Food Packaging Technology

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editor

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Foreword

This publication, *Food Packaging Technology,* contains papers presented at the symposium of the same name held in San Diego, California, on 1 November 1989. The symposium was sponsored by ASTM Committee F-2 on Flexible Barrier Materials. Debra K. Henyon, Pure-Pak, Inc., presided as symposium chairperson and was editor of this publication.

Contents

Overview

Food safety is a top issue today. Consumers are informed daily of the link between diet and health along with reports of potential food risks, such as microbial contamination, chemical adulteration, nutritional hazards, and illegal food additives. Another potential danger is that of the food package itself. What is the safety provided by the package and its interaction with the food it contains?

During the past ten years, a virtual explosion of new food product introduction has been witnessed, demonstrating a six-fold growth from 1980 to 1990. The industry has become technically more complex as new ingredients, additives, and processing techniques are introduced. The revolutions in food packaging and marketing are posing new challenges to food safety assurance.

Consumers have come to expect more of government regulators and the food industry and are asking pertinent questions related to the safety of the food supply. With regard to food packaging, questions are asked such as: How much product protection do packages supply? Do they help to preserve the nutritional worth of the food supply? Does packaging act as a source of food-related health risks by directly or indirectly contributing substances to products such as toxins or chemicals? Does packaging extend or shorten the shelf life of products? How are food packages developed, and what is the criteria for the packaging material selection?

These and other questions are being asked by the members of the F-2 Committee on Flexible Barrier Materials. The symposium on Food Packaging Technology from which this volume was taken was organized to provide a forum for the discussion of the research and test methods currently in use by members of the food and packaging industries along with academic interest. The nine papers presented at the symposium review emerging technologies in the food packaging industry. The topics include extended shelf life of food products through the use of computer modeling, time-temperature indicators, and a total system approach based on the dynamics of the food-packaging and distribution systems. Emerging markets for shelf stability versus convenience in packaging, material test method development, and new applications for high barrier plastics packaging are also discussed.

The paper by *Cage* provides a comprehensive overview of the basic principles of food packaging development, from conception to distribution; technological breakthroughs and ecological and environmental concerns are discussed.

Marsh, Ambrosio, and *Guazzo* demonstrate how one company confirmed a product's two-year shelf life in three months of research time, allowing for early product introduction with the most reasonable packaging cost. Computer modeling techniques were employed, and novel analytical procedures were developed and used for both product information and computer input.

Harte et al. evaluate the change in mechanical properties of polymers due to sorption of flavor compounds. Flavor component scalping by polymeric films is an important factor in the quality of flavored products, and the selection of appropriate packaging materials is aided by knowing the mechanical response of polymer sealant film in contact with aroma/flavor components. Sorption of three plastic films that are potential candidates as food contact material are investigated.

The use of ethylene vinyl alcohol copolymer (EVOH) resins in high-barrier plastics packaging is discussed by *Schaper.* The types of processing used with EVOH resins and how the use of these resins compare with alternative forms of packaging are reviewed, along with new and existing resin properties and applications.

Techniques used to measure the oxygen transmission rates of packaging films under humid conditions are described by *Pike.* Various methods of humidifying gas streams used in the standard methods for dry gas transmission rate measurements and the controlled humidity "sandwich" method are given. The new Modern Controls' "H-System," designed specifically for this purpose, is also described, along with advantages and disadvantages of each method.

Gyeszly contends that shelf life modeling must be based on the entire food packaging and distribution systems for selecting optimum packaging. A total system approach to modeling shelf life of packaged food products is described. Discussion of the major parameters of the shelf life simulation model includes recommendations for developing product and distribution-specific models. Development of appropriate shelf life simulation models is analyzed mainly from a packaging point of view with consideration of cost.

The paper by *Taoukis, Labuza,* and *Francis* addresses the reliability of time-temperature indicators (TTI) as food quality monitors under nonisothermal conditions. This study develops an application scheme based on the kinetic parameters of the TTI as well as the food distribution chain which allows for a direct correlation of the TTI response to the food's loss in quality. This is shown to be reliable under variable temperature conditions and should be of benefit to the packaged food industry, especially for refrigerated extended shelf life. Three major types of commercial TTI's were studied, a diffusion-based tag, an enzyme-based tag, and a polymerization-based tag.

Flavor management for food products is important because consumers want food that tastes good, in addition to safety and nutrition. *DeLassus* and *Strandburg* use "flavor" in a broad nontechnical way that includes several human responses to both chemical and physical stimuli. Results from a new experimental technique are used to illustrate the important variables for permeation of flavors and aroma in polymer films. The permeability is separated into its component parts, namely the diffusion and solubility coefficients. A review of physical interactions between food and plastic packaging that can lead to loss of flavor is given.

Matty, Stevenson, and *Stanton* provide a detailed review of techniques and equipment developed for easy-to-use, reproducible, standardized procedures to evaluate the performance of polymer-based food packages. The paper discusses test results and their relationship to package performance, with a focus on test methods, including equipment and instrumentation, applicable to container seal integrity, lid peelability, and container abuse resistance. The impact of fundamental specimen properties, instrument response limitations, and other factors influencing results is also reviewed.

This volume covers a wide range of topics in the area of food packaging, with applications and test methods that may be useful in all packaging disciplines. It was not intended to be totally comprehensive and the areas discussed are clearly not complete, but should provide the reader the kind of considerations necessary when developing packages for food.

The papers presented here have been successful both in illustrating various problems and in presenting potential solutions. This book should be useful to those in the food industry who develop, design, and test food and food packages. Hopefully, it will serve to stimulate all groups involved to work closely together to provide a safe food supply.

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James K. Cage[1]

Introduction to Food Packaging

REFERENCE: Cage, J. K., **"Introduction to Food Packaging,"** *Food Packaging Technology, ASTM STP 1113,* D. Henyon, Ed., American Society for Testing and Materials, Philadelphia, 1991, pp. 3–12.

ABSTRACT: The basic principles of packaging to preserve, merchandise, protect, market, and distribute are applied very effectively in the food industry. More recently, food packages have been developed which offer tamper-evident or tamper-resistant features, allow for product preparation, and provide dispensing features and many conveniences such as single serving portions. Often the food product and its package are developed to be an integrated unit such as an aerosol product.

Technological breakthroughs in metals, glass, paperboard, composites, and most especially plastics have provided a multitude of opportunities for improved food packaging. The plastics segment of the packaging industry has shown the most rapid growth for many reasons. Some of the most important are: some plastics can be used in microwave ovens; plastics have a wide range of physical and barrier properties; and plastics offer design capabilities and features not available with other packaging materials.

However, ecological and environmental concerns are growing rapidly, along with federal, state, and local regulations and laws which will have an effect on the whole packaging industry. Further, the demographic changes related to the increased percentage of older consumers will also have significant effects on food packaging in the future.

KEY WORDS: food packaging

The food industry with its numerous and varied products utilizes all the basic principles of packaging, which are to preserve, merchandise, protect, market, and distribute a product. In the beginning the goal was to provide a means of preserving seasonal food products. As our farm-oriented society became more urbanized, it became necessary to move or distribute food products from where they were grown to where they were used, and the package had to offer protection during this process. The distribution process lengthened the time it took to get the product to the consumers and thus increased the shelf life required for the food product. The packaging and mechanization that naturally followed make it possible for a very small segment ($\approx$4%) of the U.S. population to produce enough food to feed the entire country and to have a surplus to export to other countries as well.

As food products were distributed, they required identification and labeling. Also, the design, shape, and form of the package gained in importance. Even the color of the package became associated with certain products. The use of packaging to provide information to the consumer has placed packaging in the role of a "silent salesman," a function made necessary and of critical importance to self-service merchandising. The package communicates with the consumer on a conscious and subconscious level, through the use of materials, shapes, colors, printed words, pictures, etc. The package thus serves as the last link in the sales-communication chain, telling the consumer what the product is, how to use it, and many other pertinent facts.

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Packaging offers the food industry a marketing tool that is most useful in the growth and promotion of sales. In principle, the product and its package are an integrated unit. The properties of one determine the properties of the other. A moisture and/or oxygen-sensitive food product requires a package with adequate barrier properties. A high-acid, hot-filled food product requires a sanitary can with the proper lining material. Product development and package development should be conducted simultaneously and interactively. This could even include the changing or reformulation of a food product in order to make it easier or more economical to package. It is increasingly important for a company to plan carefully and be market smart about matching up a product with a package attractive to consumers.

The importance of this principle can be further supported by a familiar example: the retort pouch, which is a flexible packaging material made into a pouch and which can be thermally sterilized like a metal can. The retort pouch has failed as a commercial retail food package in the U.S., even though it has a long and successful history in other countries. Unlike those other countries, however, the U.S. has well-entrenched can making, glass making, and refrigerated distribution channels. The promoters of the retort pouch failed to see that the benefits the package provided were not highly prized in this society. Their focus was far too much on the package, not enough on the product.

The increase of the food industry to meet the population growth of the country was naturally followed by an expansion in the field of packaging. Of course, the packaging requirements for drugs, pharmaceuticals, hardware, personal care items, etc., also increased rapidly. The growth rate of packaging closely followed the growth of the Gross National Product over the past 30 years (Fig. 1). In fact, at year end, one of the leading national business magazines, *Forbes,* in the 9 Jan 1989 issue; treated packaging as an industry unto itself. Packaging was included when it reported trends and forecasts for major industries such as food, pharmaceuticals, electronics, steel, and other industrial segments. Previously, packaging was a manufacturing function which supplied many varied materials such as glass, paperboard, metal containers, plastic bottles, flexible films, and laminations. Except for a few major companies, packaging was segmented into the glass industry, paper industry, plastics industry, etc. Through acquisitions and growth, many glass companies now supply plastic containers and metal cans as well. The can companies now make plastic containers, trays, and jars, too. Paper companies have flexible packaging divisions. Thus, a packaging industry was born.

Initially, all the packaging materials were made from wood or wood derivatives (paper, folding cartons, and corrugated shipping cases), glass, and metals such as steel and aluminum. Increasingly, packages were made from two or more of these basic materials to obtain the optimum functional properties and economics. Even those materials that were used alone, like glass, which is made into bottles and jars, and steel, which is made into sanitary cans, were improved in shape, form, lining materials, and functional properties. Aluminum has become a very successful packaging material used for beverage cans and foil laminations. Technological breakthroughs in metals, glass, paperboard, composites, laminations, and especially plastics are providing a multitude of opportunities for improved food packaging (Figs. 2, 3). The major catalyst for packaging advancements has been the plastic materials rapidly being developed. The plastics segment of the packaging industry has shown the most rapid growth for many reasons (Fig. 4). Some of the most important are: (1) plastics have a wide range of physical and barrier properties; (2) plastics offer design capabilities and features not available with other packaging materials; and, more recently, (3) some plastics can be used in microwave ovens. Plastics can also be used in combination with coextrusions, which offer economic advantages (Fig. 5).

The opportunities for food packaging today are astronomical. The development of containers and packages is rapid and diverse to allow the food industry to meet the marketing

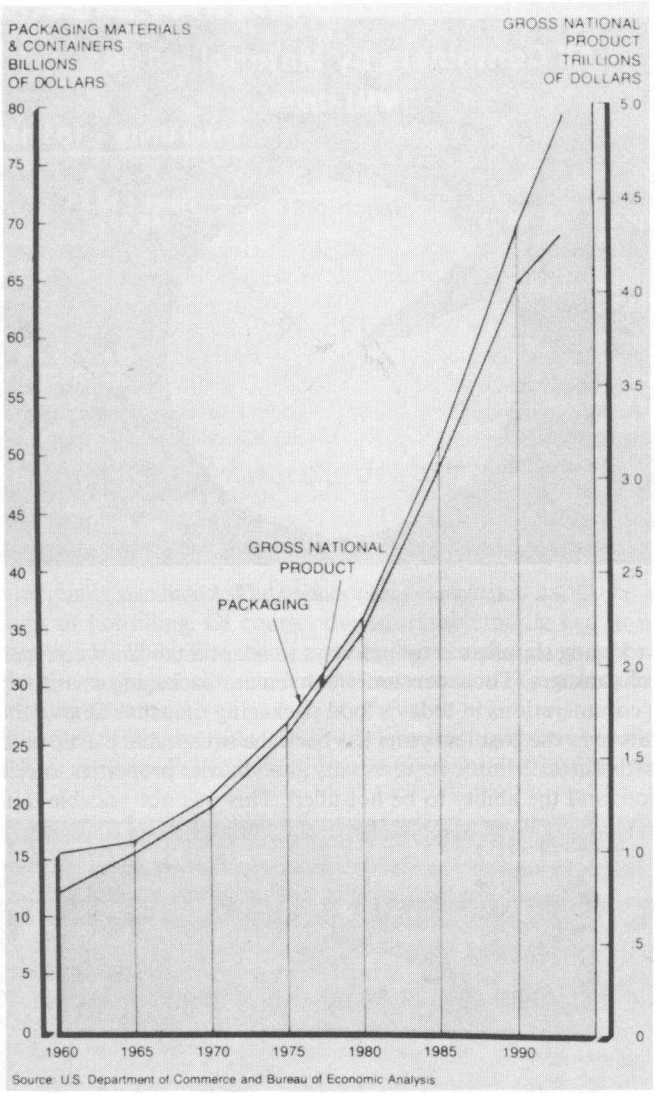

FIG. 1—*GNP and the growth of packaging.*

demands of its consumers. One major food company, the Campbell Soup Company, uses steel cans, aluminum cans, glass jars, as well as bottles, aseptic cartons, PET (polyethylene terephthalate) bottles, dual-ovenable CPET (crystallized polyethylene terephthalate) trays, microwaveable polypropylene trays and bowls, paperboard and fiber trays—just to name a few. The company seems determined to give its consumers the packaging options they want, and their wants are many and varied.

In today's intensely competitive food marketplace, a successful food package must function in a way that enhances convenience of use for the consumer. The challenge for food

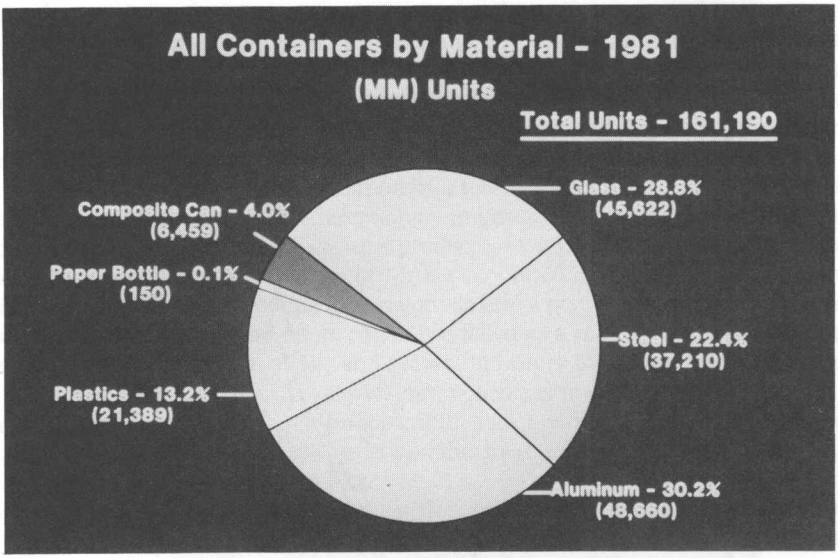

FIG. 2—*All containers by material, 1981 (mm units).*

processors and packaging suppliers is to find ways to adapt established convenience features to various types of packages. Thus, consumer convenient packaging seems to be one of the major marketing considerations in today's food packaging industry. One of the most significant developments over the past few years has been the squeezable plastic bottle for tomato ketchup. This plastic ketchup bottle requires very good barrier properties, specifically against oxygen permeation, and the ability to be hot-filled. This was not possible until coextruded plastic bottles containing a layer of a high barrier material, EVOH (ethylene vinyl alcohol),

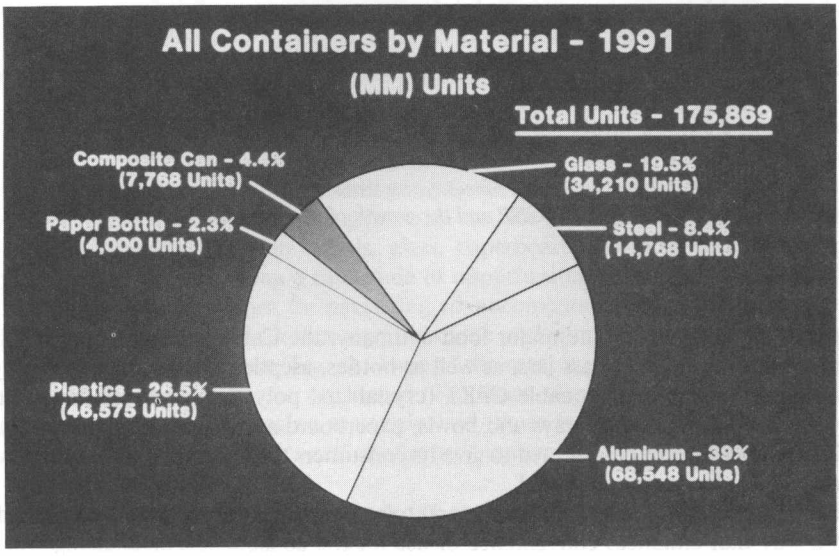

FIG. 3—*All containers by material, 1991 (mm units).*

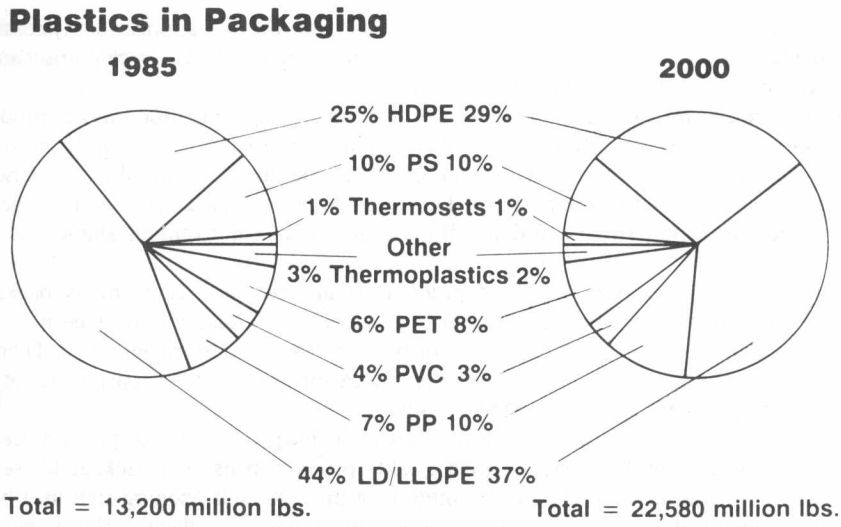

FIG. 4—*Plastics in packaging.*

could be commercially produced. The other coextruded layers had to be able to withstand the temperatures of hot-filling. Of course, this squeezable bottle had to have a dispensing closure to make it complete. The whole package system ended up costing more than the former glass bottle and metal closure, but the convenience of a squeezable ketchup bottle was a big marketing advantage.

Another convenience feature, recloseability, is now finding its way beyond traditional rigid containers such as metal coffee cans with plastic overcaps and into the flexible pouch/bag

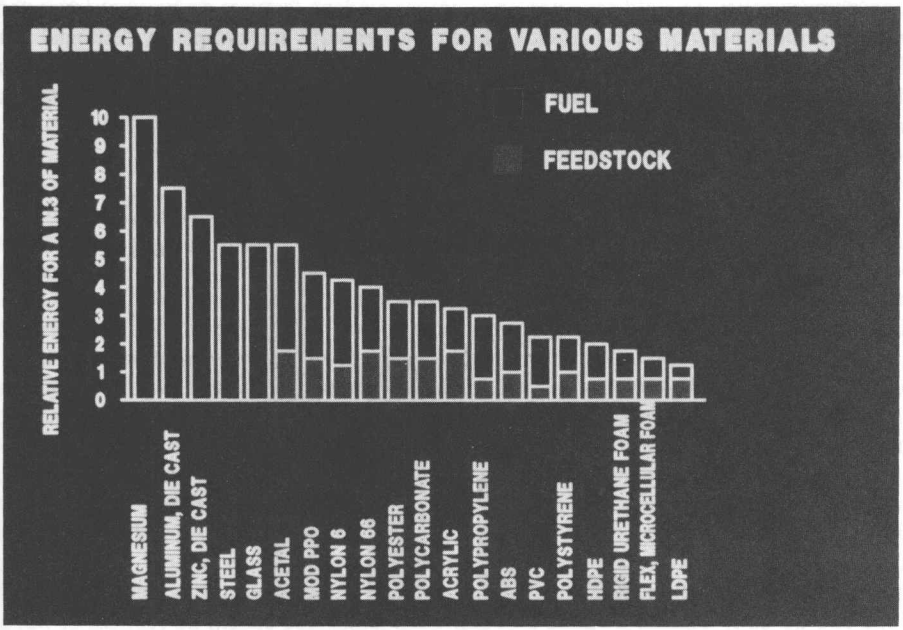

FIG. 5—*Energy requirements for various materials.*

type package. The development of "zipper pouches" and on-line application systems has provided a recloseable feature for such products as cereals, lunch meats, snack items, candies, cheeses, dry pastas, rice, and many other items.

Consumer research shows that single-serving portion packaging is much more important to consumers than it was a few years ago. Associated with portion packaging is the convenience feature of portability so that food products can be taken to school or to work and may even be microwaved in the package. The portable portion package must provide adequate protection during storing and handling, along with a convenient shape and light weight.

The use of microwave ovens for food preparation at home has led to many packaging developments. The dual ovenable CPET tray is widely used, and microwave-only, coextruded barrier polypropylene trays are used for both shelf stable and frozen foods. There are also paperboard combinations formed into tray-like cartons and more expensive plastic trays for the higher quality microwaveable food products.

Without doubt one of the most successful microwaveable products developed has been the microwave popcorn bag. It provides a high quality product in its own package for serving and in a short preparation time. The adaptation of an SOS (self-opening standup) bag to protect the product during shipping and merchandising and to withstand the preparation process in a microwave oven was a technological breakthrough. The current bags are improved by use of susceptor pads to increase the pop volume of the popcorn.

Demographic changes are a major driving force behind many recent developments in food packaging. More working mothers require the convenience of quick and easy-to-prepare foods. Singles and retired seniors like the single-serving, portion-controlled portable foods and recloseable features. Older seniors need easy-to-open-and-prepare food products. Many of these trends will continue as the population of the country grows older (Fig. 6).

Product/package safety is a major concern today even though the number of tampering complaints officially reported to the FDA has decreased over the last two years. As expected, young parents consider child-resistant and tamper-evident features to be very important. Other consumers, older ones in particular, find child-resistant and tamper-evident packaging to be effectively adult resistant, too. Efforts continue to develop more effective and economical tamper-evident features. But the recent Chilean grape incident clearly shows that not all tampering problems can be solved with packaging.

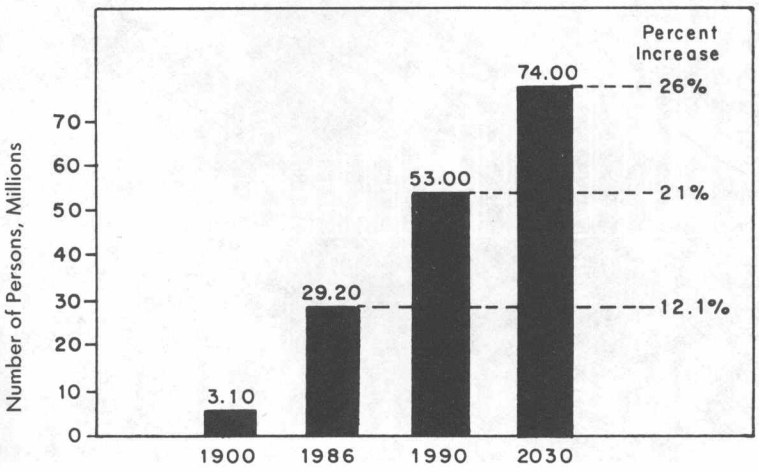

FIG. 6—*Number of persons 55+: 1900–2030.*

Packaging can aid in product safety in other unique ways. This may not be food packaging, but it's closely related. Self-treatment has complicated the problem of safe disposal of medical wastes. Diabetics alone discard an estimated one billion disposable syringes each year. One of the major syringe producers, Becton-Dickinson, has started sending thousands of letters and "Safe-Clips" storage tubes to diabetics on the East Coast. Safe-Clips are storage tubes with a 2000-needle capacity that enable the patients to clip off the hypodermic needle and dispose of it safely.

Another unique package is now available for the handling and storage of police evidence. The tube, called Safevidence, is made of a strong puncture-resistant plastic to safely contain syringes, especially in drug-related cases.

Consumers rely on the package label to not only supply product identification and the manufacturer's name and address, but much other information. A list of ingredients and preparation steps are considered important. In response to consumers' increased interest in health and nutrition, a growing number of food companies are moving to implement full nutritional labeling for their products. One such company, Sunshine Biscuit, Inc., announced intentions to have nutritional labeling on all of its cookie and cracker products by the end of 1989. The labels will include grams of fat per serving, cholesterol content, and other important nutritional information.

Some recent state and federal laws and regulations are now having a definite effect on package labeling. In the state of California, alcoholic beverage manufacturers are already required by Proposition 65 to inform consumers that their products could cause birth defects and now may have to include a cancer warning. Alcoholic beverages are already listed as reproductive toxins because they are associated with fetal alcohol syndrome. The state Scientific Advisory Committee now believes that at a very high level of alcoholic beverage consumption there is an increased risk for certain cancers. This is only one example of the role package labeling will play in the future.

Some of the convenience features, such as single-serving portions, portability, recloseability, and tamper evidence, are in direct conflict with the growing problem of solid waste management. Package design and choice of materials are now strongly influenced by the solid waste crisis. Environmental concerns could well become the packaging quality most selected by consumers in the 1990s. Even now, growing numbers of consumers are willing to pay more for more-recyclable products.

The most obvious focus is to redesign and use less packaging materials. But source reduction alone will not solve the solid waste problem. Before real progress can be made, several questions need to be clarified. Should some resins and additives be avoided because of increasing use of incineration? Should multilayer packages be avoided because they could interfere with recycling efforts? Can designers count on enough postconsumer waste collection to warrant the use of multilayer nonfood packages with recycle layers? Will container lightweighting accomplish enough source reduction or will extensive redesign be required?

Most of these serious questions involve plastics, which are really a very small portion of municipal solid waste (Fig. 7). Since plastics are basically newer packaging materials, less work has been done to recycle them. Currently, only 1% of plastics are recycled versus aluminum's 54%, papers' 30%, and glass' 25%. However, major efforts are underway by plastics companies and users to develop means of source reduction and recycling. The PET beverage bottles and the HDPE (high density polyethylene) milk containers are the two main areas for current work. This work is being done under the threat of legislation from cities, counties, states, and the federal government. Many trade associations are also cooperating in this effort. The Society of Plastics Industry (SPI) is requesting each state legislature to pass a coding law to identify all plastic packaging materials in a uniform manner (Fig. 8). The coding system developed by the SPI will facilitate recycling of plastics by identifying the resins used

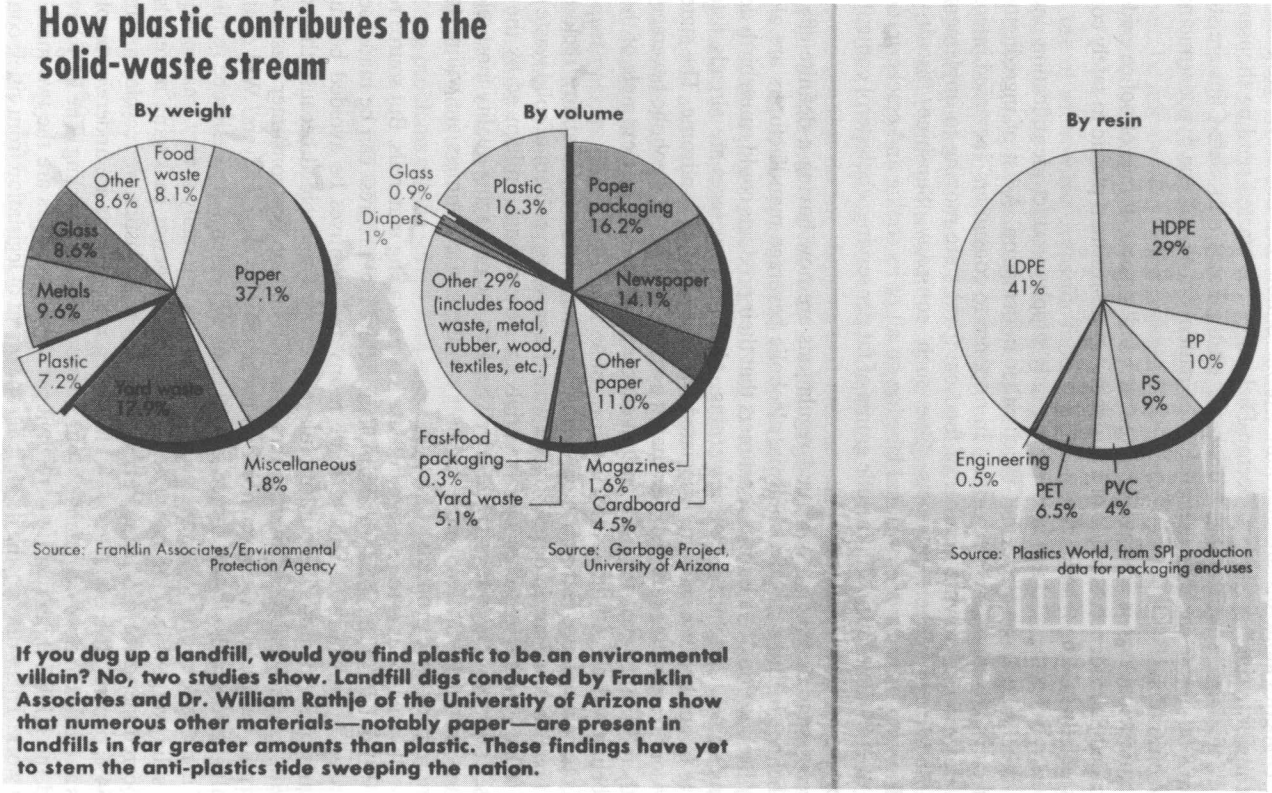

FIG. 7—*How plastic contributes to the solid-waste stream.*

VOLUNTARY GUIDELINES
PLASTIC BOTTLE MATERIAL CODE SYSTEM—
MOLD MODIFICATION DRAWINGS

FIG. 8—*Society for Plastics Industry plastic coding system.*

to make the containers. So far, 18 states have passed laws with legislation pending in 5 other states.

Besides source reduction and recycling, there are the other two means of disposing of solid waste, land fills and incineration. The areas remaining for landfills are becoming acutely scarce and expensive, and the potential cause of ecological problems (Fig. 9). Incineration is widely used in many parts of Europe (40% in West Germany, 50 to 75% in Sweden and Switzerland). In Japan, 55% of its sold waste is incinerated. All four methods will have to be considered to resolve the solid waste problem in this country. Thus, it appears that in the future, package design will be shaped by solid waste considerations.

A discussion on food packaging would not be complete without relating a role it can play in the Third World. Packaging can play a most important role in improving food distribution with the objectives of reducing waste and thus increasing food availability. The food spoilage rate in this country is the lowest in the world, about one third the level in the USSR and most developing nations. This will mean the utilization of more sophisticated packaging materials than the multiple Kraft paper and burlap bags currently being used. It is estimated that the amount of food that proper packaging would save from spoilage alone could increase significantly the ultimate yields of many existing harvests in these needy countries. It has been reported by agricultural experts that 50% of mainland China's food volume is lost to spoilage, rodents, and insects. China has invested heavily for the past several years in plastics packaging materials and converting plants. However, much of this improved packaging is now used for exported food products, and its broader internal use will take several more years.

Another benefit due to improved food packaging will be a reduction in food costs as a part

Current Disposal Practices..

	Incineration	Land Fill	Recycle
Japan	55%	20%	25%
United States	less than 10%	80+%	less than 10%
Switzerland	75%	20%	Low
West Germany	34%	60%	Low
Sweden	50%	50%	Low
United Kingdom	Low	75+%	Low

FIG. 9—*Current disposal practices.*

of disposable income. In this country, food costs are under 15% of disposable income, compared to 16% in Japan and Western Europe and much higher rates in the developing nations. The challenge for food packaging in this area is great, but the potential benefits are worthy of the effort.

The packaging industry has a wide host of opportunities before it; there are real challenges in the years ahead. As never before, the packaging users and the packaging suppliers must be partners in new package development. This is particularly true in the food and beverage business, which is strongly influenced and driven by packaging. The consumer demands for convenience food packaging will have to be reconciled with serious ecological considerations. The safety considerations of tamper-evident and child-resistant features will have to be balanced with the concerns and problems they cause senior citizens in our aging population. Last but not least, packaging must play a stronger and larger role in the preservation, protection, and distribution of food in the third world and the developing nations. This is a reversion back to the basic principles of packaging in the food industry.