested are you in this concept?

1 2 3 4 5 6 7 8 9

1 = Not Interested 9 = Very Interested

Elements are used to develop concepts that are shown to consumers.

Figure 11.5. A test concept shown to consumers in IdeaMap.

Each consumer sees a different set of concepts. When they see each one, the consumers rate it on one or more questions, for example, overall interest, uniqueness, fit to end use (fig. 11.6). The results show:

1. What consumers like
2. Average score (for the same elements across consumers)
3. Rank order of elements based on the relative utilities

In this way, the team can generate an “optimal” for total as well as subgroups of interest. The technology is very flexible as it allows you to do “what if” scenarios. The advantages of the design approach are just what is needed for speed to market. The use of IdeaMap (1) accelerates corporate brainstorming and consumer evaluation and (2) shortens time to market: traditional approach—10 weeks; IdeaMap—2–3 weeks.

The marketing and development team can now select viable options to move forward. The risk associated with traditional packaging development processes can be further reduced by use of VPS—virtual packaging simulation.

| Constant | | 50 | |
|-------------------------------|------------|---------------------------|------------|
| Shapes (all pictures) | | Sizes | |
| S ₁ Round | +12 | Sz ₁ 8 ounces | +3 |
| S ₂ Ribbed | +24 | Sz ₂ 12 ounces | +7 |
| S ₃ Wide Bottom | +3 | Sz ₃ 16 ounces | +15 |
| S ₄ Fluted | +10 | Sz ₄ 20 ounces | +10 |
| S ₅ Embossed Round | -3 | Sz ₅ 24 ounces | +7 |
| S ₆ Flex Bottle | -4 | Sz ₆ 32 ounces | +7 |
| S ₇ Slim | +5 | | |
| Closures | | Materials | |
| C ₁ Flat | -2 | M ₁ Plastic | +20 |
| C ₂ Flip | +7 | M ₂ Cardboard | -3 |
| C ₃ Pull | -10 | M ₃ Hybrid | -17 |
| C ₄ Sport | +20 | | |
| C ₅ Handle | +3 | | |

The utilities for each element are additive. They can be used to identify most preferred packaging (Optimum Concept elements are boxed).

Figure 11.6. The utility score calculated from the IdeaMap conducted for package options described in fig. 11.4.

Use Virtual Package Simulation and Analysis (VPS)

Once a stakeholder-vetted concept has been identified, detailed design should commence rapidly but with a high investment in virtual simulations and analyses. While not all problems can be simulated, most of the common ones can. It is faster and much cheaper to compute the final design parameters than to find them by experimentation. The cost benefit ratio from the various simulation and analysis tools has shown to be between 50 and 100 to 1. This ratio includes only direct product cost

benefits (lower weight, higher manufacturing throughputs) and doesn't include the value of earlier market time, better quality, and avoided rework.

If we use a plastic bottle project as an example, a smart development process will do the following things:

1. Parallel part and mold design (assembly equipment too, if applicable)
2. Virtual simulations and analysis to set final product dimensions
3. Virtual simulation of mold and molding process behaviors

Let's look at these in turn. Parallel part and mold design creates a "lean manufacturing" feedback loop as described earlier in this chapter. The benefit is a better part design and a removal of the mold design from the project critical path as happens in traditional development. In addition to the quality gained from avoiding part changes that can't be molded, a significant lead time gain is also achieved by putting mold design off of the critical path.

Virtual simulations and analysis of the product itself is a dynamic and growing activity. Users have to be aware that accurate analysis (you can cut steel to it) is involved and different than directional analysis that helps screen between product concepts in early development activities. In the case of our bottle, we can look at the following things very effectively with integrated Virtual Packaging Simulation (VPS) jointly created by Procter & Gamble and Stress Engineering Services.

1. Top load and bottle weight optimization (Bottle Optimal Weight Simulation—BOWS) (fig. 11.7a,b)
2. Pressure, vacuum, and squeeze load capabilities (figs. 11.8, 11.9)
3. Sealing systems and thread torque behaviors
4. Snap fits and other common structures
5. Conveying stability and handling behaviors

More involved analyses can consider things like drop-impact behaviors with different wall thicknesses and at different temperatures.

These analyses, in sum, allow us to evaluate the performance of the package and set its final dimensions and characteristics without having the time and expense of cutting molds, making parts, and testing parts. This process is much faster.

(a)



(b)



Figure 11.7. (a) Top load test and (b) analysis contour plot.

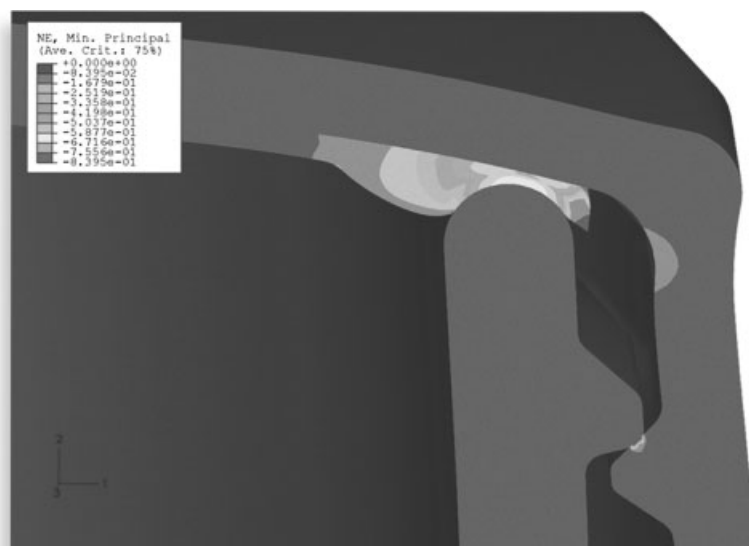


Figure 11.8. Analysis results used to evaluate the closure prior to production tooling commitment.

In all cases, we first mold the bottle and/or closure in the computer and then transfer properties and characteristics to structural simulations (fig. 11.10a,b,c,d). It is vital to accurate structural modeling that the effects of the molding process be represented in the structural model.

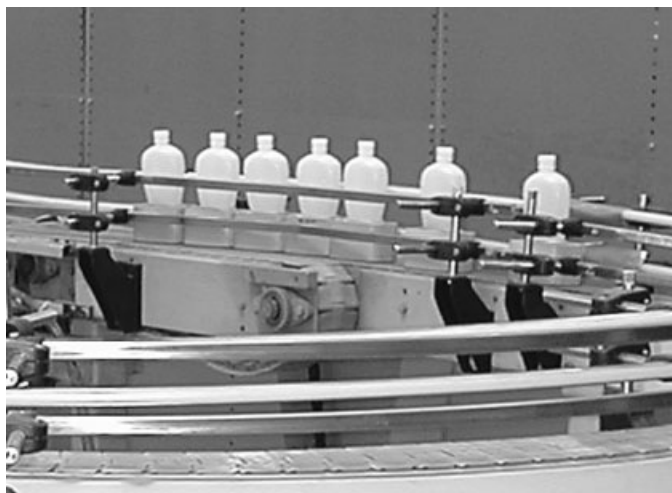


Figure 11.9. A virtual racetrack (VTR) for simulating bottle performance on a straight line conveyor.

Is the reader aware of any products in which the structure was not some result of the process by which it was made? Virtual analysis that doesn't consider the molding process is possible but, at best, directional. Accurate analysis and optimization requires consideration of the molding process before the structural modeling.

The outcome of virtual modeling loops involving the molding process and structural performance of the product is a final product design with extremely high confidence. It also should be the basis for creating the product that will be used for the final, large-scale, and definitive consumer test.

In this process, the physical prototype is a validation of the computer model accuracy. Usually, only minor tweaking is required to achieve the final design as opposed to fundamental, difficult, expensive, and time-consuming changes in a traditional process.

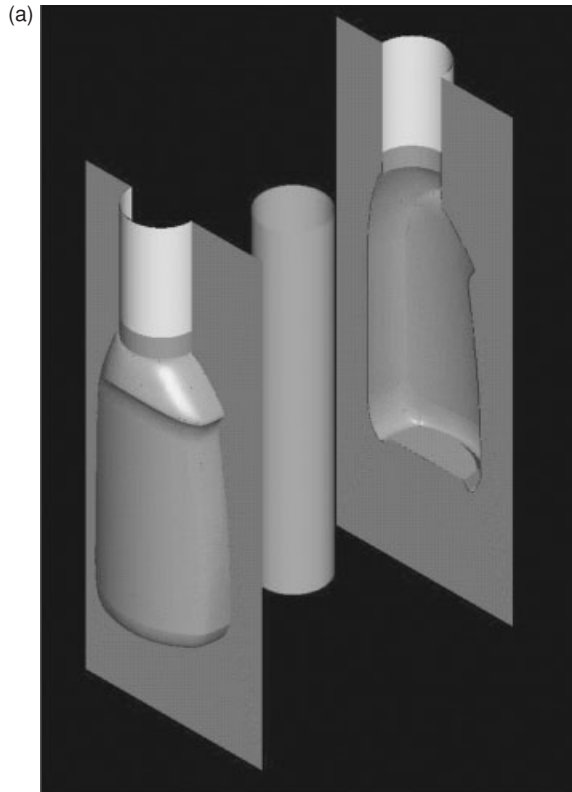
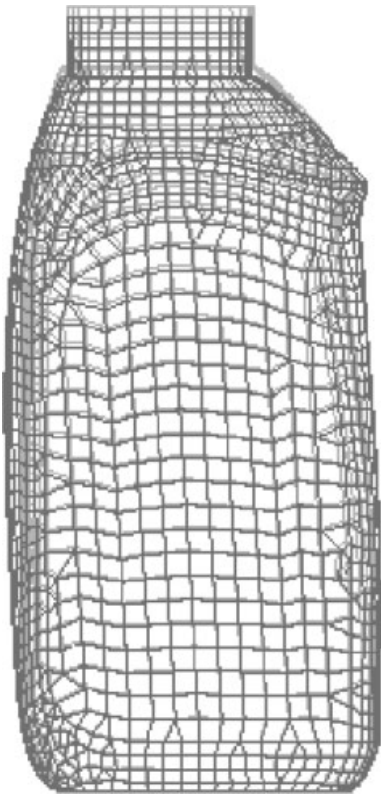


Figure 11.10. (a, b, c, d) Extrusion blow mold model, top load model, and optimized comparison.

(b)



(c)

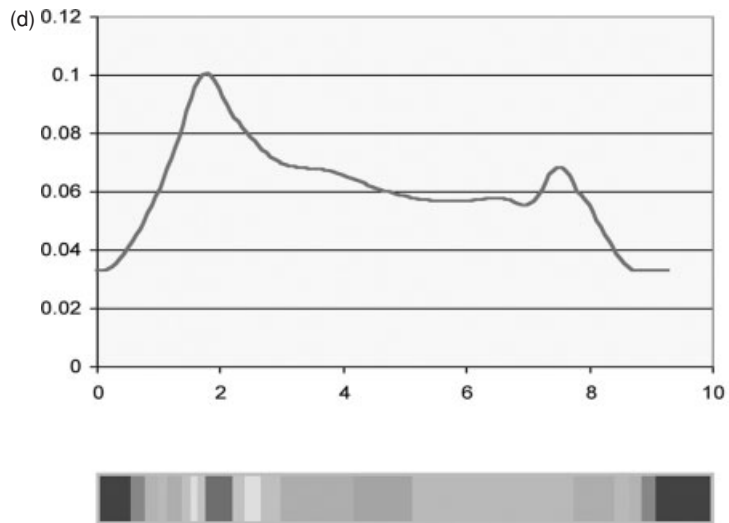
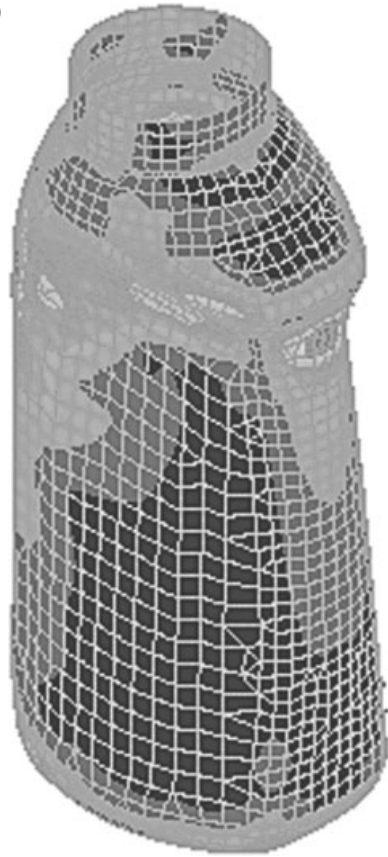


Figure 11.10. (Continued)

Test Protocepts

New packaging options must be further tested and meet historic hurdle rates before they are launched. This final phase of testing may take many forms depending on the requirements of the company and/or the importance of the change. In any event, these final tests should be done with commercially produced packages.

Several typical studies include: (1) check for appeal via a straightforward Packaging Study; (2) check for efficacy via a HUT—Home Use Test; (3) Check for impact, which may include a Choice Modeling Study or actual Test Market.

“Winning” packages are then moved forward for launch. Use of the Mindful Design process reduces risk of package failure due to technical issues. And, of course, since consumer insights were used early on to engineer the package adjustments, it is very likely packaging innovations that make it this far will be validated and introduced.

Opportunity—Not Speed Bump

The added complexity of speed to the traditional packaging process provides an opportunity to streamline and fix a process already replete with rework issues. Thus, this represents an opportunity. Careful planning—use of new tools and new technology—is the backbone of the Mindful Design process. Use of this process will assist companies in engineering and developing viable packages that:

- Look good
- Work better (even the first time!)
- Cost less
- And get to market faster!

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Chapter 12

MAKING LEMON BARS OUT OF LEMONS: USING THE POWER OF TEAMWORK TO TRANSFORM CONCEPTS TO REALITY

Mary K. Wagner and Leslie J. Herzog

Why Read This Chapter?

Dr. Mary Wagner is a successful business person who has had positions as a chief technology officer in several companies. Mr. Leslie Herzog is a successful hands-on product developer who “knows how to get things done.” Together they share some of their thinking on what it takes to make successful product development departments work today.

Introduction

Lemon bars are a favorite dessert treat in the United States, particularly among women; and are a staple at teas, baby showers, and wedding receptions. Despite their immense popularity, until the early 1990s there was no easy, quick way for consumers to make this treat at home. Thus, lemon bars were relegated to “special occasion” status. While working at Betty Crocker, Dr. Wagner participated on a product development team focused on being first to retail market with an easy-to-make lemon bar mix. All indications pointed to a real product success if this idea could be realized and a product launched. The challenge, much harder than it sounds, was faced with numerous obstacles, including that many

on the product development team believed chocolate-based products were a better bet than lemon bars. The team, however, successfully met its objective by following an effective process that brought the original idea to realization, produced a consumer “win,” and enabled families to easily prepare this one-time special occasion treat every day. For us, that experience galvanized our thinking on the keys to managing successful product development processes.

In today’s business environment, successful companies must be focused on essential activities that result in wins in the marketplace. For product research and development departments, whether it’s a Betty Crocker or a Gorton’s Seafood or Lipton Tea, teams are in a constant battle with their corporate competition to see who is best at developing new ideas, testing the worthiness of each concept, making adjustments/refinements, and deciding which ideas can be realized as a product, as quickly as possible. All of this must be done in tightly condensed time frames as winning the race to be first to market is often the difference between success and failure. The companies that do this consistently well typically utilize strong teams that rely on each member to perform his or her responsibilities and depend on accomplished team leaders who are capable of effectively managing the process. In this chapter, we talk about this team approach, as well as the process, and offer recommendations based on our experiences.

Start with the Essentials: An Overview

Management teams are constantly challenged to meet multiple stakeholder demands in a fast-paced, ever-changing, and complex business environment. In order to meet these demands, a business requires balancing trade-offs between competing external and internal interests. Successful organizations evaluate these competing interests to focus on the essential priorities identified to sustain and grow the business.

Management in these successful organizations communicates strategy and business objectives broadly, thereby ensuring all associates understand the role they play in the business. Putting together a plan should not stop at the executive level. Once the plan is established, it must be shared with the organization. The plan provides each department, work unit, and team with goals and objectives focused on results

and deliverables. Companies traditionally will “cascade” the information from the executives to individual work teams. Regular communication keeps employees informed of results and ensures alignment to strategies developed to achieve the organizational targets.

Many organizations also implement a performance management system to focus achievement on meaningful results. Common objectives from the top down ensure associates are working on the right things and that everyone is “aligned.” Regular performance reviews reinforce the performance measures and monitor progress against organizational goals. These regular meetings also allow for redirection if businesses need to refocus.

Process Management

To launch a product successfully in today’s marketplace, a process is essential. In fact, three keys separate successful product development departments from those that either fail or falter. First, a formal “Stage Gate” process is the best approach to funnel viable ideas from concept through launch. Second, an adopted project management process to facilitate delivery to the consumer solidifies the launch process. Finally, an effective team, led by an accomplished leader, will bring this approach to life. For example, while at Taco Bell, we knew through our Stage Gate concept screening that consumers wanted “hot” food. Through this approach, grilled products evolved as a front runner and were put into a formal project management structure for possible launch. The team involved everyone from marketing through operations. Leaders from the various functions worked seamlessly, and several product lines followed the initial launch of the first grilled product, the grilled stuffed burrito.

So how does this development process happen? Today, many companies manage their innovation process with a Stage Gate system (Cooper et al., 2001). They identify hurdles that ideas must meet at each stage of the process to continue to the next stage. For example, innovation teams may generate multiple ideas that are then screened by consumers or customers. Only the highest scoring ideas are moved into a second stage where they are further analyzed based on other business metrics, fit to the business and potential risks, including competitive response. Once the ideas have been fully scoped, those with the best potential

move into development where the product and proposition are further refined. One more hurdle must be passed before moving into a commercialization stage based on potential sales volume estimates. There are many techniques for formulating an “optimal” R&D portfolio (Ringuest and Graves, 2005). A balanced portfolio strategy is to have many ideas in the early phases of the gate process since as we all know many concepts need to be evaluated before coming up with real winners. For Taco Bell, grilled stuffed burritos and the entire grilling platform provided that optimal opportunity that enabled its ultimate launch as a consumer product.

Leadership Is Key

The third key mentioned was the importance of an effective team and capable leader. We firmly believe in the team concept as the best way to meet the objectives of a product development department, particularly given the need to be nimble. Of course, it ultimately comes down to talents, knowledge, and know-how of the team leader if the team is to achieve breakout success.

Based on our years of experience, effective communication between the team leader and the team is key. The communication must be inclusive, focused, and consistent. However, despite the best communication and most effective leadership, if the team members are not committed to the overall objective, the effort is destined for failure.

Team Roles and Responsibilities: Trust Beats Failure

Setting roles and responsibilities helps reduce natural redundancies that occur in some product development organizations. When you incorporate experts into a team (a wine maker or a chef), you often create overlap with the product developer or the research scientist. Clear articulation of each team member’s role and responsibility will ensure the project teams work efficiently and effectively. Every team and team member must understand their roles in the success of the business, and when the team succeeds they should be rewarded.

Defining such roles and responsibilities within the company results in swift action without a lot of overhead or a lot of time wasted. Also,

remember that selecting or coaching people to be successful in their roles and responsibilities builds a culture of trust.

Having a blend of experiences on staff creates a strong team. What surprises those of us who have traveled through several companies or several jobs assignments within a company is that every time you come to a new type of subject matter, there is so much that is so similar in terms of how you get projects done and the type of people you need, that you begin to see the rules: you need smart people, experienced people, and diverse people.

The best innovation groups have a culture of trust. They are comfortable dealing with situations that do not appear to be working out—either with personnel, projects, or businesses. Successful organizations deal effectively with team members who may not be right for the business. They identify the right assignments to leverage individual skills, provide opportunities for personal development, and support associates through transitions.

Lack of focus, negative politics, and needless spending also cause failure. Although these cannot be avoided, you can learn to manage them. Balancing business needs, personnel issues, and market realities are all the challenges of leading R&D organizations. Having a strategy and a plan will help you successfully navigate these challenges.

The Flexible Plan

Project management teams need to be focused on essential activities that will enable them to best succeed. That focus should include a thorough understanding of the customer, the consumer, and competition to provide the background for the strategy to meet the organization's mission. That means you have to have a plan, both long-term (five years) and short-term (one year); yet you have to have enough flexibility within all parts of the organization to be able to turn on a dime if an immediate business need arises.

Understand, to shift people around to meet the needs of the business means you're going to want people on the team who are fairly flexible. When Dr. Wagner started her career in product development, she worked on a project she was passionate about—a microwave dinner product. She thought it was the greatest idea. The project went through several stages of product development then other demands took priority. She never

went back to work on that product. As it was her first development project, it was hard to let it go at first, but the need to learn to be flexible and to deal effectively with change was essential. The lesson for her was that people who are willing to effectively change direction quickly are needed in today's fast-paced world. Changes in consumer trends create the need to change direction quickly.

Ideas Are Everywhere

A process to sort ideas efficiently is essential today. There's no lack of ideas, they come from all stockholders—managers, peers, consumers, and customers. Deciding what to work on in an environment where complexity rules is the challenge. Consumers have too many choices in the grocery store, which can be very confusing for people. According to a report in early 2006 (Anonymous, 2006), over 1900 new food products were introduced in 2005 from the 25 largest food companies in the United States, up from 1387 five years earlier. When consumers pick up your product and try it, you want them to pick it up again and again. A cross-functional innovation team can be useful to own this process of screening ideas. This group is charged with identifying the ideas that will work for the company.

There are a variety of techniques used to select winning ideas. One successful technique is for companies to partner with consumers more closely. By observing consumers use your product, you can find ways to improve it, reduce its cost, as well as generate ideas for new products (Mariampolski, 2006). Many of the most successful innovations come from identifying a specific problem that needed solving and inventing a solution that had a much broader application. In the area of consumer insights, be willing to try new techniques and look for gaps in the marketplace or in the portfolio. At Gorton's Seafood, the obvious consumer gap in our portfolio, and reinforced by consumer input, was a grilled product offering, hence "grilled filets" were developed and launched.

Research tools used to sort ideas or quantify potential new ones are typically standardized because it takes time to establish benchmarks and models predicting in-market measures. Innovators must have a broad understanding of the consumer, customer, and competition. Competition should be defined beyond those companies who produce similar

products to include those with products used by consumers to meet the same or similar needs. Time to innovate in the food industry is short, two years at the most to really strike big with an original solution. Within a year, we must prove it out and make sure it runs, and it truly has to be innovative to either reduce your cost significantly or create a differentiated product. New products enter the market, and if you're not noticing it, you're going to be far behind. It is helpful to experience products as consumers, sharing competitive products with the team. Talk about it, think about it, and work with it. You have to know your competition, what's worked, and what hasn't.

Adequate Funding of Research Yields Growth

Adequate funding is critical to succeed. Bowonder et al. (2005) reported R&D spending patterns of 320 global firms based on 2003 sales turnover (revenues) and R&D spending. Of the eight food processing and food products companies cited in their article, the range of R&D expenditures to percent sales varied from 0.5 (Tyson Foods) to 2.71 (Ajinomoto) with an average of 1.88% of sales for the top five food processing companies and 0.97% of sales for the three food products companies reported. Another report indicated that \$2.89 billion was spent by 12 of the largest food companies on R&D in 2004, which was a 13% increase over the previous year and a 58% increase over the amount spent five years ago (Anonymous, 2005). Food processing is one industry segment in which the R&D intensity (% sales) increased in 2004. Many companies are shifting to distributed innovation models that leverage knowledge and products from a variety of sources outside their internal R&D, including universities and contract research.

Partnerships

Business and professional networks are used by most successful R&D organizations to gain knowledge and solve problems. When Mary Wagner was working in the fast food industry, Star Link corn (a genetically modified corn targeted for animal feed) showed up in a human food product, which licensed the name of the company that she was working for at the time, Taco Bell. Being able to call on her informal

network of contacts, people she knew who could connect her to the experts, allowed her to become highly informed about the issue in a short period of time and effectively respond to the situation. Likewise, formal alliances or joint ventures are leveraged to innovate faster. For both short- and longer-term projects, leveraging external resources can help fill skill gaps (Kirschbaum, 2005).

For longer-term research or for technical challenges, you may not have the infrastructure to support a search for partnerships with universities, professional organizations, or entrepreneurial companies. In terms of appropriate alliance activities, it is best to foster collaborative business strategies. This means bringing in new or immediate perspectives to your business. For many product development organizations, partnering with packaging experts provides the perspective needed to understand choices in bottle closures, for example. In the wine industry, there are many closure choices—natural cork, technical corks, synthetic closures, screw cap closures. Finding the best partners to work with to identify solutions for your products helps sort through the options to decide what the best is for the consumer.

Remember, the additional benefit to building partnerships is that you stay focused on your own core competencies and minimize overhead and investment costs, always a win-win.

Embrace Innovation

Procter & Gamble is probably one of the leading companies in our industry (at least a portion of their total sales is from food) and within the last five years it has adopted a strategy of “open innovation,” which now (2006) produces more than 35% of the company’s innovations (Houston and Sakkab, 2006). In 2000, A. G. Lafley, CEO of Procter & Gamble, challenged P&G management to reinvent the company’s innovation business model. P&G’s management knew that “external connections” could produce highly profitable innovations. Lafley bet that these connections were the key to future growth and made it the company goal to acquire 50% of their innovations from outside the company. The strategy adopted by P&G was to better leverage the capabilities of their existing researchers and staff. Houston and Sakkab (2006) cite some interesting statistics for P&G and the use of external resources: more than 35% of P&G’s new products in the market have elements

that originated from outside P&G, up from about 15% five years ago; 45% of the initiatives in their product development portfolio have key elements that were discovered externally. Because of this new model, P&G's R&D productivity has increased by nearly 60%; its innovation "success" rate has nearly doubled. The R&D investment as a percentage of sales has decreased from 4.8% in 2000 to 3.4% in 2005.

How to value innovation is another thing. In 2006, financial reporting about P&G indicated innovation actually accounted for about 9% of the reported 34% growth. Most of the increase was attributed to price increases (Ellison, 2006).

Walking Away Is "OK"

One value of a stage gate process is identifying those projects that will not meet the business goals. Project teams invest a lot of their personal and professional lives to deliver products and it can be difficult to have them canceled. Leaders must provide the right culture to stop projects without feelings of failure. Many ideas are shelved until a better business environment comes along or a product concept is further refined.

Conclusion

One can draw many sports parallels between an athletic team and a product development team. Success for both depends on strong leaders backed by role players willing to do whatever it takes for the good of the team. Each requires a sound game plan, which will be constantly analyzed and enhanced with significant practice. Some key points to remember include:

- have a clear process in place
- have great leadership
- put a premium on effective communication
- share success with the entire team
- be vigilant in managing resources and making decisions about the potential of an idea or a proposition
- focus on the essential
- have a flexible plan

- ideas are “everywhere” and you need a mechanism to “sort” them
- don’t be scared to “walk away” from an idea if the “fit” just isn’t there at the present time

Ultimate success for any team is determined not by the mere number of victories, but rather by how the team responds to defeat. For product development teams, some of the greatest successes have been realized in the midst of the defeat of original ideas and recommendations. In those instances, success proved to be the by-product of never giving up.

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Part III

Optimizing Food Product Design and Development

Chapter 13

IDENTIFYING CRITICAL STEPS IN THE NEW PRODUCT DEVELOPMENT PROCESS

Yao-Wen Huang

Why Read This Chapter?

This chapter provides a good overview of the product development process with rationale for the steps and an understanding of how to use the process for more effective new development.

Introduction

Product development is an important activity in the food industry. It is the heart of the industry for growth and survival. Many companies use a formal product development process; however, the stages or phases of the process may vary. The product development process is a systematic approach to develop a new product. It is the entire set of activities required to bring a new concept to a state of market readiness. No matter how many stages or phases are used in industry, these stages or phases are a continuous sequence of tasks. Many stages/phases may be undertaken concurrently or performed back and forth in order to save time or modify the design, respectively. Among these stages or phases, some critical steps for the product development process need to be carefully performed to ensure a successful product.

Overview of the New Product Development Process

Published literature suggests that the product development process can be divided into different stages or phases ranging from a 3-stage process to an 11-stage process. The goal of the new product development process is to bring a new product to marketplace with the least amount of uncertainty. When each stage or phase successfully passes the management decision from the company and moves forward, the probability of a successful product in the marketplace will be much increased.

A Three-Stage Process

Two authors propose a three-stage process. Rudolph (1995) listed the process as product definition → product implementation → product introduction. In 2002, Kramer stated the process as bench-top → pilot plant → commercial plant.

A Four-Stage Process

Earlier in 1969, Crockett suggested four steps for developing new products: search opportunities → translation of concepts into products → marketing plan → implementation of marketing plan. Earle (1997) also suggested a four-stage process: product strategy → product design and process development → product commercialization → product launch and evaluation.

A Five-Stage Process

A five-stage product development protocol was stated by Graf and Saguy in 1991. This process is as follows: screening → feasibility → development → commercialization → maintenance.

A Six-Stage Process

Cooper (2001) originally developed a Stage-Gate^R product process with five stages. These are scoping → building business case → development → testing and validation → launch. Later in 1994, Fuller stated a six-phase process. The phases are listed as follow: ideation → screening ideas → development → production → consumer trials → test market.

A Seven-Stage Process

Holmes (1968) listed a seven-stage process for product development as follows: company objectives → exploration → screening → business analysis → development → testing → commercialization → product success. In 1990, Oickle suggested a protocol with seven steps: exploration → conception → modeling (prototypes) → research and development → marketing plan → market testing → major introduction.

An Eleven-Stage Process

Mattson in 1970 proposed an 11-step process for developing a new product. He listed the steps as follows: idea generation → concept screening → preliminary formulation → taste panels → final formulation → trial placement → fine tuning → package design → co-packers → minimarket test → symbiotic distribution.

Critical Steps for the New Product Development Process

Previous and current product development processes have been proposed with respect to either technology or marketing. However, the concept development, prototyping, and commercialization are critical steps to a successful new product development process.

Concept Development

The concept is the blueprint for the new product and is critical for development of a successful new product. Developing a concept needs a set of general market specifications for the product. Understanding customer needs and competition steers a design team toward the generation of a new concept. Activities in developing a concept may include portfolio planning, functional modeling, product architecture development, and concept engineering (Ott and Wood, 2001).

Identification of the Intention for a Product

Ideation for new products is generated with meeting the intention of product development. The intention of developing a new product may be used to decide the direction of concept development. In general,

the requests for developing a new product come from three sectors: customers, sales department, or internal operations of the company.

For requests from the customers' sector, the intention may clearly indicate improving the product position in the market. The target product will be decided by customers and the R&D personnel will need to work with customers to develop a concept. As for the request of a new product from a company's sales department, the new product may need to replace a competitor's product in the market. In this case, the competitor's product is used to define the target. Both R&D and sales departments will make the approval decision. As for the intention from internal operations sector, the new product is intended to improve profitability, the target exists in the existing product. In this situation, the R&D, quality assurance, and operations will decide and approve the final product concept.

New product ideas may also come from both internal and external sources. The internal sources include the R&D department, consumer service, and sales department of the company. However, the external sources may include professional conferences, libraries, government publications, patents, and trade literature.

Analysis of Business Opportunity

Techniques used for opportunity analysis include GAP analysis, SWOT analysis, and VOC.

The GAP analysis is a technique using a grid to select a particular product category. Each row of the grid, for example, describes product attributes and the columns might be labeled by the form of product. The grid will be filled in with data from the marketplace and ideas for new products may be revealed by the empty space on the grid. This technique will help examine the marketplace for a product vacuum. If no product currently exists in the marketplace, this indicates both opportunities and challenges.

The SWOT analysis represents an analysis of strengths, weaknesses, opportunities, and threats (Miller and Swaddling, 2002). It provides an evaluation of a company's core competence in terms of its advantages and disadvantages versus competitors, customer requirements, and market conditions.

The VOC process, representing the Voice of Customers, is a proactive way to capture the changing requirements of the customers with

time (Katz, 2004). It commonly uses structured in-depth interviews for eliciting needs from consumers. The technique leads interviewees through a series of situations in which they have experienced and found solutions to the set of problems being investigated. Other methods for capturing VOC include focus groups, surveys, customer service feedback, warranty data, field reports, complaint logs, and market research. The data collected are used to identify the quality attributes needed to be incorporated in the product or process.

Ideation

The generation of ideas can be achieved by using brainstorming techniques with a focus group. Brainstorming is a creative problem-solving method. The basic technique uses a group of people to creatively generate a list of ideas related to a specific subject. A larger number (8–12) instead of just the core product development team members should be used in the brainstorming process. The rules for successful brainstorming include the following techniques: defining a subject, assignment of a moderator to facilitate and write down all the ideas generated with no prejudgment allowed during the process, emphasis on quantity instead of quality, and encouragement for chaos and tangents, and making connections between ideas generated. The responses obtained from the focus group need to be properly interpreted through quantitative data for development of the product concept and future prototype.

Screening for Better Idea

Ideas generated from focus groups need to be screened to meet the company's image and core competencies. Feasibility screening uses the following criteria: marketability, technical feasibility, manufacturing capacity, and financial resources.

Bench-Top Product

Bench-top product is a physical object produced from feasible concept. The tangible product will be used for sensory research for further refinement. After the management committee evaluates the approved concepts through bench-top product and decides "Go" or "No Go," prototyping and a business are then constructed.

Prototyping

Before the prototyping step, a business plan is translated into concrete deliverables. A business plan is a document that describes market opportunity and the development program (Smith and Reinertsen, 1998). The body of a business plan can be divided into four sections: (1) business description, (2) marketing (competition, operation procedures, personnel), (3) finances (loan application, capital equipment and supply list, balance sheet, breakdown analysis, pro-forma income summary), and (4) management.

The activities in this stage include development and optimization of product formulations, experimental design and protocol testing, benchmarking, prototyping, up-scaling, sensory evaluation, shelf life testing, packaging development, defining the manufacturing process, quality standard, cost analysis, and consideration of safety and regulatory issues.

Prototyping

Prototyping is the process of quickly putting together a working model (a product prototype) in order to test various aspects of the design, illustrate ideas or features, and gather early user feedback. Prototyping is often treated as an integral part of the product development process. It is believed to reduce project risk and cost. In many cases, more than one prototype is made in a process of incremental development with each prototype being influenced by the performance of previous designs. Problems or deficiencies in previous designs can be corrected. When the prototype is sufficiently refined and meets the functionality, robustness, manufacturability, and other design goals, the product is ready for production.

Optimization

Optimization is a technique that involves finding the best or most possible desirable results in a system for a product or a process. Using statistical design along with sensory attribute requirements, a mathematical relationship between the input and output variables is established. All variables in the process must be quantifiable. Response surface methodology (RSM) can be used to achieve product optimization. In food product formulations with multicomponent (input variables) mixtures, the measured response surface (output variables) can reveal the best formulation that will maximize the attribute. Partial factorial design may

be used to determine tested product formulation. Optimization reduces the process time for developing an acceptable prototype.

Testing of Shelf Life

Shelf life testing begins once a prototype is produced. Shelf life is defined as the time when a food product no longer maintains the expected quality to the consumer. Shelf life and product quality are highly related. The criteria for shelf life testing can be based on the decline of microbial, nutritional, or sensory quality. Determination of shelf life may include static, accelerated, and use/abuse techniques. Since a food product is a complicated chemical system, many changes may occur throughout its shelf life. During the prototyping stages, the shelf life of the tested product should be a stated attribute.

Building Food Safety in New Products

Food safety for new products is an important concern throughout the development process and should be designed into the product from the start. Product developers must incorporate safety and quality design into their products through the judicious use of ingredients, processing, and packaging technology. New products may introduce unsuspected new hazards through the introduction of new raw materials and ingredients. Each product needs an HACCP program unique to itself. However, HACCP programs should be flexible and able to evolve continually to meet equally flexible, and constantly evolving, hazards of economic and public health significance, especially the emerging microbial hazards.

Commercialization

Product commercialization is a full scale-up and integration of both production and marketing. Product commercialization (Earle et al., 2001) involves (1) setting up the commercialization, design of marketing; (2) production and distribution; (3) testing of marketing production, production, and distribution; (4) and final integration of marketing, production, and finance.

Up-Scaling

This is a process to produce an identical product at a scale larger than that which was used previously for bench-top objective. A successful scale up depends on the following requirements: (1) initial process

should simulate the anticipated production process; (2) mechanisms governing the attainment of the desired results need to be understood; and (3) all processing parameters need to be measured quantitatively. The approaches used for up-scaling may include, but are not limited to, constant time and temperature, flow rate, mixing speed, torque, and geometric similarity. Up-scaling should be planned in the initial bench scale product development activities. Multistep increases in scales generally give the best results as compared to a one-step scale-up.

Market Testing

Test market is the introduction of new products into regions selected for a variety of geographical, marketing, and company reasons. Test market is a significant part of the screening process and is the first, large-scale, controlled opportunity to evaluate how customers, consumers, retailers, and the competition will react to a new product. There are three classes of market tests including a simulated test market—a concept testing technique similar in many respects to a focus group; controlled testing—similar to the traditional test market, but the entire test is farmed out to a market research company that manages the entire test from distribution to promotions; and traditional sell-in test marketing (Lord, 2000).

Launch and Evaluation

Product launch involves executing all of the activities involved in manufacturing, distributing, and selling the new product to both the trade group and the final consumers (Lord, 2000). All these functional areas must effectively and efficiently perform their designated activities.

Keys for a Successful New Product Development Process

New product development is a complicated process. In addition to the critical steps previously identified, the following key elements need to be performed along with a typical project to ensure a successful product.

- **Developing a Strategic Plan**

The developed product needs to meet the corporation's image. A strategic plan becomes an important document for a product

development team to follow. The strategic plan establishes the vision, mission, values, goals, and the strategy of the organization. Earle and associates (2001) combined product, process, marketing, and organizational innovations together to develop an overall innovation strategy. This relates to the company's overall business aims and strategy, the social, economic, and technological environment, and the company's core competencies. The product development strategy lies between the new product portfolio and the product development program. In developing the product development strategies, specifying the type of markets, such as retail, food-service or industrial, become important.

- **Forming a Cross-Functional Team**

When a new product development project is decided, it is necessary to form a cross-functional team if the product has never been produced before in that company. A cross-functional team consists of a group of people working toward a common goal and made of people with different functional expertise. It could include people from R&D, marketing, production, quality assurance, finance, logistics, and legal departments in the company. Team members may also come from outside the company including suppliers, key vendors, or consultants. Cross-functional teams often function as self-directed teams: they are empowered and respond to defined objectives. Decision making within a team may depend on consensus, but often is led by a team leader.

- **Managing a Project**

New product development is a project. It is a temporary endeavor undertaken to create a unique product or service. The duration of a project is the time from its start to its completion, which can take days, weeks, months, or even years. The project has limited resources, which may be shared with other tasks and routine programs. A project contains the following elements: mission, objectives, and constraints. The project management includes different types of activities as follows:

1. Defining the work: to setup the goal and resources needed
2. Planning: emphasize quality, time, and cost dimensions
3. Implementation: control work in progress, provide feedback, negotiate for materials, supplies, and services and resolve differences
4. Evaluation: review and discuss the results

- Involving Logistics in the Early Stage of the Development Process
Logistics encompasses the process of procurement, transportation, and storage of goods from their source to the customer. It involves purchasing, transportation, materials management, and information management. Morehouse and associates (1991) stated that effective logistics impacts a product in many ways including packaging, warehousing, physical distribution, transportation, inventory location, forecasting, production planning, and inventory control. Logistics involvement must begin early in the development process and continue throughout the entire process.

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Chapter 14

STATISTICAL DESIGN: EXPERIMENTAL UNITS AND PROPER DESIGNS

T. Kassel and J. C. Huang

Why Read This Chapter?

This chapter provides a good overview by practicing food scientists on how to use experimental design on an applied basis, written by practitioners in the field.

In this chapter, we are going to discuss experimental design. The experimental design's only concern is how the food scientist arranges the factors applied to the experimental unit and the execution of them in an orderly fashion (Huang and Anderson, 2003). For example, a food scientist plans to conduct an experiment (or should we say experimental design) to develop the best combination of new ingredient and baking temperatures for a good quality bread. These questions arise for food scientists: "What is the best design to approach? What are the differences among designs?" Before we design the experiment, first we introduce a concept in the experimental design, the experimental unit. The experimental unit is the basic unit that food scientists use to conduct an experiment. For example, a bread formula that contains a new ingredient is an experimental unit. The response from the bread (experimental unit), measured by either an instrument or a sensory panel, reflects the factor(s) effect(s) on the experimental unit. Therefore, we need to define what the experimental units and subsamples are and their differences. We first have to define the experimental unit that we, as food scientists, have agreed upon.

Definition of Experimental Unit and Subsample

The definition of “experimental unit” is a physical entity or a product exposure to a treatment(s) or factor(s) independently (Kuehl, 1994). Statistically, the experimental unit is the smallest unit in the experiment and responses from the experimental unit used are to be analyzed. However, the treatment(s) and factor(s) are sometimes identical. Factors (treatments) could come from ingredients of formulations, environmental factors, processing parameters, or storage conditions in figure 14.1. The subsample is a divided unit from the experimental unit. Let’s say a loaf of bread, an experimental unit, was divided into three slices. Every slice from this bread is considered as a subsample since each slice is not independent.

We use other examples in figures 14.2 and 14.3 to explain their difference in experimental units, based on the definitions we have just made. First, let’s discuss the experimental unit for new ingredients in figure 14.2. Food Scientist X proceeds to make one batch of dough with a new ingredient and then divides it into 15 dough balls. Food Scientist Y chooses to make 15 batches of dough with a new ingredient and then removes one small dough ball from each of the larger doughs. Now we apply the definition of the experimental unit to the doughs with the new

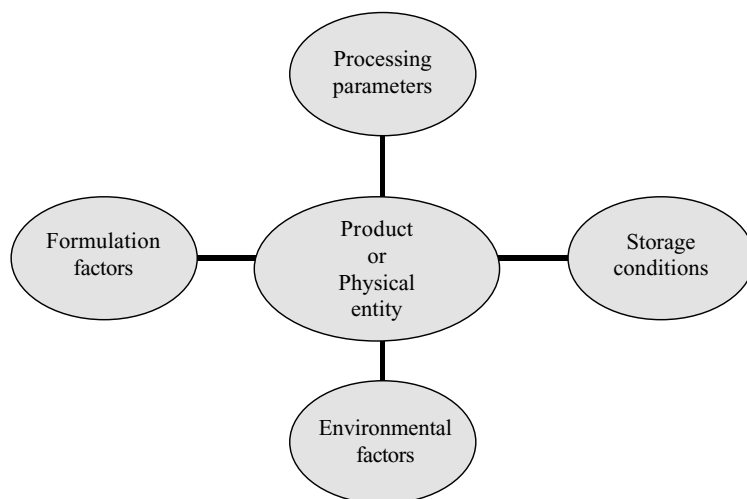


Figure 14.1. Factor sources.

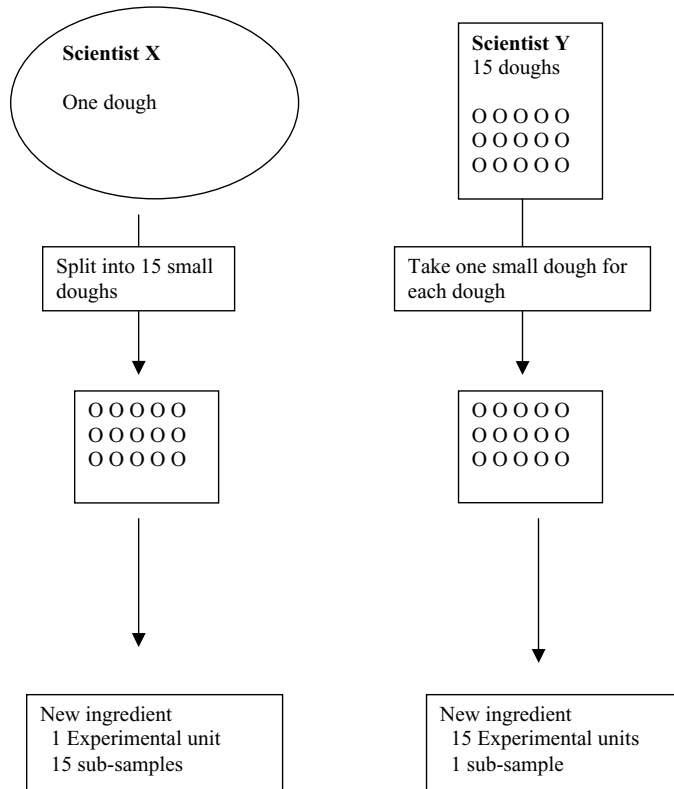


Figure 14.2. Experimental units of new ingredient for Scientists X and Y.

ingredients. The physical entity or product is the batch of dough containing (exposed to) the new ingredient, a treatment or factor. Therefore, Food Scientist X produces only one experimental unit with 15 subsamples, since 15 smaller doughs came from the same batch of dough. Meanwhile in figure 14.2, Scientist Y has 15 experimental units with no subsamples, because 15 smaller doughs came from 15 different batches of doughs. The 15 smaller doughs are not independent for the design of Food Scientist X, while the 15 smaller doughs from the 15 different doughs are independent for the design of Scientist Y. The independence separates the experimental unit from the subsample. These concepts also apply in replication. Subsamples from the same experimental unit are not true replication. We will emphasize this later on.

Now, let's take a look at the experimental unit for baking temperature in figure 14.3. Food Scientist X still makes one batch of dough with a

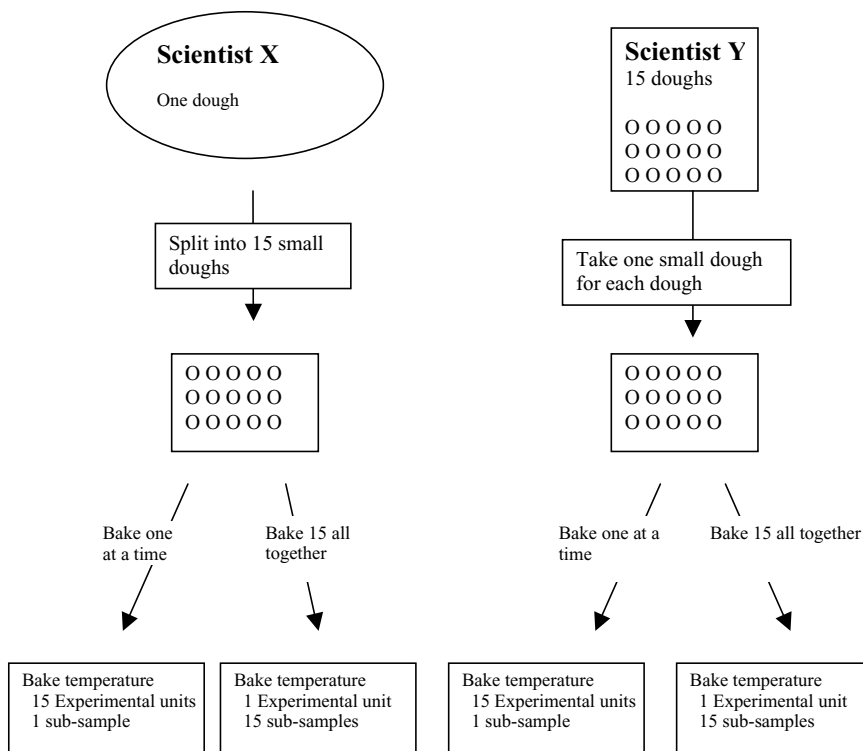


Figure 14.3. Experimental units of bake temperature for Scientists X and Y.

new ingredient and then divides it into 15 dough balls; and Food Scientist Y makes 15 batches of dough with a new ingredient and then removes one small dough ball from each of the larger doughs. However, Scientists X and Y both apply two different methods to bake doughs. Scientists X and Y each bake one dough ball at a time and bake 15 doughs all together. Again, apply the definition of experimental unit, but only to the baking temperature. The physical entity or product is the smaller doughs (with the new ingredient) that are exposed to the baking temperature, a treatment or factor. However, the physical entity or product now becomes either one small dough if baked one at a time, or 15 smaller doughs if baked all together. Fifteen smaller doughs exposed to the baking temperature all together, a treatment or factor, are considered to be one experimental unit. Alternately, 15 smaller doughs that are exposed to the baking temperature, one by one, produce 15 experimental units. So you can see that the two baking methods also

provide different numbers of experimental units and subsamples under the definition of the experimental unit. Here you may find out that there are 15 experimental units when Scientist X bakes dough individually even though 15 of them are coming from the same dough. Nonetheless, Scientist Y only produces one experimental unit when baking 15 doughs, even though each smaller dough came from a different batch of dough.

Therefore, it is very important for food scientists to distinguish what the experimental units and subsamples are.

Remember that the experimental unit is the smallest unit in the experiment. The response data from the experimental unit are used for data analysis, while responses from subsamples don't provide meaningful information (average of data from subsample becomes data for experimental unit). In addition, responses or data from subsamples are not true replications for an experimental unit, since the information that the subsamples provide is not independent (Cochran and Cox, 1957).

If Food Scientist X treats the subsample as an experimental unit, results may conclude that there is significant difference (which is not true), because variance is smaller within the experimental unit than among experimental designs. Now let's put figures 14.2 and 14.3 together. There are two factors: a new ingredient and baking temperature, respectively. Food scientists can produce four different designs to conduct the experiments, but one may wonder whether each one has the same experimental design or has the same number of experimental units for treatments as seen in figure 14.4. In this case, there are four totally different experiments. Each one has a different number of experimental units and subsamples.

Experimental Unit of Instrumental and Sensory Data

Interestingly enough, the definition of experimental unit for sensory evaluation is slightly different than the one for instrumental data. In sensory evaluation or survey data, human perception is considered to be independent for each person. Therefore, the experimental unit is a person's opinion toward a product or physical entity (Lawless and Heymann, 1999). That means that each individual expresses his or her personal feelings independently without the influence of others. The experimental unit in the sensory evaluation is each individual's feeling.

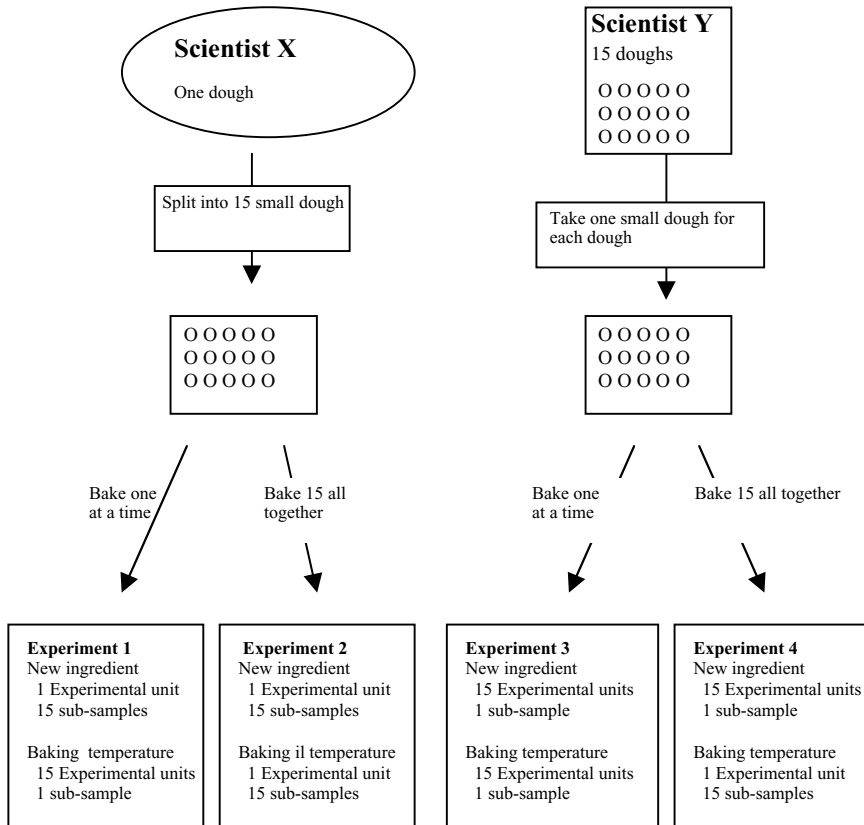


Figure 14.4. Experimental units for new ingredient and bake temperature for Scientists X and Y.

In figure 14.5 a food scientist uses an instrument or sensory panel (15 panelists) to test a bread crust with a new ingredient. Based on the definition of an experimental unit, there are 1 experimental unit and 15 subsamples, since each piece tested by an instrument is from the same dough. However, there are 15 experimental units and no subsamples if put under sensory evaluation. Nonetheless, this is different from what most statisticians view. Statisticians perceive that the sensory evaluation involves two types of experimental units: an experimental unit for the crust and an experimental unit for the human perception toward the crust. Statisticians treat these two experimental units by considering the “independency” in data analysis: independent T-test and dependent (or paired) T-test, which is covered in the next section.

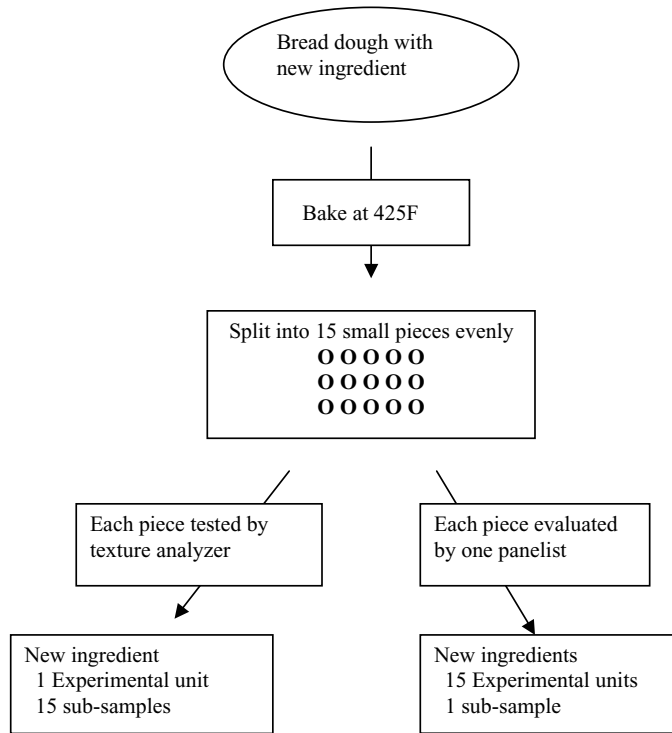


Figure 14.5. Experimental unit of instrumental and sensory measurements.

Independent T-Test and Dependent T-Test

Dependency is also crucial to experimental units in data analysis. We use the following example to show significant difference in mathematic equations. Scientists X and Y would like to compare two products, I and II, made from two different extrusion processing methods. Scientist X selects 20 semitrained panelists to perform a sensory test by using a line scale. Ten people are assigned to evaluate the product for processing method I and another 10 for processing method II. Scientist Y prefers to assign 20 people to evaluate products I and II with a mouth rinse between the two samples. So, what is the difference between these two tests methods other than the number of panelists in table 14.1? These two test plans provide two different experiments and statistical analyses. Scientist Y chooses to assign 20 panelists to taste samples, with a mouth rinse between the two samples. Food Scientist X follows the independent

Table 14.1. Independent T-test and dependent (paired) T-test for scientists X and Y.

| Scientist X: Independent T-test | | | |
|---------------------------------|---------|----------|---------|
| Panelist | Product | Panelist | Product |
| 1 | I | 11 | II |
| 2 | I | 12 | II |
| 3 | I | 13 | II |
| 4 | I | 14 | II |
| 5 | I | 15 | II |
| 6 | I | 16 | II |
| 7 | I | 17 | II |
| 8 | I | 18 | II |
| 9 | I | 19 | II |
| 10 | I | 20 | II |

| Scientist Y: Dependent (paired) T-test | | |
|--|---------|---------|
| Panelist | Product | Product |
| 1 | I | II |
| 2 | II | I |
| 3 | II | I |
| 4 | I | II |
| 5 | I | II |
| 6 | I | II |
| 7 | II | I |
| 8 | I | II |
| 9 | II | I |
| 10 | I | II |
| 11 | I | II |
| 12 | I | II |
| 13 | I | II |
| 14 | II | I |
| 15 | II | I |
| 16 | I | II |
| 17 | I | II |
| 18 | I | II |
| 19 | I | II |
| 20 | I | II |

T-test while Scientist Y adopts the dependent T-test. Note that the sample size for Food Scientists X and Y are different now. Food Scientist X has 10 replications (10 panelists for each sample) for product I and II, respectively, but Food Scientist Y has 20 replications in the test (20 panelists to take two samples in a random order). Statisticians view that the test method by rinsing the mouth between samples I and II does not provide *independent* experimental unit for individual perception. For example, if the food scientists are testing two spicy products, rinsing the mouth or eating a cracker does not always work. Nonetheless, Food Scientist Y can still assume that the first sample does not affect the second product in tasting, meaning Scientist Y assumes that there is not a crossover effect. If there is a crossover effect between samples, food scientists should apply dependent T-tests instead of independent T-tests. Let's use a mathematical view to look at these two tests in table 14.2.

Table 14.2. Statistical analysis of independent and dependent T-tests.

| | Independent T-test | Dependent T-test |
|-------------------|--|---|
| Test statistics | $= \frac{(\bar{y}_1 - \bar{y}_2) - (\mu_1 - \mu_2)}{\sqrt{S_p \left(\frac{1}{n_1} + \frac{1}{n_2} \right)}}$ | $= \frac{\bar{d} - \mu_{\bar{d}}}{S_{\bar{d}} / n}$ |
| | $\mu_1 - \mu_2 = 0$ μ_1 , mean for population I μ_2 , mean for population II | $\mu_{\bar{d}} = 0$ $\mu_{\bar{d}}$, mean for the difference between populations I and II |
| Sample variance | $S_p = \sqrt{\frac{(n_1 - 1)S_1^2 + (n_2 - 1)S_2^2}{n_1 + n_2 - 2}}$ S_1^2 variance from sample I S_2^2 variance from sample II | $S_{\bar{d}} = \sqrt{\frac{\sum (d_i - \bar{d})^2}{n - 1}}, \quad \bar{d} = \frac{\sum d_i}{n}$ d_i = difference between samples I and II of each panelist \bar{d} , mean of difference between samples I and II |
| Degree of freedom | $df = n_1 + n_2 - 2$ n_1 , number of samples for sample I n_2 , number of samples for sample II | $df = n - 1$ n , total number of samples for samples I and II |

You can see that the mathematical equation of the independent T-test for Food Scientist X is different from that of Food Scientist Y. In table 14.2, you can see that Scientist X needs to apply them independently and test the significance of the two means using an independent T-test, while Scientist Y is testing the significance of the difference between the two means using a dependent T-test. However, if Scientists X and Y both use an instrument (texture analyzer), there wouldn't be any dependency problems, since instrumental testing provides independent results. Each test will get 20 responses and apply an independent T-test to perform the data analysis. Therefore, it is critical for food scientists to make a judgment call to use either an independent or dependent T-test if sensory evaluation is involved. You could even use both tests to compare the results. However, two results may give you two totally different conclusions about products I and II.

Replications

In the previous section, we mentioned that the independence of an experimental unit is very important to statistical analysis and that each additional experimental unit represents one replication. The number of replications for your experimental units is called sample size (Fuller, 1994).

Most food scientists are using three blocks; each block has three replications for each treatment for instrumental data with the assumption of having a sampling distribution that approaches normal distribution (30 panelists—experimental unit—in a sensory evaluation). But what is the number of replications (or should we say how many experimental units) needed for the experiment? Why not have 4 or 5 replications in the instrumental data and 15 panelists in a sensory testing? Sometimes 30 replications can cost a lot of time and money. So, can we use less replication in the experiment with normal distribution assumption?

Actually, there is a simple way to determine the sample size with little assumption. The number of replications depends on which data variation and types of data the scientist chooses: continuous or discrete data and their sample variation.

Step 1. Calculate E (sampling error for preliminary test)

$$E = Z_{\alpha/2} \left(\frac{\delta}{\sqrt{n}} \right)$$

E = sampling error

δ = square root of variance

n = sample size

Z = normal distribution

α = significant level

Step 2. Calculate N (next experiment sample size)

$$N = \frac{(Z_{\alpha/2})^2 \delta^2}{E^2}$$

N = sample size for next experiment

E = sampling error for step 1

δ = square root of variance from step 1

Z = Normal distribution

α = significant level

Figure 14.6. Sample size for continuous data.

In figures 14.6 and 14.7, there are two methods to calculate the sample size based on the types of data. Food scientists could investigate the sample product by using continuous data for peak force for the textural analyzer and using discrete data of acceptance for the sensory evaluation. Each data type needs a different number of replications (sample

Step 1. Calculate E (sampling error for preliminary test)

$$E = Z_{\alpha/2} \sqrt{\frac{p(1-p)}{n}}$$

E = sampling error

p = proportion

n = sample size

Z = normal distribution

α = significant level

Step 2. Calculate N (next experiment sample size)

$$N = \frac{Z_{\alpha/2}^2 p(1-p)}{E^2}$$

N = sample size for next experiment

E = sampling error for step 1

p = proportion from step 1

Z = Normal distribution

α = significant level

Figure 14.7. Sample size for discrete data.

size) in order to have a statistical meaning for the sample. Food scientists first need to perform a certain number of experiments and calculate the estimator-sample variance. That means that food scientists need to conduct preliminarily tests to understand the data behaviors and then calculate the sampling error, E . Later on, use the calculated E to find out the number of replications for the next experiment. There isn't a true magical number for a sample size. Sometimes 30 replications don't work if the variance of the selected sample is too large. You need to increase your sample size to have a more accurate estimation.

Experimental Design Structure

Previously, we introduced the smallest unit, the experimental unit, as well as replication. Here we are going to discuss the structure of the experimental design. The structure of the experimental design consists of two important components: a treatment structure and a design structure. Each component represents a different statistical meaning.

Treatment structure is used to describe the combination (treatments) of factors such as ingredients, processing parameters, or storage conditions, which are applied to the experimental unit. The design structure is used to arrange all of the treatments into different groups in the experiment and execute them in a determined order. Let's again use the dough baking as an example to demonstrate what the treatment structure and design structure are in the experimental design.

Treatment Structure

Sometimes food scientists want to research how differing amounts of a new ingredient and baking temperature affects the baking quality. Let's first take a look at the treatment structure for a new ingredient, and then at the baking temperature. The treatment structure of the new ingredient in the experiment contains one factor, the new ingredient with three different prescribed levels (1 g, 2 g, and 3 g). Therefore, there are three treatments 1, 2, and 3; and each treatment has only one experimental unit (the dough) with 1 g, 2 g, and 3 g of the new ingredient.

The scientist also wants to know the best temperature for baking. So how about the treatment structures for differing baking temperatures? By the same token, the experiment of the baking temperature

| Factor: new ingredient | | |
|------------------------|--------------|--------------|
| Level 1 = 1g | Level 2 = 2g | Level 3 = 3g |
| Treatment 1 | Treatment 2 | Treatment 3 |

| Factor: bake temperature | | |
|--------------------------|-----------------|-----------------|
| Level 1 = 300°F | Level 2 = 325°F | Level 3 = 350°F |
| Treatment 1 | Treatment 2 | Treatment 3 |

Figure 14.8. Treatment structures of new ingredient and bake temperature.

contains one factor with three different levels (300°F, 325°F, and 350°F). Figure 14.8 is a very handy table to lay out a treatment structure. In addition, the table is easier to look at when the replications for each treatment are involved.

Design Structure

After the treatment structures are laid out, the food scientist has to execute all of the treatments in a random order. In most cases, food scientists always want to replicate the experimental units. That means that treatments 1, 2, and 3 for a new ingredient will need to be replicated once. However, if the scientist has to replicate the treatments on the next day, due to the limited resources, experimenting on different days can contribute to “day” variations, which may sometimes result in very different conclusions. These variations could include humidity fluctuation, temperature changes, chemical or physical changes of ingredients, and so on.

Figure 14.9 shows that in order to accomplish the task, the scientist can approach the experiment in two different ways. Plan A replicates treatments 1, 2, and 3 twice in the same day, while plan B replicates treatment 1, 2, and 3 twice, but on different days. In the treatment structures, each treatment has two replications. The treatment structures for plans A and B look identical, but the arrangement of replications is a little different in a statistical view. Replications of plan A’s experiment

| Plan A | | | |
|--------|-------------|-------------|-------------|
| Day 1 | Treatment 1 | Treatment 2 | Treatment 3 |
| | Treatment 2 | Treatment 3 | Treatment 1 |

| Plan B | | | |
|--------|-------------|-------------|-------------|
| Day 1 | Treatment 1 | Treatment 2 | Treatment 3 |
| Day 2 | Treatment 2 | Treatment 3 | Treatment 1 |

Figure 14.9. Design structure for treatment arrangement for plans A and B.

were conducted on the same day, but plan B replicated three treatments on the second day. Now the extra variation is coming from the day factor for the experiment of plan B.

The design structure for plan A is called a complete random design (CRD). The design structure for plan B is called a randomized complete block design (RCBD). So, what is the difference between the two designs? Here, we will use another important criterion of the experimental design, the table of Analysis of Variance (ANOVA), to explain this statistically. Each design structure presents a significant difference in the ANOVA table for statistical analysis. Design structure can help food scientists solve for the extra variable (noise) of day-to-day differences, batch-to-batch or other uncontrolled factors, by blocking them.

Analysis of Variance Table

The analysis of variance (ANOVA) is a procedure that analyzes the relationship between and among the treatments (Anderson et al., 1991). In the ANOVA procedure, the ANOVA table provides a summary of information, which includes the treatment, design, sources of variances, test statistics, and degrees of freedom (table 14.3). An experiment that involves one factor is called a one-way ANOVA. If two factors are involved, it is called a two-way ANOVA, and so on. This table also provides the information for the number of replications, which is very critical to data analysis if there are enough replications to perform a standard statistics test. The ANOVA also provides a quick overall sum-

Table 14.3. Analysis of variance table.

| Source of variance | Degree of freedom | Sum of square | Mean square | F-test |
|---------------------------|-------------------|---------------|-------------------|---------------|
| Among groups (treatments) | $t - 1$ | SSA | $MSA = SSA/t - 1$ | $F = MSA/MSE$ |
| Within groups (Error) | $N - t$ | SSE(SSW) | $MSE = SSE/N - t$ | |
| Total (experimental unit) | $N - 1$ | SS total | | |

Note: N = total number of experiments; t = number of treatments; SSA = sum of square for factor A (variance among groups); SSE = sum of square for error (variance within groups); SSTotal = total sum of square; MSA = mean of square for factor A; MSE = mean of square for error term.

mary of the experimental design plan. Now let's use the ANOVA table to summarize the experiments for plans A and B, the previous example (table 14.4).

You will see a slight difference in the ANOVA table for the two plans if plan B blocks the day effect in the experiment. You can see that the sources of variance within each treatment were split in the ANOVA

Table 14.4. Analysis of variance table for plans A and B.

| Source of variance | Degree of freedom | Sum of square | Mean square | F-test |
|---------------------------|-------------------|---------------|----------------------------|---------------|
| Plan A | | | | |
| Among groups (treatments) | $t - 1$ | SSA | $MSA = SSA/t - 1$ | $F = MSA/MSE$ |
| Within groups (Error) | $N - t$ | SSE | $MSW = SSE/N - t$ | |
| Total | $N - 1$ | SStotal | | |
| Plan B | | | | |
| Blocks | $b - 1$ | SSB | $MSB = SSB/b - 1$ | |
| Among groups (treatments) | $t - 1$ | SSA | $MSA = SSA/t - 1$ | $F = MSA/MSE$ |
| Within groups (Error) | $(b - 1)(t - 1)$ | SSE | $MSE = SSE/(b - 1)(t - 1)$ | |
| Total | $N - 1$ | SS total | | |

Table 14.5. ANOVA table for plan A and plan B.

| | Plan A | Plan B |
|------------------------------|-----------------------|--|
| Source of variance | Degree of freedom | Degree of freedom |
| Blocks | | $b - 1 = 2 - 1 = 1$ |
| Among groups (treatments) | $t - 1 = 3 - 1 = 2$ | $t - 1 = 3 - 1 = 2$ |
| Within groups (error) | $t(r - 1) = 3(1) = 3$ | $(b - 1)(t - 1)$ $= (2 - 1)(3 - 1) = 2$ |
| Total | $N - 1 = 6 - 1 = 5$ | $N - 1 = 6 - 1 = 5$ |

table for plan B. There is one category block included in the ANOVA table along with the degrees of freedom for plan B. The number of degrees of freedom can be used in a simple manner to differentiate the different experimental designs. Let's focus on the degrees of freedom for the ANOVA table for plans A and B to see the difference. The block receives one degree of freedom from within groups, meaning that variation of days is being taken into consideration and extracted out as presented in table 14.5.

Plans (experiments) A and B do not have the same testing power for F-tests since they do not have same number of degrees of freedom for within groups. That means that values for the sum of squares and the mean of squares are different. Therefore, the two food scientists could have the exact same treatment structure with three treatments and six replications for each, but their design structures are different in the experiment. They could end up having two totally different results, because they use two different data analyses. Plan A uses one-way ANOVA, and plan B uses one-way ANOVA with blocking effect.

Experimental Design Plan

Experimental design plans deal with the planning of the experimental procedure or the controlling of the experimental environment in order to produce correct results. The experimental design plan lays out combinations of treatment(s) or factor(s) that are exposed to a physical or objective entity and arranges all of the treatments systematically. The treatments are then executed orderly. Most important, the food scientist

| | | | | | | | | | | | | | | | | | | | | | | | | | |
|---------------------------|---|---------------|--------------|------------|--|--------------------|-------------------|---------------|-------------|--------|---------------------------|-----|-----|--------------|------------|-----------------------|-----|----------|--------------|--|---------------------------|-----|----------|--|--|
| Objective | Baking temperature affects dough's quality | | | | | | | | | | | | | | | | | | | | | | | | |
| Target population | Costumers | | | | | | | | | | | | | | | | | | | | | | | | |
| Response data | Continuous data | | | | | | | | | | | | | | | | | | | | | | | | |
| Treatment structure | 3 treatments: one factor with three levels-300, 325, and 350°F | | | | | | | | | | | | | | | | | | | | | | | | |
| Design Structure | Randomized complete block design (RCBD) | | | | | | | | | | | | | | | | | | | | | | | | |
| ANOVA Table | <table><tr><td>Source of variance</td><td>Degree of freedom</td><td>Sum of square</td><td>Mean square</td><td>F-test</td></tr><tr><td>Among groups (treatments)</td><td>t-1</td><td>SSA</td><td>MSA= SSA/t-1</td><td>F= MSA/MSE</td></tr><tr><td>Within groups (Error)</td><td>N-t</td><td>SSE(SSW)</td><td>MSE= SSE/N-t</td><td></td></tr><tr><td>Total (experimental unit)</td><td>N-1</td><td>SS total</td><td></td><td></td></tr></table> | | | | | Source of variance | Degree of freedom | Sum of square | Mean square | F-test | Among groups (treatments) | t-1 | SSA | MSA= SSA/t-1 | F= MSA/MSE | Within groups (Error) | N-t | SSE(SSW) | MSE= SSE/N-t | | Total (experimental unit) | N-1 | SS total | | |
| Source of variance | Degree of freedom | Sum of square | Mean square | F-test | | | | | | | | | | | | | | | | | | | | | |
| Among groups (treatments) | t-1 | SSA | MSA= SSA/t-1 | F= MSA/MSE | | | | | | | | | | | | | | | | | | | | | |
| Within groups (Error) | N-t | SSE(SSW) | MSE= SSE/N-t | | | | | | | | | | | | | | | | | | | | | | |
| Total (experimental unit) | N-1 | SS total | | | | | | | | | | | | | | | | | | | | | | | |

Figure 14.10. Experimental design plan.

has to define the experimental unit, lay out all of the treatments to determine the treatment structure, and then decide on the design structure during planning. Otherwise, the collected data may become useless. Food scientists can collect any data that they may have, but that doesn't mean that the data can be analyzed. Figure 14.10 shows a protocol for a food scientist when conducting an experimental design plan. This form contains very useful and concise information regarding experimental design and should come in very handy in the planning process.

Two Factors Experiment

In the previous section, we showed that the experiment contains one factor-ingredient or factor-temperature separately, at several levels. However, food scientists sometimes want to know the effects from a

second factor—for example, baking temperatures at different levels as well as their interactions. Furthermore, the interaction cannot be estimated or verified without combining two factors in one experiment. An experiment containing two factors, or even more than two, is considered a factorial experiment (related to treatment structure only). Statistically, factorial design should be referred to as factorial experiment, since treatment combinations are separate from the execution of the treatments of the design structure. Let us combine these two factors in one experiment in table 14.6a. The experimental unit now is the dough exposed to both the new ingredient at one level and the frying temperature at one level. The total treatments in the experiment are 3 times 3, equal to 9 treatments ($3 \times 3 = 9$) in table 14.6a. There are 9 treatments in the treatment structure. The experimental unit of treatment 1 is that the food scientist makes one dough with a new ingredient (Factor A) at 1g and bakes it at temperature (Factor B) of 300°F. Now if the food scientist makes the second dough with the new ingredient at 1 g, and bakes it at 325°F, this is treatment 4 in table 14.6a.

In this example there are two factors in the experiment, so the ANOVA table becomes a two-way ANOVA table in table 14.6b. Two-way means that there are two factors in the treatment structure of the experiment. Now the food scientist can verify if the interaction of factors A and B is significant or not by including the AB interaction term in the ANOVA table. Here we would like to point out that if the food scientist divides the dough from treatment 1 into two small doughs and bakes each at different temperatures (300°F and 325°F), the food scientist does not have an independent experimental unit for the ingredient factor. That means that the dough for treatments 1 and 4 are not independent, since the two small doughs are from the same sample dough. The experiment is considered as the split-plot experiment, since the dough in treatments 1 and 4 came from the same dough. However, the experimental units for temperature (treatments 1 and 4) are still independent. Sometimes food scientists need to replicate the experiment to increase number of degrees of freedom.

The food scientist has $3 \times 3 = 9$ treatments with no replications and the interaction term cannot be estimated, because the MSE has the denominator value equal to zero (table 14.7). Therefore, the F-test for the AB interaction cannot be tested. Statistically, replications are not just to provide more data points, but most important, they provide more

Table 14.6. Treatment structures and ANOVA table for new ingredient and oven temperature.

a. Treatment structures

| Factor A: New ingredient | | |
|--|-----------------|--|
| Factor B: Bake temperature | Level 1 = 300°F | Level 1 = 1 g Treatment 1 1 g + 300°F |
| | Level 2 = 325°F | Treatment 4 |
| | Level 3 = 350°F | Treatment 7 |
| b. ANOVA table of new ingredient and bake temperature. | | |

| Source of variance | Degree of freedom | Sum of square | Mean square | F-test |
|-----------------------|-------------------|---------------|------------------------------------|-----------------|
| Factor A | $a - 1 =$ | SSA | $MSA = SSA/a - 1$ | $= MSA/MSE$ |
| Factor B | $b - 1 =$ | SSB | $MSB = SSB/b - 1$ | $= MSB/MSE$ |
| AB interaction | $(a - 1)(b - 1)$ | SS (AB) | $MS (AB) = SS (AB)/(a - 1)(b - 1)$ | $= MS (AB)/MSE$ |
| Within groups (Error) | $ab(r - 1)$ | SSE | $MSE = SSE/ab(r - 1)$ | |
| Total | $N - 1$ | SS total | | |

Table 14.7. ANOVA table for split plot experiment.

| Source of variance | Degree of freedom | Mean square | F-test |
|--------------------------|------------------------------------|---|------------------------------------|
| Factor A | $a - 1 = 4 - 1 = 3$ | $MSA = SSA/a - 1$ | $= MSA/MSE$ |
| Factor B | $b - 1 = 3 - 1 = 2$ | $MSB = SSB/b - 1$ | $= MSB/MSE$ |
| AB interaction | $(a - 1)(b - 1)$ $= (2)(2) = 4$ | $MS(AB) = SS(AB)/$ $(a - 1)(b - 1)$ | $= MS(AB)/MSE$ $= MS(AB)/0 = 0$ |
| Within groups (error) | $ab(r - 1) = 0$ | $MSE = SSE/ab(r - 1)$ $= SSE/ab(1 - 1)$ $= SSE/ab(0) = 0$ | |
| Total | $N - 1 = 9 - 1 = 8$ | | |

degrees of freedom to be used for test statistics, the F-test in the ANOVA table. The more factors and levels of each factor, the more the treatment replications are needed. In addition, significant or not, for interaction terms of AB in this example, it is very critical for food scientists to test the main effects of A and B. The significance of A and B depends on whether the AB interaction is significant or not. If the AB interaction is not significant, then the significance of the main effects for A and B become meaningful in figure 14.11a. The food scientist is safe to conclude the main effects. Otherwise, food scientists cannot conclude the main effect of A and B significant or not if the interaction is significant. In figure 14.11b and c, there are two scenarios of AB interactions when the AB interaction is significant. Food scientists need to look at each level of factors since the AB interaction may have a negative (minus) or positive effect with the increase in temperature seen in figure 14.11b and c.

Therefore, the number of the replications in the factorial experiment is very important to ensure that there are enough degrees of freedom left to test the significance of interaction in the data analysis. That means that food scientists need to have more replications in order to have more degrees of freedom.

Now let's say there are three food scientists X, Y, and Z that conduct the same experiment with the same treatment and design structures above. However, Food Scientist X does not replicate, Food Scientist Y replicates all treatments once, and Food Scientist Z replicates twice by using CRD for design structure in table 14.8. The three food scientists

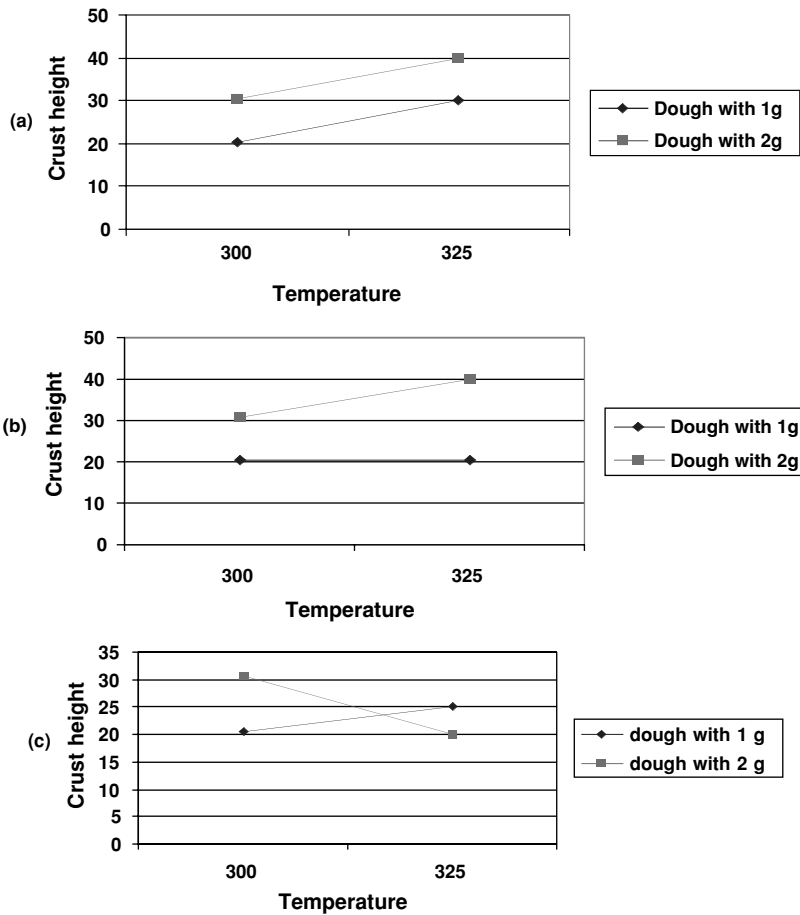


Figure 14.11. The interaction of AB: (a) not significant, (b) significant, and (c) significant.

X, Y, and Z may have different conclusions because of the different number of degrees of freedom in the ANOVA table. Scientist X does not have enough degrees of freedom left for interaction and the effect of interaction is unknown. Scientists Y and Z both have enough degrees of freedom for interaction AB; but scientist Y may conclude differently from Scientist Z due to a different number of degrees of freedom, especially when the P-value is close to the significance level. In general, the more degrees of freedom, the more testing power. Therefore, it is very important for food scientists to have enough or a sufficient number of

Table 14.8. Degree of freedom for food scientists X, Y, and Z.

| Source of variance | Degree of freedom | Scientist X | Scientist Y | Scientist Z |
|-----------------------|-------------------|-------------|-------------|-------------|
| Factor A | $a - 1 =$ | 2 | 2 | 2 |
| Factor B | $b - 1 =$ | 2 | 2 | 2 |
| AB interaction | $(a - 1)(b - 1)$ | 4 | 4 | 4 |
| Within groups (Error) | $ab(r - 1)$ | 0 | 9 | 18 |
| Total | $N - 1$ | 8 | 17 | 26 |

replications in the experiment. In this example, Food Scientist X may at least need to replicate twice to have enough degrees of freedom to test whether the AB interaction is significant or not.

Three Factors Experiment

In most research, the experiment may include multiple factors that could affect the product qualities (Huang et al., 2001). Consider the dough example above, processing methods such as different extruders, I and II, may produce two different characteristics of dough. Thus, processing method has to be considered as the third factor. Food scientists again can use two different ways to present the factorial experiment with three factors with each factor having two different levels in figure 14.12 and table 14.9.

The box in figure 14.12, often called the design box, is commonly used to visualize the three-dimensional view of a treatment structure

Table 14.9. Treatment structure for three factors.

| | | | | | | | |
|---|----|-------|-------|---|----|-------|-------|
| | A1 | | | | A2 | | |
| | | B1 | B2 | | | B1 | B2 |
| C | C1 | Trt 1 | Trt2 | C | C1 | Trt 5 | Trt 6 |
| | C2 | Trt 3 | Trt 4 | | C2 | Trt 7 | Trt 8 |

A: New ingredient

B: Bake temperature

C: Processing-Extruder

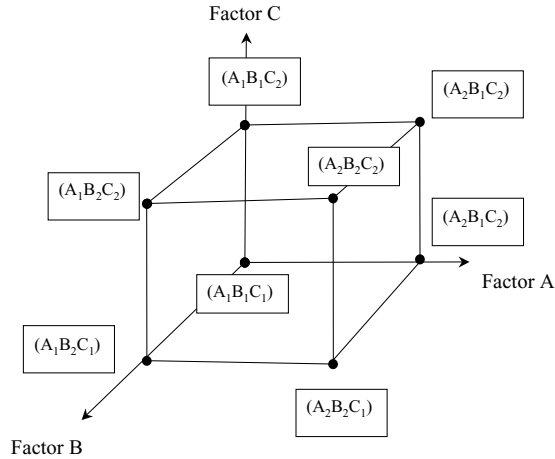


Figure 14.12. Treatment structure of three factors.

in the experimental design. This presentation is very useful when the number of factors is increasing. The ANOVA table turns into a three-way ANOVA table (table 14.10).

The experiment with multiple factors oftentimes needs a certain number of replications in order to have enough degrees of freedom to perform test statistics (meaning statistical test) for interaction terms. Let's say three food scientists X, Y, and Z conduct a three-factor experiment as summarized in table 14.11. Food Scientist X cannot test the ABC interaction term without appropriate replications while Food Scientists Y and Z have enough degrees of freedom for the ABC interaction. In table 14.12, we list several factorial experiments.

Nested Factorial Experiment and Split-Plot Design

So far, experiments that we have discussed are standard factorial experiments or standard block designs. Here we introduce two special cases if one factor resides within another.

Nested Factorial Experiment

The factorial experiment we mentioned previously is considered as a cross-factorial experiment. Each level of factors occurs with all levels

Table 14.10. ANOVA table for three factors, A, B, and C.

| Source of variance | Degree of freedom | Sum of square | Mean square | F-test |
|--------------------------|-------------------------|---------------|---|----------------|
| Factor A | $a - 1$ | SSA | $MSA = SSA/a - 1$ | $F = MSA/MSE$ |
| Factor B | $b - 1$ | SSB | $MSB = SSB/b - 1$ | $F = MSB/MSE$ |
| Factor C | $c - 1$ | SSC | $MSC = SSC/c - 1$ | $F = MSC/MSE$ |
| AB interaction | $(a - 1)(b - 1)$ | SS (AB) | $MS (AB) = SS (AB)/(a - 1)(b - 1)$ | $F = MAB/MSE$ |
| AC interaction | $(a - 1)(c - 1)$ | SS (AC) | $MS (AC) = SS (AC)/(a - 1)(c - 1)$ | $F = MAC/MSE$ |
| BC interaction | $(b - 1)(c - 1)$ | SS (BC) | $MS (BC) = SS (BC)/(b - 1)(c - 1)$ | $F = MBC/MSE$ |
| ABC interaction | $(a - 1)(b - 1)(c - 1)$ | SS (ABC) | $MS (ABC) = SS (ABC)/(a - 1)(b - 1)(c - 1)$ | $F = MABC/MSE$ |
| Within groups (Error) | $abc(r - 1)$ | SSE | $MSE = SSE/abc(r - 1)$ | |
| Total | $N - 1$ | SS Total | | |

Table 14.11. Comparisons of degree of freedom for three scientists X, Y, and Z.

| Source of variance | Degree of freedom | Scientist X | Scientist Y | Scientist Z |
|-----------------------|-------------------------|-------------|-------------|-------------|
| Factor A | $a - 1$ | 1 | 1 | 1 |
| Factor B | $b - 1$ | 1 | 1 | 1 |
| Factor C | $c - 1$ | 1 | 1 | 1 |
| AB interaction | $(a - 1)(b - 1)$ | 1 | 1 | 1 |
| AC interaction | $(a - 1)(c - 1)$ | 1 | 1 | 1 |
| BC interaction | $(b - 1)(c - 1)$ | 1 | 1 | 1 |
| ABC interaction | $(a - 1)(b - 1)(c - 1)$ | 1 | 1 | 1 |
| Within groups (Error) | $abc(r - 1)$ | 0 | 8 | 15 |
| Total | $abcr - 1$ | 7 | 15 | 23 |

of the other factors to allow the interaction to be examined. However, an experiment may have levels of one factor nested within the levels of the other. Nested factorial experiments can help food scientists solve practical problems in food research: for example, where different plants at different locations have to produce the same quality of products, or two research groups conduct a collaborated study using the same material

Table 14.12. Factorial experiment table.

| Number of factors, F | Levels of each factor, P | Number of treatments | Way to calculate, P^N |
|----------------------|--------------------------|----------------------|-------------------------|
| 1 | 1 | 1 | $1^1 = 1$ |
| | 2 | 2 | |
| 2 | 1 | 1 | $1^2 = 1$ |
| | 2 | 4 | $2^2 = 4$ |
| | 3 | 9 | $3^2 = 9$ |
| 3 | 1 | 1 | $1^3 = 1$ |
| | 2 | 8 | $2^3 = 8$ |
| | 3 | 27 | $3^3 = 27$ |
| 4 | 1 | 1 | $1^4 = 1$ |
| | 2 | 16 | $2^4 = 16$ |
| | 3 | 81 | $3^4 = 81$ |
| 5 | 1 | 1 | $1^5 = 1$ |
| | 2 | 32 | $2^5 = 32$ |
| | 3 | 243 | $3^5 = 243$ |

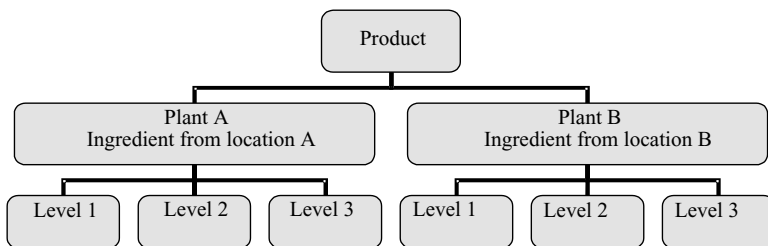


Figure 14.13. Nested factorial experiment.

but from different countries or locations. Here we use the following example to explain it in figure 14.13.

A food scientist conducts an experiment that involves two factors. The first factor is plants A and B, while the second factor is a chemical ingredient used at three different levels. The goal is to have plants A and B produce products having the same characteristics disregarding ingredient sources or manufacture locations. Nonetheless, plants A and B each receive the ingredient from their own resources and two ingredients have the same identical specifications. Based on the setting of treatment structure for two factors, plants and ingredient levels, there is no “ingredient-plant interaction” that can be measured because the ingredient from location A (used by plant A) cannot be used by plant B. That means that the factors-ingredient and production sites did not “cross” in the treatment structure. Ingredients from location A are used only for plant A and the ingredients from location B are used only for plant B. So, what is the difference between cross-factorial experimentation and nested factorial experimentation statistically? Let us look at the ANOVA table (table 14.13).

The number of treatments for the cross and the nested factorial experiment are the same. But the degrees of freedom in the ANOVA table for the nested factorial experiment are different from the cross-factorial experiment (we assume that the same design structure is applied). In addition, there is no interaction term in the ANOVA table of the nested factorial experiment, and calculations of the sum of square, mean square, and F-test are different too. Therefore, one needs to apply the nested factorial analysis to analyze nested factor experiment rather than cross-factorial experiment. This is a very useful experimental design for food scientists who wish to have products produced from two different locations with

Table 14.13. The ANOVA tables of crossed versus nested factorial experiment.

| Source of variance | Degree of freedom | Sum of square | Mean square | F-test |
|------------------------------|-------------------|---------------|-------------|--------------|
| Nested factorial experiment | | | | |
| Factor A (plant) | $a - 1$ | SSA | MSA | MSA/MSE |
| Factor B/A | $a(b - 1)$ | SS (B/A) | MS (B/A) | MS (B/A)/MSE |
| Error | $ab(r - 1)$ | SSE | MSE | |
| Total | $N - 1$ | SS total | | |
| Crossed factorial experiment | | | | |
| Factor A (plant) | $a - 1$ | SSA | MSA | MSA/MSE |
| Factor B | $b - 1$ | SSB | MSB | MSB/MSE |
| AB interaction | $(a - 1)(b - 1)$ | SS (AB) | MS (AB) | MS (AB)/MSE |
| Errors | $ab(r - 1)$ | SSE | MSE | |
| Total | $N - 1$ | SS total | | |

the same ingredients (same specifications) but the ingredients come from different regions.

Split-Plot Design

The split-plot design came from agriculture experimentation and is best suited for large plots (each plot for one variety of wheat bread) with another factor (fertilizer usage levels) applied within the large plot. Split-plot design deals with one factor within another factor by sharing the experimental unit. Split-plot designs look very similar to nested factorial experiments, but split-plots refer to design structure while nested factorial experiments refer to treatment structure. Here we use the food systems as an example to see how food scientists can apply this concept to a food experiment.

Consider baking bread dough as an example. There are two factors: oven temperature and a new ingredient. Each factor has three levels. The treatment structure of the experiment is 3×3 factorial experiment with 9 treatments for the new ingredient and temperature. There are 3 doughs with a new ingredient at levels 1 g, 2 g, and 3 g, respectively, and they are baked together in the same oven at 350°F. In this experiment, there are two different sizes of experimental units, a large one for the

| | | Factor A | | |
|----------|------------------|---|---------------|-------------|
| | | Level 1 1g | Level 2 2g | Level 3g |
| Factor B | Level 1 350°C | Oven temperature at 350°F Three doughs with 1g for treatment 1 2g for treatment 2 3g for treatment 3 | | |
| | Level 2 375°C | Oven temperature at 375°F Three doughs with 1g for treatment 4 2g for treatment 5 3g for treatment 6 | | |
| | Level 3 400°C | Oven temperature at 400°F Three doughs with 1g for treatment 7 2g for treatment 8 3g for treatment 9 | | |

Figure 14.14. Treatment structure for split-plot design.

oven temperature and three small ones for ingredients at three levels in figure 14.14.

First let us look at the experimental unit for the oven temperature 350°F, which applies to the three small doughs. The experimental unit of the oven temperature is at 350°F. Then each dough (with new ingredient levels 1 g, 2 g, and 3 g) shares 1/3 of the experimental unit of the oven temperature at 350°F. Three doughs with ingredients 1 g, 2 g, and 3 g are not independent.

The size of the experiment does not mean the weight or geometry of the diameter of doughs, but conceptual meaning in statistics. Therefore, the food scientist has two different sizes of experimental units. In this example, the design structure is a split-plot design, because each level of ingredient shares 1/3 of the experimental unit for the oven temperature at 350°F. In other words, the experimental units for the new ingredient (1 g, 2 g, and 3 g) are within the experimental unit for the oven temperatures at 350°F, 375°F, and 400°F, respectively. Let's say that two food scientists X and Y conduct the experiment with 9 treatments (same treatment structure with two replications) but apply different design structures in the experiment in table 14.14.

Table 14.14. Degree of freedom table for randomized complete design and split-plot design.

| Scientist X 3×3 factorial with randomized complete design | | Scientist Y 3×3 factorial with split-plot design | |
|--|-----------------------------------|---|---------------------------------|
| Source of variance | Degree of freedom | Source of variance | Degree of freedom |
| Factor A | $a - 1 = 2$ | Whole plot Factor A | $a - 1 = 2$ |
| Factor B | $b - 1 = 2$ | Replication of A (error of MSE_a for factor A) | $a(r - 1) = 3(1) = 3$ |
| AB interaction | $(a - 1)(b - 1) = 2 \times 2 = 4$ | Sub plot Factor B | $b - 1 = 2$ |
| Within groups (Error of MSE) | $ab(r - 1) = 9(1) = 9$ | AB interaction | $(a - 1)(b - 1) = 4$ |
| Total | $N - 1 = 17$ | Replication of B error of $MSE_{b \& ab}$ for factor B) | $a(r - 1)(b - 1) = 3(1)(2) = 6$ |
| | | Total | $N - 1 = 17$ |

The error term (MSE) in a complete randomized design is used for factors A and B as well as for interaction AB. In a split plot design, two different error terms (MSE_a for factor A and $MSB_{b \& ab}$ for factor B and interaction AB) are, however, used in a different way. The factor A, oven temperature, becomes the block for factor B, ingredient. So two replications for factor A actually create six replications for factor B, but each replication shares 1/3 of the experimental unit of factor A.

It is important to distinguish the difference between baking three doughs together—considered as cross-factorial experiment with a split-plot design—or baking doughs individually—considered as cross-factorial experiment with complete random design. Both designs may conclude totally differently due to the number of degrees of freedom and ways of calculations for the error(s) for the effects of A, B, and AB interactions. Last but not least, statistical analysis following the experimental design includes treatment structure, design structure, and replication.

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Chapter 15

CATEGORY APPRAISAL AND INGREDIENT SEARCH: IDENTIFYING KEY SENSORY FACTORS AND PRODUCT FEATURES AT THE EARLY DEVELOPMENT STAGE

Howard R. Moskowitz and Andrea Maier

Why Read This Chapter?

Moskowitz and Maier lay out the complete overview of analytical category appraisals for the reader who wants to understand this method thoroughly.

General Introduction

What does the developer do to understand a product category and where to go? We begin this chapter with a very simple question, faced by just about anyone wanting to develop a product. The question is where to start? The question is really far more profound than just where one begins. The developer might begin just about anywhere. On the other hand, some starting points are better than others. It's the knowing where to begin that often makes the difference between a product delivered on time and successful versus a product that is delivered late, if delivered at all, and often unsuccessful.

In many cases, the developer looks at what is out in the market and selling well, and attempts to copy that product. Often private label manufacturers follow this route, especially if they are selling into a store that will put its label onto the product and compete with a higher priced branded product. We're not dealing with this simplest of cases—the developer already knows where to start and the task is very simple: copy the competitor, perhaps with lower cost ingredients, perhaps with a slight twist to make the copy qualitatively superior.

In more complex and more typical cases, the branded product manufacturer is working to satisfy a marketing brief. The brief describes the characteristics of the product, more often couched in terms designed to sell the product rather than couched in ingredients. The brief gives the basic idea of the product, but usually does not (or often just simply cannot) specify what the product should contain. The brief may contain a broad outline of product characteristics, but it's left to the developer to figure out what to do. Very often the brief calls for filling a "hole" in the product category, or developing a product to fit an emerging opportunity.

Strategies—Ideation

The conventional method for developing a new product begins with some sort of ideation; that is, a disciplined exercise whose specific goal is to arrive at a product concept, or at least a list of characteristics for the new product. Ideation works at the level of ideas and concepts, rather than at the level of product. A glance at the literature devoted to new product development (especially books) quickly reveals many different methods by which the developer can understand what the product should have, at least at the level of concept (Flores et al., 2003; Kelly, 2001; Maier et al., 2005; Vance and Deacon, 1995; Wansink, 2000). Consumers can be instructed to provide lists of desired product features, or check off features that they would like to have from a list, or even react to product concepts. In the end, the developer will have a sense of what the new product might look like, smell like, taste like, feel like, and of some of the ingredients the product should have. The developer will not exactly know what to shoot for in terms of specific formulations or specific sensory levels; concept and ideation work provides only a general outline about the product, and not specific direction.

When it comes to guidance, quite often marketers believe that if the consumer can somehow “describe” the product then a lot of the work has already been done. To these marketers, and occasionally to novice developers, a lot of the hard work and effort needs to be concentrated in the discovery phase. Discovery means identifying at a concept level where the market opportunities lie. However attractive this point of view may seem, and however much it elevates the discovery phase and associated talents, the developer still needs roadmaps couched in products, not in concept terms. Indeed, as Moskowitz et al. (2005) suggest, developing products by slavishly following product concepts may limit the product and doom it to mediocrity. A better way has to be used—a way that provides concrete direction.

Strategies—Learning to Describe, Measure, and Interrelate Variables

The need to develop product-based guides to development became increasingly obvious during the 1960s, but especially in the late 1970s and into the early 1980s. Product testing at that time was evolving from testing/discovering small (often irrelevant) differences among products into describing products and learning about relations between variables. These latter two streams of research would become the foundations of what we call today “category appraisal,” a broad-based approach to understanding the relations between products in a category, and the sensory characteristics that drive acceptance. The term “category appraisal” and the analytic approaches appeared to have been first synthesized by the senior author in the early 1980s, based upon commercially oriented studies and described in depth in a book on cosmetics, rather than food (Moskowitz, 1984). The chapter introducing the approach, titled “Category Appraisal and the Free Market Intelligence System,” was strongly informed by streams of research.

Descriptive Analysis

Descriptive analysis refers to the disciplined profiling of a product on attributes. Descriptive analysis, whether by unpracticed consumers (the psychophysical approach) or by trained experts (the food science approach) provides half the input to category appraisal. With descriptive

analysis, the researcher generates a “signature of the product.” Researchers in psychology, in food science, and in perfumery had grappled with the problem of describing the dimensions of sensory perceptions for almost three-quarters of a century. By the middle 1940s, researchers had come up with various lists of characteristics for smell and texture (Cairncross and Sjostrom, 1950; Harper et al., 1961; Szczesniak et al., 1963). Visual appearance and taste presented relatively few problems when it came time to describe one’s perceptions; smell and touch, especially of foods, presented far more problems. By the middle 1940s, however, experimental psychology had created various descriptive systems for the senses, and it was time for applied researchers in the food and beverage industries to try their hand. Eventually descriptive systems emerged, generally tailored to the particular food or beverage, with the property that a careful application of these systems to a particular (relevant) product would yield a reproducible sensory profile.

Most schemes for descriptive analysis deal with so-called sensory attributes. There are lexicons of these attributes as sensory researchers have grappled with the problem of how to describe perceptions of smell and texture, which have no simple language. There are other issues as well in descriptive analysis. The world of sensory perception is not limited to the simple sensory descriptors of the amount of a characteristic. The consumer is continually bombarded with language that is neither sensory nor can it be construed as liking. These are more complex terms than simply sweet, cola-flavored, and so on, and might best be labeled as “image.” For example, in the case of bread, an image term is “whole-some.” In the case of a carbonated beverage, an appropriate term is “refreshing.”

In the end, therefore, there are three types of attributes with which we will have to deal: (1) sensory—amount of; (2) liking—acceptability; and (3) image—more complex characteristics that integrate many different attributes and experiences.

Psychophysics and the Contribution of Experimental Psychology

Psychophysics tells the other half of the story. Psychophysics is a branch of experimental psychology, probably the oldest branch, which deals with the relation between physical stimuli and sensory responses. For a

very long time, psychophysicists were under the sway of G. T. Fechner, the polymath who, in the mid-nineteenth century, began historical work on the creation of a “scale of sensory magnitude” (Boring, 1929). In Fechner’s view, the person, trained or untrained—it didn’t matter—was incapable of validly acting as a measuring instrument in the same way that, say, a scientist might use a ruler or a scale of weight. In Fechner’s mind, it seemed more reasonable to measure by “variability,” that is, to look at the variability in a person’s response to a stimulus and use that variability somehow as the basis of a psychological unit of magnitude. In the 1920s, Fechner’s intellectual descendant Leon Louis Thurstone, a psychometrician, continued Fechner’s efforts by creating a method to transform errors of judgment into sensory units of perceptual intensity (Thurstone, 1927). Such efforts required Herculean efforts to measure perception, and in the end would not generate the needed creation of knowledge for applied researchers, except when the problem was to determine whether or not two samples differed from each other.

The real breakthrough for applied sensory measurement, and thus the needed second leg of the foundation, came from the work of psychophysicists who believed that the consumer could rate perceived intensity in the fashion of a measuring instrument, on par with other types of measuring instruments. There would be tempests in teapots; some people felt that the human judge couldn’t rate anything except using scales with a limited number of points and each point labeled. Other researchers such as the famed S. S. Stevens of Harvard’s Laboratory of Psychophysics (who was given the title of The Professor of Psychophysics) believed that a well-instructed panelist could assign numbers so that the ratios of the numbers reflected ratios of perceptions (Stevens, 1975).

Today, some half-century later, Steven’s methods, known collectively as ratio scaling (e.g., magnitude estimation, magnitude production, cross-modality matching), have value for researchers, not so much because of the properties of the scale, but rather because they gave inspiration to three generations of researchers who looked for lawful relations among variables. These relations would be between ratings of sensory intensity versus physical variables (psychophysical or S-R relations), ratings of sensory intensity versus liking (R-R or sensory-liking relations), and ratings of liking versus physical variables (another version of S-R relations).

Psychophysical Thinking Unchained—Beyond S-R Thinking to R-R Thinking

Descriptive analysis and psychophysics took the researcher beyond the shackles of simple research. But it would take a simple observation to drive home the value for the food and beverage industry. The observation was that as a sensory attribute increased, liking first increased, peaked at some optimal level, and then decreased (Moskowitz, 1981a,b). We cannot overstate the importance of this rather simple and compelling observation, which governs many sensory perceptions. Add sweetener to a carbonated beverage and it goes from barely accepted to tolerable, to good, to great, to tolerable, and then down to barely acceptable. The different stimuli might be different concentrations of a sweetener, or even different sweeteners (each of which vary in type of sweetener and in concentration, generating a different perception of sweetness as well as a slightly different quality). We see this general pattern in figure 15.1. The relation is not necessarily perfect—the inverted U curve describes the data, but may not fit the data precisely. It is just an approximation, but it is very important, for three reasons:

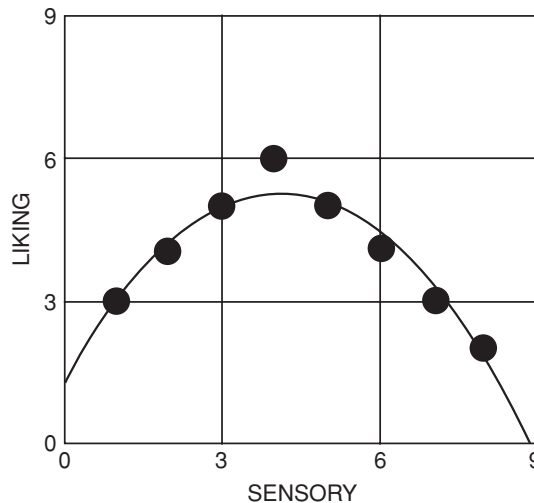


Figure 15.1. Schematic sensory-liking curve showing how changes in sensory magnitude drive changes in liking. The curve reflects the “best-fit” parabola (quadratic function).

1. The relation is between sensory intensity on the X axis and liking on the Y axis.
2. The relation derives the average from a large number of panelists—each panelist generates a unique curve, which may be of a different shape.
3. The nature of the curve can be discovered simply and empirically by having a consumer judge rate a set of products that are either systematically varied in one/several ingredients, or buying a set of somewhat related products on the shelf and having the judge rate both sensory intensity and liking.

What Does the Developer Learn from Simple R-R (Sensory-Liking) Analyses?

Given the simplicity of developing R-R relations (just buy products and get sensory, liking ratings), what can the developer learn, and how does the developer actually develop insights? It's important to note that the R-R approach does not require extensive training, although occasionally the researcher might want to know how a hard-to-define sensory attribute drives acceptance. For the most part, however, we'll just concentrate in this chapter on the type of information that one could get from working with consumers; data from experts can be incorporated simply by obtaining the sensory attributes from experts rather than from consumers.

1. The nature of the relation isn't always the same. The relation depends upon the specific product, the specific sensory attribute, and the specific liking attribute. The inverted U relation described above applies in the most general of cases. However, as figure 15.1 suggests, the relation will look different depending upon where we do the analysis of the inverted U shaped relation. If we look only at the low levels, below 5 on the sensory scale, we would conclude that liking increases with increasing sensory intensity. If we look only at the high levels, above 5 on the sensory scale, we would conclude just the opposite: liking decreases with increasing sensory intensity. So, to a great degree, the sensory-liking relation is a function of how much of the range is being studied, and on what part of the range the products lay (Moskowitz and Jacobs, 1989).

2. Individuals differ from each other. This variability isn't necessarily random, although there is a lot of subjective variation from person to person, especially when the attribute being rated is hedonic (e.g., liking). Some of this variability is the conventional variability that the researcher encounters in studies with people; there is just the inevitable person-to-person variability because people differ in their use of scales, their criteria, and so on. There is, however, a more profound variability from person to person that simply cannot be attributed to the vagaries of measurement and to the basic "noise in the system." This variability may be due to fundamentally different groups of people in the population who like products that are sensorially different from each other. These sensory-preference segments can be most easily demonstrated by giving people beverages having different levels of sweetener so the perceived sweetness varies. Some very sweet beverages are rated very low by consumers, but the same very sweet beverages can be tasty to other individuals (Moskowitz et al., 1985).

The Integrated Product Model

Looking at the relation between sensory attribute level and liking can provide only some of the picture, not all of it. Something else occurs—attributes interact with each other in ways that are difficult to understand, and the nature of this interaction may change from product to product. We know that sweet and sour tastes interact to drive beverage acceptance. The relation is probably curvilinear because beverage manufacturers strive to optimize the brix/acid ratio, which is an objective measure corresponding to the sweet and sour ingredients in a beverage.

Our state of knowledge in product development is relatively rudimentary. Despite the many hundreds of papers that have appeared on how to formulate products, for the most part these papers do not provide a corpus of knowledge allowing a new product developer to consult, in order to learn "how to develop a specific product." We really don't know what to expect when we mix together different ingredients to create a product. Furthermore, we know neither the expected sensory profiles of these newly developed products, nor the liking to be expected. We have to do the empirical study, time after time. Thus, for any randomly selected product, there is no archival, public, scientific literature that tells

us what to expect in terms of how sensory attributes drive acceptance of that particular product.

Given the lack of archival knowledge about how multiple sensory attributes drive acceptance for a specific product, it is necessary to create a system that develops this knowledge in “real time.” There is really no time in applied product development to create a science underlying each product, so that the student or developer could go to a “reference book” and determine what are the key drivers, and what are irrelevant attributes. Instead of archival knowledge, therefore, we need to create an easy to develop system that could, over time, become the foundation of that science. We deal with this system now in terms of the product model.

The organizing principles of the product model are fairly simple and easy to apply, and generate the basis of knowledge for a product category. After discussing the theory, we will deal with a worked example. The reader should keep these things in mind as organizing principles.

1. Nonlinear relations. As a sensory attribute increases, liking increases, peaks, and drops down. Thus, any equation for the product model must incorporate the ability to reach its maximum somewhere in the middle of the range. Researchers are well aware of this through experiments discussed above.
2. Multiple attributes drive liking, not just one attribute at a time. This means that the equation relating liking to sensory attributes may have several independent variables, one per attribute. The equation is represented by a paraboloid in two dimensions versus liking, but can be mathematically expressed by a simple equation even if there are five, six, or more sensory attributes driving liking. It's a lot easier to work with equations than with graphs.
3. Attributes interact with each other. We don't really know the nature of the interaction (is it a ratio, is it a product, is it some type of more complicated interaction). It is unlikely that the researcher in an applied product development problem will worry much about the precise nature of the interaction. However, it is important that the product model account for these interactions. We see a comparison of one variable, two variable (linear), two variable (quadratic), and two variable interaction in figure 15.2.
4. Redundancy requires principal components analysis prior to modeling. Sensory variables often correlate with each other, so that using

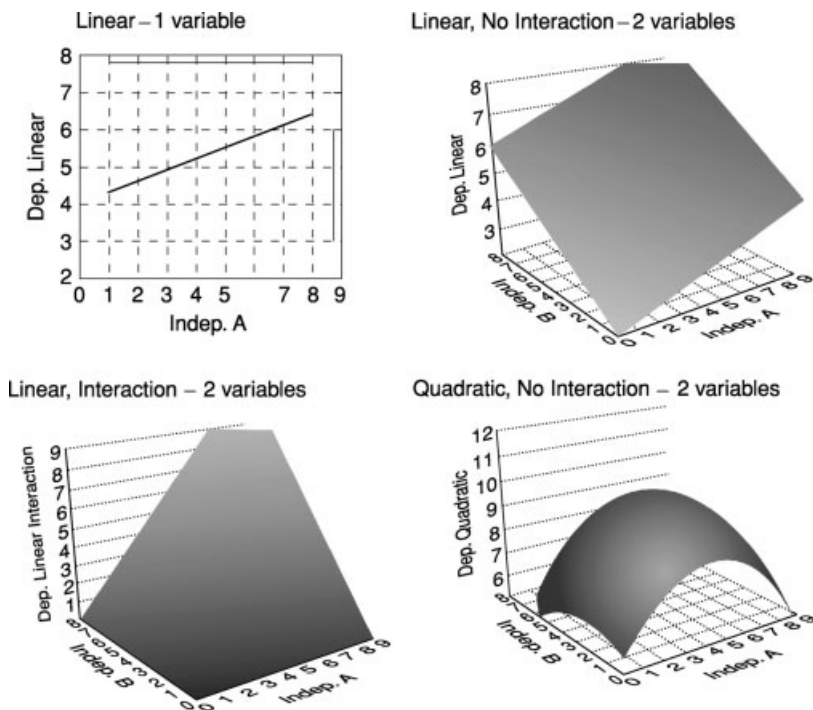


Figure 15.2. Comparison of one variable, two variable (linear), two variable (non-linear), and two variable interaction.

these correlated sensory variables as predictors might cause some statistical problems. The correlation means that the different sensory variables might be tapping the same underlying characteristics. We really cannot use sensory variables that are highly correlated with each other because we will generate a false, misleading equation. On the other hand, we can't look for sensory variables that are totally uncorrelated with each other (the ideal case) because either they may not exist, or we have not used them, or we have used them in the study and they pertain to, at most, one or two of the products, which is why they are uncorrelated. The researcher has to work his or her way out of this dilemma of correlated or redundant sensory attributes. The way out is to create a new set of attributes or predictor variables, using some type of data reduction technique (e.g., principal components factor analysis), which transforms a set of sensory terms into a more limited set of "factors." These factors are statistically independent of each other (important for modeling), are

based on the sensory attributes (important because they capture sensory information), and are parsimonious (only a few of them, rather than the myriad of attributes that the sensory or market researcher develops, are good for regression modeling because the fewer the number of predictor variables, the more likely we can believe the model).

5. Product models are created. The researcher develops the product model by combining the principal components factor analysis to generate a parsimonious set of independent variables with nonlinear regression to capture the interactions among variables and the optimum levels in the middle. This product model is expressed in pure mathematical terms, easily developed by anyone who can analyze data by today's very available programs for data reduction and regression. However, simply leaving the data in mathematical terms goes nowhere. The final set of steps uses this mathematically simple model to map, optimize, and reverse engineer.
6. Mapping. Mapping consists of locating products in a geometrical space so that products close together are similar to each other. Our principal components analysis in step 4 locates the products in a "factor space." Each product from which the principal components was done generates its own factor scores. So the principal components, which we use to develop a set of predictor variables for the product model (see below), is also useful for mapping.
7. Modeling. Modeling consists of creating a set of equations relating each of the rating attributes (sensory, liking, and others) to the independent variables. The modeling simply fits a polynomial equation to the data, using the factors as the independent variables and each of the rating attributes, in turn, as the dependent variables. Modeling is a straightforward exercise using today's regression programs. All that the researcher really needs to do is identify the equation. The equation, in turn, is simple. It comprises linear terms, square terms, and pair-wise interaction terms.
8. Optimization subject to imposed constraints. Optimization consists of identifying the combination of factor scores that maximize some dependent variable, for example, liking, subject to constraints. There are two types of constraints.
 - a. The first are explicit constraints—namely, the region of the independent variables corresponding to the highest and lowest factor scores. The explicit constraints make sense intuitively; we want

- to restrict our search for the optimum to that region where we have data. The region is the upper and lower factor scores.
- b. The second are the implicit constraints. These are ratings (e.g., perceived flavor intensity). Each of the rating attributes is represented by its own equation developed in the modeling step (step 7 above). We might want to identify the optimal product but ensure that it has a perceived flavor level between the actual ranges of the products tested, or even narrower. Once we know the levels of the independent variables, we automatically know the expected profile of the product, and the relevant targets among the products tested.
9. Reverse engineering. Let's turn the problem around 180 degrees. Rather than looking to maximize some criteria, let's identify a set of attributes to be matched. An example is an image profile, comprising a set of image attributes. Then let us identify the combination of independent variables producing that profile (always remaining within the range of independent variables or factor scores tested, as well as remaining within the range of sensory profile levels tested).
 10. Identifying holes or opportunities in the product category. The creation of a simple set of factors allows the researcher to locate all of the products in the category appraisal on a geometrical map, whose coordinates are the factor scores developed in step 4. A visual inspection of this space (if two or three dimensions), or a systematic exploration by numerical analysis (in three or more dimensions) will reveal locations where there are no products. We see a schematic example of this map in figure 15.3. The different products are shown as

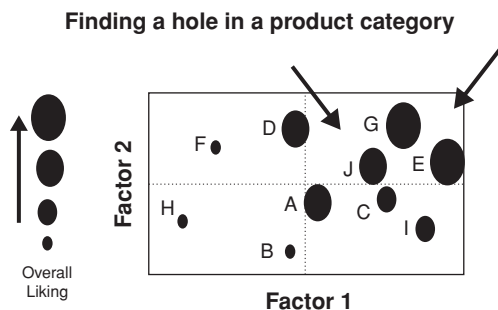


Figure 15.3. A two-dimensional product map using factor scores as the dimensions. Products are denoted by ovals, with the size of the oval proportional to the degree of liking.

ovals of different sizes, with the size of the oval proportional to the degree of liking. Inspecting the figure immediately tells the developer the location in the map where there are no products. This is an opportunity. The product model or set of equations developed in step 7 immediately tells the developer what the sensory profile is. Finally, the database of products by sensory profile shows what products act as landmarks for each sensory attribute that has been identified. Of course, we do not know which particular ingredients correspond to this profile, although the astute product developer could guess by inspecting the target products that have the relevant level.

Illustrating the Approach Through a Case History—Healthy Bread

The easiest way to discuss a category appraisal is to show the basic steps in the study, from design to field execution to simple data analysis, and onto modeling and recommendations. The case study presented here deals with “healthful bread.” In the United States the market for healthful foods (also called good-for-you foods) has been steadily increasing over the past decades. The early work in bread looked at fortifications, reducing calories, and generally using better ingredients. However, over time a more artisanal approach to bread making has come to the fore, promoted by the search for a unique market position and the willingness of consumers to pay more money for products that they deem to be of higher quality. Healthy bread is one of those products. A walk through a store such as Whole Foods reveals the increasing competition among national and local manufacturers for a position in the healthy bread market.

Our case history is based upon the desire of a manufacturer to understand what drives healthful bread, especially in light of the explosion of alternative ingredients inside the bread (e.g., nuts, olives, fruits) as well as the promotion of multigrain breads where the consumer is merely told that the bread flour comes from a variety of different grains, not just one flour alone.

There are two aspects to the category appraisal, as we see in figure 15.4. The first aspect is the analysis of in-market products. The analysis will show us how many of the sensory attributes interact to drive consumer acceptance. We will identify holes in the product category, as

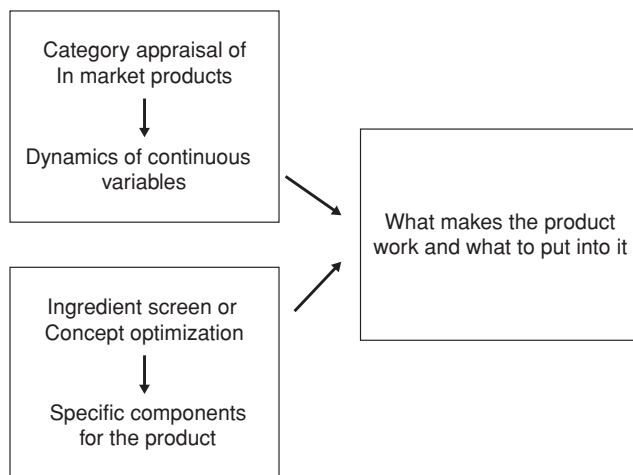


Figure 15.4. Approach used for the healthful bread study to identify product dynamics and product specifics.

well as the sensory profile of the product that might fit those holes, and whether this product is acceptable. However, that is not sufficient. We do not learn about the extra components of products, the flavors, and so on. We need a different method to learn about flavors, inclusions, vitamins. We will screen ingredients using ideation and concept optimization to identify new features of the product. The combination of category appraisal (to identify product dynamics) and ingredient screening (to identify specific opportunities) provides the product developer with a sense of how products perform and where to go next.

Setting up the Category Appraisal—Selecting the Products

Even before the researcher begins to assess the healthful bread products with consumers, it is important to understand the category. Probably the best way to do that, and the standard way, consists of purchasing the products “off the shelf.” When planning the purchase, the researcher needs to be aware of specific issues that might impact the product’s sensory profiles. For bread, freshness is critical, especially for its texture. For other products, critical aspects might revolve around method of preparation, especially if the product is a component of a complete dish, such as pasta sauce. These issues need not concern us here—they remain within the domain of standard business practices.

A key issue in the early phase is to ensure that the samples purchased generate a sufficiently wide sensory range. It is almost impossible to ensure that the samples cover the correct array of sensory attributes since the researcher must make do with the products already on the shelf. Nonetheless, there are two specific things that the researcher can do:

1. Make sure that the products do have a wide range, even to consumers. This is a relatively simple task for bread, which guards against the tendency to restrict the range. Such tendency, which reveals itself more frequently in the selection of ingredients, also makes itself known when selecting in-market products. The tendency probably exists because product developers fall prey to a myopia surrounding their own products. Small deviations around their products (if such products already exist) are regarded as large, and the actual large deviations are regarded as irrelevant. In a category appraisal, the researcher must make every effort to assess a wide range of what exists, not simply what is deemed relevant in the developer's mind.
2. Cut down redundant products to a manageable number for testing using defensible, open criteria. Submit the products to an expert panel to profile, in the happy occasion where there are many products in the market, and the need is to cut down the many to a few. For example, when doing a category appraisal of vegetable soup, there may be four dozen or more products. For breads, there are equally large numbers of products to consider, especially when the researcher opens up the definition of a healthy bread to the many different types of breads that could have even a tangential relation to "good for you." The data from the expert panel can be submitted to statistical cluster analysis, a method by which the different products are put into discrete groups, so that the products in a cluster or group are qualitatively similar to each other. By clustering the products, the researcher can cull down a large set of products into groups, and choose one product from each group, rather than testing them all.

Starting from a set of 31 products, the marketing and R&D groups were able to cull down the set to 13 reasonably different breads. The word "reasonably" is an important part of that sentence. Category appraisals provide a great deal of feedback on product performance. As such, everyone has their favorite products. It is often a tug of war between

marketing and R&D as to which products are to be tested, especially in light of who holds the budget strings, and how tight the constraints are on the number of products to be tested.

The Questionnaire and Scale

In a category appraisal, the questionnaire allows the researcher to understand the “dimensions” along which the different products vary. For foods, there are no fixed attributes, although the prudent research strategy should include sensory questions (amount of), liking questions, and image questions (more cognitively complex questions). The questionnaire should deal with the different senses that the product affects—vision (appearance), olfaction (aroma, flavor), taste, and kinesthesia (texture, mouthfeel). The questionnaire should deal with specifics as much as possible, because it is in the specifics that a deep understanding will emerge. However, the researcher should not burden the panelist with too many questions.

There is no fixed number of questions that is optimal—the authors have worked with as few as 5–10 attributes, and as many as 72. The number of attributes is a function of the complexity of the product, the motivation of the panelists (paid, unpaid), and the length of the interview. For the bread study, we used 28 attributes. The actual attributes appear in table 15.1.

The scale used for most of the attributes ranges from a low of 0 and a high of 100, with the exception of purchase intent, which used a labeled five-point scale. The 0–100 point scales were anchored at the bottom and the top to remove any issue with ambiguity. Consumer panelists usually have no problems with these types of scales. Arguments have been made from time to time that the 0–100 point scale should be narrower because panelists have difficulty knowing what precisely the scale points mean. The reality of the situation is panelists use the scale in a very general sort of way to denote magnitude, so the more points on the scale, the easier it will be for the panelists to show differences among products based on their ratings.

Field Execution of a Category Appraisal

There are two key aspects of a category appraisal that determine the nature of its field execution. First, the project should comprise many bread products (i.e., test stimuli) since the objective is to uncover relations

among variables. The only way these relations can be uncovered is by using the different products as the basis for the modeling. The second aspect is that we would like to uncover segments in the population based upon the pattern of liking ratings, and more specifically based upon the pattern relating sensory attribute level (independent variable) versus the individual's liking rating (dependent variable). The only way that this segmentation can be generated is by having each panelist evaluate a relatively large number of products (six or more). In this way, it becomes possible to develop the individual-level sensory-liking rating (group sensory level versus individual liking rating).

The number of panelists for a category appraisal is not fixed. Since the objective is to take a snapshot of the product category, there is really no fixed number of respondents. Typical practices use a minimum of 30 panelists per product. However, even if the study comprises only six products and every panelist evaluates every product, the prudent researcher typically works with many more people, for example, 60 or more. The objectives are to secure solid estimates of the sensory and hedonic profiles of the product, but also to capture segments in the population who may perceive the sensory attributes the same but may have radically different patterns of what they like and dislike. Thus, the more panelists who participate in the study, the better the results will be. However, the larger panel size also costs more because of the linear increase in field cost with increasing base size. Usually the category appraisal is also early stage so that those in charge of budgets realize that the study need not be very large (e.g., the 300+ needed for claims testing). By the time the base size reaches about 40–50, the data stabilize (Moskowitz, 1997), so the minimal sizes for category appraisals tend to be about 50 ratings/products, and the maximal sizes tend to be about 100 ratings/product. These base sizes are not legislated by statistical considerations as much as by business considerations.

For this category appraisal, the 120 panelists were invited to a central location session lasting two and a half hours, during which time they evaluated 8 of the 13 products. A key benefit of the central location format is the ability to choreograph the session so that the interview can be monitored and run by a trained interviewing staff. The panelist knows that he or she will be spending several hours, so that the panelist does not feel rushed as might be the case in a central location intercept at a mall. The prerecruit format, discussed extensively by Moskowitz (1985), does not, however, allow the study to be run in many markets, for cost reasons. Nonetheless, the prerecruit format is very productive

in terms of good data, rapidly acquired, under supervised conditions. When it comes to evaluating bread products, where the respondents do not prepare the product but simply eat it, the central location prerecruit or hall test works quite well.

Some Additional Considerations about Panelists

Category appraisals, as strategic research, always intertwine with the issue of representing the population. In some studies, the category appraisal may be done internationally, with panelists from the different countries evaluating the products. However, the more common case is for the category appraisal to be done within the confines of a single country, since it is usually initiated for a local issue, such as launching a new product in a single country.

Just because the category appraisal is launched within a single country does not mean that one market represents the entire country. Quite often marketing and R&D agree that the study must represent the “tastes” of many consumers across the country. For this reason the fieldwork for category appraisal is conducted in several markets with the objective that by sampling panelists from these different markets, the study will represent the sensory preferences of the entire country. All too often, however, when the researcher plots the average ratings for products from one market against the average rating for the same products in another market, the result is pretty much of a straight line. Winning products, that is, those that are most liked, tend to be the same from market to market. Changes in product performance by market tend neither to be systematic nor easily interpretable. There may be slight changes in the ratings, some products may shift position making one product do slightly better in Market A but slightly poorer in Market B, and so forth. On the whole, however, the researcher would be pressed to conclude that the panelists differ by market, or if they do, that’s the underlying reason for that difference. Occasionally, the products in the test comprise the “favorites” of one geographical region, so that these favorites do better than expected.

Analysis of the Bread Data

Unless the researcher really knows what to look for, category appraisals can degenerate into masses of tables. The sheer abundance of data can

Table 15.1. Summary data for 13 healthful bread products on 28 attributes.

| Type | Attribute | 101 | 102 | 103 | 104 | 105 | 106 | 107 | 108 | 109 | 110 | 111 | 112 | 113 |
|------|-------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| L/D | Overall liking | | | | | | | | | | | | | |
| | of plain bread | 35 | 30 | 47 | 39 | 51 | 59 | 53 | 58 | 66 | 59 | 71 | 53 | 61 |
| | Segment 1 | 37 | 30 | 58 | 29 | 49 | 52 | 38 | 49 | 61 | 40 | 69 | 60 | 49 |
| | Segment 2 | 33 | 29 | 36 | 49 | 54 | 66 | 67 | 66 | 72 | 79 | 74 | 47 | 73 |
| L/D | Overall liking | | | | | | | | | | | | | |
| | way normally | | | | | | | | | | | | | |
| | eat bread | 55 | 32 | 58 | 41 | 59 | 55 | 62 | 67 | 58 | 53 | 69 | 48 | 63 |
| | Purchase | | | | | | | | | | | | | |
| L/D | interest | | | | | | | | | | | | | |
| | (top 2 box %) | 28 | 21 | 41 | 31 | 51 | 43 | 37 | 36 | 42 | 35 | 51 | 38 | 62 |
| | Like overall | | | | | | | | | | | | | |
| | appearance | | | | | | | | | | | | | |
| L/D | of the bread | 34 | 33 | 36 | 52 | 37 | 53 | 59 | 60 | 46 | 54 | 53 | 37 | 71 |
| L/D | Like size | 17 | 17 | 17 | 35 | 35 | 26 | 23 | 26 | 29 | 37 | 34 | 26 | 55 |
| L/D | Like shape | 38 | 38 | 40 | 53 | 47 | 48 | 51 | 46 | 54 | 53 | 45 | 48 | 67 |
| L/D | Like | | | | | | | | | | | | | |
| | appearance | | | | | | | | | | | | | |
| | of the crust | 48 | 52 | 46 | 61 | 63 | 79 | 67 | 55 | 77 | 46 | 60 | 41 | 69 |
| | Like color | | | | | | | | | | | | | |
| L/D | of the crust | 63 | 55 | 58 | 66 | 65 | 85 | 78 | 81 | 67 | 66 | 55 | 35 | 73 |
| | Like crispy | | | | | | | | | | | | | |
| | appearance | | | | | | | | | | | | | |
| | of bread | 48 | 50 | 45 | 57 | 49 | 65 | 61 | 65 | 67 | 54 | 50 | 36 | 59 |
| SEN | Light vs. dark | | | | | | | | | | | | | |
| | color of crust | 33 | 13 | 38 | 18 | 31 | 40 | 21 | 16 | 28 | 15 | 20 | 9 | 25 |
| | Crispy | | | | | | | | | | | | | |
| | appearance | 41 | 46 | 78 | 40 | 67 | 64 | 56 | 44 | 52 | 53 | 43 | 34 | 41 |
| L/D | Like aroma | 60 | 18 | 72 | 45 | 80 | 70 | 66 | 60 | 68 | 61 | 86 | 57 | 73 |
| SEN | Strength of aroma | 26 | 33 | 48 | 29 | 47 | 38 | 33 | 35 | 29 | 38 | 29 | 27 | 35 |
| | | | | | | | | | | | | | | |

(Cont.)

Table 15.1. (Continued)

| Type | Attribute | 101 | 102 | 103 | 104 | 105 | 106 | 107 | 108 | 109 | 110 | 111 | 112 | 113 |
|------|-------------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| L/D | Like overall taste | 52 | 28 | 57 | 51 | 75 | 70 | 68 | 70 | 67 | 56 | 68 | 57 | 75 |
| L/D | Like aftertaste | 53 | 27 | 62 | 58 | 87 | 64 | 70 | 70 | 50 | 65 | 67 | 53 | 76 |
| L/D | Like taste of the crust | 52 | 48 | 47 | 49 | 84 | 69 | 59 | 67 | 73 | 67 | 83 | 61 | 77 |
| SEN | Sweetness | 28 | 22 | 27 | 24 | 28 | 29 | 27 | 25 | 27 | 27 | 27 | 24 | 30 |
| SEN | Other taste | 20 | 39 | 19 | 21 | 20 | 18 | 16 | 17 | 17 | 19 | 18 | 18 | 17 |
| | Like overall | | | | | | | | | | | | | |
| L/D | texture of bread | 51 | 41 | 54 | 45 | 60 | 57 | 61 | 73 | 65 | 58 | 69 | 55 | 73 |
| | Like texture | | | | | | | | | | | | | |
| L/D | of the crust | 56 | 39 | 54 | 53 | 59 | 73 | 64 | 77 | 58 | 50 | 77 | 56 | 59 |
| | Soft vs. hard | | | | | | | | | | | | | |
| SEN | texture of bread | 37 | 34 | 42 | 36 | 35 | 29 | 34 | 39 | 20 | 37 | 30 | 24 | 23 |
| | Very few vs. a lot | | | | | | | | | | | | | |
| SEN | of holes in bread | 60 | 25 | 66 | 49 | 67 | 47 | 47 | 43 | 66 | 49 | 50 | 48 | 62 |
| | Soft vs. hard | | | | | | | | | | | | | |
| SEN | texture of crust | 52 | 53 | 57 | 51 | 53 | 50 | 42 | 36 | 40 | 45 | 33 | 22 | 34 |
| | Homemade | | | | | | | | | | | | | |
| IMG | tasting | 29 | 29 | 33 | 20 | 32 | 29 | 34 | 37 | 35 | 26 | 46 | 37 | 50 |
| IMG | Quality | 46 | 24 | 51 | 37 | 59 | 54 | 52 | 61 | 51 | 55 | 62 | 46 | 72 |
| | Looks like an | | | | | | | | | | | | | |
| IMG | artisanal bread | 41 | 46 | 50 | 34 | 50 | 60 | 51 | 46 | 40 | 62 | 63 | 39 | 53 |
| | Hand crafted fit | | | | | | | | | | | | | |
| IMG | the appearance | 51 | 56 | 62 | 50 | 74 | 87 | 62 | 55 | 55 | 75 | 59 | 58 | 78 |
| IMG | Quality | 44 | 63 | 68 | 66 | 81 | 81 | 72 | 65 | 68 | 74 | 78 | 58 | 72 |

Note: The attributes are divided into evaluative (L/D), sensory (SEN) and image (IMG).

produce overwhelming mountains of computer printout. Contrary to what one might think, the answer is “not in there, somewhere, lurking about.” The answers in a category appraisal come from the structured way of looking at the data, not from presenting management with data tables. We first begin with a look at the data, which is presented in summary form in table 15.1.

We begin the analysis at the very simplest level—namely, how do the products score on the different attributes? Questions that need to be answered at this first stage are:

1. On the liking scale, where do the different in-market products score?

Are they all liked, are some actually disliked even though they are in-market products? One should never assume that just because a product has enjoyed a position in the market that the product is basically acceptable. It could very well be that the product is terrible, but was launched because of other issues such as the need to have a product in a particular niche to “round out the line.” It might even be the case that some of these less liked products are there in the marketplace because management has let the criteria for quality slide. In any event, the first thing to look at is how well the products perform. When management is involved, the liking ratings are often the key topic for conversation—everything else plays a secondary role. As table 15.1 shows, the commercially available products span a wide range for healthy bread, meaning that some products are acceptable, some are less acceptable. The range from 30 to 71 means, therefore, that the sensory properties of the different breads may provide clues about why products are more acceptable or less acceptable.

No data for liking can be considered complete without norms. Norms are very important in consumer research, especially in the commercial sector. Norms allow the marketer and the product developer to interpret what the numbers really mean. The applied nature of product evaluation in category appraisal makes it critical that those who use the data will be able to understand them and put the data into meaningful terms that they can later use. For these types of studies where the product is evaluated “unbranded,” typically the average rating for overall liking can be interpreted as follows: 70+ excellent; 60–70 very good; 50–60 good; 40–50 fair, needs work; below 40 poor, product significantly misses being acceptable to the panelist.

The importance of subgroups: Do the liking scores vary dramatically by conventional subgroups that the researcher can pull from the

classification data (e.g., males versus females; older versus younger; brand used most often)? For the most part, these liking ratings will be pretty similar by most conventional subgroups. Probably no other topic in the study drives as much interest, because overall liking is the key variable for many marketers. There might be the occasional difference between products that is highly accentuated when looking at one subgroup (e.g., brand used most often). However, it is quite difficult to come up with an organizing principle that can handle these group-to-group differences. One organizing principle may be the magnitude of the liking rating—even though the product-to-product variation is hard to explain, it often turns out that one group down rates all of the products, whereas another group up rates all of the products. It's not clear whether this consistent difference in rating is due to differences in scale usage or differences in actual product acceptance. Differences in scale usage are not particularly interesting to the developer.

2. How does sensory attribute liking drive overall liking? Each product category has a set of dynamics for overall liking that can be discovered empirically. One of these dynamics is the specific nature of sensory inputs, specifically how overall liking and attribute liking covary. If we look at the attributes for healthful bread in table 15.1, we see that the panelist rates overall liking, as well as the liking of appearance, liking of aroma, liking of taste/flavor, and liking of texture, as well as liking of aftertaste. A factor analysis of these attributes reveals that they are highly correlated. However, the specific relation between attribute liking and overall liking may provide more information if the relation is captured by a linear equation of the form: Overall liking = $k_0 + k_1$ (attribute liking). We know that the coefficient k_1 will be positive—increases in attribute liking will covary with increases in overall liking. However, the question is the numerical value of k_1 . Is it high, meaning that a one unit increase in attribute liking covaries with a high increase in overall liking? We interpret that to mean that the sensory input is important. Conversely, the coefficient k_1 may be low, meaning that the one unit increase in attribute liking doesn't generate a particularly high increase in overall liking. We see a schematic of this liking relation in figure 15.5. For our healthful bread study, we see the slopes in table 15.2. We see, not particularly surprising, that the taste/flavor dimension is the most important one.

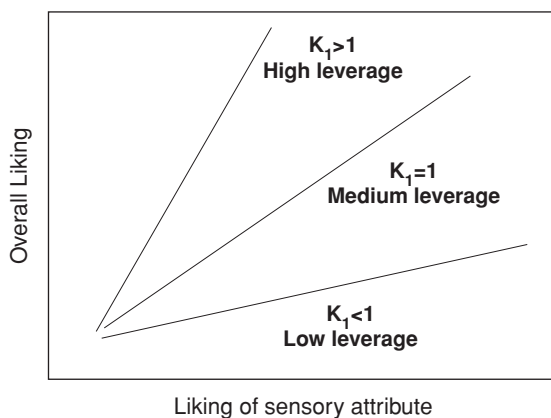


Figure 15.5. Schematic for leverage analysis.

3. How do the products perform on sensory attribute level? The objective here is to look at the sensory profiles of the different products, and abstract from those profiles the ranges of sensory attributes, the distribution of levels, and so forth. Perhaps all of the products except a very few have modest aroma intensities, but a few products have very strong intensities. There is very little to do at this stage, other than report the sensory ranges, and make some observations about the distribution of sensory attribute levels across the products. The data in table 15.1 allow the estimation of range of ratings and

Table 15.2. Slopes for leverage analysis.

| Independent | Slope | R-square |
|------------------|-------|----------|
| Appearance | 0.60 | 0.58 |
| Size | 0.59 | 0.51 |
| Shape | 0.81 | 0.52 |
| Appearance crust | 0.42 | 0.42 |
| Bread color | 0.19 | 0.20 |
| Crust appearance | 0.50 | 0.37 |
| Aroma | 0.53 | 0.74 |
| Taste | 0.73 | 0.77 |
| Aftertaste | 0.43 | 0.52 |
| Crust taste | 0.75 | 0.79 |
| Texture inside | 1.03 | 0.84 |
| Texture of crust | 0.76 | 0.68 |

distributions. We don't yet know anything about these attributes—whether they are statistically independent of each other, whether they are relevant as drivers of liking, etc.

4. How do the different sensory attributes drive liking for the total panel?

The objective here is to look at the relation between sensory attribute level and liking, to identify which sensory attributes should be considered more deeply in product development. Sensory attributes play two roles—description of a product, and driver of liking. We already know whether the panelists differentiate among products on an attribute, but we need to better understand whether that attribute is relevant to liking. Fortunately, as discussed above, we can plot liking as the dependent variable (ordinate) versus sensory attribute as the independent variable (abscissa). In the category appraisal, we of course do not control the sensory attribute level, so the analysis is really R-R (response-response); we are trying to relate two dependent variables to each (liking which is a function of the product; and sensory intensity of an attribute, which is also a function of the product). We are looking for patterns in this R-R analysis. We plot the data, and fit a quadratic equation to the results using standard regression modeling (Moskowitz, 1981a, b). The quadratic equation is simple to fit, allows for nonlinearities and for an intermediate optimum. We do this for each of the sensory attributes. Figure 15.6 shows two of these fitted curves. Of course, the data will be scattered around this curve, so that in reality the fitted equation is only an approximation, but this analysis still gives a general sense of how liking changes with a single sensory attribute, all other factors being fixed.

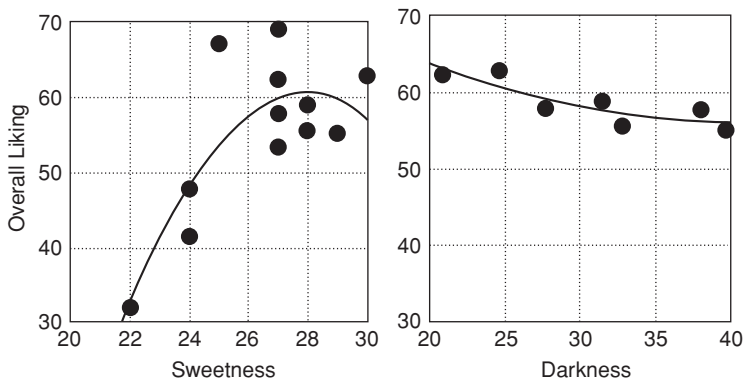


Figure 15.6. Two sensory-liking curves for bread.

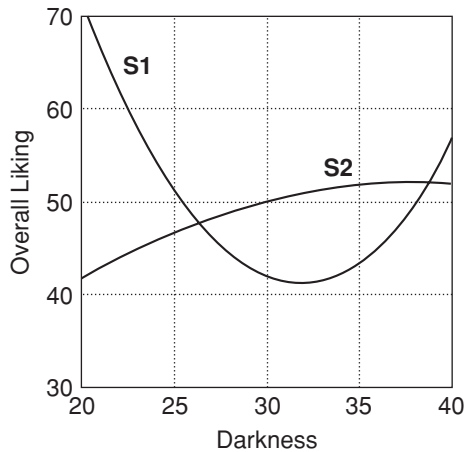


Figure 15.7. How sensory darkness “drives” overall liking for the two segments (S1, S2) emerging from the healthful bread study.

Sensory-Preference Segmentation

Sensory preference segmentation refers to the division of panelists by the pattern of what they like. The organizing principle of such segmentation comes from observations over the past century that the relation between sensory intensity and liking may not be the same across people. For example, as a product becomes increasingly sweet some people like the product more, others like the product less. This observation holds for model systems (simple aqueous solutions; Ekman and Akesson, 1964; Engel, 1928; Pangborn, 1970) but is more dramatic when we deal with actual foods. Sensory segmentation appears most strongly in the world of flavors, but may also emerge for appearance and texture, albeit to a less marked degree. We see an example of such segmentation for the bread data in figure 15.7, wherein two segments were extracted. The nature of the darkness-liking relation varies by the segment.

The nature and characteristics of sensory segmentation must be established by experiment for each food and beverage product. There is no guide, no *vade mecum* for the world of food products that gives ready answers about these segments. However, it is straightforward to identify these segments. The methods have been previously described (e.g., Moskowitz, 1986; 1994). It is important to note that the sensory segments are developed by a holistic analysis of all sensory attributes as they drive liking, but that the analysis further recognizes that

there is redundancy among the sensory attributes. This redundancy is removed later in the process by a principal components factor analysis on the optimal sensory points, so that the segmentation can take into account all sensory inputs, not just a few relatively uncorrelated inputs.

Map the Products by Locating the Different Products on a Factor Map

The objective of mapping is to identify where the opportunities lie. Mapping for the bread begins with a principal components factor analysis of all sensory attributes, which have been used by consumers. One might also use expert panel data and instrumental measures at the same time, integrating them into the data set so that the factor scores come from a variety of sources (consumer sensory, expert sensory, instrument measures). We will confine our attention to the consumer sensory data. The principal components analysis locates each of the products as a set of factor scores on this reduced space, whose dimensions are the factors. For the bread study, the analysis generates two factors, which have the statistical property of being both parsimonious (only two instead of eight) and statistically independent of each other (orthogonal). Each of the 13 bread products generates its own profile of factor scores from the principal components analysis, as is shown in table 15.3. Principal components analysis, like the other statistical analysis techniques discussed here, can be found in most statistical analyses programs available in off-the-shelf software. The key thing to keep in mind is that the 13 bread products now have two more characteristics provided by the principal components. The researcher can map the products in the geometrical space defined by the principal components since each product has a profile of factor scores (see fig. 15.8). There are other very important benefits that we will see below in the next step.

Creating an Integrated Product Model for Bread

We have already seen how the different sensory attributes drive acceptance, and how these attributes are nonlinearly related to liking, but correlated among themselves. The integrated product model combines all of these independent attributes into a parsimonious few through principal components to generate the two factors and then uses these

Table 15.3. Location of the eight sensory attributes on two factors, and factor score locations of the 13 test breads.

| Loading or correlation of attributes with two factors | | |
|---|----------|----------|
| | Factor 1 | Factor 2 |
| Hardness of crust | 0.90 | −0.14 |
| Crispness of crust | 0.85 | 0.34 |
| Aroma intensity | 0.80 | 0.26 |
| Hardness inside | 0.68 | −0.35 |
| Dark | 0.63 | 0.63 |
| Sweet | 0.15 | 0.89 |
| Amount of holes | 0.18 | 0.86 |
| Nonsweet taste | 0.25 | −0.82 |
| % Variability accounted for by the factors | 39 | 37 |
| Locations of products on factor (factor scores) | | |
| P101 | 0.24 | −0.11 |
| P102 | −1.34 | 2.37 |
| P103 | 1.87 | 0.89 |
| P104 | −0.61 | 0.59 |
| P105 | 1.42 | 0.30 |
| P106 | 0.98 | −0.11 |
| P107 | 0.00 | −0.11 |
| P108 | −0.57 | 0.20 |
| P109 | 0.08 | −1.19 |
| P110 | 0.01 | 0.31 |
| P111 | −0.58 | −0.69 |
| P112 | −1.61 | −0.97 |
| P113 | 0.11 | −1.47 |

factors as independent variables. Let us do this analysis for the bread products, following the steps shown in table 15.4. Keep in mind that the regression analysis is fairly straightforward. The regression modeling generates a quadratic function for each attribute, whether the attribute be sensory, overall liking, attribute liking, and even image. The researcher need not profoundly understand the product category in order to create this model because the specific steps are well laid out and correct from a statistical viewpoint. An example of the equations that the

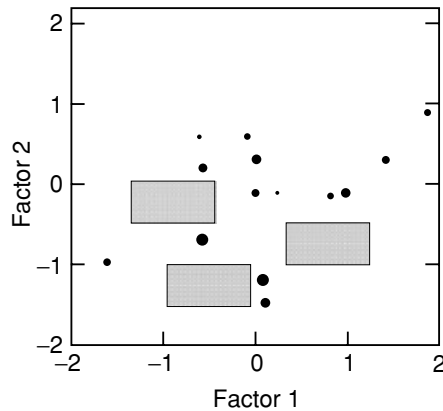


Figure 15.8. Map of the 13 bread products in the factor space defined by principal components. The size of the circle is in proportion to the degree of overall liking. For convenience, a two-dimensional space has been chosen to illustrate the mapping and modeling, although the number of dimensions is a function of the particular product, sensory attributes, and decision criteria for factor-extraction chosen by the researcher.

model comprises appears in table 15.5. The equations by themselves are only shorthand expressions showing how a dependent variable covaries with the independent variables (the factors). Of course, if we know the levels of the factors then we automatically know the value of the dependent variable, because we need only substitute the values of the factors into the equation, and then solve the equation. The result is the value of the dependent variable, by simple algebraic substitution. If we have the equations for all of the attributes, based on the same set of factors, then we know the profile of the product corresponding to that vector or set of factor scores.

Using the Product Model—Finding a Hole in the Bread Category

The product model (i.e., the set of equations) allows us to identify the sensory profile corresponding to a hole in the category, as long as we can identify the holes. If we look at figure 15.8, we see that there is a lot of empty space in the category. Each region in this empty space corresponds to an opportunity. However, not all opportunities are good. The real issue is how to qualify an opportunity, and then identify the sensory profile corresponding to that opportunity. Looking for holes is fairly

Table 15.4. Steps followed to create the product model based on ratings for the bread products.

| Step | Action | Rationale |
|------|--|--|
| 1 | Array all the products so that the sensory attributes are together. | The sensory attributes will be the ones considered for the principal components factor analysis. |
| 2 | Perform a principal components factor analysis on the sensory attributes. | Reduce the larger number of intercorrelated attributes to a smaller set of uncorrelated factors that will be used both for mapping and for modeling. |
| 3 | Rotate the solution by quartimax rotation and estimate the factor scores. | The quartimax rotation generates an easy to understand and “clean” solution. The factor scores will be used as new attributes, within this factor structure. For these data, two factors emerged, so each of the 13 products now has two new numbers corresponding to the factor scores. |
| 4 | Map the products in the factor space using the factor scores. | Allows for discovery of holes or opportunities. Make the size of the circle on the map proportional to a criterion variable such as overall liking. |
| 5 | Use the factor scores as independent variables. Create models relating the factor scores to each attribute, whether sensory, liking, or image. | The factor scores are orthogonal and parsimonious, making them perfect variables for regression. This step generates the factor model. |
| 6 | Holes: Identify holes or opportunities in the category and the sensory profile corresponding to those holes. If possible, find products with the requisite sensory levels to act as landmarks. | The product model maps the factor scores to attributes. |

Table 15.4. (Continued)

| Step | Action | Rationale |
|------|---|--|
| 7 | Optimization: Identify the optimal level of an attribute subject to constraints. | The constraints are the explicit levels of the factor scores. Implicit constraints are the sensory levels of the product. Ideally the optimum should lie within the range of sensory levels tested (so-called convex hull). |
| 8 | Reverse engineering: Identify a profile (e.g., of image attributes) and then identify the factor scores and in turn the sensory profile corresponding to this set of factor scores. | Reverse engineering should be done by holding the factor scores within the range tested, and the sensory level within the range tested. Explore many alternative combinations of factor scores until the expected profile of the combination matches as close as possible the desired goal, and yet lies within the imposed constraints. |

simple in one or two dimensions. Discovery can be done visually by inspection as long as the research covered considers a full array of products so the hole really represents an opportunity rather than a product that missed being tested. Let's just look at three locations in the map that appear empty, and determine whether they are worthwhile. These locations are shown as the three rectangles. As table 15.6 (columns marked A–C) shows, the expected profile corresponding to these products

Table 15.5. Example of equations.

| | Ltotal | Lsize | Sdark | Ihome |
|-------------------------|--------|-------|-------|-------|
| Multiple R ² | 0.5 | 0.4 | 0.9 | 0.6 |
| Constant | 53.6 | 29.6 | 22.3 | 31.0 |
| Factor 1 | 1.3 | 1.8 | 9.3 | 0.9 |
| Factor 2 | −7.4 | −5.1 | −4.8 | −4.9 |
| Fact1*Fact1 | −1.5 | −3.3 | 3.4 | −1.3 |
| Fact2*Fact2 | 0.4 | 2.6 | −2.0 | 4.2 |
| Fact1*Fact2 | 1.4 | 1.2 | −6.2 | 3.5 |

Table 15.6. Different product profiles emerging from the analysis of the bread products.

| | A | B | C | D | E | F |
|-------------------------------------|--------|--------|--------|-------|-----------|-----------------------------|
| | Hole 1 | Hole 2 | Hole 3 | Best | Artisanal | Artisanal but lighter color |
| Factor 1 | −1 | −0.5 | −0.9 | −0.26 | 1.03 | −0.52 |
| Factor 2 | −0.3 | −1.5 | −0.8 | −1.47 | 0.59 | 1.01 |
| Liking | | | | | | |
| Like total (plain) | 54 | 66 | 58 | 65 | 50 | 45 |
| Like total (as normally used) | 53 | 63 | 57 | 63 | 60 | 52 |
| Like—Segment 1 (plain) | 50 | 61 | 55 | 59 | 45 | 35 |
| Like—Segment 2 (plain) | 57 | 71 | 62 | 72 | 55 | 55 |
| Like—% top 2 box purchase intent | 36 | 51 | 41 | 52 | 37 | 26 |
| Like appearance | 46 | 60 | 51 | 61 | 48 | 50 |
| Like size | 27 | 42 | 32 | 43 | 27 | 25 |
| Like shape | 47 | 61 | 52 | 61 | 47 | 45 |
| Like appearance of crust | 56 | 52 | 52 | 59 | 49 | 45 |
| Like color | 60 | 51 | 55 | 58 | 67 | 64 |
| Like appearance of crispiness | 51 | 52 | 50 | 56 | 53 | 54 |
| Like aroma | 60 | 71 | 65 | 72 | 67 | 48 |
| Like taste | 63 | 61 | 62 | 65 | 57 | 47 |
| Like aftertaste | 62 | 57 | 60 | 59 | 65 | 54 |
| Like taste of crust | 67 | 64 | 65 | 69 | 54 | 49 |
| Like texture inside | 58 | 71 | 63 | 71 | 58 | 54 |
| Like texture of crust | 66 | 51 | 61 | 54 | 54 | 52 |
| Image attributes | | | | | | |
| Image homemade | 32 | 50 | 38 | 48 | 31 | 28 |
| Image high quality | 48 | 63 | 54 | 64 | 54 | 44 |
| Image artisan bread | 45 | 50 | 46 | 50 | 53 | 49 |
| Image healthful bread | 60 | 56 | 57 | 61 | 60 | 51 |
| Sensory attributes | | | | | | |
| Sensory darkness | 16 | 17 | 15 | 20 | 28 | 15 |
| Sensory crispness | 40 | 40 | 39 | 42 | 63 | 47 |
| Sensory aroma | 28 | 29 | 28 | 30 | 41 | 32 |
| Sensory sweetness | 25 | 28 | 26 | 28 | 27 | 25 |

Table 15.6. (Continued)

| | A | B | C | D | E | F |
|---------------------------|--------|--------|--------|------|-----------|-----------------------------|
| | Hole 1 | Hole 2 | Hole 3 | Best | Artisanal | Artisanal but lighter color |
| Sensory other taste | 19 | 16 | 17 | 17 | 18 | 23 |
| Sensory hardness inside | 30 | 24 | 28 | 23 | 42 | 42 |
| Sensory amount of holes | 44 | 65 | 52 | 65 | 61 | 44 |
| Sensory hardness of crust | 34 | 29 | 31 | 32 | 54 | 48 |

Note: Columns A–C correspond to holes in the category. Columns D and E correspond to the optimum product, without versus with an extra implicit constraint imposed on the solution.

(or more correctly to the map coordinates of these products) suggests that one product (A) is not particularly acceptable (liking = 54), one product is modestly acceptable (C, liking = 58), and one product is more acceptable (B, liking = 66).

Using the Product Model—Optimizing for Acceptance or for an Image Characteristic

Let's use the bread data to identify the location of a product that is highly accepted, and whose characteristics lie within the range of sensory characteristics achieved by the actual breads tested in the study. The location of this newly synthesized product appears in table 15.6 in column D. Just for fun, let's also try to place an additional constraint on an image attribute, as shown in column E. All the constraint does is narrow down the range of viable products to a much smaller feasible set. What is most important about the optimization is that once the optimal level is discovered, the developer need only go to the array of products to identify which specific product tested is closest to a particular attribute to the forecasted optimum. The product model does not, and cannot, identify the actual formulation because the category appraisal works with existing products. By not doing one's homework up-front, the researcher has, of course, saved time and money as well as reduced effort, but at a cost. That cost is the need to understand what formula variables will generate the desired response profile corresponding to the optimum.

Using the Product Model—Identifying a Location Corresponding to an Image Profile

The final application of category appraisal identifies the sensory characteristics of a synthesized product corresponding to a desired image profile. Image attributes, coming as they do from marketing and marketing research, aren't always well defined, and indeed in the world of the sensory specialist the image attributes are usually ignored as being scientifically intractable and not easy to define. However, despite these issues, the product model still provides a way by which the researcher can identify the location of a product in the space such that the product delivers a good "image profile." That is, we turn around the problem 180 degrees. The researcher specifies a response profile to act as the goal, a profile comprising these more cognitively complex image attributes such as "looks like artisanal bread" and "homemade tasting." The response profile comprises levels of these image attributes that we are trying to create in our bread by adjusting the sensory profile. The optimization program then searches through different locations in the map (i.e., factor scores) until it discovers the combination of factor scores that generates a profile as close as possible to this target profile. Once the program identifies the factor scores, it is a simple task to identify the sensory profile. Of course, just as in the optimization phase, it is important to remain within the limits of factor scores originally achieved by the 13 breads. We see four of the results of this reverse engineering in table 15.7, for two image attributes—artisanal bread and healthful bread. The nice thing about the approach is its ability to estimate potential product acceptance. Quite often, marketing specifies image profiles to R&D in "briefs" that do not talk about potential product acceptance. Just because the product is expected to fit a specific image profile does not mean that it will be accepted. The reverse engineering helps to estimate, at least guess beyond chance, as to whether or not the product will be promising.

An Overview to the Product Modeling

The discussion thus far deals with actual products, and attempts to understand what drives overall liking, as well as how to identify the sensory components of a product with desired properties (e.g., maximal acceptance, maximal acceptance subject to constraints, fit to an image profile). The objective is to help the developer better understand the

Table 15.7. Reverse engineering (four alternatives—artisanal bread and homemade tasting).

| | | | | |
|--|-------|-------|------|------|
| Goal to be matched by finding a location in the space generating the desired profile of artisan bread and health bread | | | | |
| Goal to be achieved: Artisanal = | 40 | 40 | 55 | 55 |
| Goal to be achieved: Health = | 60 | 75 | 60 | 75 |
| Location in the map generating the desired profile | | | | |
| Factor 1 | −1.55 | −1.61 | 1.30 | 1.02 |
| Factor 2 | −0.67 | 1.29 | 0.73 | 0.01 |
| Expected Rating Profile | | | | |
| Liking Attributes | | | | |
| Like total (plain) | 54 | 36 | 49 | 53 |
| Like total (as normally used) | 50 | 32 | 59 | 58 |
| Like—Segment 1 (plain) | 60 | 39 | 47 | 48 |
| Like—Segment 2 (plain) | 49 | 32 | 50 | 59 |
| Like—% top 2 box purchase intent | 39 | 27 | 38 | 44 |
| Like appearance | 38 | 25 | 45 | 46 |
| Like size | 25 | 13 | 25 | 28 |
| Like shape | 45 | 33 | 46 | 47 |
| Like appearance of crust | 51 | 75 | 45 | 72 |
| Like color | 45 | 67 | 62 | 78 |
| Like appearance of crispiness | 41 | 51 | 50 | 59 |
| Like aroma | 60 | 34 | 69 | 72 |
| Like taste | 63 | 58 | 56 | 72 |
| Like aftertaste | 59 | 51 | 65 | 72 |
| Like taste of crust | 69 | 76 | 51 | 73 |
| Like texture inside | 56 | 40 | 57 | 59 |
| Like texture of crust | 67 | 72 | 51 | 67 |
| Image Attributes | | | | |
| Image homemade | 35 | 20 | 32 | 31 |
| Image high quality | 46 | 26 | 54 | 55 |
| Image artisanal bread | 40 | 39 | 53 | 51 |
| Image healthful bread | 60 | 74 | 60 | 75 |
| Sensory Attributes | | | | |
| Sensory darkness | 12 | 19 | 30 | 35 |
| Sensory crispness | 36 | 42 | 67 | 62 |
| Sensory aroma | 27 | 30 | 43 | 40 |
| Sensory sweetness | 24 | 22 | 27 | 28 |
| Sensory other taste | 19 | 32 | 19 | 19 |
| Sensory hardness inside | 24 | 25 | 43 | 32 |
| Sensory amount of holes | 43 | 18 | 64 | 57 |
| Sensory hardness of crust | 25 | 43 | 55 | 51 |

category. For the most part, the exercise is valuable for two reasons. First, the approaches do reveal opportunities in the marketplace and landmarks for the developer to fix upon in the process of identifying what to do. Second, most developers rarely if ever look at the entire competitive frame in a disciplined fashion. If truth were known, most development flies fairly blind, using perhaps the profile of the leading in-market product as a guide. The unexpressed guiding belief is that “after all, if they’re the market leaders then they must be doing the right thing.” Category appraisal forces a discipline upon an essentially undisciplined development process. The discipline itself generates a lot more than information—it generates insight into how the category operates.

But What about the Specific Ingredients Themselves?

Internet-Ideation, It! Foundational Studies, and Concept Optimization

Why specific ingredients? Category appraisals work with the products currently on the market. This empirical work is both a strength and a weakness. The strength is that the research identifies winning products, strong sensory inputs, and appropriate sensory levels. The researcher understands the dynamics of the category, and learns about many of the features that drive product success. The weakness of the conventional category appraisal is that it fails to provide specific direction about the discontinuous variables—namely, the specific ingredients or flavors that the product should have. Such direction about the specific components can either be gotten by testing an exceptionally high number of qualitatively dissimilar products (occasionally possible, always expensive), or by doing a separate, parallel research study on reactions to specific components. Unlike category appraisal, which works with existing products, this parallel piece of research works with ideas, either screening them or testing them in the body of a product concept. In either case, the objective is to understand what specific ingredients or flavors in a product category consumers want. We might look at concept category appraisal as the other part of understanding the category.

Getting Ideas for Features of the Healthy Bread Product

In the search for new product features, researchers and developers have traditionally used two methods—competitive analysis (what are other

companies doing?), and brainstorming (let's sit together and identify new product features that we could put into our product). The brainstorming methods by far have proved most popular. Manufacturers hire ideation specialists who are able to bring together consumers or in-house product developers for a short time (several hours). During the sessions, the participants develop several hundred ideas about the product features. At the end of the session, the ideation specialist works with the company to cut down this very large list to several dozen promising product features, which the company then tests in concept research. At the end of the process, the developer may have a half a dozen new ideas about product features.

Recently, the explosive growth of the Internet has made ideation possible among participants who live very far away from each other (Pawle and Cooper, 2001). It should come as no surprise that ideation of new product ideas has flourished under this explosive growth. We finish this chapter on category appraisal with three methods that can complement the product-based, competitive analysis research. One method is directed ideation, the second method is analysis of foundational databases (It! Studies), and the third is customized concept assessment. The three methods allow the developer a clearer understanding of what features should be further considered for the healthful bread.

Online Ideation about Specific Product Features

The first method to identify new ingredients for the healthy bread uses the method of collaborative filtering, where one participant offers an idea, and other participants pick up the idea as being relevant, as well as vote on the importance of the idea. The notion of collaborative filtering has a long history. One of the approaches, the Delphi method was developed by the Rand Corporation to allow experts to provide insights into situations (Brown, 1968). A specific version of this method, Brand Delphi, was used to develop new ideas for the healthful bread. The participants were asked to read a short description about healthful bread, then look at ideas given by previous participants (perhaps just an hour ago in the session), select those ideas that were relevant, rate the ideas, and then offer some of their own new ideas. The process has been discussed elsewhere (Moskowitz et al., 2005). What concerns us here is the list of features for the new healthful bread, and then the prioritization of those features.

The Brand Delphi process enables a large number of participants to offer ideas about the ingredients of a healthful bread. There are more opportunities with many elements than with fewer elements, so the Internet-empowered Brand Delphi method possesses an exceptional power, whether in actuality or even in potential. As the reader might suspect, not all of the ideas offered by participants are selected by others as being relevant; sometimes an idea seems reasonable to only one or two people, not to others who see the ideas. These others reject it. With the Brand Delphi process, the ideas have a chance to make an appearance, be selected, or die out because of irrelevance. In table 15.8, we see a subset of the most promising ideas—those that are selected many times when they appear (Select > 10), those that are selected a greater proportion of times when they appear (Select P > 20%), and those that

Table 15.8. Some popular ideas from Brand Delphi, where panelists selected promising ideas from other panelists, rated them, and offered new ideas.

| Flavor and other “discontinuous” features of health bread | Sel | SelP | Rate |
|---|-----|------|------|
| I would crave a hearty wholesome grain bread that satisfies my hunger and gives me a feeling of fullness. | 68 | 60 | 7.9 |
| I’d like a break from white bread for a change of pace. I prefer bread varieties such as rye, multigrain, oatmeal, cheese, etc. | 63 | 48 | 8.1 |
| Multigrain breads | 53 | 54 | 8.1 |
| FRESH bread & bread with lots of iron in it but . . . it must taste like Fresh Baked bread. | 49 | 55 | 8.2 |
| I love European specialty bread such as Italian ciabatta, French bread, Dutch pumpernickel, or other ethnic bread. | 48 | 48 | 7.6 |
| I used to enjoy cinnamon and raisin as a breakfast bread. | 44 | 48 | 7.8 |
| Something wholesome with not a lot of calories or carbs | 44 | 48 | 8.3 |
| Cheese | 42 | 44 | 7.9 |
| Cinnamon without the raisins. Cherry or strawberry bread sounds like it would be good too. | 40 | 39 | 7.6 |
| Honey bread | 40 | 53 | 7.8 |
| I would love bread with excellent taste and texture that also was high in fiber and low in carbs. | 40 | 75 | 8.4 |
| I love whole grain breads with nuts in it. | 38 | 47 | 8.2 |
| Sour dough with Italian seasoning (one of the ways I make bread in my bread making machine). It’s excellent. | 37 | 41 | 8.0 |

Note: The actual exercise generated 608 ideas, of which we see only 13 here.

are rated high on a nine-point relevance scale (>7). One aspect of the power of Brand Delphi is its ability to have the output be subject to metrics dealing with the production of ideas.

Identifying Features Using Existing It! Foundational Databases

Our second way to identify the specific product features looks at pre-compiled databases of product ideas that have been put through the exercise of concept evaluation and optimization. The ideas that come out of these databases can be quantified in terms of how much interest they bring to a concept (e.g., about healthful bread) and who likes them.

The research approach, which generates the database, is known as conjoint analysis, a method that enjoys a 40+ year history in the research world, and has been very popular for at least 30 years in the business community (Moskowitz et al., 2005). In conjoint analysis, the researcher follows these steps, which quickly identify what is important.

1. Identifies the concept elements, puts these into buckets or silos, and then mixes and matches the elements from the different silos, to create short, easy to understand concepts.
2. Presents these test concepts to consumers by Internet, instructing the respondents to rate the concept on interest, or appropriateness for a given occasion.
3. For each individual, identify how the concept element drives interest. The analysis uses so-called dummy-variable regression. The elements for the food are either present in the concept or absent from the concept. The researcher relates the presence/absence of the concept elements to the rating as to whether the concept was interesting or not interesting.
4. The results show how the different elements about the food drive interest in the food. Each element in conjoint analysis generates a utility, showing the conditional probability of concept acceptance generated by including the specific element in the concept. Positive utilities (i.e., positive coefficients from the dummy variable regression equation) mean that including the element in the concept increases the conditional probability or odds of a consumer being interested in the concept. Conversely, negative utilities (i.e.,

negative coefficients from the dummy variable regression equation) mean that including the element in the concept actually decreases the conditional probability of the consumer being interested in the concept.

5. Finally, the regression model has an additive constant, which shows the basic level of interest in the concept (i.e., the conditional probability of a consumer being interested), if there is no element in the concept. Clearly this is an estimated parameter, but it is a fairly good baseline measure of interest.

Armed with this approach, let's see how different features of "healthful bread" drive interest in the bread product (table 15.9). The data come from the Healthy You! Foundational Studies. The goal of those studies was to generate a database about healthful foods. Each of the 30 different studies was run using conjoint analysis, pertaining to a different product. One of the products was healthful bread.

1. The additive constant for healthful bread is 38, meaning that about two of every five participants in the study are interested in the idea of a healthful bread, even if they don't know anything more about the specific features of the bread.
2. There are some features that stand out, driving interest, albeit not dramatically. For example, the element "thick and crunchy bread, made with whole grains, nuts or fruit" achieves a utility value of +7, which means that an additional 7% of the participants find the concept interesting if this element is added to the product concept. Not all elements are positive. For example, the element "Contains soy protein—clinically proven to reduce the risk of heart disease" has a utility of -1, so in fact 1% fewer of the participants find the idea of a healthful bread interesting if the developer puts in soy protein and talks about it.
3. Looking at the performance of the items by key subgroups suggests some group-to-group differences. Age makes a difference in the predisposition to be interested in a healthful bread. Younger respondents in the conjoint study (ages 20–30) show an additive constant of 43, whereas older consumers (ages 60–70) are less interested in a healthful bread because their constant is 30.
4. However, it's the ingredients that make all the difference for the older consumer, who really pays attention. Put in an idea such as

Table 15.9. The utilities for concept elements from the Healthy You! study on healthful bread.

| | Tot | Age (yrs) | | Concept response segments | | |
|--|-----|-----------|-------|---------------------------|----|-----|
| | | 20–30 | 60–70 | S1 | S2 | S3 |
| Base size (number of participants) | 250 | 42 | 24 | 143 | 48 | 59 |
| Additive constant (basic interest) | 38 | 43 | 30 | 35 | 39 | 46 |
| Category #1—Product features, general | | | | | | |
| A1 Healthy eating that tastes great | 5 | −1 | 5 | 2 | 4 | 12 |
| A2 The delicious, classic taste of your favorite bread . . . white, whole wheat, or rye | 9 | 10 | 14 | 7 | 9 | 13 |
| A3 The rich, exotic flavors of super premium, sweet or savory, specialty, and artisan breads | 6 | 7 | 14 | 10 | 0 | 0 |
| A4 A soft and feathery texture | 2 | 2 | −3 | −2 | 4 | 9 |
| A5 Thick and crunchy bread, made with whole grains, nuts, or fruit | 7 | 4 | 26 | 18 | 3 | −18 |
| A6 Made with the freshest ingredients | 5 | 1 | 10 | 5 | 6 | 3 |
| A7 Low fat . . . only 1 g fat per slice | 5 | 7 | 2 | 4 | 5 | 6 |
| A8 All natural . . . no artificial flavors, no preservatives | 8 | 7 | 12 | 7 | 10 | 10 |
| A9 100% organic | 0 | 3 | −4 | −1 | 3 | 1 |
| Category #2—Product features, health-related | | | | | | |
| B1 Provides essential minerals your body needs, including potassium, magnesium, and zinc | 7 | 8 | 21 | 12 | −2 | 4 |

Table 15.9. (Continued)

| | Tot | Age(yrs) | | Concept response segments | | |
|---|-----|----------|-------|---------------------------|-----|----|
| | | 20–30 | 60–70 | S1 | S2 | S3 |
| Base size (number of participants) | 250 | 42 | 24 | 143 | 48 | 59 |
| Additive constant (basic interest) | 38 | 43 | 30 | 35 | 39 | 46 |
| B2 An essential source of the nutrients that are important for heart health . . . like potassium, magnesium, and folic acid | 7 | 3 | 19 | 13 | –2 | 0 |
| B3 Full of antioxidants and phytonutrients that help you maintain a healthy heart | 7 | 8 | 5 | 14 | –5 | –1 |
| B4 A good source of fiber, important in reducing your risk of chronic diseases like heart disease and diabetes | 9 | 6 | 17 | 15 | –2 | 4 |
| B5 With soy isoflavones . . . shown to moderate symptoms of menopause and decrease bone loss | 2 | 3 | 7 | 9 | –18 | –1 |
| B6 Contains the essential nutrient choline . . . shown to improve memory and learning | 5 | 3 | 11 | 10 | –15 | 12 |
| B7 Contains essential omega-3 fatty acids, which may reduce your risk of heart disease | 5 | –1 | 9 | 11 | –7 | 0 |
| B8 Contains soy protein . . . clinically proven to reduce the risk of heart disease | –1 | –3 | 5 | 8 | –21 | –6 |
| B9 Made with plant sterol esters . . . clinically proven to lower cholesterol | –3 | –6 | 2 | 2 | –14 | –3 |

Note: Only the utilities for the different product features are shown. Data courtesy of It! Ventures, Inc.

“thick and crunchy bread, made with whole grains, nuts or fruit” and 26% of the older participants switch from being disinterested to being interested. The dynamics of the older and younger consumers differ. For the younger consumer, there is high initial interest, but no ideas score great breakthroughs. For the older consumer, there is lower initial interest, but a number of product features really push through.

5. There are three concept response segments. Segment S1 comprising most of the respondents (~60%) is interested in old-fashioned artisanal bread with nuts and seeds. Segment S2 is interested in all natural products but very disinterested and negative to specific health benefits. Segment S3 is interested in bread that helps performance, but little else (*Contains the essential nutrient choline . . . shown to improve memory and learning*). More than likely the search for ingredients for the healthful bread should concentrate the preferences for features shown by Segment S1.

Getting Ideas for the Healthy Bread Product Through Customized Concept Research

Our final approach for identifying the components of the healthful bread is to run a study using ideas about the bread obtained from the Brand Delphi, as well as competitive analysis of what other companies have featured in bread and in other healthful products that might be applied to bread. The study is run using the same approach as the It! studies, namely conjoint analysis. The research requires that the developer create the categories or buckets/silos of ideas, and populate these categories with features as well as with benefits. The original custom study comprised four silos of nine elements each. Some of the elements are not relevant to the category appraisal search for ingredients, and don't appear here.

The original custom study was done to identify the ingredients for two types of healthful bread; bread to be eaten in the morning and bread to be eaten in the afternoon. The morning-relevant breads should be sweet (A new variety of sweet flavored bread like cinnamon, vanilla swirl, cinnamon raisin, almond raisin . . . mom, the flavors will simply delight you), the evening-relevant breads should be savory (Real garlic bread . . . garlic and other herbs mixed into the dough and baked for a perfectly delicious bread; Good European style bread . . . French, Italian, focaccia, and sourdough).

Table 15.10. Utilities of specific product features for a healthful bread positioning as either a morning or an evening bread.

| | Average | Morning | Evening |
|--|---------|---------|---------|
| Base Size | 654 | 448 | 206 |
| Additive | 46 | 46 | 46 |
| A new variety of sweet flavored bread like cinnamon, vanilla swirl, cinnamon raisin, almond raisin . . . mom, the flavors will simply delight you. | 15 | 19 | 10 |
| Real garlic bread . . . garlic and other herbs mixed into the dough and baked for a perfectly delicious bread | 9 | 0 | 18 |
| Good European style bread . . . French, Italian, foccacia, and sourdough. | 8 | 2 | 13 |
| Simply the best bread . . . high in fiber, low in carbohydrates, tastes great and it's good for you. | 4 | 3 | 4 |
| Low in calories, high in vitamins . . . provides 100% of the daily value of 10 essential vitamins and minerals. | 4 | 3 | 5 |
| A healthy bread with a homemade taste . . . just like grandma used to make. | 3 | 4 | 2 |
| Guaranteed freshness without preservatives | 3 | 2 | 3 |
| With added minerals such as calcium, magnesium, zinc for strong bones and muscle tissue | 2 | 2 | 2 |
| Made with all natural ingredients . . . no artificial flavors, preservatives, or any other additives | 2 | 2 | 2 |
| A new line of bread with added fruit, like cranberry, blueberry, dates, or raisins | 0 | 5 | −5 |
| A large variety of whole grain bread like wheat, rye, or oat with added poppy, sunflower, or sesame seeds . . . for those who want to eat healthy and have some extra zing | 2 | 1 | 2 |
| Enriched with lots of vitamins and nutrients as part of a balanced diet | 2 | 0 | 4 |
| With added soluble fiber to reduce the risk of coronary heart disease and lower your cholesterol | 2 | 1 | 2 |
| A variety of small loaves in one bag . . . white, whole grain, rye, or oat | 2 | 1 | 3 |
| A variety of cheese bread . . . three cheeses bread, cheese and onions, the possibilities are endless | 2 | −2 | 6 |

(Continued)

Table 15.10. (Continued)

| | Average | Morning | Evening |
|---|---------|---------|---------|
| Base Size | 654 | 448 | 206 |
| Additive | 46 | 46 | 46 |
| Low cholesterol, low fat, low sodium . . . but still tastes great | 1 | 0 | 1 |
| Comes in half loaves for smaller families or single people | 1 | 1 | 0 |
| An essential source of nutrients in every slice . . . satisfies your hunger | 0 | 1 | −1 |
| With antioxidants such as lycopene and other cancer fighting compounds | 1 | −1 | 2 |
| A large variety of whole grain bread with fruits and nuts | −3 | 0 | −6 |
| 100% organic and GMO (genetically modified) free | −2 | −2 | −2 |
| Yeast free, lactose free, egg free | −6 | −5 | −7 |
| Vegan bread with no added ingredients such as eggs, lactose, animal fat, etc. | −5 | −6 | −3 |
| The flavor of rich and dark chocolate in bread . . . chunks of chocolate and nuts, try something new, get out of the ordinary | −12 | −10 | −13 |
| White bread with bits of bacon or vegetables like dried tomatoes, carrots, for a change of taste | −18 | −20 | −16 |

Note: The relevant elements (i.e., those presenting specific features) are sorted by the average utility, combining the morning and evening data sets.

The actual fieldwork for this two-pronged custom study of healthful bread was run with consumers who were invited by an e-mail invitation to participate in one of two studies about healthful bread. The studies were actually identical. One study was positioned as being for a “morning bread,” the other study was positioned as being for an “evening bread.” Other than the positioning, the elements were identical. The computer program mixed and matched the concept elements so that each participant received a different set of combinations. We see the results of the exercise in table 15.10, which shows how the different product features drive interest in the two types of healthful breads. It’s

clear that the product features for the healthful bread tend to be on the sweet side for breakfast and on the savory side for dinner. However, it's not the generality that interested the developer as much as the specifics; namely, which particular elements do well for a bread designed for each of the two day-parts.

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Chapter 16

APPLICATIONS OF DISCRIMINANT AND LOGISTIC REGRESSION ANALYSIS FOR CONSUMER ACCEPTANCE AND CONSUMER-ORIENTED PRODUCT OPTIMIZATION STUDY

Witoon Prinyawiwatkul and Penkwan Chompreeda

Why Read This Chapter?

The case study approach presented in this chapter allows the reader to fully understand two advanced methods of quantitatively studying consumer response patterns.

Introduction

Multivariate statistical techniques are very useful for analyzing complex data obtained from consumer sensory research. For the last two decades, there has been an explosion of work in the theory and methods of multivariate analysis. Development of advanced computer technology makes it easy to handle very sophisticated multivariate techniques, and statistical packages such as SAS and SPSS are available and being used worldwide. There are many books or book chapters on the multivariate statistics (Manly, 1986; Powers and Ware, 1986; Hosmer and Lemeshow, 2000; Agresti, 1996; Huberty, 1994; Allison, 1999; Huberty

and Olejnik, 2006). However, books or book chapters that address practical applications of discriminant and logistic regression analysis with simple interpretation, particularly in the area of consumer acceptance and consumer-oriented product optimization are very rare.

Discriminant analysis (DA) and logistic regression analysis (LRA) are powerful statistical techniques for analyzing categorical consumer sensory data. They can be used to predict and classify products into known groups based on a set of explanatory variables. For example, an R&D staff in a food company wants to predict whether its products would be rated acceptable or nonacceptable, or would be purchased or not purchased by the consumers. Discriminant analysis can be categorized into descriptive discriminant analysis (DDA) and predictive discriminant analysis (PDA) (Huberty, 1994; Huberty and Olejnik, 2006). PDA is used for classification and/or prediction purposes. DDA, often performed after multivariate analysis of variance (MANOVA), is used to identify explanatory variables that underlie differences among samples, individuals, and units in the groups.

Both PDA and LRA give similar, but not identical, results for prediction. PDA is, however, more powerful and robust if multivariate normality of the data is met. Both PDA and LRA provide a classification table and % hit rate (correct classification). The variable ordering technique can be used to identify consumer sensory attributes that are critical to product acceptance and purchase intent, and, thus, need to be focused for further product refinement or product optimization.

One of the critical requirements for success of new food products is that they taste good. Product formulations must be optimized to obtain desirable sensory quality expected by targeted consumers. Optimization can be defined as a procedure for developing the best (most accepted/liked/preferred) possible product in its class and/or category given a fixed set of ingredients. In consumer sensory optimization research, consumer liking or acceptance is the dependent variable, whereas independent variables are product properties (e.g., sensory characteristics, % ingredients added, processing conditions, etc.) that are the basis for product differentiation. Consumer liking or acceptance implies positive perception and satisfaction, and actual purchase/repurchase of a product. To obtain optimal formulation, it is critical to identify consumer sensory attributes driving product acceptance and purchase decision.

The traditional product optimization involves (1) consumers evaluating acceptability of multiple samples using a nine-point hedonic scale;

(2) the mixed-model used to obtain a regression equation that is subsequently used to plot response surface (RS) for each sensory attribute measured; (3) superimposition of optimal RS areas from all sensory attributes to attain optimal product formulation range. This traditional product optimization approach disregards critical relationship between the nine-point-hedonic sensory acceptability and consumers' purchase decision, which indicates preliminary market potential. The logit, or logistic regression analysis, can be used to identify sensory attributes influencing or determining consumers' purchase decisions. These sensory attributes are used as limiting factors for obtaining optimal formulation range. By means of proper data analysis, these variables are related and optimal formulation range can be attained.

In this chapter, the authors wish to demonstrate, using two case studies, how PDA, DDA, and LRA, in conjunction with other related statistical methods, can be applied for consumer acceptance and consumer-oriented product optimization study, without a burden of having to deal with fuzzy mathematical equations. In these two case studies, a series of data analyses was performed. Restricted (nonintercept) regression model was used to predict acceptability of consumer sensory attributes. PDA and LRA were used to identify sensory attributes critical to acceptance and purchase intent; the mixture response surface (MRS) of these identified critical sensory attributes was plotted. Superimposition of optimal MRS areas was used to attain the optimal formulation range.

Case Study I: Acceptance and Purchase Intent of the U.S. Consumers for the Nonwheat Rice Butter Cakes

Introduction and Justification

Celiac spruce disease (CSD) is a problem of malabsorption of certain proteins, mainly gluten, in the diet. It has been estimated that 1 in 250 people in the United States is currently living with CSD. CSD affects the small intestine, which prevents the absorption of several important nutrients including iron, folic acid, calcium, and fat-soluble vitamins. The only way to ensure a life free of complication is to strictly follow 100% gluten-free diet.

The market potential for rice ingredients in processed foods is enormous, and rice flour is currently used in many different food products

(Bond, 2004). Rice flour is free of gluten and is considered as a nonallergic food. Therefore, it can be used to provide a number of gluten-free baked products. However, rice flour cannot form a dough without an added thickening agent.

Aromatic rice varieties, such as Khoa Dak Mali 105, are widely accepted in United States among the Asian-Americans due to their taste, soft texture, and unique aroma. Very limited work has been carried out on utilization of the Jasmine rice flour in the butter cake formulation. Development of the gluten-free butter cake products made from Jasmine rice flour would provide an alternative for utilization of broken Jasmine rice and an alternative gluten-free product for the U.S. consumers with celiac spruce disease.

We successfully developed nonwheat butter cake products prepared from Jasmine rice flour. However, in order to warrant the product success, consumer acceptance and purchase intent of these products must be evaluated, and consumer sensory attributes influencing overall acceptance and purchase intent of these products must also be identified.

Consumer Acceptance Test

American consumers ($n = 400$) participated in the central location test for consumer acceptance. Three nonwheat butter cakes were formulated (product A, B, and C, respectively, containing 0, 7.5, and 15% emulsifier) and the commercial wheat-based product (D) served as the control. Following the randomized completed block design, each consumer was presented with four coded products. Consumers rated acceptability for nine sensory attributes, including overall appearance, visual puffiness, crumb color, odor, softness, moistness, overall texture, taste, and overall liking using a nine-point hedonic scale (1 = dislike extremely, 5 = neither like nor dislike, and 9 = like extremely). Overall acceptance and purchase intent were evaluated using the binomial (yes/no) scale.

Statistical Data Analysis

All data were analyzed ($\alpha = 0.05$) using SAS, version 9.1.3 (SAS Inst., 2003). Analysis of variance (ANOVA) was performed to determine if differences existed among the four butter cake products in terms of acceptability of each sensory attribute and overall liking. The Tukey's studentized range test was performed to locate the differences among the four butter cake products. Multivariate analysis of variance (MANOVA)

was performed to determine if the four butter cake products were different when all nine sensory attributes were simultaneously considered. Descriptive discriminant analysis (DDA) (Huberty, 1994), along with principal component analysis (PCA), were performed to identify sensory attributes underlying group differences among the four butter cake products. Logistic regression analysis (LRA) (Allison, 1999) was performed to identify sensory attributes influencing overall acceptance and purchase intent.

Overall Product Differences and Discriminating Sensory Attributes

Based on the MANOVA results (the approximate F value of 18.26 and the Wilks' lambda statistic with $p < 0.0001$), we concluded that the four butter cake products (A, B, C, and D) were significantly different when all nine sensory attributes were compared simultaneously. Since there were significant differences among all four products, DDA was performed to determine which attributes were mainly responsible for the group differences.

Table 16.1. Descriptive discriminant analysis (DDA) reporting the canonical structure r's for describing group differences among the four butter cake products.

| Attribute | Can 1 | Can 2 | Can 3 |
|-------------------------------|---------------------|---------|---------|
| Overall appearance | 0.2517 | -0.7560 | 0.4167 |
| Visual puffiness | 0.3329 | -0.5979 | 0.3403 |
| Crumb color | 0.0435 | -0.3545 | 0.5045 |
| Odor | -0.0014 | 0.0726 | 0.7012 |
| Softness | 0.7290 ^a | -0.1473 | 0.1984 |
| Moistness | 0.7135 ^a | 0.0210 | -0.0959 |
| Overall texture | 0.7903 ^a | 0.0737 | 0.4558 |
| Taste | 0.6031 ^a | 0.0975 | 0.5769 |
| Overall liking | 0.6795 ^a | -0.0261 | 0.5103 |
| Cumulative variance explained | 79.57% | 97.15% | 100.00% |

Note: Based on the pooled within-group variances. Can 1, 2, and 3 refer to the first, second, and third canonical discriminant functions, respectively.

^aIndicates attributes that accounted for the group differences in the first canonical discriminant function.

Results from DDA (table 16.1) report the canonical structure r 's (Huberty, 1994), which identified constructs that largely accounted for the group differences. Analysis of dimensionality (data not shown) indicated that three dimensions (Can 1, 2, and 3) shown in table 16.1 were needed to explain the total variance. According to the pooled within group variances, the first dimension (Can 1), which accounted for 79.57% explained variance, identified overall texture (with a canonical correlation = 0.7903), softness (0.729), moistness (0.7135), overall liking (0.6795), and taste (0.6031) as sensory attributes contributing to the group differences among the four butter cake products. Based on the canonical correlation values (table 16.1), we may conclude that the main construct that accounted for the group differences was the texture attribute, a composite of overall texture, softness, and moistness.

The PCA biplot analysis, using PC 1 and PC 2 (fig. 16.1), revealed the relationship between products and sensory acceptability. Products B and C (containing 7.5 and 15% emulsifier, respectively) were closely positioned to each other, but distant from product A (0% emulsifier gel) and the control. The biplot revealed five discriminating attributes including softness, moistness, overall texture, taste, and overall liking, similar to those obtained from DDA in the first dimension (Can 1) (table 16.1).

Implications of the results from table 16.1 and figure 16.1 must be made with caution because the purpose of DDA and PCA used here was to identify the sensory attributes that accounted for group differences, rather than to identify those attributes that influenced overall product acceptance and purchase intent. The latter will be further discussed in this chapter.

Consumer Acceptability, Overall Product Acceptance, and Purchase Intent

Based on the overall liking and sensory acceptability profile (table 16.2), consumers preferred the commercial product (D) more than the non-wheat rice butter cake products. They also preferred products B and C equally but more than product A. According to table 16.1, the DDA analysis identified softness, moistness, overall texture, taste, and overall liking as discriminating attributes; the mean consumer acceptability scores (table 16.2) for these five discriminating sensory attributes for product A were lowest among the four products; these five mean consumer

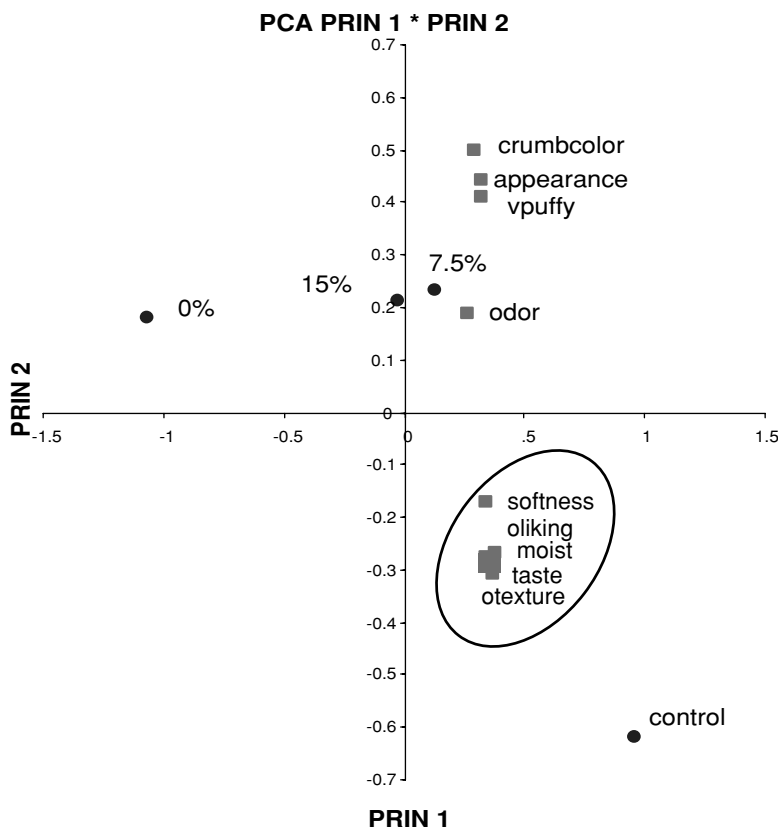


Figure 16.1. The PCA product-attribute biplot involving Principal Component (PRIN) 1 and Principle Component (PRIN) 2.

acceptability scores for products B and C were not significantly different from each other, but they were significantly lower than those of product D (control). The lowest acceptability score for overall texture (5.44) of product A was likely due to the lowest scores for softness (5.56) and moistness (5.42). The overall liking and sensory acceptability profile (table 16.2) supported the results from the PCA biplot (fig. 16.1) in that products B and C were closely positioned to each other, but distant from product A and the control, and that product A was most distant from product D.

At least 81% of the participating consumers indicated their positive overall acceptance for products B, C, and D, whereas only 69% for

Table 16.2. Mean consumer scores for sensory acceptability and positive overall product acceptance and purchase intent (%) of four butter cake products.

| Attribute | Product ^b | | | |
|--|----------------------|-------------------|-------------------|--------------------|
| | A | B | C | D |
| Acceptability ^a | | | | |
| Overall appearance | 6.03 ^b | 6.93 ^a | 6.92 ^a | 6.71 ^a |
| Visual puffiness | 5.90 ^b | 6.73 ^a | 6.75 ^a | 6.74 ^a |
| Crumb color | 6.49 ^b | 6.93 ^a | 6.79 ^a | 6.66 ^{ab} |
| Odor | 6.82 ^{ab} | 6.98 ^a | 6.66 ^b | 6.84 ^{ab} |
| Softness | 5.56 ^c | 6.42 ^b | 6.44 ^b | 7.32 ^a |
| Moistness | 5.42 ^c | 6.07 ^b | 6.18 ^b | 7.16 ^a |
| Overall texture | 5.44 ^c | 6.26 ^b | 6.14 ^b | 7.33 ^a |
| Taste | 5.46 ^c | 6.17 ^b | 5.95 ^b | 7.00 ^a |
| Overall liking | 5.39 ^c | 6.20 ^b | 6.06 ^b | 7.03 ^a |
| Positive Overall acceptance (%) ^c | 69.0 | 83.7 | 81.5 | 90.8 |
| Positive purchase intent (%) ^c | 31.1 | 42.1 | 47.0 | 74.3 |

^a Mean values based on 400 consumer responses and on a 9-point hedonic scale (1 = dislike extremely, 5 = neither like nor dislike, 9 = like extremely). Mean values in the same row not followed by the same letter are significantly different ($p < 0.05$).

^b Product A, B, and C, respectively, contained 0, 7.5 and 15 % w/w emulsifier. Product D was the commercial sample.

^c Based on the binomial (yes/no) scale, and on 400 responses.

product A (table 16.2). All nonwheat rice butter cakes had lower positive purchase intent than that of the commercial product. Up to 47% of the participating consumers indicated that they would purchase product C if commercially available.

Predicting Overall Acceptance and Purchase Intent Using Logistic Regression Analysis

In this study, the logistic regression or logit analysis was used (1) to identify sensory attributes that influenced overall acceptance and purchase intent of the butter cake products and (2) to predict overall acceptance and purchase intent based on those identified influencing sensory attributes. Results (table 16.3) indicated that overall liking was the most critical attribute influencing overall acceptance, followed by taste. The odds ratio of overall liking was 2.453 for overall acceptance, indicating that the probability of the product being accepted is 2.453

Table 16.3. Parameter estimates, probability, and odds ratio estimates for predicting overall acceptance and purchase intent of the butter cake products.

| Variables | Overall acceptance | | | Purchase intent | | |
|--------------------|--------------------|----------------------|------------|-----------------|----------------------|------------|
| | Estimate | $\text{Pr} > \chi^2$ | Odds ratio | Estimate | $\text{Pr} > \chi^2$ | Odds ratio |
| Intercept | -6.2403 | <0.0001 | N/A | -8.5876 | <0.0001 | N/A |
| Overall appearance | 0.0354 | 0.6907 | 1.036 | -0.0847 | 0.9139 | 0.992 |
| Visual puffiness | 0.0711 | 0.3974 | 1.074 | -0.0360 | 0.6259 | 0.965 |
| Crumb color | -0.1094 | 0.1844 | 0.896 | -0.0680 | 0.3512 | 0.934 |
| Odor | 0.0351 | 0.5764 | 1.036 | -0.1913 | 0.0014 | 0.826 |
| Softness | 0.1138 | 0.1138 | 1.121 | -0.0333 | 0.6049 | 0.967 |
| Moistness | -0.0208 | 0.7828 | 0.979 | 0.0402 | 0.5391 | 1.041 |
| Overall texture | 0.1398 | 0.0685 | 1.150 | 0.1142 | 0.1325 | 1.121 |
| Taste | 0.2799 | 0.0023 | 1.323 | 0.3190 | 0.0003 | 1.376 |
| Overall liking | 0.8974 | <0.0001 | 2.453 | 1.2417 | <0.0001 | 3.462 |

Note: Based on the logistic regression analysis, using a full model with nine sensory attributes. The analysis of maximum likelihood estimates was performed to obtain parameter estimates. Significance of parameter estimates was based on the Wald χ^2 value at $p < 0.05$. N/A refers to “not applicable.”

times higher (than not being accepted, $p < 0.0001$) with every one-unit increase of the overall liking score (based on a nine-point hedonic scale).

For purchase intent, odor, taste, and overall liking were influencing attributes with the odds ratio estimate of 0.826, 1.376, and 3.462, respectively (table 16.3). The odds ratio estimate of overall liking for purchase intent (3.462) was higher than that for overall acceptance (2.453), indicating that consumers perceived overall liking as more critical to purchase intent than to overall acceptance. Likewise, consumers also perceived taste as a somewhat more critical attribute to purchase intent than to overall acceptance, with the odds ratio estimate increasing from 1.323 (for overall acceptance) to 1.376 (for purchase intent). Odor influenced purchase intent ($p = 0.0014$), but not overall acceptance ($p = 0.5764$) (table 16.3).

When overall liking was used as a sole predictor variable in a single-variable logistic regression model, the odds ratio estimate for overall acceptance and purchase intent ranged from 2.327 to 4.047 (table 16.4). Except for product A, increasing a one-unit score for overall liking would lead to a greater chance that the products B and C would be accepted (up to 1.14 times higher) and purchased (up to 0.743 times higher) more than product D.

Based on the full logit model with nine sensory attributes, overall acceptance and purchase intent of the butter cake products could be

Table 16.4. Parameter estimates, probability, and odds ratio estimates for predicting overall acceptance and purchase intent of each butter cake product.

| Product ^a | Overall acceptance | | | Purchase intent | | |
|----------------------|--------------------|---------------|------------|-----------------|---------------|------------|
| | Estimate | Pr > χ^2 | Odds ratio | Estimate | Pr > χ^2 | Odds ratio |
| A | 0.8481 | <0.0001 | 2.335 | 0.8447 | 0.0002 | 2.327 |
| B | 1.2461 | <0.0001 | 3.477 | 1.3980 | <0.0001 | 4.047 |
| C | 0.8824 | 0.0001 | 2.417 | 1.3513 | <0.0001 | 3.863 |
| D | 0.8458 | 0.0031 | 2.330 | 1.1953 | <0.0001 | 3.304 |

Note: Based on the logistic regression analysis, using a single-variable model with overall liking as a sole predictor variable. The analysis of maximum likelihood estimates was performed to obtain parameter estimates. Significance of parameter estimates was based on the Wald χ^2 value at $p < 0.05$.

^aProduct A, B, and C, respectively, contained 0, 7.5, and 15% w/w emulsifier. Product D was the commercial sample.

Table 16.5. % hit rate (correct classification) for overall acceptance and purchase intent of butter cake products.

| Attributes | % Hit rate | |
|-------------------------------|--------------------|-----------------|
| | Overall acceptance | Purchase intent |
| A full model with 9 variables | 89.3 | 83.3 |
| A single-variable model | | |
| Overall appearance | 82.1 | 62.9 |
| Visual puffiness | 81.7 | 62.6 |
| Crumb color | 81.1 | 60.3 |
| Odor | 81.2 | 61.0 |
| Softness | 83.1 | 67.5 |
| Moistness | 82.7 | 70.6 |
| Overall texture | 83.7 | 73.9 |
| Taste | 86.6 | 79.6 |
| Overall liking | 89.4 | 83.7 |

Note: Based on the logistic regression analysis at p -event of 0.05. Hit rate (%) is the correct classification of an unknown product classified into a group (either accepted vs. not-accepted and/or purchased vs. not-purchased).

predicted with 89.3% and 83.3% accuracy, respectively (table 16.5). Overall liking or taste alone could be used to predict overall acceptance with 89.4% and 86.6% accuracy, respectively. Only overall liking, when served as a single predictor of purchase intent, could yield up to 83% prediction accuracy.

Conclusions for Case Study I

The study demonstrated feasibility of completely substituting wheat flour with Thai jasmine rice flour for production of butter cake products that are acceptable to the American consumers. Based on DDA, we may conclude that the main construct that accounted for the group differences was the texture attribute, a composite of overall texture, softness, and moistness. LRA identified overall liking, taste, and, to a lesser extent, odor as the critical attributes influencing overall acceptance and purchase intent of the butter cake products. These attributes should be focused for further product refinement and consumer-oriented product optimization, and scale-up production for commercialization.

Case Study II: Consumer-Oriented Product Optimization of Butter Cake Formulations Made Predominantly with Long-Grain Rice Flour***Introduction and Justification***

Rice is a important worldwide agricultural commodity. The rice milling process yields about 15% broken rice kernels. Farmers sell broken rice kernels at a price almost half of that of whole rice kernels. The magnitude of the less economic-valued broken rice, available in the United States as a resource for value-added products, suggests a strong economic impact on the entire U.S. rice industry.

The market potential for broken rice in processed foods is enormous. However, its potential in food systems has not been fully explored. Because broken rice is not aesthetically pleasing to consumers, it is most often used for making beer, flour, or pet foods. Potential exists for development of retail food products from broken rice, which will, in turn, increase revenues for the farmers and processors.

Rice is an optimal food ingredient in entrees, sides, soups, snacks, baby foods, health foods, confections, and beverages (Bond, 2004). Rice flour can be used in many food applications. In the United States, the use of rice flour in making both cakes and breads is still relatively new. Several studies have been attempted to improve quality of baked products, such as breads, cakes, and cookies, which were formulated with rice flour alone or in combination with other flour substitutes or novel ingredients (Bond 2004).

The purpose of this study was (1) to systematically formulate prototype butter cake products made predominantly from broken long-grain rice flour; (2) to optimize consumer sensory quality of the prototype butter cake products using a three-component mixture design; (3) to identify sensory attributes critical to acceptance and purchase decision of the butter cake products made predominantly with rice flour.

Experimental Design and Consumer Acceptance Test

Butter cake products were prepared using wheat (0–100%), rice (0–100%), and pregelatinized rice (PGR, 0–50%) flours, with the 100% wheat flour formulation serving as the control. Ten different mixtures (fig. 16.2 and table 16.6) were formulated following the

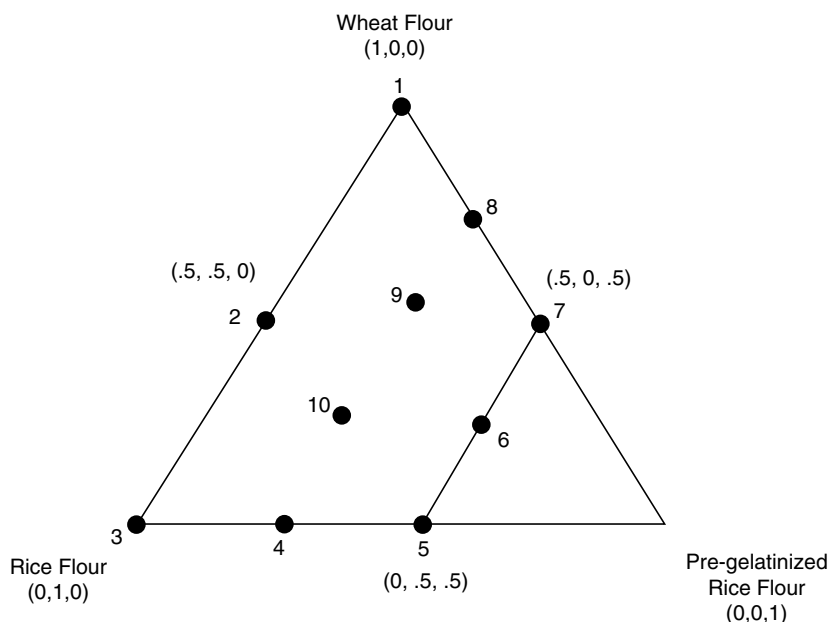


Figure 16.2. The constrained region in the simplex coordinate system defined by the following restrictions: $0.0 \leq X_1 \leq 1.0$; $0.0 \leq X_2 \leq 1.0$; and $0.0 \leq X_3 \leq 0.5$; where X_1 = wheat flour, X_2 = rice flour, and X_3 = pregelatinized rice flour. Numbers 1–10 represent the 10 formulations and correspond to the numbers in table 16.6.

Table 16.6. Ten butter cake formulations in the three-component constrained simplex-lattice mixture design.

| Formulation ^a | Wheat flour (%) | Rice flour (%) | Pregelatinized flour (% PGR) |
|--------------------------|-----------------|----------------|------------------------------|
| 1 | 100 | 0 | 0 |
| 2 | 50 | 50 | 0 |
| 3 | 0 | 100 | 0 |
| 4 | 0 | 75 | 25 |
| 5 | 0 | 50 | 50 |
| 6 | 25 | 25 | 50 |
| 7 | 50 | 0 | 50 |
| 8 | 75 | 0 | 25 |
| 9 | 50 | 25 | 25 |
| 10 | 25 | 50 | 25 |

Note: The flour component system (100% in the mixture design) was 24.8% of the total composition. Corn syrup, butter, eggs, milk, sugar, baking powder, vanilla, and cream of tartar made up the remaining part of the formulation.

^aFormulation numbers (1–10) correspond to the numbers shown in figure 16.2.

three-component constrained simplex-lattice mixture design (Cornell, 1986). The mixture design consisted of wheat (X1), rice (X2), and PGR (X3) flours. The flour mixture comprised 24.8% of the total formulation, and was the only component that was varied during the experiment. The proportions of the components were expressed as fractions of the mixture. The sum of the component proportions ($X1 + X2 + X3$) equaled 1.0 or 100%.

Following the balanced incomplete block (BIB) design plan 11.15 ($t = 10$, $k = 3$, $r = 9$, $b = 30$, $\lambda = 2$, $E = 0.74$, Type II) (Cochran and Cox, 1957), 300 consumers evaluated 3 out of 10 products for acceptability of visual puffiness, appearance/color, aroma, taste, texture/mouthfeel, moistness, and overall liking using a nine-point hedonic scale (1 = dislike extremely, 5 = neither like nor dislike, 9 = like extremely). Overall acceptance and purchase decision were rated using the binomial (yes/no) scale. According to the BIB design, 90 observations were collected for each of the ten products tested.

A Series of Statistical Analyses

A series of data analyses was conducted at $\alpha = 0.05$ (SAS Inst. 2003). ANOVA and multivariate analysis of variance (MANOVA) were used to determine if ten butter cake formulations were different. Descriptive discriminant analysis (DDA) (Huberty, 1994) was used to identify sensory attributes underlying overall product differences. Restricted (nonintercept) regression mixed models were used to predict acceptability of sensory attributes (Prinyawiwatkul et al., 1993; Prinyawiwatkul et al., 1997). Predictive discriminant analysis (PDA [Huberty, 1994]) and logit analysis (LRA) were used to determine sensory attributes critical to overall product acceptance and purchase decision; the mixture response surface (MRS) of these identified critical sensory attributes were subsequently used to obtain optimal formulation range.

Tracking Purchase Decision Changes

In this study, the nonparametric McNemar test (Agresti, 1996) was used to determine changes in consumer purchase decisions before and after consumers had been informed of health benefits from rice. The McNemar test is one way of comparing proportions from two dependent samples (in this case, responses before and after consumers had

been informed of health benefits from rice) using binary response variables. The test follows a chi-square distribution with $df = 1$ (Agresti, 1996). A 95% confidence interval was calculated using marginal sample proportions ($p_{+1} + p_{1+}$), which can be used to estimate the actual differences in the means of purchase decision responses.

In order to calculate the sample proportions (p_{ij}), the equation

$$(p_{ij} = n_{ij}/N)$$

was used, where n_{ij} is the number of consumers making response i before and response j after knowing the “fact” about the health benefits from rice, and N represents the total number of responses from consumers. Next, the 95% confidence interval for the difference in proportions was calculated using the equation

$$[(p_{+1} + p_{1+}) \pm z_{\alpha/2}(ASE)]$$

where $(p_{+1} + p_{1+})$ represents the difference in proportions between consumers who answer yes after knowing the fact (p_{+1}) and those who answered yes before knowing the fact (p_{1+}); the term $z_{\alpha/2}$ equals 1.96 and represents the standard normal percentile having a right-tailed probability of $\alpha/2$; ASE is the estimated standard error for the proportion difference and was calculated using the equation

$$[ASE = \{[p_{1+}(1 - p_{1+}) + p_{+1}(1 - p_{+1}) - 2(p_{11}p_{22} - p_{12}p_{21})]/N\}^{1/2}]$$

where p_{11} indicates the number of consumers who answered yes both before and after knowing the fact, p_{22} indicates the number of consumers who answered no both before and after knowing the fact, p_{12} indicates the number of consumers who answered yes before and no after knowing the fact, and p_{21} indicates the number of consumers who answered no before and yes after knowing the fact. By determining the 95% confidence interval, we knew that the calculated difference of proportions would be correct 95% of the time.

Attaining the Optimal Formulation Range

The predictive models derived from the restricted (nonintercept) regression analysis were used to plot the mixture response surface (MRS) of critical sensory attributes that were identified by the PDA and LRA results. Areas within the MRS plots having a score equal to or greater than 6.0 were selected for optimization. Superimposition of the optimal

acceptable areas from the MRS plots of all critical sensory attributes yielded the optimal formulation range.

Consumer Acceptability, Overall Acceptance, and Purchase Intent

The mean overall liking scores for the ten butter cake products are shown in table 16.7. The formulations with the overall liking score greater than 6.0 were numbers 2, 8, and 9. However, in order to determine the best possible formulation range for this product, product optimization was subsequently performed and will be discussed later in this chapter.

The formulation with the highest overall acceptance rating was formulation 8 (85.6%), followed by formulations 2 (83.3%) and 9 (80%) (table 16.8). Formulation 8 contained 75% wheat flour and 25% PGR flour, while formulation 9 was made up of 50% wheat flour, 25% rice flour, and 25% PGR flour, and formulation 2 contained 50% wheat flour and 50% rice flour. Formulation 8 was also rated highest for purchase intent (53.3%), followed by formulation 9 (52.2%). When consumers were asked about their purchase intent if they were not able to consume wheat gluten (celiac spruce), without exception, the purchase intent

Table 16.7. Mean consumer acceptance scores for sensory attributes and overall liking of ten butter cake formulations.

| Sample no. | Mean consumer acceptance score | | | | | | Overall liking |
|------------|--------------------------------|------------------|------------|---------|-----------|-----------|----------------|
| | Visual puffiness | Appearance/color | Odor/aroma | Taste | Texture | Moistness | |
| 1 | 5.67 cde | 6.27 bcd | 6.47 ab | 5.81 ab | 6.27 ab | 6.78 a | 5.90 ab |
| 2 | 6.91 a | 7.09 a | 6.90 a | 5.83 ab | 6.04 abc | 6.57 ab | 6.13 a |
| 3 | 6.80 a | 7.26 a | 6.88 a | 5.59 ab | 5.20 cd | 5.78 b | 5.57 ab |
| 4 | 6.52 ab | 6.79 ab | 6.68 ab | 5.34 b | 5.04 d | 6.21 ab | 5.22 b |
| 5 | 5.79 bcde | 6.16 bcde | 6.26 ab | 5.16 b | 5.42 bcd | 5.84 b | 5.20 b |
| 6 | 5.46 de | 5.65 de | 6.07 b | 5.47 ab | 5.60 abcd | 6.17 ab | 5.59 ab |
| 7 | 5.10 e | 5.41 e | 6.06 b | 5.54 ab | 5.66 abcd | 6.14 ab | 5.58 ab |
| 8 | 5.96 bcd | 5.93 cde | 6.42 ab | 6.28 a | 6.34 a | 6.57 ab | 6.17 a |
| 9 | 5.63 cde | 5.72 de | 6.39 ab | 6.01 ab | 6.28 ab | 6.52 ab | 6.09 a |
| 10 | 6.34 abc | 6.56 abc | 6.36 ab | 5.93 ab | 5.90 abcd | 6.28 ab | 5.87 ab |

Note: Based on 90 consumer responses and on a 9-point hedonic scale. Sample numbers correspond to those in figure 16.2 and table 16.6. Means within the same column followed by different letters are significantly different ($p < 0.05$).

Table 16.8. Positive responses (%) for overall product acceptance and purchase intent of butter cake products.

| Formulation ^a | Overall acceptance | Purchase intent (before) | Purchase intent (after) ^a |
|--------------------------|--------------------|--------------------------|--------------------------------------|
| 1 | 75.6 | 36.7 | 58.4 |
| 2 | 83.3 | 37.8 | 69.7 |
| 3 | 73.3 | 37.8 | 51.7 |
| 4 | 64.4 | 27.8 | 48.9 |
| 5 | 62.9 | 31.5 | 47.2 |
| 6 | 74.4 | 33.3 | 53.9 |
| 7 | 66.7 | 37.8 | 45.6 |
| 8 | 85.6 | 53.3 | 63.6 |
| 9 | 80.0 | 52.2 | 64.0 |
| 10 | 75.3 | 42.7 | 59.1 |

Note: Based on 90 consumer responses and on a binomial (yes/no) scale. Sample numbers correspond to those in figure 16.2 and table 16.6.

^aConsumers were asked if they would purchase the product if allergic to wheat gluten and after being informed of health benefits from rice.

increased for all ten butter cake formulations; formulations 8, 9, and 2 had greater than 63% positive purchase intent (table 16.8). These results corresponded directly to the mean consumer acceptance scores (table 16.7), where the three above formulations (2, 8, and 9) had higher mean overall liking scores compared with other formulations.

Overall Product Differences and Discriminating Sensory Attributes

In order to determine if the ten formulations differed considering all of the sensory attributes simultaneously, MANOVA was performed. The Wilks' lambda p-value of <0.0001 (table 16.9) indicated that all ten formulations were significantly different when considering all seven sensory attributes simultaneously; this finding was substantiated by other test statistics (Pillai's trace, Hotelling-Lawley trace, and Roy's greatest root). DDA was then performed to determine which attributes significantly accounted for group differences among the ten formulations. According to the canonical structure *r*'s in the first dimension (Can 1) shown in table 16.10, visual puffiness (a canonical correlation = -0.668), and appearance/color (-0.725) were the two attributes contributing significantly to the overall differences among the ten butter cake formulations.

Table 16.9. MANOVA statistics and F approximations.

| Test criteria and F approximations for the hypothesis of no overall form effect | | | | | |
|---|---------|---------|-----------------|-------------------|---------|
| H = Type III SSCP matrix for forms | | | | | |
| E = Error SSCP matrix | | | | | |
| S = 7 M = 0.5 N = 437 | | | | | |
| Statistic | Value | F Value | Numerator DF | Denominator DF | Pr > F |
| Wilks' lambda | 0.7198 | 4.71 | 63 | 4939.8 | <0.0001 |
| Pillai's trace | 0.3048 | 4.46 | 63 | 6174.0 | <0.0001 |
| Hotelling-Lawley trace | 0.35628 | 4.94 | 63 | 3327.4 | <0.0001 |
| Roy's greatest root | 0.2457 | 24.07 | 9 | 882 | <0.0001 |

Identifying Sensory Attributes Critical to Overall Acceptance and Purchase Intent Using PDA and LRA

Using PDA and based on the full model with all seven sensory attributes, the overall acceptance and purchase intent (before and after) could be predicted with prediction accuracy (hit rate) of 85.5, 80.9, and 74%, respectively (table 16.11). The variable ordering technique (Huberty,

Table 16.10. Descriptive discriminant analysis (DDA) reporting the canonical structure r's describing group differences among ten butter cake formulations.

| Variable | Can 1 | Can 2 | Can 3 |
|-----------------------------------|---------------------|-------|--------|
| Visual puffiness | −0.668 ^a | 0.697 | 0.079 |
| Appearance/color | −0.725 ^a | 0.397 | 0.484 |
| Odor/aroma | −0.317 | 0.381 | 0.272 |
| Taste | 0.112 | 0.728 | −0.052 |
| Texture | 0.293 | 0.831 | 0.402 |
| Moistness | 0.156 | 0.545 | 0.549 |
| Overall liking | 0.132 | 0.849 | 0.123 |
| Cumulative variance explained (%) | 68.97 | 80.52 | 88.37 |

Note: Based on the pooled within-group variances. Can 1, 2, and 3 refer to the first, second, and third canonical discriminant functions, respectively.

^aIndicates sensory attributes which largely accounted for the group differences in the first dimension (Can 1).

Table 16.11. Predictive discriminant analysis (PDA) result reporting % hit-rate for predicting overall acceptance and purchase intent.

| Attributes | % Hit Rate | | |
|---|--------------------|--------------------------|--------------------------------------|
| | Overall acceptance | Purchase intent (before) | Purchase intent (after) ^a |
| A full-model with all 7 attributes combined | 85.5 | 80.9 | 74.0 |
| A Single-Variable Model | | | |
| Visual puffiness | 65.7 | 64.0 | 61.5 |
| Appearance/color | 58.2 | 59.2 | 59.2 |
| Odor/aroma | 64.0 | 63.0 | 62.8 |
| Taste | 80.4 | 72.3 | 72.8 |
| Texture | 78.1 | 80.7 | 72.7 |
| Moistness | 76.4 | 72.6 | 69.4 |
| Overall liking | 83.3 | 84.3 | 74.9 |

Note: Hit rate (%) is defined as $(100 \text{ [numbers of samples correctly classified/total sample numbers]})$, and based on the posterior probability of membership with a threshold of 0.55. The prior probability was 0.5. The Leave-One-Out PDA method was used.

^a Consumers were asked if they would purchase the product if allergic to wheat gluten and after being informed of health benefits from rice.

1994), that is, a single-variable model in this case, was used to identify sensory attributes that were critical to overall acceptance and purchase intent. Results from table 16.11 indicated that the top four influencing sensory attributes were overall liking, taste, texture, and moistness. Since the data were not multivariate-normally distributed (results not shown), LRA may offer a better approach to identify sensory attributes influencing overall acceptance and purchase intent.

Based on the LRA results (tables 16.12 and 16.13), overall liking, taste, and texture (particularly if the α level was increased to 0.1) were critical attributes influencing both overall acceptance and purchase intent. However, moistness was not significant for both overall acceptance ($p = 0.3561$) and purchase intent ($p = 0.8894$). Considering that LRA would be more powerful and robust when our data were not multivariate-normally distributed, we concluded that overall liking, taste, and texture were critical attributes (excluding moistness) to overall acceptance and purchase intent. As such, they were considered as critical limiting

Table 16.12. Logistic regression analysis (LRA) result reporting parameter estimates, probability, and odds ratio estimates for predicting overall acceptance.

| Independent variable | Prob > χ^2 (a full model) | Odds ratio estimate (a full model) | Odds ratio estimate (a single-variable model) |
|----------------------|-----------------------------------|---------------------------------------|--|
| Visual puffiness | 0.9473 | 0.993 | 1.442 |
| Appearance/color | 0.2069 | 1.144 | 1.429 |
| Odor | 0.8939 | 1.012 | 1.656 |
| Taste | 0.0019 | 1.361 | 2.776 |
| Texture | 0.0870 | 1.181 | 2.480 |
| Moistness | 0.3561 | 1.078 | 1.952 |
| Overall liking | <0.0001 | 2.496 | 3.920 |

Note: The analysis of maximum likelihood estimates was used to obtain parameter estimates. Significance of parameter estimates was based on the Wald χ^2 value at $p < 0.05$.

factors, which were subsequently used to plot mixture response surface (MRS) to obtain the optimal formulation range.

Interpreting the Odds Ratio Estimates

The odds ratio estimate of overall liking for purchase intent (6.915) was higher than that for overall acceptance (3.92) (tables 16.12 and 16.13), indicating that consumers perceived overall liking as more critical to

Table 16.13. Logistic regression analysis (LRA) result reporting parameter estimates, probability, and odds ratio estimates for predicting purchase intent.

| Independent variable | Prob > χ^2 (a full model) | Odds ratio estimate (a full model) | Odds ratio estimate (a single-variable model) |
|----------------------|-----------------------------------|---------------------------------------|--|
| Visual puffiness | 0.9412 | 0.993 | 1.490 |
| Appearance/color | 0.8834 | 0.985 | 1.405 |
| Odor | 0.3650 | 0.919 | 1.622 |
| Taste | 0.0170 | 1.331 | 3.499 |
| Texture | <0.0001 | 1.568 | 3.240 |
| Moistness | 0.8894 | 1.014 | 2.361 |
| Overall liking | <0.0001 | 4.019 | 6.915 |

Note: The analysis of maximum likelihood estimates was used to obtain parameter estimates. Significance of parameter estimates was based on the Wald χ^2 value at $p < 0.05$.

purchase intent than to overall acceptance. The probability that the product would be accepted is 3.92 times higher (than not being accepted, $p < 0.0001$) with every one-unit increase of the overall liking score (based on a nine-point hedonic scale). For example, the least preferred product (formulation 5, table 16.7) had the overall liking score of 5.2. In order to increase the probability of this product being accepted up to 3.92 times higher than not being accepted, the overall liking score of this product must be increased from 5.2 to 6.2. With this increase, the probability of this product being purchased would be 6.915 times higher than being not purchased. Interpretation of the odds ratio estimate must be done with practicality in mind, as an increase in one unit score on a nine-point hedonic scale may not be that easy or practical, especially for the product already having a high overall liking score, such as formulation 8.

Purchase Decision Changes

In order to determine if a change occurred in the probability of the purchase intent of consumers before and after they had been informed of the health benefits from rice, the McNemar test was performed. In this case, the null hypothesis ($H_0: \pi_{1+} = \pi_{+1}$) stated that the probability of the purchase intent was the same before and after consumers knowing the fact, that is, no significant difference in the probability of purchase intent before and after consumers knowing the fact. Thus, it was being tested whether the probability of consumers who answered yes after (π_{+1}) and the probability of those who answered yes before (π_{1+}) were significantly different.

According to the results of the McNemar test (table 16.14), the probability of the purchase intent of the butter cake product, after consumers had known the fact about potential health benefits from rice, was significant at $\alpha = 0.05$ for all formulations, except for formulation 7 (50% wheat and 50% PGR flours). We could predict with a 95% confidence interval that the probability of the purchase intent would be increased by at least 21% and at most 42% for the formulation 2 (50% wheat and 50% rice flours). Also, for the formulation 3 (100% rice flour), we could predict with a 95% confidence interval that the probability of the purchase intent after consumers being informed of potential health benefits would be increased by at least 4% and at most 23% (table 16.14).

Table 16.14. Purchase decision changes analyzed by the nonparametric McNemar Test.

| Formulation ^a | χ^2 | p-value | 95% confidence interval for purchase decision (%) |
|--------------------------|----------|---------|---|
| 1 | 15.696 | <0.0001 | 11.8–30.9 |
| 2 | 24.500 | <0.0001 | 20.9–42.1 |
| 3 | 7.200 | 0.0073 | 4.0–22.9 |
| 4 | 13.500 | 0.0002 | 10.4–30.5 |
| 5 | 12.250 | 0.0005 | 7.6–23.9 |
| 6 | 15.696 | <0.0001 | 11.8–30.9 |
| 7 | 3.267 | 0.0707 | –0.5–16.1 |
| 8 | 4.000 | 0.0455 | 0.4–17.8 |
| 9 | 5.000 | 0.0253 | 1.7–20.8 |
| 10 | 9.800 | 0.0017 | 6.5–25.3 |

Note: The test follows a chi-square distribution with $df = 1$.

^aSample numbers correspond to those in figure 16.2 and table 16.6.

Product Optimization and Optimal Formulation Range

Product optimization was performed using the three-component mixture design experiment in conjunction with the logistic regression. The predictive models (data not shown) were obtained using a restricted regression analysis (without intercept) and used to plot the mixture response surface (MRS) shown in figure 16.3. The values within constrained area in the triangle were based on a nine-point hedonic scale.

Interpretation of the MRS for each sensory attribute requires information from figure 16.2 and table 16.6. For example, overall liking, taste, and texture acceptability scores decreased with increased rice flour content. Moistness and odor were not greatly affected by changes in the flour mixture content, and the predicted score was around 6–6.75 for both attributes. The acceptability profiles for appearance/color and visual puffiness were similar, and increased rice flour content increased acceptability scores.

For the traditional product optimization approach, all seven sensory attributes would be used to obtain optimal formulation range. However, we only used overall liking, taste, and texture, which were considered as critical limiting factors (tables 16.12 and 16.13), to obtain optimal

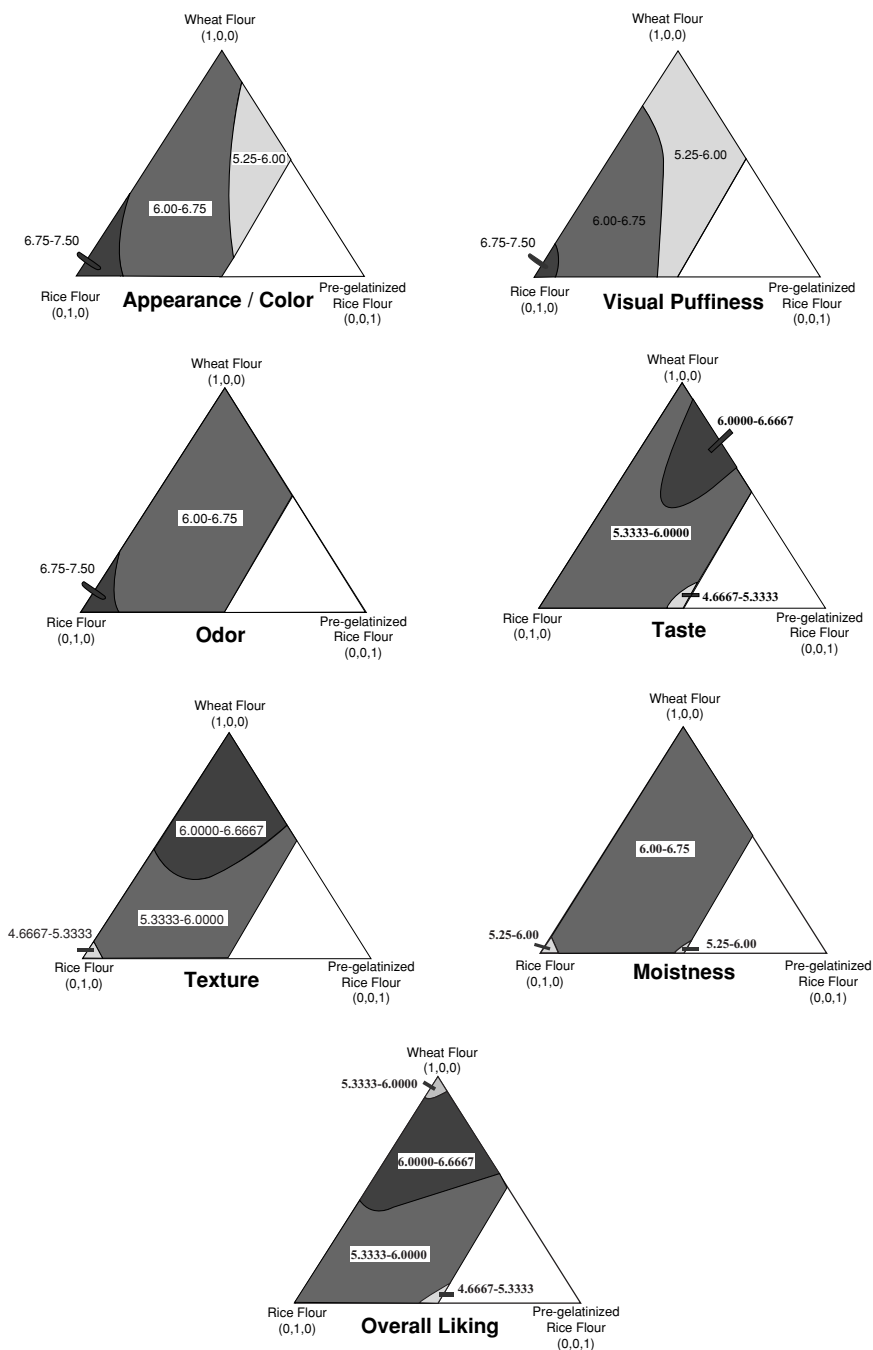


Figure 16.3. Mixture response surface (MRS) for predicted acceptability values (based on a 9-point hedonic scale) of sensory attributes. See figure 16.2 and table 16.6 for coordinate points and formulations.

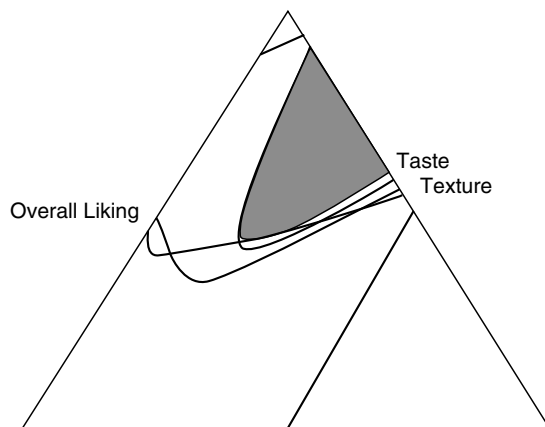


Figure 16.4. Superimposition of critical sensory attributes to attain optimal formulation range. See fig. 16.2 and table 16.6 for coordinate points and formulations.

formulation range. The optimal formulation range was determined by superimposing the MRS of critical sensory attributes. Areas within the MRS plots having a score equal to or greater than 6.0 were selected for optimization. The superimposition of the selected areas of the MRS plots (fig. 16.4) of overall liking, taste, and texture indicated that any formulations with 50–95% wheat, 0–50% rice, and 0–40% pregelatinized rice flours would yield an acceptable product that would potentially be accepted and purchased by the consumers.

Conclusions for Case Study II

The main purpose of this study was to systematically develop a butter cake product prepared mainly with rice flour and to determine its optimal formulation range. A series of statistical analysis techniques was performed. Both PDA and LRA were used to identify sensory attributes (overall liking, taste, and texture) critical to overall product acceptance and purchase intent. Unlike the traditional product optimization approach, the approach we used only considered crucial sensory attributes for determining the optimal formulation range. It was determined through the superimposition of the acceptable selected areas of the MRS plots of the three critical sensory attributes that any formulations containing 50–95% wheat, 0–50% rice, and 0–40% PGR flours would yield an acceptable product.

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Chapter 17

RESPONSE SURFACE METHODOLOGY AND CONSUMER-DRIVEN PRODUCT OPTIMIZATION

Howard R. Moskowitz and Andrea Maier

Why Read This Chapter?

If reviewing one of the classic analysis methods for understanding optimization of a product space written is of interest to you, try reading this chapter. It was created by one of the leading experts in the field. This is a classic methods chapter.

Introduction

Knowing the formulation/processing profile of a food or beverage and how it quantitatively relates to consumer perceptions opens up a world of development, quality, and marketing opportunities for a company. Whereas previously the formulation was deemed to be a fixed point, to be sought after and maintained, today's thinking is that there is an array of products around this "target," which can be equally acceptable, and in some cases far more cost effective or stable.

Forty years ago a lot of product development consisted of "giving it your best shot." In simple terms, this approach meant using all the knowledge about the product to "guess" what might be the optimal combination of ingredients. It was hard to know whether one was correct or wrong; the feedback systems were so slow and there was so little

competition compared to today that a product could be off target and yet achieve acceptance in the marketplace. Indeed, one urban legend has it that an advertising agency boasted that the product need not be acceptable at all—only the advertising had to persuade and the product would be a market success.

Today's competitive environment clearly doesn't allow for this type of arrogance, guesswork, and decisions that are not based on experimentation. Certainly, there are many instances wherein the developer or marketer feels sufficiently comfortable with the product that a simple test might suffice, with the research playing the so-called role of disaster check. More and more, however, developers are coming to realize that doing one's homework, systematically exploring all of the available options, and putting out products that result from careful experimentation can spell the difference between market success and inadequate performance.

Methodical exploration of product features, today known commonly as RSM (response surface methodology), began in the middle 1960s when the computer found increasing use as an aid to statistical description of data, and later on in statistical modeling (Hill and Hunter, 1966). In the decades before, and even during the early 1960s, a great deal of advancement had occurred in procedures such as regression and factor analysis (Draper and Smith, 1981). The advancements provided more power, but often had to be accompanied by computational formulas that the user could employ on mechanical calculators such as the Friden and the MonroeMatic. Looking back almost half a century, it seems quite reasonable that RSM for experimental design would have a hard time finding much use in that type of environment, which featured weak, laborious computing.

With the advent of the more powerful IBM computers, and especially with the 360 Series and with the widespread popularity of the Fortran programming language, more powerful statistical methods found their way into widespread use. Statistical modeling lies at the heart of experimental design. Although with the correct experimental design a researcher can estimate some effects (e.g., interactions) by simple addition and subtraction, once computers could be used to fit equations and solve these equations for specific conditions in a production-level mode, RSM thinking began in earnest. The computer had given an infusion of robustness and realism to the elegant experimental designs of the statisticians.

What Is RSM and What Does It Do?

RSM refers to a class of procedures designed by statisticians. The key objective is to identify the relation between the independent variables under the experimenter's control and the dependent variables that are measured. The RSM approach divides into three parts:

1. Experimental design—layout of different combinations
2. Data acquisition—get the appropriate data from the target population
3. Modeling—create an equation that relates the dependent variable to the proper combination of independent variables

The logic underlying the RSM procedure is simple. Rather than relying on one's best guess for the new product, it is better to identify a region where one believes the optimal formulation to be, measure responses around that region, look for patterns of responses, and then use those patterns to identify the best formulation that is optimal within a set of applied constraints.

A Short History of RSM in the Food World

RSM in foods can be formally traced to the 1960s, although a number of professionals in the field might wish to trace it back earlier to the late 1940s. Joan Gordon published a seminal paper on mixtures (Gordon, 1965). Other statisticians recognized the value of RSM starting in the 1970s (e.g., Hare, 1974).

RSM as a research strategy really began in earnest in the 1970s, with the contributions of Al May at Pillsbury. Others can claim codevelopment as well (e.g., Robert Carbonell from Standard Brands, Inc.). These early developments used simple, systematic variations of ingredients to identify regions of optimal formulations (Joglekar and May, 1991). At that time, DuPont was sponsoring courses on DOE (Design of Experiments), attracting some of these forward-looking, senior players in the food industry. Other, more junior players, including statisticians, were being recognized at the same time for their current and potential contribution to the field. Companies such as CompuServ, Inc., were offering experimental design packages on a time-share basis, which in the 1970s became quite important in spreading the word about the power of experimental design.

The early developments in RSM concentrated on the simpler experimental designs, such as rotatable designs (Mullen and Ennis, 1979). Eventually, however, the increasing popularity of RSM as a topic for articles in food-related research journals and even mentions in business journals talking about the power of experimental design and modeling had their effects. The growing familiarity with the notion of systematic experimentation motivated researchers to take the approach seriously, especially when they saw successes emerge from modeling objective physical phenomena such as product yield from different processes. The notion of using subjective attributes such as product acceptance as a criterion did not meet with much resistance from those who had already accepted the power of RSM. Unlike practitioners in other disciplines such as manufacturing, those involved in the food and beverage industries were always well aware of the importance of consumer acceptance. By the late 1950s, scales of acceptance were already widely used, so that by 20 years later the thought of incorporating these acceptance scales into an RSM experiment was fairly straightforward, risk free, and not particularly novel.

The rest of the history is just that—an increasing acceptance of RSM, from its basis in experimental design to its execution in consumer fieldwork, to the analysis by computer programs now readily available and “off the shelf.” For the most part, the technology is fairly simple—design, regression, some nice plots. The history of such applications can now be written in decades (e.g., Rabino and Moskowitz, 1984). There are new developments in RSM worth mentioning (e.g., reverse engineering). However, it is the applications that are important, and the way the applied product developer merges this branch of statistics with consumer research, and comes up with a method to increase customer satisfaction and the likelihood of market success.

Experimental Design

We begin the substance of this chapter with a short treatment of experimental design as applied to food and beverage. Experimental design consists of the systematic variation of several independent variables across a range of alternative levels. The objective of experimental design is to “cover the space”—that is, cover within reason a range of independent variables, so that the researcher can develop some type of model and explore that range. The analysis may simply be to identify

how the dependent variable changes with known changes of the independent variable, or it may be more complicated—for example, whether there exists any interactions of one independent variable with another when determining the value of the dependent variable, and the nature of that interaction.

Univariate Modeling

The fundamental experimental design comprises the change of one variable across a range. The absolutely simplest is the change of this variable from absent to present, or from option A to option B. At a slightly more complicated level, the experimental design for one variable might comprise systematic changes in the independent variable from low to high in gradations. The objective underlying this simple univariate analysis is to trace out the relation between independent and dependent variables. Is the relation linear? Is it nonlinear? If so, what does the relation look like? Knowing the relation between the independent and dependent variable gives the researcher a sense of the likely change to occur with known changes in the independent variable. We get a sense of the relation between the independent and dependent variables from figure 17.1.

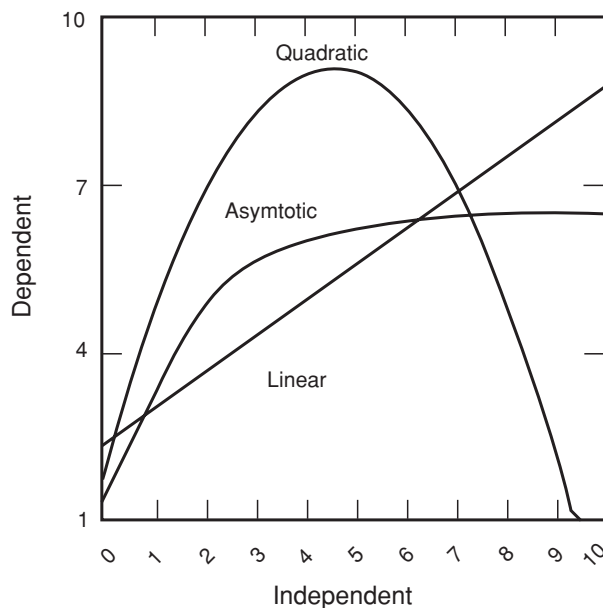


Figure 17.1. Three types of relations between independent and dependent variables.

We can express the relation between the independent and the dependent variables by a number of simple linear equations. Indeed, looking at scientific programs for the PC, the reader can find any number of off-the-shelf, so-called shrink-wrapped statistical programs that take raw data of this univariate form and fit an equation to it. The equation can be expressed in any of a number of ways, but the most common and easiest to understand are the first two below, linear and quadratic.

Linear: $\text{Dependent} = k_0 + k_1(\text{Independent})$

Quadratic: $\text{Dependent} = k_0 + k_1(\text{Independent}) + k_2(\text{Independent})^2$

Logarithmic: $\text{Dependent} = k_0 + k_1[\text{Log}(\text{Independent})]$

Power: $\text{Dependent} = k_0(\text{Independent})^n$

Exponential: $\text{Dependent} = k_0 + e[n(\text{Independent})]$

Multivariate Modeling

Matters become a little more complicated when we deal with two variables. Two variables have several possibilities in the way they interact with each other. The variables can each take on different function forms (linear, quadratic, etc.), and they can interact with each other in a number of ways (e.g., multiplicative or ratio).

In traditional research, the ingoing assumption was that the relation between the dependent and the independent variables was monotonic. That is, the researcher was not sure about the precise nature of the relation, but the assumption was that as the independent variable increased, so did the dependent variable. This approach led to fairly simple experimental designs, where the independent variable took on two levels. Some of these designs appear in table 17.1. It is clear that as the number of independent variables increases, the potential set of combinations increases dramatically, so at some point (which is a function of the researcher's finances), the full set of combinations (so-called full factorial) will give way to a fractional factorial or incomplete design.

Once the experimental design is developed for 2^n , where n is the number of independent variables, a lot of the foundation of experimental design has been done, at least for the easier and more common designs. Beyond the simple full factorial designs lie the different so-called fractional designs. For example, with six variables, the full experimental design, or so-called full factorial design, requires a 2^6 combination,

Table 17.1. Designs for 2^n for one, two, three, and four independent variables (A, B, C, D), each of which takes on two alternative values (coded as 1, -1).

| PROD | A |
|------|----|
| 1 | 1 |
| 2 | -1 |

| PROD | A | B |
|------|----|----|
| 1 | 1 | 1 |
| 2 | 1 | -1 |
| 3 | -1 | 1 |
| 4 | -1 | -1 |

| PROD | A | B | C |
|------|----|----|----|
| 1 | 1 | 1 | 1 |
| 2 | 1 | 1 | -1 |
| 3 | 1 | -1 | 1 |
| 4 | 1 | -1 | -1 |
| 5 | -1 | 1 | 1 |
| 6 | -1 | 1 | -1 |
| 7 | -1 | -1 | 1 |
| 8 | -1 | -1 | -1 |

| PROD | A | B | C | D |
|------|----|----|----|----|
| 1 | 1 | 1 | 1 | 1 |
| 2 | 1 | 1 | 1 | -1 |
| 3 | 1 | 1 | -1 | 1 |
| 4 | 1 | 1 | -1 | -1 |
| 5 | 1 | -1 | 1 | 1 |
| 6 | 1 | -1 | 1 | -1 |
| 7 | 1 | -1 | -1 | 1 |
| 8 | 1 | -1 | -1 | -1 |
| 9 | -1 | 1 | 1 | 1 |
| 10 | -1 | 1 | 1 | -1 |
| 11 | -1 | 1 | -1 | 1 |
| 12 | -1 | 1 | -1 | -1 |
| 13 | -1 | -1 | 1 | 1 |
| 14 | -1 | -1 | 1 | -1 |
| 15 | -1 | -1 | -1 | 1 |
| 16 | -1 | -1 | -1 | -1 |

or 64 combinations. For business objectives, this number of combinations is simply too large. Generally, sufficient funding does not exist that could deal with this many combinations. The prudent thing is to cut back the 64 or 26 combinations to a more tractable number, such as 16 or even 8. The funds are there to test these combinations, which are still greater than the 2 or 3 that might be tested based upon the view of “give it your best shot.” Yet out of the 64, what particular 16 or 8 should remain for testing? Statisticians tell us that it’s not good to select a random set. The likelihood is that the 16 will be correlated, or will not cover the space of ingredients in the most efficient manner. Thus, for six independent variables, each with two levels, we could be dealing with a specific 64 combinations (full factorial), a specific $2^{(6-1)}$ 32 of 64 combinations, a specific $2^{(6-2)}$ or 16, or even a specific $2^{(6-3)}$ or 8 of 64 combinations. These are, respectively, the full factorial, or a 1/2, 1/4, or 1/8 design. Books on experimental design provide instructions on how to generate these fractional designs (see Box et al., 1978).

We end this very brief introduction to experimental design by looking at two very popular modifications. These are the screening designs and the central composite designs.

Screening Designs

Screening designs are experimental designs that allow the researcher to look at the expected effects of many different variables, each of which takes on two levels. For example, suppose the researcher wishes to identify which of 10 ingredients makes a difference in a pasta sauce. A full factorial, 2^n experimental design, would require 2^{10} or 1024 combinations, an exceptionally high number of combinations just to find out which variables “work” and which do not. Screening designs are very efficient. With some 16 combinations, the researcher is able to identify which of the 10 variables is important and which is not. Of course, 16 combinations do not cover the space covered by 1024; they cannot, because the magnitude of the study has been reduced by about 98.5%. Nonetheless, by combining these 10 variables, each of which has two levels, into 16 combinations and testing the combinations, the researcher can quickly determine which variable(s), if any, drive the reaction. The experimental design is highly fractionated, or highly unsaturated. Tables of these screening designs have been published, showing the combinations to create. The designs don’t allow the researcher to really optimize

Table 17.2. Example of a two-level screening design for up to 11 variables in 12 combinations. Each variable, A–K, can take on one of two values, denoted by 1 or -1 , respectively.

| PROD | A | B | C | D | E | F | G | H | I | J | K |
|------|----|----|----|----|----|----|----|----|----|----|----|
| 1 | 1 | 1 | -1 | 1 | 1 | 1 | -1 | -1 | -1 | 1 | -1 |
| 2 | 1 | -1 | 1 | 1 | 1 | -1 | -1 | -1 | 1 | -1 | 1 |
| 3 | -1 | 1 | 1 | 1 | -1 | -1 | -1 | 1 | -1 | 1 | 1 |
| 4 | 1 | 1 | 1 | -1 | -1 | -1 | 1 | -1 | 1 | 1 | -1 |
| 5 | 1 | 1 | -1 | -1 | -1 | 1 | -1 | 1 | 1 | -1 | 1 |
| 6 | 1 | -1 | -1 | -1 | 1 | -1 | 1 | 1 | -1 | 1 | 1 |
| 7 | -1 | -1 | -1 | 1 | -1 | 1 | 1 | -1 | 1 | 1 | 1 |
| 8 | -1 | -1 | 1 | -1 | 1 | 1 | -1 | 1 | 1 | 1 | -1 |
| 9 | -1 | 1 | -1 | 1 | 1 | -1 | 1 | 1 | 1 | -1 | -1 |
| 10 | 1 | -1 | 1 | 1 | -1 | 1 | 1 | 1 | -1 | -1 | -1 |
| 11 | -1 | 1 | 1 | -1 | 1 | 1 | 1 | -1 | -1 | -1 | 1 |
| 12 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 | -1 |

a product; rather they show the magnitude of impact of each variable, which is often sufficient at the very early stages of development. An example of a screening design for up to 11 variables in 12 combinations appears in table 17.2. The design, one of a family of designs for different numbers of independent variables, was created during World War II by Plackett and Burman to explore errors in guiding missiles, and only subsequently declassified after the war.

Three-Level Designs

These designs comprise three levels of each variable, set up in such a way that the resulting analysis can accommodate both nonlinearity and interactions among pairs of variables. These designs are set up for product developers because the designs are efficient, they cover a wide range of alternatives, and they can be immediately used in regression modeling. We see examples in table 17.3. The designs can be fractionated so that the researcher can deal with 2, 3, 4, 5, or 6 independent variables without making thousands of products. Of course, the greater the fractionation or the fewer the products (out of the possible set of products), the more unsaturated the design and the less likely the design will pick up interactions among pairs of ingredients. The designs are

Table 17.3. Three level designs, showing three variables (A, B, C), each at three levels (−1, 0, 1 corresponding to low, medium, and high).

| PROD | A | B | C |
|------|----|----|----|
| 1 | 1 | 1 | 1 |
| 2 | 1 | 1 | −1 |
| 3 | 1 | −1 | 1 |
| 4 | 1 | −1 | −1 |
| 5 | −1 | 1 | 1 |
| 6 | −1 | 1 | −1 |
| 7 | −1 | −1 | 1 |
| 8 | −1 | −1 | −1 |
| 9 | 1 | 0 | 0 |
| 10 | −1 | 0 | 0 |
| 11 | 0 | 1 | 0 |
| 12 | 0 | −1 | 0 |
| 13 | 0 | 0 | 1 |
| 14 | 0 | 0 | −1 |
| 15 | 0 | 0 | 0 |

limited to two-way interactions because of the considerations in terms of the number of combinations to test. It would be nice to test three-way interactions, but if truth be told, virtually no researcher knows how to interpret these three-way interactions.

Beyond Design to Modeling

As noted in the introduction above, experimental design leads naturally to modeling by regression analysis. Regression analysis attempts to fit a straight line or a curve (or surface) to the data. The researcher begins the study with the experimentally varied combinations, presents these to panelists, and obtains a rating. In food and beverage research, the panelist may generate a number of ratings. Rather than limiting the response to one rating, the researcher instructs the panelist to assign a profile of ratings, covering sensory attributes (appearance, aroma, taste/ flavor, texture), liking ratings, and image ratings (more complex attributes, such as “refreshing” for a beverage). The panelists may evaluate all or some of the products, depending upon the specific field execution. The researcher averages the data to generate a database that can be readily analyzed by regression analysis.

Without an underlying experimental design, the researcher cannot easily relate the independent variables to dependent variables using regression, and ensure that the results of the regression are unbiased estimates of what the independent variables contribute. The researcher could always run regression on the data, because the regression program doesn't recognize the experimental design. However, if at the start of the study the researcher simply chooses different levels of the independent variables rather than systematically varying them, it would be possible to run a regression analysis, but the results would not be as strong. More than likely, some of the variables would be correlated with each other, and thus not strictly independent.

Most modeling is done by fitting a simple, polynomial equation to the data. The statistics are straightforward to compute, and the polynomial can be rapidly estimated by today's programs.

It is easy to see relations among variables when the researcher can plot the results graphically. We'll deal here with two independent variables, which in concert drive responses to an attribute rating. When the researcher deals with two independent variables and a single dependent variable, the response surface relating the variables looks in some ways like figure 17.2. Figure 17.2a,b,c shows three different types of surfaces in the various panels. All of the data can be accommodated by using the quadratic or second-order polynomial equation just presented above. Depending upon the nature of the relation between the independent and dependent variables, the equation can generate a surface that peaks in the middle for both independent variables, peaks at one end or the other for either independent variable, or peaks at one level for an independent variable, but is seen to drop for the other independent variable (so-called saddle point). It's all a matter of the actual data. What is important, however, is that a simple polynomial equation can describe the data. It may describe the data accurately, or not so accurately.

The effort to fit a curve using regression analysis may seem a bit too much effort to those unschooled in the use of experimental designs and modeling. After all, with the data, it stands to reason that the researcher will have covered a wide range of alternative levels. Why not simply choose the best performing combination among the systematically varied products? This simplistic and very rational approach is often followed: after all of the design, prototype creation, testing, and analysis, quite often the management simply says to go with the winning product. However, there is error in the data, so the winning product may be a winner simply because by accident a product that is better scored a

little lower. By picking the empirical winner, the developer chooses to ignore all of the other information provided by the different prototypes. Yet, by creating a model relating the acceptance rating to the independent variables, it is possible to get a better estimate of where the real optimum lies, as figure 17.3 shows. It is the pattern developed across all of the prototypes, not the single best scoring prototype itself, that is the true winner. The goal of experimental design, data acquisition, and modeling is to discover that pattern, and truly identify where the best product lies.

On the Role of Equal Intensity Contours—Do They Matter and What Do They Teach?

During the early part of this century, many researchers became interested in interactions among pairs of variables. When they dealt with these

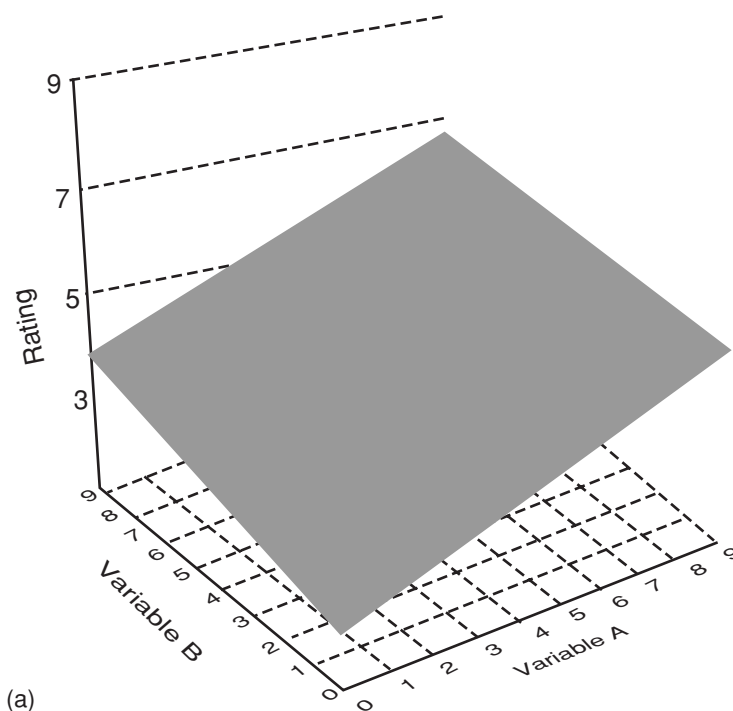
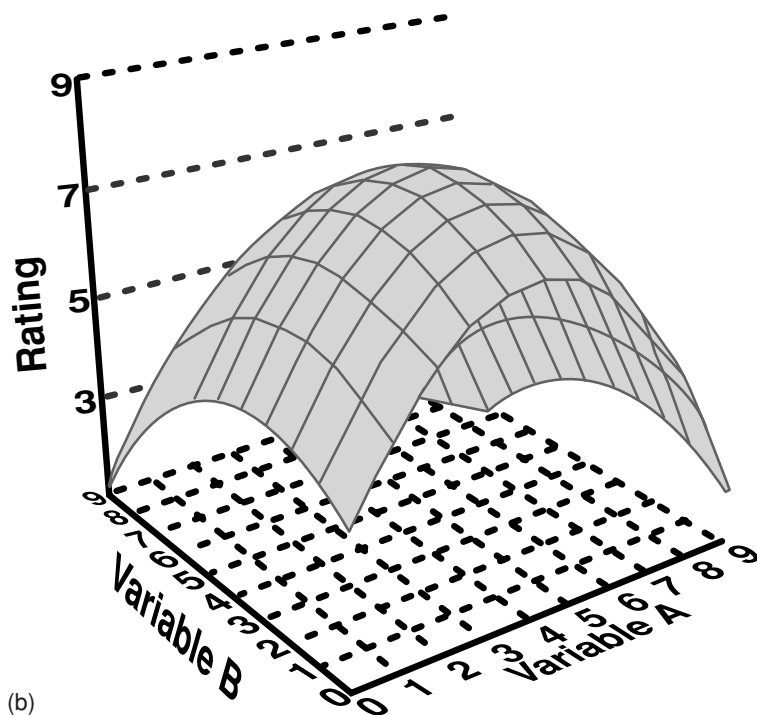
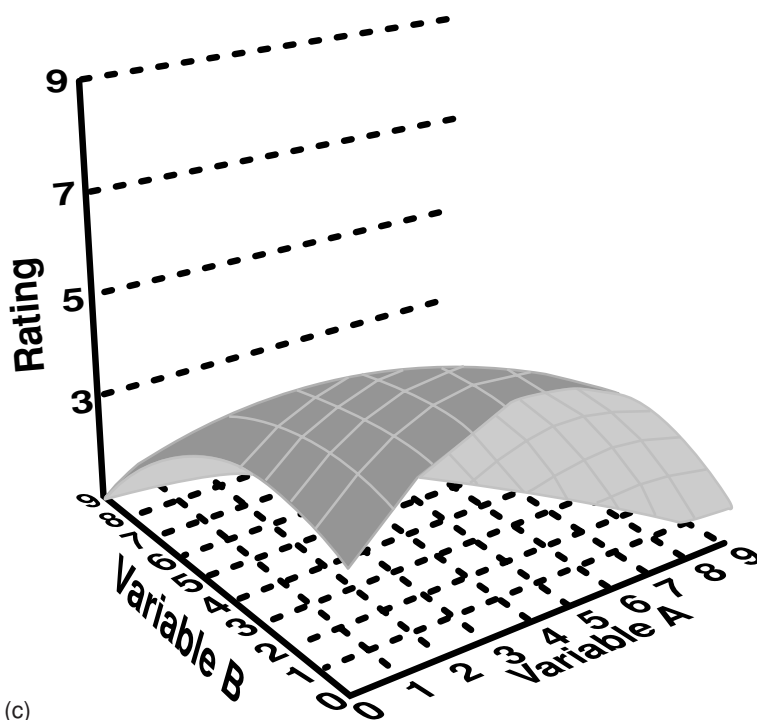


Figure 17.2. Three polynomial surfaces that might emerge from RSM studies: (a) Linear, (b) quadratic, and (c) quadratic with interactions. Each surface shows the relation between two independent variables (A,B) and a dependent variable (rating).



(b)



(c)

Figure 17.2. (Continued)

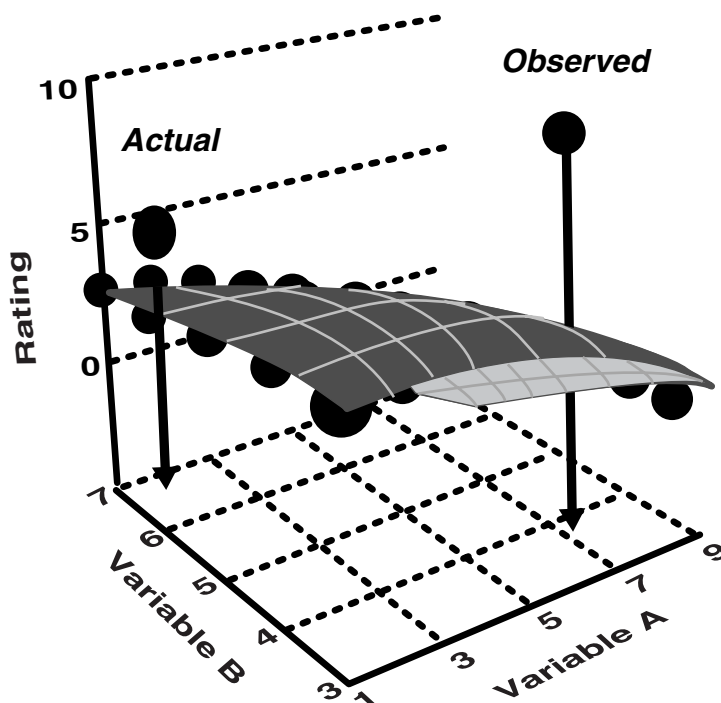


Figure 17.3. A case where the optimum product is probably not the best scoring product.

pairs, they often presented the pairs as two-dimensional contours or plots with shaded regions of equal response magnitude, such as those shown in figure 17.4. Depending upon the degree of interaction between the variables, the contours will depart from circles toward ellipses and have other distortions as well.

The real question in RSM is whether these equal-intensity contours teach and inform, or whether they are simply plots of relations between variables that either have no relevance to insights or actually detract from insight. Unfortunately, it does not appear that the researcher really gets very much from equal intensity contours because of three reasons:

1. More than two independent variables makes the plot hard to understand: A lot of RSM work deals with three or more independent variables. For equal intensity contours to be meaningful, it is important to hold the third, fourth, and additional variables constant. To get

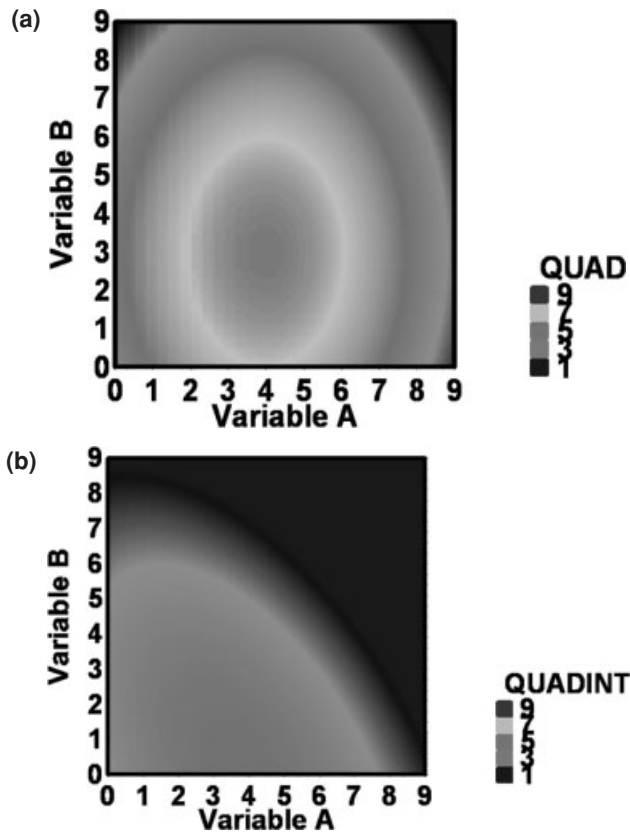


Figure 17.4. Two equal intensity contours. The darkness of the shade is proportion to the degree of liking. (a) The first contour shows data where there is no interaction between the two independent variables. (b) The second contour shows data where there is substantial interaction between the two independent variables.

any sense of the data requires, therefore, that the researcher produce many of these pairs of contours, one contour for each level of the variables not shown, but held constant. Anyone watching a presenter show contour after contour soon realizes the futility of conveying information this way. Of course, many researchers work in reverse, dealing with only two independent variables in order to present the data in this contour format.

2. Not much learning emerges: Univariate relations between stimulus level and response teach more because they paint a picture that can be easily summarized. Whether the relation is presented in table format

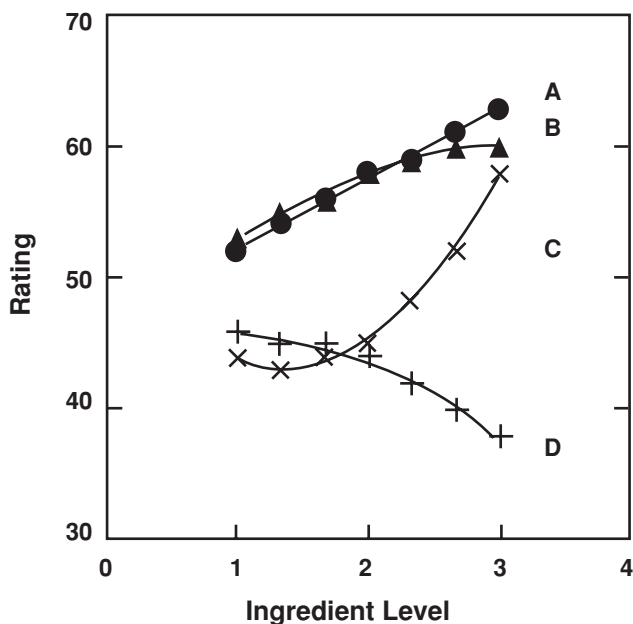


Figure 17.5. Dose response curve for different levels, for four different rating attributes (A, B, C, D), as a function of changes in a single independent variable. All other independent variables were held constant at a specific value.

or in graphical format doesn't matter. The information is easy to understand. If there are interactions between two variables A and B, as they influence the sensory or liking response, then the researcher can plot the sensory response versus A (one curve), and plot several of these univariate curves on the same graph, as shown in figure 17.5. The learning is clearer.

3. Explaining the contour plot is difficult and often obscures more than it enlightens: Probably the most disturbing thing about equal intensity contours is that they are hard to explain. What exactly do they mean, beyond the statistical definition of how to get them? What does the customer of RSM really learn from that? Probably very little, in the opinion of the authors. It's easy to plot these equal-intensity contours with today's technology, and perhaps that's why they are so prevalent. The story would be quite different if the researcher had to expend a lot of effort making the plots. Perhaps we'd see less plotting, less reliance on the computer, and more reliance on one's insight.

Emotional Reactions to Experimental Design and Product Optimization Exercises

The corporate reactions to experimental design have been mixed, not so much because of the true usefulness of design ensuing product optimization, but because of other factors that are probably emotional. Most product developers who begin with product optimization end up being happy with what they have discovered, and when the data are properly implemented, the results tend to generate product success. However, the path to such happy endings is not filled with equal parts of joy and encouragement. Experimental design requires a commitment of corporate resources to develop products, some of which are clearly not going to win the consumer's heart because they represent extremes of product formulation that simply don't taste good. Other combinations may be too expensive, and so forth. It is a natural tendency of people to eliminate these implausible products right from the start, rather than eliminate them afterward. The logical thought is why bother working with products that will never be used later on in the actual marketplace? So, one problem is that the corporation is reluctant to expend resources, and certainly doesn't want to expend resources on seemingly irrelevant products.

The second problem is that experimentation goes against the very nature of one's expertise. It is hard for young product developers, those most attuned to new ideas, to realize that a great number of older professionals get ego satisfaction from their ability to "know" a product category, to "instinctively know what works and what doesn't." Experimental design for these individuals could be threatening, because it substitutes experimentation for judgment. Certainly there is the judgment about what ingredients to vary, but then the task is left to science, to experimentation, to research with consumers, and to regression analysis for statistical summarization. The "golden palate" of the expert, the "golden nose" of the flavorist/perfumer, and such types of talents that have been developed over time, appear to be less relevant in the face of such experimental design. The truth is they are not; the experimental design and product optimization approaches come later in the fine-tuning of the product. Nonetheless, there is the ever-present resistance.

Despite the aforementioned problems associated with disciplined development using design and optimization, for the most part when a

company follows the discipline, the results become embedded in the corporate archives, and are consulted, often year after year. The senior author (HRM), having been in the research business for 30+ years, has seen the same pattern repeat itself. Management at companies first balk at the exercise, then may execute the study. Almost always, companies boast years later that the data and models emerging from the product optimization were good for 5 to 10 years of continued use. The uses ranged from developing a series of new products for total panel and key subgroups (e.g., Campbell Soup Inc.'s Prego), on to refining the product formulation to take account of changing costs (e.g., Maxwell House coffees), and even on to the development of totally new products (e.g., Tropicana's Grovestand Orange Juice). However, these happy endings occur only when the corporation follows the approach of design and optimization with an open mind, and with a readiness to use the data for product development and refinement rather than secreting the data in some dusty cabinet, satisfied merely to have gone through the motions of doing an experiment.

Business Issues Involved with RSM

When a company decides to use RSM technology, it incurs a number of costs and has to make several trade-offs. As the reader might expect, RSM technology does not necessarily enter the corporation in a peaceful, dignified manner, although it could. Rather, for the most part today and during virtually all of its history in business, RSM has had to fight to get a position in the corporation. The fight is carried on by those who believe that systematic research pays out, and that unsystematic research, the type exemplified by "choosing the best shot," may occasionally win but in the long run probably leads to more disasters than would be admitted in open circles.

Let's look at some of these considerations, which have sparked so much controversy during the past decades. While we look at them, it's important to keep in mind that when corporations look at processes, they do so with multiple points of view. We should keep in mind the different roles of science, resource administrator, financial officer, and corporate knowledge archivist.

1. *The scientist*: The scientist is interested in learning about the product, and by so doing, solving the problem. Scientists like RSM. It

appeals to their worldview, the way they are constructed, to their title as scientist. In a sense, each RSM study produces a systematized database for a particular product or process. To the scientist, RSM represents one of the apotheoses of the scientific method. RSM does not so much validate or refute a hypothesis as much as provide a systematized database from which various hypotheses can be developed and their truth/falseness determined by the specific facts in the RSM database.

2. *The resource administrator:* Companies have limited physical resources. Quite often developing prototypes requires use of the pilot plant, bench space, and so forth. Usually physical resources are not very much of a problem unless the opportunity for the product in the marketplace is perceived to be low. In such cases, the resource administrator will usually make a strong case either to abandon the development entirely, or to contract the development of the prototypes outside to another organization.
3. *Financial officer:* Money in corporations is allocated in proportion to specific criteria. A lot of the money that is allocated goes to standard tracking work, and ongoing quality assurance. RSM studies, not being part of a continuous and ongoing data-feed, have to be considered one at a time. Almost no company makes provisions for RSM work up front, since the need for RSM work often comes unexpectedly. However, this one-off nature of RSM work is not too much of a problem. The particular RSM project can usually be accommodated within the budget already assigned to the R&D group. Occasionally, when emergencies arise (e.g., a competitor comes out with a best-selling product that promises to wreak havoc on the corporate flagship brand), the financial officer will authorize additional, one-time expenditures for RSM work.
4. *Corporate knowledge archivist:* By the time of this writing (mid-2006), most companies have made some provision to archive and access old reports. There is a growing recognition that previous studies, especially with consumers, can lead to new insights, but only if the studies are properly archived and indexed can the already-paid-for knowledge be recycled for new projects. Most old studies with consumers are converted to some type of electronic format, with a set of keywords, and put into the corporate archives to be retrieved with a computerized knowledge-management system. RSM studies occupy an interesting, unique, and often inspiring role for the archivist. Most

RSM studies, especially those dealing with important topics such as formulations of major products, enjoy a *living existence*, day after day, and rarely fade into obscurity as so many other studies do. Client feedback given to the senior author (HRM) consistently reveals that in many companies the RSM studies often are used on a weekly basis for years after the study, in order to guide new product development and product reformulation. When these studies are accompanied by software that can “dial a product formulation,” that software itself both enters the archive, and continues to enjoy a vital life for a half decade or more after the study has been completed.

What Are the Real Costs and Real Benefits?

The important thing to keep in mind when contemplating an RSM study is what will be the effort up front, and what will be the benefit at the end of the study? One productive way to tackle these questions consists of putting oneself in the shoes of general management faced daily with practical business problems. Taking the larger-scale view of management allows those contemplating the RSM exercise to look beyond their immediate issues, and into the benefits (or costs) that the company will accrue.

The costs of RSM are fairly simple. They are time and money. RSM research takes time to plan, time to produce products, time to execute. RSM costs money. The money is both in salary and in opportunity costs for other types of research. Even the most ardent proponent of RSM realizes that the corporation is in business to make money, and so should look at the RSM exercise as a way to increase long-term corporate sales or profits. Questions that one might ask prior to the RSM exercise are:

1. Are we going to learn something new, or is this just going to be an exercise to relearn what we already know?
2. Do we really expect the products to be different enough for the consumer to perceive these differences, and do we believe that any changes in the product make a difference to consumers anyway?
3. Can we tie cost of goods into the exercise so that we change both the product and the cost of goods? RSM can, with cost variables, identify both product opportunities and cost-savings opportunities.
4. Are we doing the best possible RSM study, or are we configuring the study to some off-the-shelf software that deals with three independent

- variables? That is, what is leading the study design—solution to a business problem or expediency of analysis?
5. Who in the company will be the RSM champion? Is the champion sufficiently knowledgeable about the benefits of this particular project? Have we specified those benefits to the champion and is the champion sufficiently convinced to “go to the mat” for this project?
 6. Who in the company is the greatest doubter of this project particularly, or of the benefits of RSM? Can we marshal sufficient arguments to convince the doubter? Are the doubts real, and should we modify the design?
 7. Can we role-play the results, for example, with a product optimizer (simulator)? Can we go through some “dummy results” of this study, before we run it, and with those results define exactly what course of action the company should take? That is, do we know the “inner game” of product optimization, or do we have to search through the data to find a story? If we know the inner game, then more than likely we know what we’re doing. If we expect the results to guide us, then it’s likely we don’t know what we’re doing.
 8. What specifically are we going to get from the data, once the experiment is completed? Can we foresee a specific scenario beginning with the results, and going toward the implementation? If the researcher cannot describe accurately what is likely to happen with the data, how he will explain the results, and how the results will be used in business, then it’s likely that the researcher does not really understand what the RSM is actually going to contribute.

Explicating the Method by Two Case Histories

The easiest way to understand the RSM approach is through a case history, or in this chapter, through two case histories. The first case history deals with the selection of options from many different alternative ingredients, using experimental design and screening designs. Screening designs are used when there are many variables and where the researcher really doesn’t know which alternative to use. The second case history deals with the actual optimization of a product formulation, subject to constraints. The case history also shows how reverse engineering methods can be applied to the data as well, so that the product can either be optimized (e.g., to increase acceptance), or can be modified to deliver what a concept promises.

Both of these case histories deal with the RSM approach. The former, using screening designs, is generally used when there are a lot of independent variables, and where the objective is to discover which of the independent variables actually make a difference. The latter, using three or higher level designs, is generally used when there are a relatively limited number of variables, and where the objective is to identify the precise location or at least the region where maximal acceptance is reached.

Screening Designs

When the researcher undertakes to develop or improve a product, all too often there is very little knowledge about the product. Certainly the developer can guess about the relevant ingredients, and if the developer has done the appropriate category appraisal (see chapter 15) then it is likely that the drivers of liking have already been established. However, more often than one might admit, product developers really don't know what is going to work and what is not. Product development is not so scientific that one can interchange two formula variables generating approximate equal sensory magnitude, without at the same time affecting both sensory perception and liking ratings. The number of variables and options with which the developer must cope is so great that a strategy that efficiently sorts through many independent variables is welcome. Screening designs are just such arrays that allow efficient sorting of effects.

The Business Problem—Identifying the Features of a New Still, Health-Oriented Fruit Beverage

In the past five years, the growth of still (noncarbonated), lightly or strongly flavored, colored or clear fruit flavored beverages have grown far more than have the cola and other carbonated beverages. As people worldwide in the more developed countries age, their preferences change. At a concept level, people ask for refreshing, light, modestly flavored beverages. Companies have concept-tested many of these beverages and know the idea to be a winner in the marketplace. The problem is simple—what are the key formula variables that should be used? Should the product be sweeter or less sweet; strongly fruit flavored or modestly fruit flavored; colorless or colored, etc., etc., etc.?

Furthermore, there were a number of “health ingredients” that could be incorporated. Each of these had a slight taste. All of them had scored well on preliminary concept tests; the question was whether some or all of them could be easily incorporated into the beverage without seriously diminishing product acceptance. If an ingredient could be incorporated into the product, and did not affect acceptance, then it was deemed important to keep this ingredient because it would positively affect the image of the product. On the other hand, if the ingredient reduced acceptance, marketing management did not want to spend extra resources trying to overcome the negative taste effects of this product. The incremental acceptance of the product incorporating the bad-tasting ingredient was simply not high enough, at least based on the concept testing. It wasn’t worth the effort to compensate for the ingredient.

By now most product developers know that to create a successful product they have to create a beverage that consumers like, both at the first sip and later on after the product has been complete. Furthermore, the more seasoned product developers know that they cannot use the participant’s description of the beverage product from concept research as the final blueprint against which they create the product. For exactly, the idea of “rich fruit flavor” does not really denote more fruit flavoring, but rather may be pushed by adding more sweetener. The worst thing that the developer could do would be to follow the dictates of the product concept, no matter what its score on an acceptance scale.

Upon careful consideration, the product developer realized that there were nine alternative variables that could affect the beverage. Six of the variables (#1–6) were relevant for the sensory characteristics of the product. Three of the variables (#7–9) were relevant because they were attracting a lot of interest in the world of “good for you products,” and the ingredients scored well when tested in concepts.

Each of these variables had to be constrained to two options, meaning that certain variables had to be constrained to far fewer options, making the incorporation of those variables more of a judgment call because a number of options for the variables simply could not be investigated.

The variables were:

- A. Sweetener—Type A versus type B
- B. Cloud—absent versus present
- C. Lemon flavor—absent versus present

- D. Lime flavor—Type A versus type B
- E. Spice “X” flavor—absent versus present
- F. Spice “Y” flavor—Type A versus type B
- G. Added “health ingredient” A—absent versus present
- H. Added “health ingredient” B—absent versus present
- I. Added “health ingredient” C—absent versus present

The conventional RSM problem, dealing with nine independent variables such as the ones listed above, poses a daunting problem, especially when we realize that the developer is at the very early stages of the problem. Without an efficient (read “low-cost” and “easy”) design, more than likely the issues might well be resolved by judgment alone. Without the screening design, the odds are very high that at least half or perhaps almost all of the ingredients would be selected by the simple process of tasting some combinations and deciding. Perhaps this might not be a particularly poor idea—unless, of course, the judgment of R&D was to be wrong. Of course, subsequent tests would prove that some of these judgment calls were simply incorrect, but then the idea of a screening design is to have consumers participate early on in identifying what works and what does not. If consumers can help guide the selection of ingredients, then it’s likely that subsequent development will be more efficient. Much of the preparatory work will have been consumer driven, and the winning options for the ingredients will have been selected on the basis of consumer input.

Selecting an Appropriate Experimental Design

The very early nature of the business problem means that we’re not expecting the results to yield the optimum formulation. We’re simply in the business of “range-finding,” or ingredient selection. Each of the independent variables that the researcher uses in the design should correspond to either an ingredient being present/absent, or a choice between two alternative options for ingredients. The reality of the product development issue may be that for some of the development issues, there will be more than two alternatives. However, the existing screening designs, which will be used because they are efficient and require far fewer products than a fuller design, are set up for two options corresponding to each dependent variable. With more than two options, other custom screening designs need to be created.

We will use the two-level Plackett-Burman screening design. These designs are highly efficient, covering all of the variables with not many more “runs” or “prototypes” than there are variables. For example, with our nine independent variables, we may be able to use a Plackett-Burman design calling for 12 runs, which can handle up to 11 variables. Table 17.2 above shows this experimental design. There are 11 columns, one per variable. We need not use all 11 columns—in fact, we should stop at column 9. Each row of the experimental design tells us the precise combination of the 9 variables that we are going to use.

When choosing an experimental design, it is always a trade-off between the minimum number of combinations to create (always a costly affair) and a solid estimate of the performance of the different variables, which is a function of increased number of combinations tested.

Creating Prototypes for the Screening Design

Once the researcher identifies the combinations, it is a straightforward matter (at least in the design phase) to create these combinations. Quite often the developer mentally “edits” the combinations, deciding that some combinations are feasible, some are infeasible. The rationale behind this editing is that to the developer it doesn’t make sense to work with those combinations that would not ever be considered from a business standpoint. It is important to stress to the developer the criticality of following the experimental design, even if some of the alternative prototypes don’t make the developer “shine.” This emotional reaction, discussed above, is far more common than one might believe.

When creating the prototypes, it is best if the developer can create them in a randomized order, rather than in the order they are listed by the design sheet. A randomized order at least mixes up the products so that there is unlikely to be a confounding order of product (or length of storage) with any key ingredient. Conversely, if the experimental design is “ordered” so that all of the products created first have “Ingredient A_1 ” and all of the products created later have “Ingredient A_2 ,” then there is a good chance that there is a confounding between product age and ingredient. All of the older products have Ingredient A_1 . If storage time makes a difference, then the performance of the products may be as much due to storage time as to ingredient. However, the developer would never learn that directly.

Developing the Questionnaire

The questionnaire provides the mechanism by which the panelist can communicate with the researcher. Typically, the questionnaire comprises three types of questions:

1. *Sensory—amount of a characteristic*: The sensory characteristics should be easily understood, and should tap into appearance, aroma, taste/ flavor, and mouthfeel. The number of such characteristics that the consumer rates may be as few as 2–3 or as many as 20–30. Remember, however, that just because the consumer rates many characteristics, it does not mean that all of these characteristics are understood by the consumer (they follow orders), are relevant (consumers do not really know), or easy to discern in the product (empirical questions, answerable only when the data are analyzed). As an example, a sensory attribute might be phrased as follows for sweetness: Please rate the sweetness as you perceive it. Let the value of 0 reflect no sweetness, and let the value of 100 reflect extreme sweetness. Where on the scale would you rate this beverage?
2. *Liking—goodness/badness, accept/reject*: The liking rating may deal with an overall impression, in which the panelist is asked to consider everything about the product. This is “overall liking.” The liking rating may deal with attributes, in which the panelist rates the liking/disliking of each attribute (e.g., like appearance). The liking rating may even deal with more specific attributes, in which the panelist must focus on a specific sensory attribute (e.g., liking of the color of the product). As an example, the liking attribute might be phrased as follows: Rate how much you like the beverage overall. Let the value of 0 reflect that you hate the beverage. Let the value of 100 reflect that you love the beverage. Where on the scale would you rate how you feel about this beverage?
3. *Image—more complex cognitive attributes, such as refreshing*: Consumers can ascribe to beverages (and other food/drink products) a large number of characteristics that we would say are neither representations of sensory attributes nor liking. For example, attributes that have the notion of “image” are “refreshing,” “appropriate for evening,” “unique,” etc. It’s clear from this simple list that almost any relevant situation, emotion, or impression of a product can be turned into an image characteristic. Sensory researchers in the threes

of product description probably don't think often about using image characteristics because scientific research in descriptive analysis concentrates on sensory percepts. In contrast, look at any market research questionnaire and one will quickly find dozens of such image characteristics. For screening research, however, where the goal is to identify relevant product features, it is more useful to limit the number of image attributes in the questionnaire than to increase them, unless one is trying to link together the presence of a formula variable and an image characteristic. As an example, the image attribute might be phrased as follows for the attribute of refreshing: Rate how refreshing you feel the beverage to be. Let the value of 0 reflect that the beverage is not at all refreshing. Let the value of 100 reflect that the beverage is extremely refreshing. Where on the scale would you rate how refreshing this beverage seems?

Rating Scales

A continuing issue in questionnaires is the nature of the rating scale. How many points should the scale comprise? However, professionals often argue over issues that, on the surface appear trivial, but more deeply reflect different intellectual backgrounds and viewpoints. The rating scale is one of these issues that hint at a very profound set of differences.

1. Experimental psychologists and especially psychophysicists who study the relation between sensory perception and physical stimuli often opt for a ratio scale, such that ratios of ratings reflect ratios of perception. These researchers like to use the method of magnitude estimation (Stevens, 1975), which instructs participants to assign numbers to the stimuli so that the ratios of the ratings reflect ratios of perceived intensities. Thus, a 20 is assumed to reflect twice as much subjective intensity as a 10. Magnitude estimation and allied scales (e.g., the labeled magnitude estimation scale; Green et al., 1993) provide solid data that discriminate among products quite well, generate nice relations between physical stimuli and responses, and are thus favored by academic researchers. However, for practical applications, magnitude estimation scales may require a little extra fieldwork, especially for orienting the participants in how to use the scale (Moskowitz, 1977).

2. Food scientists like to use line scales, which require the participant to mark his or her perception of the product on a linear scale, anchored at both ends. This method is popular, especially when the researcher uses a computer to acquire the data. The method is not popular among market researchers.
3. Many food scientists and most market researchers use short, anchored fixed-point category scale (e.g., nine-point category scale for liking; five-point category scale for purchase intent, etc.). These scales are easy to use in practice, and generally, but not always, discriminate among products. However, the panelists often avoid the extremes of the scale, fearing that they will “run out of numbers.” This end-point effect is problematic, especially with the shorter scales. The problems are hidden but do not go away when the data from many participants are averaged to generate the mean. Furthermore, many researchers count the number of panelists who use a certain part of the scale (e.g., the top three scale points on a nine-point scale; the top two scale points on a five-point scale). They use the percent data rather than the metric data.
4. The authors have had good experience with anchored 0–100 scales. These are fixed-point category scales. However, the scales are easy to explain, easy to use, and quite discriminating. For the most part, the scales do not require any orientation in the field when the questionnaire is being answered. Most panelists have little problem understanding the scale or the meaning of the attributes.
5. Almost never in larger-scale modeling and optimization does the reader see paired comparison data with the dependent variable being the proportion of times a panelist chooses one product over another. Although paired comparison data are often used to measure performance of a test product against a market leader or the company’s current product, respectively, it’s quite rare to find paired comparison data used in product development.

Acquiring the Data—Field Execution of the Study

Generally, screening studies in RSM research involve a large number of products, most times created at the bench and not necessarily shelf stable. As a consequence, it is important to acquire data rapidly, while the products are still fresh, using field research techniques that can generate the data from a limited number of panelists. Each panelist

evaluates a relatively large number of the prototypes, sometimes as few as 6, but often as many as 12 or more, depending upon the nature of the fieldwork. The studies are done in a prerecruit fashion, so that the panelists are called ahead of time to participate, usually in groups of 10–25. This strategy, known as a “hall” test, or a “central location prerecruit,” enables the researcher to maintain control over the product, over the test situation, and over the panelist so that the test can be executed properly (Moskowitz, 1985). It also generates data that are reliable, and typically predicts results from home-use tests when both hall and home-use tests are run with the product prepared and used in the same way (Griffin and Stauffer, 1990).

For the beverage study, dealing as it did with 12 products and 2 controls (in-market products serve as benchmarks), every panelist evaluated a randomized 7 of the 14 test stimuli. The products were stored in a refrigerator to maintain proper temperature. Each panelist evaluated the 7 products in a totally randomized order, rating the product on a set of attributes. The evaluations were monitored by interviewers, with a five-minute break between samples. The entire interview took 90 minutes, for which the panelists were recruited to show up at particular times and paid for participation. A total of 120 panelists participated, generating approximately 60 ratings for each of the test products.

Data Analysis Using Two-Level Screening Designs

The initial pass through the data consists of taking the average of the ratings from the different panelists. The researcher may want to divide the panelists into different, mutually exclusive sets (e.g., gender, age). We may also want to assign panelists to other, overlapping groups such as products previously consumed in the past three months, and so on. Whatever criteria the researcher chooses, the data will look schematically like table 17.4. The rows of the table corresponding to the 12 products, and the columns correspond to the liking and sensory ratings. The numbers in the body of the table are the averages of the ratings.

From a practical perspective, the analysis of data should concentrate on the total panel and a few key subgroups. It is just simply too much data to look at all subgroups. Furthermore, the study comprised evaluation of the 14 different products on a large number of attributes. It makes little sense to look at the ratings of the products on

Table 17.4. Example of data from the beverage study.

| Formula variables | | | | | | | Mean attribute ratings from panelists | | | | | | |
|-------------------|---|---|---|---|-----|-------|---------------------------------------|-------|---------|------|--------|------------|--|
| | | | | | | | Liking | | Sensory | | | Image | |
| | | | | | | | Group | Group | | | | | |
| PROD | A | B | C | D | E-I | Total | 1 | 2 | Sweet | Tart | Flavor | Refreshing | |
| 1 | 1 | 1 | 0 | 1 | — | 44 | 53 | 35 | 46 | 41 | 40 | 45 | |
| 2 | 1 | 0 | 1 | 1 | — | 54 | 72 | 36 | 52 | 46 | 44 | 51 | |
| 3 | 0 | 1 | 1 | 1 | — | 46 | 69 | 23 | 44 | 44 | 50 | 50 | |
| 4 | 1 | 1 | 1 | 0 | — | 54 | 57 | 51 | 54 | 49 | 46 | 55 | |
| 5 | 1 | 1 | 0 | 0 | — | 52 | 72 | 32 | 51 | 46 | 45 | 62 | |
| 6 | 1 | 0 | 0 | 0 | — | 53 | 53 | 53 | 50 | 46 | 45 | 52 | |
| 7 | 0 | 0 | 0 | 1 | — | 55 | 66 | 44 | 49 | 47 | 47 | 53 | |
| 8 | 0 | 0 | 1 | 0 | — | 57 | 58 | 56 | 58 | 50 | 53 | 59 | |
| 9 | 0 | 1 | 0 | 1 | — | 53 | 57 | 49 | 52 | 49 | 52 | 53 | |
| 10 | 1 | 0 | 1 | 1 | — | 58 | 69 | 47 | 47 | 52 | 50 | 59 | |
| 11 | 0 | 1 | 1 | 0 | — | 56 | 49 | 63 | 55 | 58 | 55 | 64 | |
| 12 | 0 | 0 | 0 | 0 | — | 43 | 65 | 35 | 56 | 50 | 50 | 55 | |

Note: The table shows mean ratings from the panelists who rated the particular product.

attributes other than overall liking. The remaining attributes, whether sensory, liking, or image can be handled at the total panel level. It's not to say that there isn't valuable information in the analysis of subgroups for the different attributes. Rather, with limited time and with a limited budget, most of the valuable information will be obtained by looking closely at overall liking, and taking a broad view of the other attributes.

The easiest analysis to do with screening designs is so-called dummy variable regression. The phrase "dummy variable" means that the independent variables (the nine ingredients for our beverage) are coded as either 0 or 1. We can do this coding very easily by setting one of the two options as "0" and the other as "1." The coding is, of course, arbitrary and the decisions we make will not be affected by which of the ingredients we choose to be 0 and which we choose to be 1. However, convention is that if the two options are related by low/high or by absent/present, then the low/absent option is coded as 0, and the high/present is coded as 1. This coding convention makes it easy to understand the data and to relay the results. Following this coding convention, the values of -1 in

table 17.2 will be coded as “0,” and the values of “1” will remain as “1.” This convention prepares the data set for dummy variable regression, explicated below.

Dummy variable regression is a simple way to look at the data. The independent variables are all the 9 factors that we chose to vary. The dependent variable is a specific rating, for example, overall liking. We can either look at the raw data, which means that for each panelist we have 6 rows of data, corresponding to the 6 products that the panelist evaluated. With 100 panelists, this means we have 600 rows of data or 50 rows of data for each of the 12 beverages. An easier way to look at the data, which will give the same result, is to average the ratings from all of the panelists who evaluated a specific beverage. In that way, we will end up with 12 rows of data, and 9 independent variables, sufficient to run the regression analysis.

We see the results of this analysis in table 17.5. The regression model shows an array of parameters that tell the developer a lot about the beverages, with the most important parameters being the coefficients of the 9 variables, which tell us the effects of changing from option coded

Table 17.5. Models showing the effects of the nine variables on the ratings of overall liking for 12 products.

| Dep Var: LTOT N: 12 | | Multiple R: 0.99 | | | |
|--------------------------|----------------|-----------------------------------|-------------|---------|------|
| Squared multiple R: 0.97 | | Adjusted squared multiple R: 0.84 | | | |
| Effect | Coefficient | t | P (2 Tail) | | |
| CONSTANT | 43.00 | 23.31 | 0.00 | | |
| A | 0.83 | 0.71 | 0.55 | | |
| B | −2.50 | −2.14 | 0.17 | | |
| C | 4.17 | 3.57 | 0.07 | | |
| D | −0.83 | −0.71 | 0.55 | | |
| E | 1.50 | 1.29 | 0.33 | | |
| F | 3.17 | 2.71 | 0.11 | | |
| G | 5.50 | 4.71 | 0.04 | | |
| H | 2.17 | 1.86 | 0.20 | | |
| I | 4.17 | 3.57 | 0.07 | | |
| Analysis of variance | | | | | |
| Source | Sum-of-squares | df | Mean-square | F-ratio | P |
| Regression | 268.75 | 9 | 29.86 | 7.31 | 0.13 |
| Residual | 8.17 | 2 | 4.08 | | |

as “0” to option coded as “1.” Let’s review the results in detail, first schematically and then immediately by looking at the results for overall liking.

1. The dependent variable. Here the model looks at relating overall liking (LTot) from all of the panelists to the 9 independent variables.
2. The multiple R, which is a measure of goodness of fit. The multiple R is very high ($R = 0.99$). The reason for this very high value is purely statistical—there are 9 variables and an additive constant, or 10 parameters to be estimated, with only 12 observations. The screening design is highly unsaturated. Almost any random data with this condition would generate a good fit. If the researcher is worried about insufficient number of data points, and wants to be sure that the coefficients are truly significant, then the solution is to select a bigger screening design (e.g., 23 variables in 24 products), and simply work with the first 9 variables. The result will be a more robust model, albeit with much more effort.
3. The adjusted squared multiple R (adjusted R^2) corrects the goodness of fit results by taking into account the number of degrees of freedom (additional cases) that exist. The adjusted R^2 is 0.84, meaning that with such an easy-to-fit data set this performance is really not as perfect as we might have believed.
4. One of the key benefits of the screening design is that it allows the researcher to investigate many variables with relatively few runs or cases. For our study of 9 variables, we are using only 12 combinations. This means that there are very few degrees of freedom, or extra cases that we can use to “check” our model. The closer the number of variables is to the number of cases, the more perfectly the model will fit the data. This is not necessarily good for the robustness of the data. We want a situation where the model we fit is robust. In theory, we should have 20 or 30 cases with our 9 variables, not 12. On the other hand, it takes a lot of effort to make up these prototypes. Most developers balk at the additional effort. So we’re in a quandary that we solve expeditiously. On the one hand, we have 9 variables. We know we want solid data so we’re going to use a screening design, not just random selection. We know that we want to expend as little effort as possible, so we’re opting for 12 runs or combinations, not 20. Thus, we give up the robustness of the model, by

not having more cases (i.e., so-called degrees of freedom) to check our model. We would have been better with the 20 cases, but it's impossible to do that in the real world, and so we make the best of the situation.

5. The additive constant. This is the expected liking rating on the 0–100-point scale if all of the 9 variables are set to 0. For some variables, this means that the variable is missing from the beverage. For other variables, this 0 condition means that the variable is set at the option labeled 0. The additive constant can be thought of as being a baseline. For the total panel, the additive constant is 43, meaning that if all of the variables are set to the level “0,” then we expect the rating of liking to be 43. This is the baseline rating for liking. All comparisons will be from this baseline. The choice of the “0” condition is arbitrary. Every comparison is made against the “0” condition. However, when the researcher reconstructs the expected score for the alternatives chosen in the product, it won't matter which alternative was coded “1” and which was coded “0.”
6. Each of the 9 variables generates its own coefficient. Regression modeling generates an equation, comprising an additive constant and a coefficient for each of the 9 variables. The coefficient tells us the number of rating points that are added to the additive constant when the specific variable changes state from “0” to “1.” Thus, we see that the coefficient for the first variable (type of sweetener) is 0.83. This means that when that variable goes from state “0” (sweetener A) to state “1” (sweetener B), we gain only 0.83 points of liking. Not all coefficients are positive. Some coefficients are negative, such as cloud. This means that when the variable goes from state “0” to state “1” (i.e., when cloud shifts from absent to being present in the beverage), all other variables held constant, we actually lose 2.5 points on liking.
7. The developer can immediately see from the table of coefficients which particular variables make a difference in driving the response. However, it is important to keep in mind that the effects are relative—we are looking at the impact of changes from state “0” to state “1.” Of course, if all of the 9 variables were simply the addition of ingredients, then state “0” would be absent, state “1” would be present, and we could interpret the effects as the absolute change in degree of liking when the ingredient is added. However, some of these variables

Table 17.6. Coefficients showing the part-worth contribution of each of the nine independent variables, as it goes from state 0 to state 1.

| | Variable | LTot | LGroup1 | LGroup2 | Sweet | Tart | Flavor | Refresh |
|-----|--------------------------------|------|---------|---------|-------|------|--------|---------|
| Con | All variables held at 0 option | 43.0 | 64.5 | 33.2 | 54.0 | 47.7 | 48.3 | 53.0 |
| A | Sweetener B | 0.8 | 2.0 | −2.7 | −2.3 | −3.0 | −6.2 | −1.7 |
| B | Cloud | −2.5 | −4.3 | −3.0 | −1.7 | −0.7 | −0.2 | 0.0 |
| C | Lemon | 4.2 | 1.3 | 4.7 | 1.0 | 3.3 | 3.2 | 3.0 |
| D | Lime type B | −0.8 | 5.3 | −9.3 | −5.7 | −3.3 | −1.8 | −6.0 |
| E | Spice X | 1.5 | −9.3 | 10.0 | 2.0 | 0.3 | 0.2 | −1.7 |
| F | Spice Y type B | 3.2 | −1.0 | 5.0 | −0.3 | 1.7 | 0.5 | 4.3 |
| G | Health Ingred A | 5.5 | −6.3 | 15.0 | 0.0 | 4.0 | 2.2 | 2.3 |
| H | Health Ingred B | 2.2 | 2.7 | −0.7 | −1.7 | −0.7 | 2.2 | 2.0 |
| I | Health Ingred C | 4.2 | 4.0 | 2.0 | 3.0 | −0.7 | −0.5 | 1.3 |

Note: The additive constant is the expected rating of the attribute when all of the options are held at state 0. All changes are relative to that additive constant, and represent additions to the constant or subtractions from the constant.

such as sweetener represent variables that are simply changes in type of flavoring, meaning that the effect we are measuring is relative.

Looking at the results in table 17.6 for liking (total panel, two subgroups), for sensory attributes (sweet, tart, flavor) and for image (refreshing), the researcher now sees the part-worth contribution of each option, when the flavoring ingredient goes from state “0” to state “1.” It’s easy to see in a relative way which particular ingredients make a difference. Looking more closely at the subgroups will also tell us immediately whether the pattern that we see for the total panel is replicated in the subgroups. For example, an ingredient may make a difference for one group and not for another. The prudent product developer can now look at the contributions of the different product features to liking and decide which of the variables to choose (will it be level “0” or level “1” for each of the 9 variables). Furthermore, the regression model gives a sense of the degree of liking to be expected for any given profile of the 9 ingredients in the beverage.

The reader should keep in mind that it’s not the ingredient that makes the difference—consumer panelists do not think of ingredients.

Rather, it's the sensory change in the product that comes from changing the ingredient that makes the difference. To learn about how sensory changes drive liking, look at chapter 15 on category appraisal.

An Overview of Screening Designs

The foregoing section on the Plackett-Burman screening design shows us that it is quite possible to deal with many variables in an efficient way using experimental design. Despite the fact that the screening design only covers a small number of combinations from the many hundreds or thousands (9 variables alone generate 512 possible combination, i.e., 2^9), the screening design forces discipline on the development process, and allows for consumer input early on. Consumer input is important; all too often developers and marketers believe that somehow they have an innate knowledge of the consumer, perhaps by virtue of having worked with the product for many years or perhaps by virtue of being anointed and put into the marketing job. It is the proclivity of such experienced professionals to disdain empirical work at this early stage, averring very strongly that they intuitively understand what is to be done. The screening design promotes empirical work with consumers, with only slightly more effort than developers make in coming up with products to test in larger-scale studies.

There are some nagging issues, however, about screening designs that should be brought forth and dealt with.

1. *Can the wrong answers emerge, even with this disciplined approach?*

Those who have not had experience with experimental design are often worried that the disciplined approach will override what they believe to be the right answer, and force the creation of product, data from which will simply muddy the scene. The short answer to the question is “no.” It is highly unlikely that experimentation will come up with the wrong answer. It is more likely that the experimentation will reveal that none or perhaps only one of the product variables makes a difference, leading to the righteous indignation of those who felt that they knew the “right answer” all along. Of course, the data might mislead if the researcher uses a highly unsaturated design (few degrees of freedom) with few ratings behind the average. In that case, there is no way to ensure that the average is statistically robust. The problem is easily remedied by making more prototypes

(larger design, same number of independent variables), or by ensuring that the mean is more robust (more people on which the average is based).

2. *Why should I believe these results when the experimental design has covered only a part of the space, and not all of the possible combinations?* One of the most vexing issues in screening variables is the issue of partial data. Those who do not necessarily believe in experimental design often argue, from the other side of their mouth, that the approach cannot be valid because it fails to cover all of the alternative combinations. After all, goes the common reasoning, with 9 variables there are 512 combinations, so these 12 combinations cover a very small proportion of the total possible ($12/512 = 0.023$ or 2.3% of the possible combinations). The reality of the situation is much different. The screening design forces disciplined evaluation of different regions of the product “space.” Obviously, dealing with 2.3% of the combinations is not as good as dealing with 20% or more of the combinations. Yet, at least this disciplined evaluation generates data on which one can make a proper inference about what variables make a difference. Contrast this fact-based decision with opinion, which might be more persuasive emotionally but is far less cogent scientifically.
3. *How do I know I’m dealing with the right variables?* Errors of omission are often far more frequent than errors of commission. It’s not clear that simply testing a limited set of 9 variables will ensure that the developer is actually capturing the variables that make a difference. An easy way to answer this question either uses more variables (larger design) or runs the studies sequentially, throwing out nonperforming variables, keeping performing variables as constants, and trying out new variables in the subsequent designs
 - a. What about those cases wherein a variable has 3, 4, 5, or even 6 options? Quite often a variable can take on more than two states. For example, a flavor variable can be sourced from one of several different suppliers. Is it possible to deal in a screening design with several flavor options of one type of flavor, presumably equally intense levels? The answer is yes. What must be done in these cases is opt for a screening design with more variables (e.g., 15 variables in 16 runs), keep the variables down to the original 9, but for the ninth variable, which has four options, recode the independent variables in a simple way.

The “Bottom Line” for Screening Designs

As we see from the worked example, screening designs simply help choose among discrete alternatives. They do not find optimal levels, although they clearly identify which option is better, or whether the two options of a variable are equivalent. Nor do screening designs identify intermediate optima, perhaps even levels that were not tested but which are bracketed by levels that were tested. Finally, screening designs do not identify significant interactions among variables that could lead to synergisms or suppressions. Nonetheless, screening designs are powerful tools with which to sort through alternative levels. If the researcher can reduce the selection problem to pairs of options, then the two-level screening designs recommend themselves.

Product Optimization Designs

In the galaxy of product development methods, optimization designs hold the key position. With these optimization designs and research approaches, the product developer can accomplish many different objectives ranging from understanding how ingredients drive ratings, to optimizing a product subject to nonlinear constraints, and even reverse-engineering a formulation so that knowing the sensory or image profile can help determine what combination of formulation/process variables reproduce that subjective attribute profile.

Our case history continues the topic of beverages. The objective of the optimization is to more fully explore the space of alternative formulations, recognizing that the ingredients interact with each other and that for some continuous variables, the acceptance level may be a function both of interactions among variables, and of nonlinearities in the sensory-liking relation. These nonlinearities show themselves as optimal liking in the middle range of sensory perceptions (e.g., just an intermediate amount of perceived sweetness). From the viewpoint of product optimization, such nonlinearities manifest themselves as optimal levels in the midrange of formulations tested, that is, within the range tested and not at the extremes. Of course, if the researcher is sufficiently unlucky or better unwise as to test the wrong range of sweetener levels, producing in its wake the wrong levels of sweetness, then the optimal formulation for sweetener may emerge as one of the extreme levels.

The optimization study need not emerge directly from the screening design, and for the most part it rarely does. Screening studies show the formulation and the sensory attributes that seem to make a difference. Screening designs suggest ingredients, but not levels. However, when it comes time to do the optimization study, the developer identifies what he or she believes to be the key variables that make a difference. Such suggestions might come directly from the screening design, but the direct link between screening designs and optimization is generally not taken. More often than not, information and learning from the screening design will have been absorbed some months before, other prototypes explored, and then later on the developer will do a product optimization.

For the beverage study, the developer realized that there were five variables that appeared relevant, both from the screening study and from other knowledge about the product. These were carbonation, depth of coloring agent, sweetener, acid, and added flavoring X. Some of these variables were deemed to be more relevant than others, but the less-relevant ingredients (e.g., acid level) were believed to affect sweetness and flavor intensity, and were thus included in the consideration. Only one of the variables, flavoring X, had been previously explored in the screening design. The data from that design led to deeper development work with flavoring X.

Five variables mean that the researcher has to use some type of experimental design that can deal with five variables simultaneously. However, simply choosing the experimental design from a set of prepared designs would not necessarily do until the different considerations are made explicit.

1. Each of the variables was to be continuously variable over a range.
2. The range was to extend sufficiently far so that the two extreme levels would generate noticeably different products, everything else held fixed. This is an important consideration in product development and optimization. All too often developers with a great deal of expertise in a product category such as beverage feel that they “know” what is going to work. When these experts hear the word “reasonable range,” they immediately opt for a narrow range that they think is large in the mind of the consumer, but which turns out to be small so that the sensory differences of the extremes (highest level, lowest level) are negligible.

3. R&D said that it would be able to make up to 50 prototypes without problem using their current equipment, but would not be able to make more than 50 prototypes without some type of external help. The product developer pointed out that it would be best to have the product prototypes created under the same conditions for comparability. This limit in the number of prototypes was fine with management because the importance of the project was deemed to be “moderate,” so the 50 products would constitute a reasonable upper limit.
4. Management did not want to spend more than a predefined amount of money, which constrained the total project cost. A quick analysis of fieldwork suggested that there was only enough money for about 3000 product evaluations in total, defined as number of products to be tested by the number of ratings per product. The two options allowed within that limit of 3000 total evaluations were to make more prototypes but test with fewer panelists, or to make fewer prototypes but test each with more panelists.
5. Armed with those constraints, it appeared that with five variables deemed relevant, with the need for nonlinearities and interactions to be captured, a three-level design in five variables would be necessary.

The Experimental Design

With five variables, each of which is to be continuous, and with the desire to study nonlinearities and pairwise interactions, almost always the case, the researcher selected the Box Behnken design. This design and its variants appear schematically in table 17.7. There are three options that the researchers could have followed:

1. Full replicate. The number of combinations here is $2^5 + (2 \times 5) + 1$ or 43
2. Half replicate. The number of combinations here is $2^{(5-1)} + (2 \times 5) + 1$ or 27
3. Quarter replicate. The number of combinations here is $2^{(5-2)} + (2 \times 5) + 1$ or 19

The optimum study would comprise the full replicate. In that way, the researcher could identify all pairwise interactions if they exist. However, the full replicate requires 43 combinations. A half replicate was more

Table 17.7. Five-level Box Behnken design and alternative fractions.

| PROD | A | B | C | D | E | Full | Half | Quarter |
|------|----|----|----|----|----|------|------|---------|
| 1 | 1 | 1 | 1 | 1 | 1 | x | x | x |
| 2 | 1 | 1 | 1 | 1 | -1 | x | | |
| 3 | 1 | 1 | 1 | -1 | 1 | x | | |
| 4 | 1 | 1 | 1 | -1 | -1 | x | x | |
| 5 | 1 | 1 | -1 | 1 | 1 | x | | |
| 6 | 1 | 1 | -1 | 1 | -1 | x | x | x |
| 7 | 1 | 1 | -1 | -1 | 1 | x | x | |
| 8 | 1 | 1 | -1 | -1 | -1 | x | | |
| 9 | 1 | -1 | 1 | 1 | 1 | x | | |
| 10 | 1 | -1 | 1 | 1 | -1 | x | x | |
| 11 | 1 | -1 | 1 | -1 | 1 | x | x | x |
| 12 | 1 | -1 | 1 | -1 | -1 | x | | |
| 13 | 1 | -1 | -1 | 1 | 1 | x | x | |
| 14 | 1 | -1 | -1 | 1 | -1 | x | | |
| 15 | 1 | -1 | -1 | -1 | 1 | x | | |
| 16 | 1 | -1 | -1 | -1 | -1 | x | x | x |
| 17 | -1 | 1 | 1 | 1 | 1 | x | | |
| 18 | -1 | 1 | 1 | 1 | -1 | x | x | |
| 19 | -1 | 1 | 1 | -1 | 1 | x | x | |
| 20 | -1 | 1 | 1 | -1 | -1 | x | | x |
| 21 | -1 | 1 | -1 | 1 | 1 | x | x | |
| 22 | -1 | 1 | -1 | 1 | -1 | x | | |
| 23 | -1 | 1 | -1 | -1 | 1 | x | | x |
| 24 | -1 | 1 | -1 | -1 | -1 | x | x | |
| 25 | -1 | -1 | 1 | 1 | 1 | x | x | |
| 26 | -1 | -1 | 1 | 1 | -1 | x | | x |
| 27 | -1 | -1 | 1 | -1 | 1 | x | | |
| 28 | -1 | -1 | 1 | -1 | -1 | x | x | |
| 29 | -1 | -1 | -1 | 1 | 1 | x | | x |
| 30 | -1 | -1 | -1 | 1 | -1 | x | x | |
| 31 | -1 | -1 | -1 | -1 | 1 | x | x | |
| 32 | -1 | -1 | -1 | -1 | -1 | | | |
| 33 | 1 | 0 | 0 | 0 | 0 | | | |
| 34 | -1 | 0 | 0 | 0 | 0 | | | |
| 35 | 0 | 1 | 0 | 0 | 0 | | | |
| 36 | 0 | -1 | 0 | 0 | 0 | | | |
| 37 | 0 | 0 | 1 | 0 | 0 | | | |
| 38 | 0 | 0 | -1 | 0 | 0 | | | |
| 39 | 0 | 0 | 0 | 1 | 0 | | | |
| 40 | 0 | 0 | 0 | -1 | 0 | | | |
| 41 | 0 | 0 | 0 | 0 | 1 | | | |
| 42 | 0 | 0 | 0 | 0 | -1 | | | |
| 43 | 0 | 0 | 0 | 0 | 0 | | | |

Note: The variables are coded as +1 for high, 0 for medium, and -1 for low.

in keeping with the original management constraints. The half replicate design misses or confounds some of the pairwise interactions, but still gets most of the information with the 27 prototypes. The quarter replicate, with 19 prototypes, is clearly the most cost efficient, but misses too many interactions and is simply too sparse for this study. We see the differences among these three designs in table 17.7. It's simply a matter of which combinations in the 2^5 portion will be left out. Box et al. (1978) show fast and easy ways to construct these fractional designs.

Questionnaire Attributes, Scales, Field Considerations

The questionnaire, scales, and field execution were similar to that discussed with the screening design. The actual study comprised 27 prototypes, along with 3 in market competitors (benchmarks), for a total of 30 samples. The products were served in a totally randomized order to the panelists. The original design called for 100+ ratings per product, with each panelist evaluating a randomized 15 of 30 products over two sessions, conducted on two consecutive days. This necessitated 200 panelists for the entire study, a base size fairly typical in such optimization studies. The objective of the study is to obtain solid data for each of the 27 design points, which would then allow a model to be created for that design. Previously reported results suggest that the data for products begin to reach an equilibrium and settle into high reliability after around 30–40 ratings per product are obtained. With 200 panelists, each of the products generated about 100 ratings, providing very reliable data for total panel, and the ability to read data from two or three comparable subgroups of base size 30 or so. Examples of these subgroups include age, income, brand used most often, gender, and so forth. The study was run in four markets, to represent different groups of individuals, with perhaps different responses to products.

Data Preparation

Correctly laying out the data for the product optimization study goes a long way toward ensuring that the data will be analyzed correctly. From long experience, the senior author (HRM) has observed that a lot of the insights to be gained come from the correct analysis of data. Furthermore, correct analysis is generally facilitated by a good initial setup of the data. Many researchers have observed the same thing in

their statistical analyses; most of the time the effort they spend is on setting up the data in proper form for statistical analysis. Often, reformatting the data takes hours; the corresponding statistical analysis takes seconds and minutes. As the researcher shapes and reshapes the data matrix for the different statistical analyses, this seemingly clerical task teaches a lot about the results, perhaps by osmosis and by sheer exposure to the results. The researcher gets to experience the data first hand. When working with means rather than with raw data, the reshaping exercise for data preparation forces the researcher to look at the inputs to the model. Such data inspection often reveals errors, problems in the data, and just as often generates its own brand of insights about the results.

The standard analysis for optimization data is regression analysis, generally of the simple type called ordinary least squares (OLS). We used OLS in the analysis of data from the screening design. Our data matrix is a bit more complicated here.

The data matrix for optimization needs to be set up in such a way as to allow for nonlinearities and interactions. Thus, we might conceive of the data matrix as a series of columns for our five variables and rating attributes. We see a screen shot of these data in Excel format in figure 17.6, with the data arrayed in the way it would be normally set up for most regression programs.

Developing the Model for an Attribute—What Terms to Use and Why

Creating the model relating independent and dependent variables is very simple with today's off-the-shelf regression programs. The data for the beverage study have already been set up in the appropriate format for regression (see fig. 17.4). We will discuss regression as if it were being done with the standard software, although it's easier to do the modeling and the optimization by writing one's own software. For example, the senior author has used a suite of home-written programs called simply the Forestepper, the Product Optimizer, and the GoalFitter to do all of the work. These programs do all the data storage and manipulation, making the modeling exercise far easier.

The first step in modeling decides which of the attributes to use as the dependent variable and which terms to use as the independent variables. All of the relevant terms are present in the database, so in

| | A | B | C | D | E | F | G | H | I | J | K | L | |
|----|------|-------|--------|------|--------|--------|------|--------|--------|---------|--------|--------|-----|
| | PROD | Iacid | Isweet | ICO2 | IFlavX | IFlavY | Cost | Ltotal | Laroma | Lflavor | Lmouth | Saroma | Sca |
| 2 | 1 | 3 | 3 | 3 | 1 | 3 | 90 | 59 | 55 | 60 | 66 | 47 | |
| 3 | 2 | 3 | 3 | 1 | 3 | 3 | 92 | 61 | 59 | 59 | 60 | 51 | |
| 4 | 3 | 3 | 3 | 1 | 3 | 1 | 80 | 63 | 57 | 63 | 69 | 54 | |
| 5 | 4 | 3 | 1 | 3 | 3 | 3 | 73 | 57 | 63 | 55 | 68 | 55 | |
| 6 | 5 | 3 | 1 | 3 | 3 | 1 | 61 | 56 | 62 | 56 | 70 | 56 | |
| 7 | 6 | 3 | 1 | 1 | 3 | 1 | 58 | 50 | 54 | 49 | 53 | 51 | |
| 8 | 7 | 3 | 1 | 1 | 3 | 3 | 70 | 48 | 42 | 48 | 42 | 37 | |
| 9 | 8 | 1 | 3 | 3 | 3 | 3 | 87 | 65 | 63 | 63 | 70 | 57 | |
| 10 | 9 | 1 | 3 | 3 | 3 | 1 | 75 | 68 | 61 | 69 | 77 | 57 | |
| 11 | 10 | 1 | 3 | 3 | 1 | 1 | 70 | 65 | 55 | 64 | 71 | 47 | |
| 12 | 11 | 1 | 3 | 1 | 1 | 3 | 79 | 50 | 48 | 53 | 45 | 38 | |
| 13 | 12 | 1 | 1 | 3 | 1 | 3 | 60 | 49 | 50 | 48 | 55 | 45 | |
| 14 | 13 | 1 | 1 | 3 | 1 | 1 | 48 | 56 | 52 | 53 | 61 | 46 | |
| 15 | 14 | 1 | 1 | 1 | 3 | 3 | 62 | 47 | 48 | 47 | 47 | 51 | |
| 16 | 15 | 1 | 1 | 1 | 3 | 1 | 50 | 56 | 50 | 57 | 51 | 48 | |
| 17 | 16 | 1 | 1 | 1 | 1 | 1 | 45 | 50 | 43 | 49 | 42 | 39 | |
| 18 | 17 | 3 | 2 | 2 | 2 | 2 | 74 | 54 | 57 | 52 | 62 | 48 | |
| 19 | 18 | 1 | 2 | 2 | 2 | 2 | 66 | 66 | 57 | 66 | 64 | 49 | |
| 20 | 19 | 2 | 3 | 2 | 2 | 2 | 81 | 67 | 59 | 67 | 68 | 49 | |
| 21 | 20 | 2 | 1 | 2 | 2 | 2 | 59 | 46 | 53 | 44 | 50 | 44 | |
| 22 | 21 | 2 | 2 | 3 | 2 | 2 | 71 | 73 | 63 | 73 | 74 | 52 | |

Figure 17.6. Screen shot of the data in Excel format prior to the creation of square terms and cross terms. Only partial data are shown due to the size of the data file. The screen shot shows the product ID (Prod), the five ingredients and their levels (prefaced by the letter I), the cost of goods, the liking ratings (prefaced by the letter L), and the sensory ratings (prefaced by the letter S).

today's PC-based statistical programs, the choice becomes a matter of "point and click." Let us take the attribute of overall liking (coded as LTot, or Liking Total). When we do the modeling, we take into account the considerations enumerated below:

1. We know that we have five independent variables. Let us force all of those into the equation because we believe that they drive interest. We now have five independent variables, A,B,C, D, and E, respectively. If one of the five variables does not covary with acceptance or another attribute, then the equation will show a coefficient close to 0 for that specific variable. Thus, in a sense we can't really "lose" by forcing in the linear value of the variable.

2. We also know that the relation between liking and formula variables tends to follow a curve. It's rarely a straight line (Moskowitz, 1981). The real question here is whether we want to force in the square terms (and capture any nonlinearity that exists), or simply allow the square terms to enter the equation if the square term can pass statistical muster, and add significant predictability to the equation. The authors have tried both. Despite the fact that it may rankle traditional statisticians, we suggest that a productive analysis will come from *forcing in the square terms, even if they are not statistically significant*. We now have forced in another five independent variables, A^2 , B^2 , C^2 , D^2 , and E^2 , respectively. Generally, a lot of the variability in the data comes from the linear terms (A, B, C, D, E). Some, but not much additional predictability comes from the square terms. However, if there is any curvilinearity in the ingredient-rating relation, the square term will allow that curvilinearity to make itself known.
3. We are now left with the interaction terms. Most of the predictability of the equation has already been accounted for by the linear terms (greater part), and by the quadratic or square terms (lesser part). However, from time to time there are very strong pairwise interactions. We can set the statistical level of the interaction to allow a number of interactions to enter the equation, if and only if those terms add a lot more predictability once the linear and square terms have done their job. The rationale for allowing the interaction term to enter is that it accounts for variation in the data that was not accounted for by linear or square terms. We typically set this criterion to be reasonable ($F > 2$ or some other simple criterion).
4. It should be clear from the foregoing three steps that the process of creating a mathematical model using experimental design is not completely dictated by statistical considerations "engraved in stone." Rather, when we create models, we make some assumptions about the relation between the independent and the dependent variables, force in some relevant predictor terms, and allow the remaining terms to enter.
5. We follow this strategy for all of the variables except cost of goods. We know ahead of time that cost of goods is linearly related to the ingredients. There aren't nonlinearities in cost of goods (at least nonlinearities that should concern us), nor should we concern ourselves that ingredients interact with each other when cost is an issue. So,

for the cost of goods equation, we simply use the linear terms A, B, C, D, E.

6. Most regression programs now have the capability of estimating the parameters of the equation in one of two ways.
 - a. The dependent variable need not take on the value 0 when the independent variables are all 0. We opt for that alternative. The regression program assumes that we are going to have an equation with an additive constant.
 - b. The dependent variable takes on the value 0 when the independent variables are all 0. We do not opt for that alternative. If we did, then we would instruct the program to estimate the coefficients, making sure that the additive constant would be 0.
 - c. Options a and b generate different coefficients. Option a, which uses additive constant, does not force the model to conform to an additional condition, called “passing through the origin.” Option b does.

Result from Modeling

We get a sense of the results from looking at the equations. By themselves, the equations are simple expressions showing the quantitative relation between the stimulus levels (coded as 1–3) and the attribute ratings. We really don’t learn very much from inspecting the equations themselves, other than the fact that some equations don’t have interaction terms, other equations do have interaction terms, some equations fit the data better (as shown by the multiple R^2 statistic), whereas other equations fit the data poorly. By and large, we will find that most of the equations do a reasonably good job fitting the results. We see some of these results in table 17.8. We should keep in mind, however, that equations themselves, while summarizing relations among variables, really do not give the developer the guidance that is needed. Such information will be provided next in the sensitivity, optimization, and reverse engineering steps.

Using the Model to Understand Sensitivity—Changes of Attributes with Ingredients

One of the most important benefits of an RSM project is the ability to explore how an array of attributes changes with known changes in a

Table 17.8. Summary of some equations.

| | Dependent variable | | | |
|--------------------------|--------------------|---------|--------|----------|
| | Ltotal | Lflavor | Saroma | Isophist |
| Multiple R ² | 0.83 | 0.81 | 0.74 | 0.76 |
| Constant | 32.18 | 32.87 | 26.53 | 21.16 |
| Coefficients of equation | | | | |
| Linear terms | | | | |
| Iacid | −13.80 | −14.07 | −1.39 | −7.11 |
| Isweet | 6.68 | 7.33 | 8.71 | 18.07 |
| ICO2 | −18.79 | −27.21 | 4.90 | −22.33 |
| IFlavX | 50.47 | 56.87 | −11.02 | 40.30 |
| IFlavY | −8.70 | −8.55 | 10.21 | −8.75 |
| Square terms | | | | |
| Iacid*Iacid | 3.18 | 3.15 | 0.22 | 1.59 |
| Isweet*Isweet | −0.32 | −0.35 | −1.78 | −3.41 |
| ICO2*ICO2 | 5.68 | 7.65 | −0.28 | 6.59 |
| IFlavX*IFlavX | −11.82 | −13.35 | 4.22 | −8.91 |
| IFlavY*IFlavY | 1.68 | 1.65 | −2.78 | 1.59 |

Note: Only linear and square terms are shown. No pairwise interaction terms emerged as being statistically significant, so they were not included in the equation.

physical stimulus. This type of thinking, informed by psychophysics, provides insights into the dynamics of a product. For example, as sweetener increases, what is to be expected? If all other formulation variables are held constant, then we expect the perceived sweetness to increase, and we expect the perceived tartness or sourness of the beverage to decrease. We form these expectations based upon our knowledge of how sensory attributes covary; increases in sweetness tend to come at the expense of decreases in tartness.

Some of the real understanding from RSM comes from this sensitivity analysis or dose-response analysis. Since we have the equation, we can understand which particular ingredients drive an attribute, holding all other ingredients constant. We don't really know how two ingredients combine to drive the attribute, but the learning from one ingredient is far more than the developer typically gets from other types of research. We also learn how changing an ingredient changes the profile of all of the attributes, including liking, sensory, and image. This is also a key piece of learning.

Table 17.9. How concentration of an ingredient in the carbonation drives overall liking, all other ingredients held constant at the middle level, 2.0 (top panel), and how level of sweetener drives ratings, all other ingredients held constant at the middle level, 2.0.

| Level of the ingredient versus overall liking | | | | | | | | |
|---|-----|-----|-----|-----|-----|-----|-----|--------------------|
| Level of ingredient | 1.0 | 1.3 | 1.7 | 2.0 | 2.3 | 2.7 | 3.0 | Pattern |
| Acid | 62 | 60 | 58 | 58 | 57 | 58 | 60 | Slight U |
| Sweetener | 52 | 54 | 56 | 58 | 59 | 61 | 63 | More is better |
| Carbonation | 59 | 57 | 57 | 58 | 59 | 63 | 67 | More is better |
| Flavoring X | 42 | 50 | 55 | 58 | 57 | 54 | 49 | Inverted U |
| Flavoring Y | 61 | 60 | 58 | 58 | 57 | 57 | 57 | Downward asymptote |

| Level of sweetener | | | | | | | | |
|--------------------|-----|-----|-----|-----|-----|-----|-----|------------------|
| | 1.0 | 1.3 | 1.7 | 2.0 | 2.3 | 2.7 | 3.0 | |
| Cost | 59 | 63 | 66 | 70 | 74 | 77 | 81 | Linear increase |
| Ltotal | 52 | 54 | 56 | 58 | 59 | 61 | 63 | Increase |
| Laroma | 53 | 53 | 53 | 54 | 55 | 56 | 58 | Increase |
| Lflavor | 50 | 53 | 55 | 57 | 59 | 60 | 62 | Increase |
| Lmouth | 54 | 56 | 58 | 60 | 62 | 64 | 65 | Increase |
| Saroma | 44 | 46 | 47 | 48 | 48 | 48 | 48 | Upward asymptote |
| Scarbon | 48 | 52 | 55 | 57 | 58 | 57 | 55 | Inverted U curve |
| Staste | 59 | 62 | 64 | 65 | 66 | 66 | 66 | Upward asymptote |
| Stypflav | 48 | 52 | 55 | 56 | 57 | 56 | 55 | Upward asymptote |
| Ssweet | 44 | 43 | 44 | 45 | 48 | 52 | 58 | Increase |
| Start | 46 | 45 | 45 | 44 | 42 | 40 | 38 | Decrease |
| Safter | 39 | 41 | 42 | 42 | 41 | 39 | 36 | U curve |
| Irefresh | 53 | 55 | 56 | 58 | 59 | 60 | 60 | Upward asymptote |
| Isophist | 43 | 47 | 49 | 51 | 52 | 53 | 52 | Upward asymptote |

Let's look at an example of such sensitivity analysis shown in table 17.9. We could plot the data to show the curve relating changes in physical level to changes in response, but the table is just as instructive. Rather than focusing on any particular attribute, the reader should simply look at the data and try to summarize the pattern. The mathematical modeling that generates a regression equation also masks the natural variability in the data, replacing such variability with a simplified curve. One nice result is that the user doesn't have to contend with noisy data. Rather, the user simply needs to look at the relation and give

a verbal summary such as that shown on the right-hand side of table 17.9. It is important to keep in mind that if there are any interactions, changing the level of the other ingredients could affect the nature of the attribute-vs-ingredient curve.

Optimizing Acceptance Without and With Imposed Constraints

Most companies used RSM in order to identify optimal formulations. These formulations are those that generate the highest expected rating on an attribute (e.g., liking), while satisfying certain explicit and implicit constraints. An explicit constraint is defined as a specific range of ingredients, that is, the independent variables, within which the product formulation must lie. The reason to call the constraint explicit is that we are making sure that the optimization program remains explicitly within the ranges specified. There is no search outside the explicit range tested in the study. In contrast, implicit constraints are other dependent variables that act as limits. For example, we can require that the optimal product not have a cost of good above a certain maximum. We are free to search anywhere within the explicitly defined region of ingredients, but we have to make sure for each option we find that the cost is within our limits. We do this by estimating the cost of goods for each possible solution, and then either considering that solution because it satisfies the implicit constraints, or moving on to another alternative formulation. It is difficult in the most general of cases to know whether a potential product formulation obeys the implicit constraints ahead of time, until the formulation is specified and the values of the implicit constraint are then computed.

We can get a sense of the different optima from table 17.10. We specify the explicit constraints ahead of time, that is, the range tested in the study, but we could narrow that range if we wanted. Then we also specify the implicit constraints. We may choose not to impose any implicit constraints, or impose as many as we wish, up to the number of dependent variables for which we have developed equations. Thus, there can be one, two, three, or more implicit constraints. Obviously, with everything else held constant, the greater the number of implicit constraints that we impose on the optimizer program in its search for a new product, the smaller the potential region of viable products might be, and in fact in some cases, we may discover that no viable formula exists because the implicit constraints effectively eliminate any viable set of formulations

Table 17.10. Alternative formulation optima for beverages subject to implicit constraints imposed on the product.

| | Best | Sweet<50 | Cost<60 | Cost<50 |
|----------|------|----------|---------|---------|
| Iacid | 1.00 | 1.00 | 1.00 | 1.00 |
| Isweet | 3.00 | 2.31 | 1.85 | 1.21 |
| ICO2 | 3.00 | 3.00 | 3.00 | 1.00 |
| IFlavX | 2.12 | 2.19 | 2.08 | 2.10 |
| IFlavY | 1.00 | 1.00 | 1.00 | 1.00 |
| Cost | 73 | 65 | 60 | 50 |
| Ltotal | 80 | 77 | 74 | 63 |
| Laroma | 67 | 64 | 62 | 52 |
| Lflavor | 82 | 78 | 75 | 64 |
| Lmouth | 82 | 79 | 76 | 53 |
| Saroma | 51 | 52 | 50 | 41 |
| Scarbon | 66 | 70 | 67 | 47 |
| Staste | 67 | 68 | 65 | 57 |
| Stypflav | 62 | 65 | 63 | 51 |
| Ssweet | 60 | 50 | 46 | 41 |
| Start | 38 | 42 | 44 | 46 |
| Smouthfl | 12 | 14 | 15 | 20 |
| Safter | 31 | 37 | 38 | 32 |
| Irefresh | 74 | 72 | 71 | 62 |
| Isophist | 70 | 70 | 68 | 55 |

Note: The objective was to maximize overall liking (Ltot), subject to constraints on either sweetness or on cost of goods.

that could satisfy the implicit constraints simultaneously. Furthermore, by imposing implicit constraints, we may force the optimizer to come up with a formulation that doesn't quite score particularly well. We can see this in the case of imposing cost constraints; some cost constraints generate quite poor performing products, simply because there are no high scoring products within the region bounded by these constraints.

Once the optimization algorithm searches through the many tens of millions of alternative formulations and identifies the combination that is the "highest," subject to constraints, it is now possible to identify the expected rating profile of this optimum product. One of the earliest steps in the optimization analysis was modeling, which created a set of equations relating the ingredients to the ratings. Once the ingredients are identified, the optimization program plugs these ingredients into each

equation, one equation at a time, and estimates the likely rating. One value emerges for each dependent variable.

Reverse Engineering

Reverse engineering refers to a method by which the researcher begins with an objective to match, for example, a response or rating profile, and then searches among the alternative ingredient combinations to identify the specific combination that generates this profile, or comes as close as possible to this profile. The rationale behind reverse engineering is that once the profile is specified, it becomes a simple matter of searching among many alternatives to discover the proper set of ingredients.

Where does the profile come from? Well, anyone who has ever worked in a company knows that quite often the pressure is put on product development to change the formulation in order to use a less-expensive ingredient, or even just to reduce the cost of the ingredients by decreasing the level of the most important ingredient. Suppose that the developer is working with some “gold standard product,” that is, a product that is deemed to be the best or the most representative product of its type. As is always the case, business realities intrude and the developer finds that there is an entirely new set of ingredients that must be used in light of the new cost issues. Yet, it’s important to develop a product whose sensory profile is similar to that of the gold standard. Anyone tasting the two products side by side will immediately see that they are different, so it’s not a question of precisely “matching” the gold standard—which cannot be done with the new formulation. Rather, it’s a question of being qualitatively similar, of similar sensory profile. In this situation, reverse engineering gets the developer closer to the new profile fairly quickly.

Another use of reverse engineering is to interrelate sensory attributes from consumers, from experts, and from objective measures from machines. Suppose in the development program, the researcher submits the prototypes to consumers to get their sensory profiles, to experts who use expert language to profile the products, and also to machines designed to measure the physical properties of the samples. Rather than simply working with only five or so consumer attributes, as we’re doing here, the developer might be working with an additional 20 expert attribute scales, and perhaps 10 physical measures, as well as with perhaps 30 consumer attributes. It’s still possible to create a big product model,

Table 17.11. Results from reverse engineering.

| Goals and constraints to be satisfied | | | | |
|---|------------------------------|--------------------------------------|---------------------------------------|--|
| | A fit an image profile | B fit a mid- intensity profile | C fit a lower intensity profile | D fit a lower intensity profile but make liking higher (>65) |
| Ltotal | | | | >65 |
| Saroma | | 60 | 55 | 55 |
| Scarbon | | 60 | 55 | 55 |
| Staste | | 60 | 55 | 55 |
| Stypflav | | 60 | 55 | 55 |
| Ssweet | | 55 | 45 | 45 |
| Irefresh | 65 | | | |
| Isophist | 65 | | | |
| Formula levels satisfying the goals and constraints | | | | |
| Iacid | 1.00 | 1.00 | 1.00 | 1.00 |
| Isweet | 2.17 | 2.81 | 1.06 | 1.03 |
| ICO2 | 3.00 | 3.00 | 2.81 | 2.99 |
| IFlavX | 3.00 | 1.55 | 1.87 | 1.82 |
| IFlavY | 1.00 | 2.03 | 1.99 | 1.88 |
| Expected cost and rating profiles | | | | |
| Cost | 66 | 75 | 56 | 56 |
| Ltotal | 67 | 72 | 62 | 65 |
| Laroma | 61 | 64 | 60 | 62 |
| Lflavor | 67 | 73 | 62 | 65 |
| Lmouth | 76 | 70 | 62 | 63 |
| Saroma | 60 | 50 | 48 | 48 |
| Scarbon | 81 | 61 | 55 | 56 |
| Staste | 75 | 63 | 59 | 58 |
| Stypflav | 75 | 57 | 54 | 53 |
| Ssweet | 43 | 55 | 45 | 45 |
| Start | 45 | 36 | 45 | 43 |
| Safter | 49 | 34 | 38 | 36 |
| Irefresh | 65 | 68 | 61 | 64 |
| Isophist | 65 | 62 | 53 | 56 |

relating the ingredients to the consumer ratings, the expert ratings, and the instrumental measures. There will be many more equations, one equation for each dependent variable, whether that be from consumer, from expert, or from instrument, respectively. This time, however, if the developer has a profile from the experts, it becomes possible to discover through reverse engineering the combination of ingredients that generates that profile. Furthermore, once the developer discovers that set of ingredients, it's a simple matter to estimate the full profile of ratings from consumers, experts, and instruments. Thus, the developer has a fully integrated system, interrelating ingredients, consumer data, expert data, and instrumental data. Profiles in any one of the four domains (ingredients, consumer, expert, instrument) can be related to profiles in the other three domains.

As an example of some reverse engineering, let's finish this section on optimization with some tabled results. We've used the same set of equations generated in table 17.8. This time, however, we specify some sensory profiles and some image profiles as "targets" or goals to be matched. The reverse-engineering program searches through the ingredient space to identify the combination of ingredients generating this target profile, or at least come as close as possible. After having discovered the combination of ingredients that generate a similar profile, we use that combination of ingredients to estimate the full sensory attribute profile of the beverage. As we can see from table 17.11, it's not always possible to "hit the mark." This failure to be exact comes from two causes. One cause is that the goals may not be 100% mutually compatible. For example, we may want a very sweet and a very tart beverage. They don't coexist; we can have one without the other. The second is that we may have reached the limits of the ingredient range, and the actual solution to the reverse engineering problem may lie outside the explicit constraints that we have imposed on ourselves. By not allowing the search to move beyond the explicit constraints, we force ourselves to come up against a barrier that we cannot pass.

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Chapter 18

ACCELERATING AND OPTIMIZING NEW FOOD PRODUCT DESIGN AND DEVELOPMENT—STATUS AND STATE OF THE INDUSTRY: DO YOU RENT OR BUY?

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J. C. Huang, and Witoon Prinyawiwatkul*

Why Read This Chapter?

Why not?

We all want to work for innovative companies. There is a culture of excitement, opportunity, freshness and success that these companies exude. Innovation can set a company apart from its competition, enhance the value of the company if it is publicly held and the halo that the innovation concept provides tends to continue to increase the gap in public perceptions about the company.

—Larry Wu, author of chapter 6 of this book

In “Eager Sellers and Stony Buyers,” John Gourville quotes Ralph Waldo Emerson regarding how the world will beat a path to one’s door if they can build a better mousetrap. Gourville laments that today marketers only wish their innovations were that simple (Gourville, 2006). The dialogue we hope you have just finished in this book, *Accelerating New Food Product Design and Development*, has brought you

voices of many people who are practicing innovation, creativity, design, and development in the food industry today. We have attempted to capture their voices for you as a learning tool. We are instructed that the food technologist is a very critical component of food product development success (Stewart-Knox and Mitchell, 2003). As we reflect on the dialogue our authors have provided, the concept of communicating and sharing one's point of view is clear. All of our authors struggle with the balance between the routine and innovation daily. That is part of their job and probably yours. This book should be about going fast (accelerating) and doing the best (optimizing). But for what? For the special, the extraordinary, the innovation or for the everyday, the ordinary?

But why does it matter? It matters because we believe it will lead to business success. We are told that it will lead to business success (Earle, 1997). Business success can lead to financial reward for the company and its employees. Financial reward can lead to a more comfortable life and recognition and reward and

Let's stop a moment and reflect. What the research into innovation suggests is the following:

1. Wu's comments in the first paragraph summarizes much of the research. From a *Business Week*/Boston Consulting Group (BCG) survey (McGregor, 2006), business people can easily name companies they feel are innovative. What is fascinating about this is that of the top 25, there are NO food companies. The only one that comes close to food is Starbucks and they say they are not a food company! Every other company is oriented to technology, automotive, travel, and design. Does that mean that the food industry is just very behind or that innovation is different for food? And once a company is recognized as innovative, does it become an immutable truth? Or is innovation or almost everything we do related to some imprinting on all of us busy people, who then default to what we can recall (memory, either top-of-mind or deeply anchored)? Table 18.1 compares a number of reported measures from popular business publications over a period of about a year. It makes a case for admiration (as measured by the testing vehicle) and innovation having a relationship. However, we do not know if admiration comes because we think the companies are innovative or whether they are felt to be innovative because we admire them.

Table 18.1. Innovation perception and its linkage to other survey measures.

| Company | Rank 2006 | Rank 2005 | Top 25 for Innovation (1) | 10 Best Breakway Brands (2) | 10 Best Breakway Brands (3) | Best Companies to work for Top 25 (4) | Reputation Top 10 (5) | Most Admired, US Top 20 (6) | Most Admired, World, Top 25 (7) | Most Admired, Top Innovation, World, Top 10 (7) |
|-----------|--------------|--------------|------------------------------------|--------------------------------------|--------------------------------------|--|--------------------------|--------------------------------------|--|---|
| | | | | | | | | | | |
| Apple | 1 | 1 | | x (iPod) | x (iPod) | | | x | x | x |
| Google | 2 | 8 | | x | | | | | | |
| 3M | 3 | 2 | | | | x | | x | | |
| Toyota | 4 | 14 | | | | | | x | x | |
| Microsoft | 5 | 3 | | | | x | | x | x | |
| General | 6 | 3 | | | | | | x | x | |
| Electric | | | | | | | | | | |
| Procter & | 7 | 9 | | | | | | x | x | x |
| Gamble | | | | | | | | | | |
| Nokia | 8 | 9 | | | | | | | x | |
| Starbucks | 9 | 19 | | | | | | x | | |
| IBM | 10 | 7 | | | | | | x | x | |
| Virgin | 11 | 11 | | | | | | | | |
| Samsung | 12 | 12 | | | | | | | | |
| Sony | 13 | 5 | | | x | | | | | |
| Dell | 14 | 6 | | | | | | x | x | |
| IDEO | 15 | 18 | | | | | | | | |

(Cont.)

Table 18.1. (Continued)

| Company | Top 25 for Innovation | | 10 Best Breakway Brands | | Best Companies to work for | | Most Admired, US Top 20 | | Most Admired, World, Top 25 (7) | | Most Admired, Innovation, World, Top 10 (7) | |
|--------------------|-----------------------|-----------|---------------------------|-----------------------------|-----------------------------|---------------------------------------|-------------------------|-----------------------------|---------------------------------|---|---|---|
| | Rank 2006 | Rank 2005 | Top 25 for Innovation (1) | 10 Best Breakway Brands (2) | 10 Best Breakway Brands (3) | Best Companies to work for Top 25 (4) | Reputation Top 10 (5) | Most Admired, US Top 20 (6) | Most Admired, World, Top 25 (7) | Most Admired, Innovation, World, Top 10 (7) | Most Admired, Innovation, World, Top 10 (7) | Most Admired, Innovation, World, Top 10 (7) |
| BMW | 16 | 20 | | | | | | | | | | |
| Intel | 17 | 16 | | | | | | | x | | | |
| eBay | 18 | 15 | | x | | | | | | | | |
| IKEA | 19 | new | | | | | | | | | | |
| Wal-Mart | 20 | 13 | | | | | | | | | | |
| Amazon | 21 | 16 | | | | | | x | | x | | |
| Target | 22 | new | | | | | | | | | | |
| Research in Motion | 24 | new | | | | | | | | | | |
| Southwest Airlines | 25 | 21 | | | | | | x | | | | |

Sources: (1) McGregor, 2006; (2) McGirt, 2006; (3) Ehrbar, 2005; (4) Levering and Moskowitz, 2006; (5) Alsop, 2005; (6) Fisher, 2006; (7) Demos, 2006
 x = presence on list

2. There is a lot written about how much innovation rewards a company. Ashman set the stage with this discussion in chapter 9. In 2006, Henry reported that the top 25 innovative companies achieved median profit margin growth of 3.4% a year since 1995 compared with Standard & Poor's Global 1200 companies (Henry, 2006). This conclusion of the value of innovation clashes with another study reported by Copulsky and his associates who suggest that there is more randomness than not with corporate innovation (Copulsky and Hutt, 2006). Review of standard food industry reports of R&D expenditures (Anon., 2006a) lined up against current New York stock exchange information tends to support the latter conclusion since Hormel's R&D expenses were .33% with a 12-month stock market performance up 14%, whereas Kellogg's R&D expenses were reported as 1.78% and a performance up 12%. Does this mean that R&D expenditures in the food industry just don't have the same value as in other industries? Are the variables around what we do in the food industry that different (Anon., 2006c)?

Perhaps the best direction is to have many voices (diversity of thought) and to find a way to have a robust way of hearing both the voices that we want to hear (complementary thinking) and those we really wish had nothing to say at all (classic iconoclast thought). In its global CEO study on innovation, IBM tends to support this approach by suggesting that one broaden what is considered innovation (Anon., 2006b).

What would that look like? It would be an answer like Bill Gates gives about why Microsoft is so successful. He claims Microsoft excels at *hiring* (Colvin, 2006)! Why is this an innovative answer and maybe part of the secret for success? First, you are not expecting Gates to speak on anything but technology. That is the primary attribute mentioned during innovation discussions. But think about it, if you really work hard at hiring, hiring the best, hiring people who matter to your company, everything else might just take care of itself. So, if we look at the companies who are the CEO machines, we find that most of these are the same companies who are part of the most innovative list above (table 18.2).

What does this mean? You hire really good people (apparently Gates himself will pick up the phone and call people to invite them to come work at Microsoft) and then give them stuff to work on in fairly tight timetables. But since Microsoft is thought of as one of the best places, a lot of workers leave the company because they believe they are the best

Table 18.2. Companies that incubate the most CEOs.

| Company | No. of CEOs |
|------------------|-------------|
| Procter & Gamble | 11 |
| General Electric | 10 |
| General Motors | 7 |
| IBM | 7 |
| McKinsey | 7 |

Source: McGregor, 2006

and other people believe they are the best (reread Larry Wu's chapter). And many of them are. Most of us in the food industry have worked with a fair number of P&G alumni. What else happens in this process (besides these people having great self-esteem ["if P&G is the best, then I am too"])? Well people change over fairly quickly, so you keep getting a diverse workforce and that diversity helps the innovation process. Maybe this is one of the "secrets" of innovation.

Another secret for good innovation is to figure out how to care for the people who work for you that you keep. There are lessons with Topp (chapter 4), McCall et al. (chapter 10), and Wagner/Herzog (chapter 12). Other good discussions are found in *The Fifth Discipline* (Senge, 1994) and chapter 2 in *Sensory and Consumer Research in Food Product Design and Development* (Moskowitz et al., 2006).

But have you "bought" this person or have you "rented" him or her? What about open innovation? It is a very popular conversation within innovation (Chesbrough, 2006). Several of our authors talk about forms of open innovation—Feicht (chapter 3), de la Huerga/Topp (chapter 5), and Eitmant/Haynes (chapter 11). If we explore the food industry, it has been utilizing an open approach for a long time where companies with the expertise (flavors, specialty ingredients, etc.) are more than happy to fill the gap in skill or knowledge. Is this part of the reason food sector companies are not thought of as innovative? Because ADM or McCormick or IFF or Cargill or National Starch can do it, does it mean that it was not innovative? Are these companies recognized for their innovations or their contributions to happiness? That is hard to say. When we understand that 60% of innovations come about by skunk works project (Copulsky and Hutt, 2006), what is gained or lost with open innovation?

Let's return to the beginning. Toops (chapter 2) teaches us that almost everything has been done before, somehow. Review of a current trend—molecular gastronomy—in which we dine, enjoy the chemistry, and pay very high prices for art and magic with our food at places like Blumenthal's Fat Duck or Dulfresne's wd50 or Adria's elBulli (O'Reily, 2006) echoes back to Olney's Entertainments (Olney, 1981) and her comments regarding the poet Marinetti in 1932 with *trompe l'oeil* food, suggests that Toops has given us a good lesson. In figure 18.1, you can see that wonderful discussion Blumenthal provided scientists during a keynote speech at a conference in 2005. Yes, the food and entertainment are fun, but is it an innovation or a renovation?

One of our editors who works in a large food organization said, "innovation is no guarantee for success." It is hard for management or the workers to develop something the consumer doesn't have a need for today, but *might* need in the future. This person cautions, "Right, open innovation. Does anyone really understand how much it takes to work with suppliers to have them develop 'something' they don't already do?"

Another one suggests that "you can do more with less, but eventually you can only do more with more." The trade-off required for more is not very easy to achieve with some management.

This editor suggests that it is all about the money and trade-offs. They are summarized by:

- *Wild animals are wild animals.* Creative tension—you cannot take your eye off of the ball with existing business. Small growth in the current big business is often "bigger" and more "organic" in the short term than new growth. Maintaining relevance for existing brands requires work and attention.
- *Old dogs need new tricks or more dogs.* Innovating and creating NEW brands means either reallocating existing resources or adding new ones. In either case, strain is put on the existing resources (new training, integrating into existing systems/processes/space). There is no free ride.
- *New dogs need to know where the newspaper is.* When you buy new brands, they have to become part of the family at some point in the business system. This takes time, money, and resources. It is not free and it is not easy.
- *Old dogs know some good tricks.* The only time you should replace existing products is if you can demonstrate more value—you can't just keep making room for the new stuff on the shelf by replacing



Figure 18.1. A Mindmap made at the 6th Pangborn Sensory Science conference in the UK in 2005 when Heston Blumenthal of the Fat Duck restaurant spoke on his cooking process. The Mindmap captures the essence of the keynote presentation.

your own facings. More value comes from higher profit, higher turn rates, expanding user base, and so forth. But trading out a product that brings value for an unknown is a poor idea.

- *Old dogs may take a while to learn new tricks.* Even when you innovate for new users/occasions or new channels, current systems are stressed. Current systems can be broken or worn down. This situation will impact the system and the innovation.
- *Borrow a dog or own it?* While outsourcing might help you reduce risk and go faster, it doesn't always help in the long term because eventually these ideas have to become part of the core business system if they succeed. You cannot do both. You cannot outsource design, development AND commercialization. Otherwise, why are you in business?

So maybe the counsel to all of us is from a friendly businessman who wrote the essentials: "Above all, innovation is not *invention*. It is a term of economics rather than of *technology*. Nontechnological innovations—social or economic innovations—are at least as important as technological ones." Managers must convert society's needs into opportunities for profitable business. That, too, is a definition of innovation (Drucker, 2001).

So do you rent or buy? Reflecting on this book, this means having a balance. So buy and rent within your budget. Life should be enjoyed. Escoffier told us that!

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