“十二五”普通高等教育本科规划教材
包装工程专业系列教材
（双语教学用）

李瑞琴　主编

包装科学与技术基础

Fundamentals of Packaging Science and Technology

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本书为英文教材，介绍包装科学与技术的基础知识。共分八个单元，涵盖以下方面的内容：包装工程总论、包装材料与包装容器、包装技术、包装设备、包装印刷、运输包装、包装标准与法规以及计算机辅助包装设计与包装开发过程。本书附录内容提供了包装组织与协会以及国外高等院校包装教育的网址信息，便于读者获取更为广泛的包装工程与包装教育领域的信息。

本书可作为包装工程专业本科生技术基础类课程的双语教学用书，也可作为从事包装工程及相关专业的技术人员的参考用书。

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前 言

随着我国包装科学与技术的迅速发展，我国正在逐步从世界包装大国向包装强国跨越。包装工程作为一门学科交叉性和应用性都很强的学科，涉及面较广泛。这对我国的包装工程高等教育提出了更高的要求，迫切需要从事包装专业的技术人才能更有效地学习和应用国际上先进的包装技术。

在教育国际化和人才国际化的趋势下，英语作为一种有效的学术交流工具，在人才培养中的地位越来越重要。双语教学作为一种有效的教学模式，有利于学生吸收国外英语原版的包装专业知识，有利于进一步的国际学术交流与合作。

本书为英文教材，共分八个单元。第 1 单元为包装工程总论，介绍包装的发展过程、包装的功能与分类，包装组织及包装教育等；第 2 单元为包装材料与包装容器，介绍纸与纸板、金属、塑料等常用包装材料与容器；第 3 单元为包装技术，介绍气调包装、收缩与拉伸包装、智能包装、防伪包装、热压成型包装等包装技术；第 4 单元为包装设备，介绍常用包装机械、包装生产线等包装设备的工作原理，以及折叠纸板与纸箱的机器人系统工作原理等；第 5 单元为包装印刷，介绍印刷方法、常用印刷设备及包装印刷的发展趋势等；第 6 单元为运输包装，介绍运输包装设计过程、缓冲包装设计等技术；第 7 单元为包装标准与法规，介绍各类国际包装标准与法规；第 8 单元为计算机辅助包装设计与包装开发过程，介绍包装计算机辅助设计软件工具及包装开发过程等。为了便于学习理解，本书附录列出了重要专业名词与术语的中英文对照。附录还列出了包装组织与协会以及国外著名高等院校包装教育的网址信息，便于读者获取更为广泛的包装工程与包装教育领域的信息。

本书可作为包装工程专业本科生技术基础类课程的双语教学用书，也可作为从事包装工程及相关专业的技术人员的参考用书。

参加本书编写的有李瑞琴（第 1、2、3、5 单元），梁晶晶（第 4 单元），管兰芳（第 6 单元），齐明思（第 7 单元），李清（第 8 单元）。全书由李瑞琴任主编并统稿。

在本书的编写过程中，参阅了一些同类论著及包装工程专业相关网站内容，在此特向其作者表示衷心的感谢。感谢参与本书讨论、建议与校对的研究生们，有益的讨论与建议对编者的修改及论证有很大的帮助。感谢化学工业出版社编辑的大力支持以及在编辑、审读方面付出的辛勤劳动。

由于编者水平有限，书中疏漏及欠妥之处在所难免，敬请广大读者批评指正。

李瑞琴

2014 年 9 月

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UNIT 1 Perspective on Packaging Engineering

Section A Development of the Packaging

A. 1 Packaging Conception

The best description of packaging is a coordinated system of preparing goods for transport, distribution, storage, retailing, and usage. It is a complex, dynamic, scientific, artistic, and controversial business function. Its most fundamental form has contains, protects/preserves, transports, and informs/sells. Also, packaging may be defined in terms of its protective role as "packaging is a means of achieving safe delivery of products in sound condition to the final user at a minimum cost" or it can be defined in business terms as "a techno-economic function for optimizing the costs of delivering goods whilst maximizing sales and profits" .

A. 2 Primitive Packaging

No one knows for sure when the first container was fashioned by man. The earliest ones, no doubt, were used principally to hold liquids, wild berries, and other foods provided by nature. Later, as man began to cultivate the soil, they were probably employed to hold crops, shells, leaves, hollowed pieces of wood, earthenware, and animal skins probably made up the earliest packaging materials.

Although there are records of urns and other vessels being used by the early oriental and other civilizations, the beginning of packaging as we know it today probably started around 4000 B. C. with the exchange of goods between Egypt and Mesopotamia. Agricultural products from Egypt and manufactured items from Mesopotamia, along with some from India and possible China made up the early trade.

In spite of these early uses of packages to contain cosmetics and related products, the principal use of the package through the years was to store, protect, and help transport the product. Leather bags gradually replaced the earthen jars which were prone to breakage, and about 300 B. C. the technique of using the blow pipe to make hollow glass articles was developed. This made it possible to blow large containers at a much faster production rate than had been possible before.

Product and package identification became widespread with the protection of the printing press by Johann Gutenberg about 1450. This made it possible for the use of printed paper labels for packages.

During the 1600's, the manufacture of glass containers became widespread in England, and glass largely replaced leather and earthenware containers of liquids. One of the earliest American industries was a glass container factory established in Jamestown, Virginia. As early as 1740 such remedies were being sold in England. The early bottles were usually corked and sealed with wax. Crude paper labels printed in black and white were fastened on the bottle or tied around the neck with a string. The patent medicine industry was probably the first industry to utilize packaging to any great extent in the sale of consumer product. Other items began to be packaged in consumer quantities and unit packages, although the package was still used primarily to hold and protect the product without attempting to merchandise it.

Developments of great significance to packaging were rapid during the 1800's. In 1800, food was first preserved in a glass container sealed with cork wired in place. This is the first instance of food preservation packaging. In 1810, metal cans were also used for the preservation of food products by means of packaging.

Packaging innovations were concerned mostly with protecting products better and for longer periods of time. The ability to produce large volumes of merchandise transformed many producers from local to national and international distributors.

It is worth to note that as late as the 1890's unit packaging of consumer products was still not prevalent. The retail stores of that time still stocked most food items in bulk containers. Customers carried home tea, coffee, spices, sugar, flour, butter, and other items in paper bags or wraps. Bulk containers were best in this situation, as far as the producers were concerned. Because of the voluminous amount of products produced, the ready markets, and the methods of distribution in use, few saw any benefit in packaging to appeal to the consumer.

During 1890's and early 1900's a change took place in England and the United States. With continued improvements in production and ever-increasing numbers of competitors, a greatly increased volume of output was realized, in fact, overproduction has arrived. Products were no longer automatically consumed. People could select in the marketplace. The seller's market had shifted to a buyer's market. A considerable number of marketing and packaging changes took place as a result of this shift to a buy's market. Many of these innovations originated in the United States.

Partially as a result of consumer demands for better quality goods at lower prices, and worker demands for higher pay and fewer hours, the system of mass production was developed in this country. The result of mass production was to enable more people to afford the things they produced. This, of course, expanded the total demand for goods.

A. 3 Modern Packaging

Modern packaging had the effect of allowing consumers to minimize their human interactions in the marketplace. Consumers could get information from package labels that they had previously relied upon shopkeepers. Shopping became less time-consuming and less

of an emotional drain when shoppers no longer felt compelled to share personal information with the grocer each time they visited his store. Packages were especially attractive to people newly arrived in cities because labeled packages could often be trusted more.

Fast-food outlets made their appearance in 1950's and created a demand for new kinds of packaging. The consumer met disposable single-service packing for the first time, while the fast food outlets demanded the bulk delivery of ready-to-cook food portions in their own special type of packaging. Fast food outlets boomed and later joined by increasing levels of public healthcare and a rapidly growing trend eating out rather than at home. Today this market is large enough to form its own sector, sometimes called the HRI (Hospital, Restaurant and Institution) market.

The 1950's also saw the growing convenience of prepared food packages, such as cake mixes, TV dinners, boil-in-bag foods, and gravy preparations. A rapidly growing technology added petroleum-derived plastics to the package designer's selection of packaging materials.

The 1970's and early 1980's brought numerous changes, many of them were legislated. Child-resistance closures were mandated for some products. Tamper-evident closures were brought in for others. Labeling laws required listing of ingredients, and in Canada, language equality laws were tightened. Standards for the acceptance of new packaging materials were raised. Consumerism showed a concern for the environment started to be important factors for those who watched the future trends.

The last decades of the 20th century witnessed rapid change. The population aged, and many social habits changed. Families became smaller. Singe-person households became common. The domestic housewife became a relic of the past as both partners in a marriage sought professional careers or higher income levels. For the modern urban dweller, "convenient" and "fast" became the operative words.

Today's packages are often complex, inside and out. Inside, they are often a sophisticated sandwich of micro-thin plastic layers, as many as nine or more, with each doing a special job such as helping with clarity, barrier control, physical strength, interlayer adhesion, or peel/seal performance. Outside, packages are engineered for printability, folding or forming requirements, special needs such as sterilization, puncture resistance, and acceptance of zippers, dispensing valves, caps, pull tabs or other features.

Today, there are many kinds of modern packaging materials, such as many of the plastics, coating and other materials that make packaging work, and also many packaging innovation technologies, such as intelligent packaging, active packaging and safe packaging, etc. with the development of graphic arts, packaging machinery and packaging service, package will make much progress.

A. 4 Modern Packaging Industry

Drawing clear-cut boundaries around the packaging industry is difficult. Obviously, those actually manufacturing the physical package (cans, bottles, wraps) are part of the

packaging industry. Their function is to take various raw materials and convert them (hence, the general classification of this part of the industry as "converters") into useful packaging materials or packages. Viewed from this perspective, packaging becomes a materials application science.

In most instances, the company forming the physical package will also print or decorate the package. Thus, part of the printing industry and all its attendant suppliers are also viewed as part of the packaging industry.

Many user-sector companies, the firms that package products, are also regarded as part of the packaging industry. Package users can be divided into a number of categories (Fig. 1. A. 1) and each of these can be further subdivided. Each subsector has its own unique package design requirements.

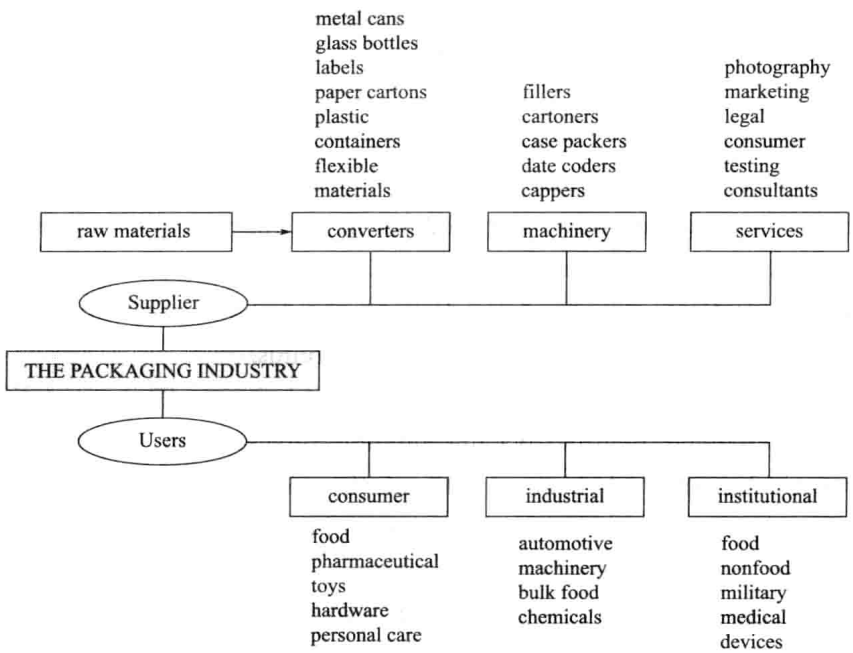

Fig. 1. A. 1 The categories of packaging industry

The supplier sector, manufacturers of machines for the user sector and the suppliers of ancillary services, such as marketing, consumer testing and graphic design, are also important sectors of the packaging industry.

The industry is served by a large number of trade journals. Like associations, trade journals can be either broadly based or more specifically focused on a particular package type, material, process, or product category.

Lastly, the modern packaging industry is highly regulated. Added to the basic complexity of the industry are the jurisdictional complexities ranging from the federal to the local, and it is not always entirely clear which authority has jurisdiction over a particular issue. Ensuring that all legal requirements are met can be an especially challenging task.

A. 5 Development of Packaging in Modern China

China was one of the birthplaces of the human civilization, and the four great inventions were all created from this land, including paper and printing which have close relations with packaging. Furthermore, paper packaging got its application in China firstly. But many factors, just like the feudalism, slowed the pace of the national capitalism, so packaging industry had made a few progress. However, it was not still staying in the state of small handicraft workshop.

After the foundation of New China, packaging industry had made some progress. However, it was not still taken seriously. Although some design bodies and packaging educational institutions were founded by government, there was huge disparity between China and abroad.

From the later of 1973, government of China began to have high regard for packaging industry. The First Packaging Exhibition was founded in Guangzhou which helped Chinese people to learn advanced ideas for packaging and feast their eyesight.

Section B Packaging Function and Classification

B. 1 Definitions of Different Packaging Levels

Packaging is the enclosure of products, items, or other packages in pouches, bags, boxes, cups, trays, cans, tubes, bottles, or other container forms to perform one or more of the following basic functions:

① Contain;

② Protect/Preserve;

③ Transport;

④ Inform/Shell.

When discussing packaging functions, the following different packaging levels should be kept in mind.

1. Primary package

Primary package is the first wrap or containment of the product that directly holds the product for sale.

2. Secondary package

A wrap or containment of the primary package.

3. Distribution package

A wrap or containment whose prime purpose is to protect the product during distribution and to provide for efficient handling.

4. Unit load

A number of distribution packages bound together and unitized into a single entity for

purposes of mechanical handling, storage, and shipping.

Packages are often defined by their intended destination.

5. Consumer package

A package that will ultimately reach the consumer as a unit of sale from a merchandising outlet.

6. Industrial package

A package for delivering goods from manufacturer to manufacturer. Industrial packaging usually, but not always, contains goods or materials for further processing.

The basic packaging functions have different degrees of importance, depending on the particular packaging level and intended destination. It is common for several packaging levels to contribute to a single function (Fig. 1. B. 1).

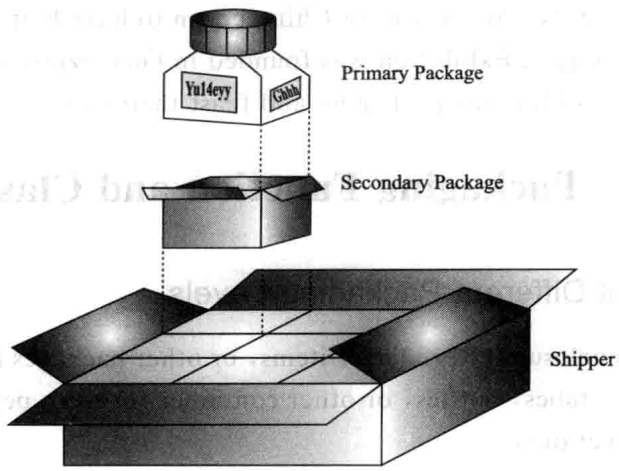

Fig. 1. B. 1 Different packaging levels

The primary packaging for a breakfast cereal is the inner undecorated bag. Its main function is to contain and preserve the product, and to a lesser extent, to protect it. The secondary package, a paperboard carton, provides physical protection, informs the consumer and motivates the purchase decision. Twelve cartons are packed into a corrugated shipping container to protect the product and to facilitate distribution. The information printed on the corrugated shipper primarily identifies the product for distribution purposes. Finally, corrugated shippers are assembled into a unit load, whose primary purpose is to facilitate transport and distribution.

In some instances, a package will be required to assure all the functions. The primary package for a power tool may be feature all the necessary information to inform and motivate the consumer.

Typically, the inform/sell function plays a less significant role in industrial packaging.

B. 2 Contain Function

The first step in preparing a package design is to consider the nature of product and

the kind of packaging needed to contain the product. These considerations include:

The product's physical form

mobile fluid	viscous fluid	solid/fluid mixture
gas/fluid mixture	granular material	paste
free-flowing	non-free-flowing powder	solid unit
discrete items	multicomponent mix	

The product's nature

corrosive	corrodible	flammable
volatile	perishable	fragile
aseptic	toxic	abrasive
odorous	subject to odor transfer	easily marked
sticky	hygroscopic	under pressure
irregular in shape		

Throughout this discussion, we will examine the characteristics of various packaging materials and how their qualities influence effective containment packaging design.

B. 3 Protect/Preserve Function

In the context of this discussion, "protect" refers to the prevention of physical damage, while "preserve" refers to stopping or inhibiting chemical and biological change.

To provide physical protection, specifics on what will cause loss of value (damage) must be known. Specifics means knowing not only the general condition, but also a quantified measure of the level of that condition at which unacceptable damage starts to occur, as shown in Table 1. B. 1.

Table 1. B. 1 Examples of protective packaging problems and concerns

Condition	Quantification or Design Requirement
Vibration	Determine resonant frequencies
Mechanical shock	Determine fragility factor (drop height)
Abrasion	Eliminate or isolate relative movement
Deformation	Determine safe compressive load
Temperature	Determine critical values
Relative humidity	Determine critical values
Water	Design liquid barrier
Tampering	Design appropriate systems

The preservation function most often refers to the extension of food shelf life beyond the product's natural life or the maintenance of sterility in food or medical products. Like the protective function, the preservation function needs to be defined and quantified, as shown in Table 1. B. 2.

Table 1. B. 2 Typical preservation packaging problems and concerns

Condition	Quantification or Design Requirement
Oxygen	Determine required barrier level
Carbon dioxide	Determine required barrier level
Other volatiles	Determine nature and barrier level
Light	Design opaque package
Spoilage	Determine nature/chemistry
Incompatibility	Determine material incompatibilities
Loss of sterility	Determine mechanism
Biological deterioration	Determine nature
Deterioration over time	Determine required shelf life

B. 4 Transport Function

The transport function entails the effective movement of goods from the point of production to the point of final consumption. This involves various transport modes, handling techniques and storage condition. In addition to the general physical rigors of distribution, there are a number of carrier rules that will influence package design. Examples of some of the information required to design successful distribution packaging appear in Table 1. B. 3.

Table 1. B. 3 Typical transport handling and storage information

truck	rail	aircraft
cargo ship	storage duration	storage conditions
handling methods	unitizing methods	specific shipping unit
weight considerations	stock-picking	dimension limits
carrier rules	environmentally controlled storage	

Transportation and distribution is generally regarded as an activity that is hazardous to the product being moved. In many instances, the stresses that the product will experience are greater than the durability of the unprotected product. In such instances, it will be necessary to design additional packaging to isolate or cushion the product from the external forces.

Packaging contributes to the safe, economical, and efficient storage of a product. Good package design take into account the implications of transport and warehousing, not just for the distribution package and unitized load, but for every level of packaging.

B. 5 Inform/Sell Function

The communication role of packaging is perhaps the most complex of the packaging functions to understand, measure and implement because of the many levels at which this communication must work. Law or customs dictate certain messages without much leeway