1 Introduction to Food Packaging

1.1 INTRODUCTION

In today's society, packaging is pervasive and essential. It surrounds, enhances and protects the goods we buy, from processing and manufacturing, through handling and storage, to the final consumer. Without packaging, materials handling would be a messy, inefficient and costly exercise and modern consumer marketing would be virtually impossible. The packaging sector represents about 2% of the gross national product (GNP) in developed countries, and about half of all packaging is used to package food.

The historical development of packaging has been well documented elsewhere and will not be described in depth here. However, an appreciation of the origins of packaging materials and knowledge of the early efforts in package development can be both instructive and inspirational and for this reason they are discussed briefly in the appropriate chapters. Suffice it to say that the highly sophisticated packaging industries that characterize modern society today are far removed from the simple packaging activities of earlier times.

Very few books can lay claim to be the first to expound or develop a particular area, and the present work is no exception. An increasing number of books have appeared over the past few years with the words "food" and "packaging" in their titles, and several are listed at the end of this chapter. The whole field of food science and technology has undergone tremendous development over the last 30 years, and this has been reflected in a plethora of books, many of which address quite specific subject areas (Robertson 2009a, b). In addition, there has also been a significant increase in the number of papers dealing with food and packaging published in the scientific literature, and many of them are referenced at the end of the appropriate chapters.

Food packaging lies at the very heart of the modern food industry, and successful food packaging technologists must bring to their professional duties a wide-ranging background drawn from a multitude of disciplines. The interdisciplinary nature of food packaging is evident from the chapter headings in this book. Sufficient material has been included in the text for it to stand alone as a textbook for undergraduate and graduate students who are taking a two-semester course in food packaging. The earlier editions of this book were also widely used in industry, often by those with no formal education in food science and technology. Therefore, brief descriptions of the basic composition and manufacturing processes used for a wide range of foods are included, with an emphasis on those aspects that influence package choice and performance. Key references are given at the end of each chapter so that those who wish to pursue particular aspects in more depth will have some guidance to start them on their way.

1.2 DEFINITIONS

Despite the important and key role that packaging plays, it is often regarded as a necessary evil or an unnecessary cost. Furthermore, in the view of many consumers, packaging is, at best, somewhat superfluous, and, at worst, a serious waste of resources and an environmental menace. Such views arise because the functions that packaging has to perform are either unknown or not considered in full. By the time most consumers come into contact with a package, its job, in many cases, is almost over, and it is perhaps understandable that the view that excessive packaging has been used has gained some credence.

Packaging has been defined as a socio-scientific discipline that operates in society to ensure the delivery of goods to the ultimate consumer of those goods in the best condition intended for their use (Lockhart, 1997). The now-defunct Packaging Institute International (*Glossary of Packaging Terms*, 1988) defined packaging as the enclosure of products, items or packages in a wrapped pouch, bag, box, cup, tray, can, tube, bottle or other container form to perform one or more of the following functions: containment, protection, preservation, communication, utility and performance. If the device or container performed one or more of these functions, it was considered a package.

Other definitions of packaging include a coordinated system of preparing goods for transport, distribution, storage, retailing and end use, a means of ensuring safe delivery to the ultimate consumer in sound condition at optimum cost and a techno-commercial function aimed at optimizing the costs of delivery while maximizing sales (and, hence, profits) (Coles and Kirwan, 2011).

It is important to distinguish between the words "package," "packaging" and "packing." The package is the physical entity that contains the product. Packaging was defined in the previous paragraphs and, in addition, it is also a discipline as in "Packaging Technologist." The verb "packing" can be defined as the enclosing of an individual item (or several items) in a package or container.

A distinction is usually made between the various "levels" of packaging. A primary package is one that is in direct contact with the contained product. It provides the initial, and usually the major, protective barrier. Examples of primary packages include metal cans, paperboard cartons, glass bottles and plastic pouches. It is frequently only the primary package that the consumer purchases at retail outlets. This book will confine itself to a consideration of the primary package.

A secondary package, for example, a corrugated case or box, contains a number of primary packages. It is the physical distribution carrier and is increasingly designed so that it can be used in retail outlets for the display of primary packages, in which case it is referred to as shelf ready. A tertiary package is made up of a number of secondary packages, with the most common example being a stretch-wrapped pallet of corrugated cases. In interstate and international trade, a quaternary package is frequently used to facilitate the handling of tertiary packages. This is generally a metal container up to 40 m in length that can hold many pallets and is intermodal in nature, that is, it can be transferred to or from ships, trains and flatbed trucks by giant cranes. Certain containers are also able to have their temperature, humidity and gas atmosphere controlled; this is necessary in particular situations such as the transportation of frozen foods, chilled meats and fresh fruits and vegetables.

Although the aforementioned definitions cover the basic role and form of packaging, it is necessary to discuss in more detail the functions of packaging and the environments where the package must perform those functions.

1.3 FUNCTIONS OF PACKAGING

Packaging performs a series of disparate tasks: it protects its contents from contamination and spoilage, makes it easier to transport and store goods and provides uniform measuring of contents (Hine, 1995). By allowing brands to be created and standardized, it makes advertising meaningful and large-scale distribution possible. Special kinds of packages with dispensing caps, sprays and other convenience features make products easier to use. Packages serve as symbols of their contents and a way of life and, just as they can very powerfully communicate the satisfaction a product offers, they are equally potent symbols of wastefulness once the product is gone.

Four primary functions of packaging have been identified: containment, protection, convenience and communication. These four functions are interconnected and all must be assessed and considered simultaneously in the package development process.

1.3.1 Containment

This function of packaging is so obvious as to be overlooked by many, but, with the exception of large, discrete products, all other products must be contained before they can be moved from one place to another. The "package," whether it is a bottle of cola or a bulk cement rail wagon, must contain the product to function successfully. Without containment, product loss and pollution would be widespread.

The containment function of packaging makes a huge contribution to protecting the environment from the myriad of products that are moved from one place to another on numerous occasions each day in any modern society. Faulty packaging (or under-packaging) could result in major pollution of the environment. Even today, the containment function of packaging is not always addressed satisfactorily, as evidenced by the number of packaged foods that leak their contents, especially around the closures and seals.

1.3.2 Protection

This is often regarded as the primary function of the package: to protect its contents from outside environmental influences such as water, water vapor, gases, odors, microorganisms, dust, shocks, vibrations and compressive forces.

For the majority of foods, the protection afforded by the package is an essential part of the preservation process. For example, aseptically packaged milk and fruit juices in paperboard cartons only remain aseptic for as long as the package provides protection. Likewise, vacuum-packaged meat will not achieve its desired shelf life if the package permits O_2 to enter. In general, once the integrity of the package is breached, the product is no longer preserved.

Packaging also protects or conserves much of the energy expended during the production and processing of the product. For example, to produce, transport, sell and store 1 kg of bread requires 15.8 MJ (megajoules) of energy. This energy is required in the form of transport fuel, heat, power and refrigeration in farming and milling the wheat, baking and retailing the bread, and in distributing both the raw materials and the finished product. To manufacture the low density polyethylene (LDPE) bag to package a 1 kg loaf of bread requires 1.4 MJ of energy. This means that each unit of energy in the packaging protects 11 units of energy in the product. While eliminating the packaging might save 1.4 MJ of energy, it would also lead to spoilage of the bread and a consequent waste of 15.8 MJ of energy.

1.3.3 Convenience

Modern industrialized societies have brought about tremendous changes in lifestyles and the packaging industry has had to respond to those changes. Now an ever-increasing number of households are single person, many couples either delay having children or opt not to at all and a greater percentage of women are in the workforce than ever before.

All these changes, as well as other factors such as the trend toward "grazing" (i.e., eating snack-type meals frequently and on the run rather than regular meals), the demand for a wide variety of food and drink at outdoor functions such as sports events, and increased leisure time, have created a demand for greater convenience in household products. Products designed to increase convenience include foods that are preprepared and can be cooked or reheated in a very short time, preferably without removing them from their primary package, and sauces, dressings and condiments that can be applied simply through aerosol or pump-action packages that minimize mess. Thus, packaging plays an important role in meeting the demands of consumers for convenience. Convenient packages promote sales.

Two other aspects of convenience are important in package design. One of these can best be described as the apportionment function of packaging. In this context, the package functions by reducing the output from industrial production to a manageable, desirable "consumer" size. Thus, a vat of wine is "apportioned" into 750 mL bottles; a churn of butter is "apportioned" by packing into 25 g minipats and a batch of ice cream is "apportioned" by filling into 2 L plastic tubs.

Put simply, the large-scale production of products that characterizes modern society could not succeed without the apportionment function of packaging. The relative cheapness of consumer products is largely because of their production on an enormous scale and the resultant savings. But, as the scale of production has increased, so too has the need for effective methods of apportioning the product into consumer-sized dimensions.

For a product that is not entirely consumed when the package is first opened, the package should be resealable and retain the quality of the product until completely used. Furthermore, the package should contain a portion size that is convenient for the intended consumers; a package that contains so much product that it would deteriorate before being completely consumed clearly contains too large a portion.

An associated aspect is the shape (relative proportions) of the primary package with regard to consumer convenience (e.g., easy to hold, open and pour as appropriate) and efficiency in building into secondary and tertiary packages. In the movement of packaged goods in interstate and international trade, it is clearly inefficient to handle each primary package individually. Here, packaging plays another very important role in permitting primary packages to be unitized into secondary packages (e.g., placed inside a corrugated case) and secondary packages to be unitized into a tertiary package (e.g., a stretch-wrapped pallet). This unitizing activity can be carried a stage further to produce a quaternary package (e.g., a container that is loaded with several pallets). If the dimensions of the primary and secondary packages are optimal, then the maximum space available on the pallet can be used. As a consequence of this unitizing function, materials handling is optimized since only a minimal number of discrete packages or loads need to be handled.

1.3.4 Communication

There is an old saying that "a package must protect what it sells and sell what it protects." It may be old, but it is still true; a package functions as a "silent salesman" (Judd et al., 1989). The modern methods of consumer marketing would fail were it not for the messages communicated by the package. The ability of consumers to instantly recognize products through distinctive shapes, branding and labeling enables supermarkets to function on a self-service basis. Without this communication function (i.e., if there were only plain packs and standard package sizes), shopping in a supermarket would be a lengthy, frustrating nightmare as consumers attempted to make purchasing decisions without the numerous visual clues provided by the graphics and the distinctive shapes of the packaging.

Other communication functions of the package are equally important. Today, the widespread use of modern scanning equipment at retail checkouts relies on all packages displaying a universal product code (UPC) that can be read accurately and rapidly. Nutritional information on the outside of food packages has become mandatory in many countries. Smart labels that can be read by camera phones are also appearing on packages and these are discussed in Chapter 9.

But it is not only in the supermarket that the communication function of packaging is important. Warehouses and distribution centers would (and sometimes do) become chaotic if secondary and tertiary packages lack labels or carry incomplete details.

When international trade is involved and different languages are spoken, the use of unambiguous, readily understood symbols on the package is imperative. UPCs are also frequently used in warehouses where handheld barcode readers linked to a computer make stocktaking quick and efficient. Today, the use of RFID tags attached to secondary and tertiary packages is revolutionizing the supply chain.

1.4 PACKAGE ENVIRONMENTS

The packaging has to perform its functions in three different environments (Lockhart, 1997). Failure to consider all three environments during package development will result in poorly designed packages, increased costs, consumer complaints and even avoidance or rejection of the product by the customer.

1.4.1 Physical Environment

This is the environment in which physical damage can be caused to the product. It includes shocks from drops, falls and bumps, damage from vibrations arising from transportation modes including road, rail, sea and air and compression and crushing damage arising from stacking during transportation or storage in warehouses, retail outlets and the home.

1.4.2 Ambient Environment

This is the environment that surrounds the package. Damage to the product can be caused as a result of gases (particularly O_2), water and water vapor, light (particularly UV radiation) and temperature, as well as microorganisms (bacteria, fungi, molds, yeasts and viruses) and macro-organisms (rodents, insects, mites and birds) that are ubiquitous in many warehouses and retail outlets. Contaminants in the ambient environment such as exhaust fumes from automobiles and dust and dirt can also find their way into the product unless the package acts as an effective barrier.

1.4.3 Human Environment

This is the environment in which the package interacts with people, and designing packages for this environment requires knowledge of the variability of consumers' capabilities including vision, strength, weakness, dexterity, memory and cognitive behavior. It includes knowledge of the results of human activity such as liability, litigation, legislation and regulation. Because one of the functions of the package is to communicate, it is important that the messages are clearly received by consumers. In addition, the package must contain information required by law such as nutritional content and net weight.

1.5 FUNCTIONS/ENVIRONMENT GRID

The functions of packaging and the environments where the package has to perform can be laid out in a two-way matrix or grid as shown in Figure 1.1 (Lockhart, 1997). Anything that is done in packaging can be classified and located in one or more of the 12 function/environment cells. The grid provides a methodical yet simple way of evaluating the suitability of a particular package design before it is actually adopted and put into use. As well, the grid serves as a useful aid when evaluating existing packaging.

Separate grids can be laid out for distribution packaging analysis, corrugated packaging analysis, legal/regulatory impact or for any mix of package-related concepts that are of interest. In a further refinement of the grid, a third dimension has been suggested to represent the intensity of the interactions in each cell.

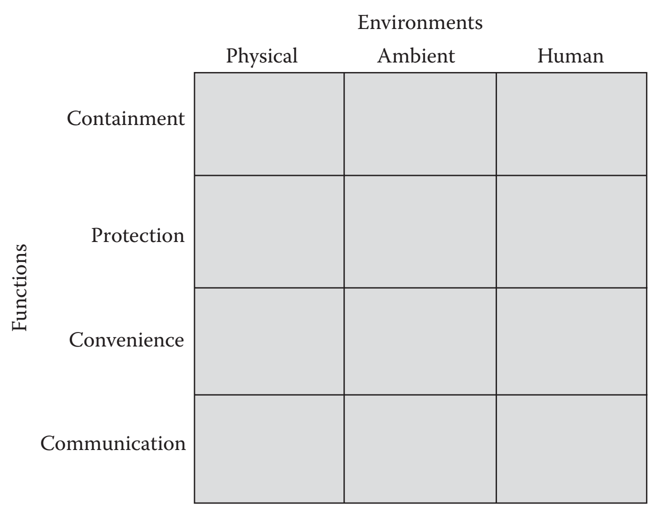

FIGURE 1.1 Functions/environments grid for evaluating package performance. (From Lockhart, H.E., *Packag. Technol. Sci.*, 10, 237, 1997.)

Missing from the grid is an opportunity to evaluate the environmental impacts of the package. This aspect has now become such an important element in package design that it should be considered fully in its own right and in addition to the evaluation carried out using the grid shown in Figure 1.1; it is the subject of the last chapter in this book as part of the broader topic of sustainability.

Knowledge of the functions of packaging and the environments where it has to perform will lead to the optimization of package design and the development of real, cost-effective packaging. Despite the several functions that a package must perform, this book focuses almost exclusively on the protective and containment functions of the primary package and possible food and package interactions in relation to the ambient environment. Package performance in the physical environment is usually considered under the heading of packaging engineering (Hanlon et al., 1998). The communication function of package performance in the human environment is properly the major concern of those with a primary interest in marketing and advertising. For those focusing on the convenience-in-use aspects of packaging, books in the area of consumer ergonomics are the best source of information.

The standard ISO 11156 provides a framework for design and evaluation of packages so that more people, including persons from different cultural and linguistic backgrounds, older persons and persons whose sensory, physical and cognitive functions have been weakened or have allergies, can appropriately identify, handle and use the contents. It considers varying aspects of the packaged product life cycle from identification of the product, through purchase and use of the product to the separation and disposal of the package. However, ISO 11156 does not apply to dimensions, materials, manufacturing methods or evaluation methods of individual packages.

In recent years, greater attention has been given to the difficulties faced by an ageing population in accessing packaging. The openability of packaging is of increasing concern, with a survey of consumers aged over 60 finding that more than 50% of respondents had problems very often or frequently in opening peelable induction seals, lug closures and continuous thread closures (Duizer et al., 2009). If products and their packaging are designed with the weakest target consumer in mind, then the entire target population will be able to physically access the package and product. Yoxall et al. (2010) showed that larger-diameter jars (85 mm) required much higher opening forces than smaller ones (75 mm and below). Smaller jars required lower opening torques, although the force required to open many jars was still higher than many elderly people are able to generate. The authors noted that further work is required to more accurately determine the strength of consumers and the forces required to open common items of food packaging. This topic is discussed further in Chapter 10.

The term "biomechanical data" is used to describe quantities relating to motion, position and force, that is, the movements of a person when interacting with a product and the forces acting on the product during such an interaction. A survey of packaging design professionals revealed that biomechanical data were rarely used and inclusive (or universal) design principles were not routinely incorporated into company procedures (Carse et al., 2010). Although there are some standards and methods provided as a guideline for universal design (UD), it does not reflect packaging requirements for consumers. Yiangkamolsing et al. (2010) identified the five principles relevant to UD as (1) convenient, intuitive, simple and safe use; (2) perceptible information; (3) structure and graphic design; (4) easy opening; and (5) equitable use. For each group of UD performance measures, a minimal but relevant set of consumer requirements were identified for flexible packaging that ensures that the flexible packaging designer conforms to UD principles.

1.6 PACKAGING INNOVATION

Innovation has been defined as invention plus exploitation (Roberts, 2007). The invention process covers all efforts aimed at creating new ideas, concepts, devices or processes and getting them to work. The exploitation process includes all stages of commercial development, application and transfer, including the focusing of ideas or inventions toward specific objectives, evaluating those objectives, downstream transfer of research and/or development results and the eventual broad-based utilization, dissemination and diffusion of the technology-based outcomes. Whereas invention is marked by discovery or a state of new existence (usually in the laboratory or at the bench), innovation is marked by first use in manufacturing or in a market.

The patent literature is full of packaging inventions but fewer than 10% will ever be exploited and, thus, qualify as innovations. The process of technological innovation can take as long as 20–30 years according to some studies, but for most industrial product innovations, the duration from initial idea to market is more likely to be 3–8 years (Roberts, 2007). Awareness of customer needs plays a powerful role in invention and innovation, leading to what is known as "market pull" in contrast to "technological push," which is less likely to be successful. Mostly, innovation is all about small changes that build on inherent flexibility in existing products or systems. Occasionally, something big happens, and a completely new idea is born that can best be described as a mutation rather than an adaptation.

There are several drivers for packaging innovations. One is the fast-changing social trends and the increasing consumer demand for convenience and safety. Another is growing environmental awareness, while profitability and differentiation are also important for food companies seeking to attract consumer attention. Sustainability will receive increasing attention and a plethora of labels such as carbon footprint and paper from sustainably managed forests will indicate how companies are performing in this area. Because consumers want innovation and value novelty, the packaging industry must continue to innovate or risk stagnation.

An interesting way to view innovations is provided by the Gartner hype cycle (Morris, 2011), introduced in 1995 by technology consulting firm Gartner Research. It characterizes the typical progression of an innovation from overenthusiasm through a period of disillusionment to an eventual understanding of the technology's relevance and role in a market (see Figure 1.2). The first part of the hype curve begins with an innovation trigger from a potential technology breakthrough or invention. Early proof-of-concept stories and media interest trigger significant publicity, although often no usable products exist and commercial viability is unproven. This positive hype (mainly by the media and especially the trade press in the case of packaging innovations) speculates on the technology's prospects and is followed by negative hype when the innovation fails to immediately deliver as promised. The message to companies at this stage is not to invest in or adopt a technology just because it is being hyped, nor ignore a technology just because it is not living up to early overexpectations. After a period of disillusionment, an eventual understanding of the technology's relevance and role in a market or domain emerges, driven primarily by performance gains and adoption growth and the release of second- and third-generation products (Fenn and Raskino, 2008). By understanding the hype cycle, it can be ridden more skillfully and investment decisions timed so that the innovations adopted stand the best chance of succeeding in the long term.

However, there have been numerous criticisms of the hype cycle, prominent among which are that it is not a cycle, that the outcome does not depend on the nature of the technology itself, that it is not scientific in nature and that it does not reflect changes over time in the speed at which technology develops. Another is that the cycle has no real benefits to the development or marketing of new technologies and merely comments on preexisting trends. Despite these criticisms, it has remained a popular and useful way for companies to evaluate innovations.

In the area of food packaging, smart packaging is still subject to positive hype, together with biobased polymers such as bioPET and bioHDPE. Antimicrobial packaging is also at this early stage but is unlikely to ever reach the plateau of productivity. Biobased polymers such as PLA and PHA are now experiencing negative hype as more companies trial them. Time–temperature indicators, after more than 40 years, have moved up the slope of enlightenment but are unlikely to ever become more than a niche market. The retort pouch is approaching the plateau of productivity. It is important to remember that the big innovations in food packaging such as MAP and aseptic packaging took 20–30 years before they reached the plateau of productivity.

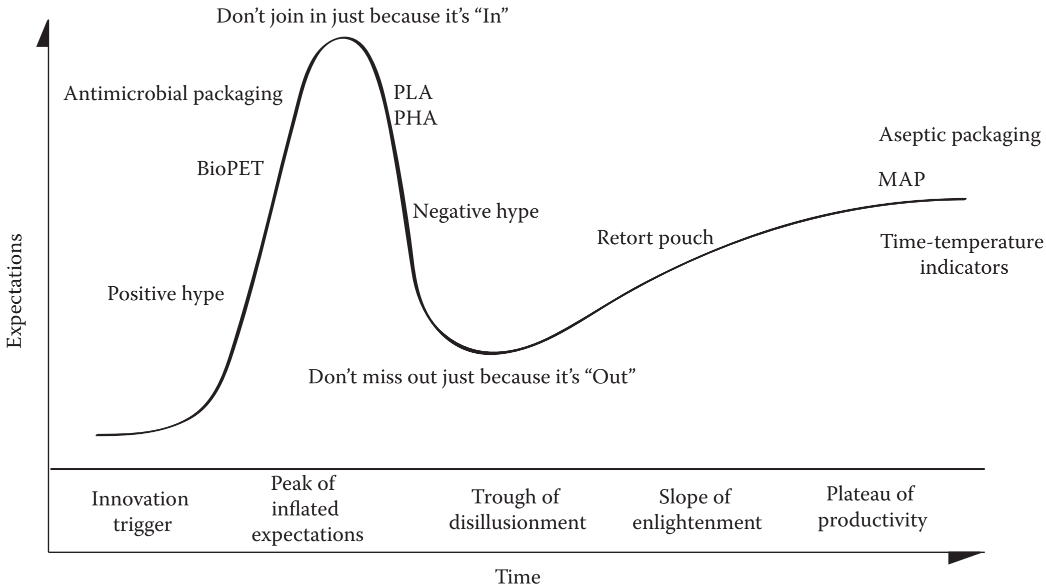

FIGURE 1.2 Gartner hype cycle characterizing the typical progression of an innovation from overenthusiasm through a period of disillusionment to an eventual understanding of the technology's relevance and role in a market or domain. (Adapted from Gartner Inc. Used with permission.)

1.7 FINDING INFORMATION

It has never been simpler to keep up-to-date or find the latest information, provided one has an Internet connection. Although there are various approaches that one can adopt, Google Scholar (www.scholar.google.com) is free and provides a simple way to broadly search for scholarly literature. From one place, you can search across many disciplines and sources: articles, books, theses and abstracts from academic publishers, professional societies, online repositories, universities and other websites. With Google Scholar, you can find relevant work across the world of scholarly research, including where it was published, who it was written by, as well as how often and how recently it has been cited in other scholarly literature.

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