PACKAGING is tremendously useful for protecting food during marketing—not just a necessary evil increasing food costs. Consumers now receive products in fresher condition, with more potential shelf life, and greater appeal and convenience because of packaging advances.

Packaging is a multibillion-dollar business and food packaging, with its thousands of consumer-packaged items, is the largest segment of the industry. New packages and great numbers of new or improved packaging materials are in continuous development. They provide better protection for our food than ever before in history.

WORLD POPULATION is increasing at a rate of about 144,000 every day. So the task of producing enough food, and processing, storing, marketing, and continuously protecting it, will become increasingly important.

For many centuries inadequate transportation and refrigeration prohibited wide distribution of perishable foods. These foods had to be consumed locally in season. Less perishable foods received only crude bulk packaging with little concern for sanitation or for quality maintenance.

Beginning about 1800 and continuing till today man has made giant technological advances in many fields of science. He developed sources of power to run machinery; transportation improved. During this same timespan, he developed the science of food technology and gradually learned new ways to process and package foods.

Progress in canning has been continuous since about 1809.

Today’s canning plants are highly efficient operations where a single processing line may produce more than 600 containers of wholesome food every minute.

We are all familiar with the sight of thousands of cans and glass jars in our supermarkets. Some are transported great distances, as sardines from Norway and pineapple from Hawaii.

We see the great supermarket array of packaged frozen foods now commonplace and we accept vacuum-packed foods, gas-packed foods, dried foods, chemically preserved foods, and packaged fresh produce.

Materials used for food packaging include wood, wood veneer, fiberboard, paperboard, paper, cotton, burlap, packaging films, aluminum foil, steel, aluminum, and glass.

Packages made from these materials may be rigid or flexible, large or small,
and produced in hundreds of combinations and variations with and without coatings or liners to achieve desired protective characteristics.

The types of food packages in use today seem endless. Most provide product protection, some do another job.

There are egg cartons, window-boxed pies, canned juice, variety cereal packs, shrink-wrapped ham, cellophane-packed spinach, frozen dinners, 20-bushel bulk boxes for handling and storing apples, fiberboard cartons for shipping 24 heads of lettuce, and individual serving packs of crackers and jelly.

We have take-home cartons, disposable bottles, multiple packs, combination food packs, vacuum packs, see-through packs, reclosable packs, and packages within a package. Some packages may be frozen, some may be baked, and some may be boiled. Other packages pour, have easy-open features, may be squeezed, or operate with a pushbutton.

Product protection to maintain quality for an adequate marketing period is the major function of food packaging.

But it no longer is enough just to design a package that protects the product. The package must be economical to use and must promote sales. It may provide convenience, save time in shopping, save shelf space, prevent pilfering, make handling easier by unitizing, or provide a host of other services.

Protective packaging should retard deterioration from all sources that lower product quality from point of production to the consumer's table. With many highly perishable foods, this is still difficult, and shelf life is short even with today's protective packaging plus refrigeration.

Causes of deterioration must be known and understood for each product, along with the product's special needs, and its physical and chemical properties. For example, how deep can ripening fresh tomatoes be packed if pressure bruising is to be avoided?

Major protective packaging requirements are as follows:

- Physical protection is needed to prevent product crushing or bruising and to provide stacking strength for normal handling—wood boxes, fiberboard cartons, cans, and glass jars provide this protection.
- Moisture loss or moisture gain must be minimized. Product shriveling and underweight packages result when moisture loss is excessive. Dried foods lose crispness or they mold when moisture content increases above specified levels.
- Sanitary protective barriers are required to prevent contamination from dust, and entry and destruction by micro-organisms and insects.
- Gain or loss of gases such as oxygen, carbon dioxide, and nitrogen from packages is critical for many products and must be minimized. Excess contact with atmospheric oxygen hastens quality deterioration of many processed products.
- Odor loss or pickup often must be avoided. Product aroma may pass rapidly out of some packages, resulting in quality deterioration. A better barrier film or container is needed in these cases.
- Flavor loss should be minimized.
- Grease or fat loss must be minimized in some products.
- Color changes have to be avoided. Often this involves partial or complete exclusion of light.

The importance of these packaging requirements is associated with length of shelf life desired. A container like a glass jar, metal can, or foil-film laminated pouch may be needed when long shelf life is desired. Less expensive packaging, providing less protection, may be adequate if there is a rapid product turnover.

More and more food companies now realize the importance of packaging and have established packaging departments. Others use packaging consultants.

Much testing of proposed new packages goes on under simulated
marketing conditions before commercial acceptance. Continual research and evaluation of existing packages is essential to escape loss of business to competitors.

Michigan State University offers a 4-year course in packaging. Many other universities also teach courses in packaging.

The Packaging Institute, the Produce Packaging Association, and many other trade associations provide adult education in packaging. Trade journals like Modern Packaging, Package Engineering, Food Engineering, and Food Technology publicize the results of packaging research.

Fresh fruits and vegetables of many kinds are highly perishable and deteriorate rapidly, if not handled carefully and refrigerated.

Packaging of produce is particularly important to prevent damage during handling that can cause bruising and thus reduce salability or open the surface to infection and spoilage by micro-organisms.

A primary function of produce packaging is to retard moisture loss and prevent deterioration like shriveling of peppers, berries, and root crops, or wilting of vitamin-rich leafy green vegetables.

Sanitation is another reason for modern produce packaging. Products like fresh spinach and tossed salad mixes which may be eaten raw need to be properly packaged to reduce the chance of contamination. Fruits often attract gnats or fruit flies while on display in stores. Packaging fruits in transparent bags helps keep them more sanitary.

Fresh produce gives the packaging researcher a special problem.

Tissues are still alive after harvest and after packaging and must be kept alive if produce is to be marketed in fresh form. Respiration continues. Oxygen must be supplied for respiration, and carbon dioxide and heat are given off. Thus, usually there must be some provision for gas exchange.

In this respect, the problems of fresh produce packaging are different from those in canning or freezing, which kill the tissues. An airtight container normally cannot be used for fresh produce.

In a film package with low oxygen permeability, all the free oxygen is used by the produce in a short time at room temperature, and respiration becomes anaerobic. In anaerobic respiration—respiration in the absence of free oxygen—alcohol and carbon dioxide are produced. This type of respiration is sometimes referred to as fermentation or suboxidation.

Free oxygen is no longer being used, but carbon dioxide is still being produced, so the total volume of gas in the package increases and the package swells. This can be demonstrated easily by sealing sweet corn or other items with a high respiration rate in a non-ventilated film bag.

Carbon dioxide concentrations of 20 to 40 percent may develop in airtight packages in a day or two at warm temperatures.

As a result of the absence of oxygen and the accumulation of carbon dioxide, alcohol, and other products of anaerobic respiration, the cells may be killed and the product becomes unsalable. Even before this occurs, fruits and vegetables may develop winey or other undesirable odors and flavors under such conditions.

Film ventilation is a means of allowing more gas exchange through produce films which have inadequate oxygen and carbon dioxide permeability.

Some of the more permeable films allow sufficient oxygen passage to supply a certain fruit or vegetable held at 40° F. without any added ventilation. But the packer cannot guarantee temperatures during marketing or in consumers' homes. These films would have to be many times more permeable to oxygen than they are at low temperature to supply the much higher respiration needs for oxygen at 70°, 80°, or even 90° F. existing in some stores or homes.

Thus perforated film packages for
Automatic packaging machine at a Boston plant simultaneously forms the film bags and fills them with a predetermined amount of radishes.

Produce are a common sight in supermarkets. Experiments by the author showed that the oxygen concentration in small film packages perforated with two 1/8-inch holes or four 1/6-inch holes will stay close to that in normal air, which contains 21 percent oxygen. This amount of ventilation has a negligible effect on weight loss.

More perforations may be needed when it is desired to allow more water vapor to escape and provide some control of relative humidity. This is discussed later in the chapter.

Let’s look at the development of carrot packing. Most readers will remember the days of bunched carrots. They were shipped long distances from production areas to market in heavy crates with snow ice between layers of carrots to maintain freshness.

Green tops were thought to be essential to convince housewives they were getting fresh carrots, not storage carrots. But it was not easy to keep them fresh during retailing. Flabby carrots with wilted tops were a common sight before 1950.

Research by horticulturists of the U.S. Department of Agriculture showed that the carrot tops draw moisture from the roots and hasten shriveling. Removing the tops doubles the shelf life. Removing tops and packaging in 1-pound moistureproof film bags further reduces moisture loss and markedly increases the shelf life.

Bunched carrots displayed 6 days at 70°F with 50 percent relative humidity lost 48 percent in weight, with tops removed 29 percent, and in a perforated polyethylene bag 4 percent. Under refrigeration polyethylene packaged carrots have a shelf life of at least 2 to 3 weeks and moisture loss is usually less than 1 percent.

Retailing studies by R. L. Hawes and D. R. Stokes of the Agriculture Department showed that waste and spoilage losses of prepackaged carrots were much less than for bunched carrots—less than 1 percent compared with more than 8 percent—principally because there was less breakage of the packaged roots in consumer handling and no loss of salability from deterioration of the tops.

Consumer packaging of carrots is now done in producing areas. Not shipping the inedible tops—they make up 15 to 30 percent of the weight of a bunch—allows more carrots to be shipped per rail car. Use of less expensive shipping containers like veneer wirebound crates, multiwall-kraft bags, or heavy-duty polyethylene bags each holding twenty-four or forty-eight 1-pound polyethylene bags was also possible with the switch to consumer packaging.

A scant 1 percent of fresh carrots marketed in 1951 were prepackaged in
Lettuce is harvested, packaged, and boxed in one continuous operation in the field, at Salinas, Calif. At top, lettuce is picked and put on conveyors that take it inside packing van. At right, lettuce head is placed on sheet of plastic film and pushed through hole. Lettuce comes out on other side of hole (left) where a worker passes film-wrapped head over hotplate, which seals film around head. Lettuce is then boxed and dropped off for another truck to pick up.
film bags. Most of them are in 1966 and with less spoilage, a longer shelf life, and better salability. Prevention of moisture loss is equally important for radishes, parsnips, and some other root crops, and a similar switch to moisture-proof polyethylene bags has occurred.

*Increased usage of moistureproof film bags for marketing potatoes, onions, and citrus has developed since 1953. This occurred under the pressure of attempts to make produce departments self-service.*

Mesh or paper bags were used to unitize loose produce. They did not restrict moisture loss.

Tests showed that either polyethylene or rubber hydrochloride film bags could be used for packaging potatoes, onions, and oranges. Moisture loss during marketing was minimized. However, further testing by the author and others in the Agriculture Department determined that the films were more moistureproof than desired for these particular produce items.

This problem has called for more research on use of the films.

*Most fresh fruits and vegetables keep best under high relative humidity of 85 to 95 percent to retard moisture loss. However, moistureproof films like polyethylene when used for produce maintain even higher relative humidities, approaching or reaching 100 percent.*

Humidity approaching saturation is detrimental to good keeping of onions, sweetpotatoes, potatoes, and oranges. Decay, surface mold, and rooting may be stimulated by the high humidity, particularly at warm temperatures.

The author and other researchers found that ventilation of film bags with punched holes was a way of providing some regulation of package humidity. To illustrate, the humidity as measured with an electric hygrometer averaged 98 percent in 3-pound polyethylene bags of onions without perforations. In 2 weeks at 75°F, 71 percent of the onions were rooted. Rooting is undesirable in onions as the bulbs soften.

Relative humidity was much lower in bags perforated with thirty-two \(\frac{1}{4}\)-inch holes and only 4 percent of the onions developed roots. This amount of film ventilation increased weight loss but did not cancel the desirable moisture-retentive property of polyethylene bags. Moisture losses are still less than would occur in mesh or kraft paper bags.

Potatoes packed in nonperforated polyethylene or in polyethylene bags with only a few holes developed surface mold and in some lots decay was high. Keeping quality was much better in these 10-pound film bags when they were ventilated with 48 or 64 of the \(\frac{1}{4}\)-inch holes, as this allowed some moisture vapor to escape.

Early experiments in shipping Florida oranges in polyethylene bags showed decay in them was higher than in open-mesh bags. The high humidity maintained in the film bags favored mold growth. Perforating the bags reduced the amount of decay.

Currently 5-pound polyethylene bags are still used for oranges but they are ventilated with as many as 64 to 80 of the \(\frac{1}{4}\)-inch holes. In addition, fruit is often hydrocooled and treated with fungicides before packaging to inhibit spoilage.

Shrink-film packaging is one of the newer packaging developments. It was first used in France about 1936 for the packaging of meat.

Some lettuce is now trimmed and overwrapped with heat-shrinkable films in production areas. Sometimes giant machines that move through the fields do the job. Quality maintenance is good when lettuce is precooled before shipment and adequately refrigerated in transit.

Pulpboard or chipboard trays of fruit or loose vegetables are sleeve wrapped or fully overwrapped with shrinkable film and then passed through a heat tunnel to shrink the film and immobilize the contents. Apples develop fewer bruises during retail handling in shrink-wrapped packages than in the widely used polyethylene bags.
With either of these consumer packs, good shipping containers with dividers between units are needed to prevent handling damage during shipment.

Other successful uses of shrink packaging are with fresh, smoked, and cured meats; fresh and frozen poultry; and with cheese.

Packaging films shrink up to a maximum of about 80 percent when exposed to heat in hot water or in hot-air tunnels.

For many shrink-packaging jobs involving a final shrink to tighten a loosely wrapped package, only a small 5 to 10 percent shrink is needed. However, for a contour wrap of a frozen turkey or an odd-shaped tray of produce, film shrinkage of 50 percent or more may be desirable.

Balanced shrink in both the longitudinal and transverse directions is usually needed.

Heat-shrink characteristics are built into films during manufacture by stretching under controlled temperatures and tensions to create molecular orientation, and then locking the film in this stretched condition by cooling.

One outstanding feature of shrink films is their ability to make a skin-tight package over irregular shaped objects. Products are immobilized so damage during normal handling may be reduced.

Major types of shrinkable films are polyethylene, polypropylene, polystyrene, polyester, polyvinyl chloride, polyvinylidene chloride copolymer, and rubber hydrochloride. They provide a broad variety of desirable characteristics.

Shipping containers made from wood, metal, corrugated board, solid fiberboard, and multiwall paper deserve tremendous credit for protecting our food supply, yet often are not seen by consumers.

Throughout distribution, packaged products are handled and rehandled many times, loaded, unloaded, and stacked in storage several layers deep. Each shipping container must withstand high vertical pressures to which it may be subjected, and the impacts of sudden stops and starts of trains and trucks.

Growth in use of corrugated shipping containers continues to expand. They are light in weight, free from rough surfaces inside and out, and usually low in cost compared with wood containers.

Lettuce, citrus, apples, and many other kinds of produce which formerly were shipped in wood containers now move to market in corrugated fiberboard boxes.

These containers continue to be modified to improve stacking strength and resistance to moisture. More protective cushioning materials are used with corrugated boxes.

Apples are commonly packed in full-telescope-type corrugated boxes with molded-pulp trays for each layer of fruit. High quality Golden Delicious and McIntosh apples, which are easily bruised, are often packed in cell-type corrugated boxes with each apple partitioned in its own cell. Bruising damage is less than in older place-packing methods faced with a bulge before lidding.

Corrugated boxes of 50-pound capacity are now used increasingly for potatoes and sweetpotatoes.

Sweetpotatoes shipped in corrugated boxes developed less decay than comparable roots shipped in bushel baskets in tests conducted by the Agriculture Department. Decay in baskets was reduced about 50 percent by using an excelsior cushion between the cover and the roots.

With California potatoes, shipping in corrugated cartons reduced bruising, skinning, and skin discoloration compared to potatoes packed in 100-pound burlap bags.

Corrugated boxes cost more than burlap bags, but this is partially offset by reduction in waste.

A new 38-pound capacity veneer-fiberboard box is used increasingly for shipping eastern peaches, as it has
good strength and provides added protection. Peaches shipped in these boxes reportedly had only a third to a half as many cuts and bruises as peaches which were shipped in veneer baskets with crown covers.

The changeover to fiberboard boxes from wood boxes for apples, citrus, and other perishables has increased the problems of cooling.

Produce in bulge-packed wood containers cooled readily because the bulge kept containers separated and exposed to circulating cold air.

Packed fiberboard boxes usually have no bulge. Consequently, boxes may be stacked tightly against each other in rows or on pallets unless care is taken to space them for desired circulation. If fiberboard boxes are tightly stacked, cooling is slow.

This problem is solved, allowing good keeping quality, if fruit is precooled before packing. For nonprecooled fruit in fiberboard boxes, spacing between rows of containers for air circulation is essential.

The cooling rate is increased further by venting the boxes with holes or slits, providing that the vents are in positions where they are exposed to moving air.

Polyethylene box liners are used extensively to lengthen storage life of pears, sweet cherries, and Golden Delicious apples.

Pears are stored at 30° F. in regular boxes with thin gage (0.0015 inch) polyethylene film liners. Fruit respiration builds up a beneficial modified atmosphere within the tightly sealed liners, which is usually about 2 to 4 percent carbon dioxide, 10 percent oxygen, and the balance nitrogen. This allows a storage period 6 to 8 weeks longer than without liners.

Pears packed and stored in sealed liners are firmer, greener in color, have less scald on removal from storage, and have a better shelf life than pears stored without liners.

A 1965 innovation was to enclose a waxed kraft paper pad or envelope containing 1 pound of hydrated lime in each film-lined box. The lime absorbs carbon dioxide, keeping it at about 2 percent. Allowing carbon dioxide to accumulate to a concentration of 4 or 5 percent may cause brown core, which is an internal disorder of pears.

Golden Delicious apples benefit from film liners chiefly through reduction of moisture loss and shriveling. Consequently the liners need not be sealed but are usually just overlapped. A storage life of 5 to 7 months at 31° to 32°F. is possible with the liners, and moisture loss can be kept at 1 percent or less.

Sweet cherries are protected in sealed polyethylene liners for as much as 2 to 3 weeks at 31° F. following harvest, and then may be shipped long distances to market. Here again a beneficial modified atmosphere of about 6 to 9 percent carbon dioxide and 3 to 10 percent oxygen and high humidity develops.

This atmosphere reduces decay during storage and transit, minimizes moisture loss, and preserves the green color of the stems and bright color of the cherries for longer periods than without liners.

Use of bulk boxes or pallet boxes holding 14 to 24 bushels of produce is expanding because of handling economies possible with modern forklift trucks. These giant containers originated in New Zealand in 1953.

Sometimes harvesting is directly into these containers followed by movement to processing plants or storage. Depending on the dimensions of pallet boxes, about 20 percent more produce can be stored in the same storage space compared with individual bushel boxes handled on pallets.

Bruising and mechanical damage in these bulk boxes is usually no worse and often is slightly less than in regular wooden field crates. A possible reason is that when bulk boxes are full of apples or other produce, they are too heavy to be lifted manually and dropped or carelessly handled by
workers. Also, a smaller percentage of the fruit is in contact with surfaces of the container.

Insect infestation of packaged foods is a cause of tremendous losses in the United States each year.

Food processors have to adopt good insect-control programs which insure that their product is insect-free when it leaves the plant. They must also protect their commodity against insect infestation throughout marketing and until opened by consumers. Here the only suitable means is to use insect-resistant containers.

Research at the Stored-Product Insects Laboratory of the Agriculture Department in Savannah, Ga., showed that improved packaging methods now will provide protection against insect infestation.

Packaging materials, container construction, and tightness of closures are important. However, certain borers and beetles can enter food packages made of cloth, paper, film, foil, or combinations of these materials regardless of how well they are constructed. So chemical treatment to prevent penetration is essential.

Pyrethrum in combination with piperonyl butoxide applied as a coating to the outer ply of properly constructed multiwall paper bags is effective as a repellent in preventing insect infestation.

Meat and seafood packaging for the self-service supermarket has expanded tremendously. An ever-increasing number of consumer-size items are protectively packaged, using a full range of container types including metal cans, aluminum foil, films, paper, paperboard, and combinations of these different materials.

Packaging problems and requirements are complex. There is a great variety of products—red meats, poultry, fish, and other seafoods—and they come in fresh, frozen, cured, and heat processed forms. Adequate packaging of these perishable products is a challenge to the industry.

Color probably is the most important single factor for consumer acceptance of packaged meats. Control of moisture loss to prevent product drying or desiccation is also important. Fresh meat will turn dark red if permitted to dehydrate in the open air.

Flavor and odor loss or pickup must be avoided. Undesirable odors and flavors may be due to contamination before packaging, absorption during storage, or from foreign matter in containers or packaging materials.

Desirable texture and juiciness should be preserved. Greaseproof packaging materials must be used because of the fat content of meats.

Associated with the fat content and storage of meats is the rancidity problem. Oxidative rancidity can be minimized in frozen meat products if packaging materials exclude oxygen. Since fresh meats are generally marketed rapidly, they do not encounter the problems of rancidity.

Microbial contamination and spoilage must be avoided. Meat is an excellent medium for growth of many types of micro-organisms, particularly bacteria.

Fresh meats are usually packaged in supermarkets because of their high perishability even after packaging.

A moistureproof cellophane, coated on one side with nitrocellulose, is most widely used to overwrap trays of fresh meats.

The coating on the cellophane, placed away from the meat, is permeable to oxygen but quite impermeable to moisture vapor. Thus some oxygen can enter, which is desired, but moisture loss from the package is restricted.

Freshly cut beef has a purple-red color that has little display value or consumer appeal. This color is attributed to the presence of the complex protein myoglobin. After a few minutes' exposure to the air, a bright red color develops that is very desirable. The oxygen of the air converts the purplish-red myoglobin to bright red oxymyoglobin; this is accomplished in only a few minutes.
A desirable packaging film must continue to supply enough oxygen to keep the bright red color as long as possible.

Prolonged exposure to oxygen changes the red color to brown, as oxymyoglobin is converted to metmyoglobin. This may occur in 24 to 48 hours or less, even under good refrigeration and sanitary handling procedures.

Surface drying, elevated temperatures, and bacterial contamination will speed discoloration.

Fresh meats can be packaged in flexible films which are impermeable to both moisture vapor and oxygen, and shelf life is much longer. Exclusion of oxygen keeps the meat purplish-red, which is less appealing to consumers. But even after extended storage, the meat will still develop good red color when it is opened and exposed to the air.

This use of impermeable films, sometimes called anaerobic packaging or vacuum packaging, will allow fresh meat packaging at a centralized warehouse rather than in supermarkets.

Experiments by Z. J. Ordal of the University of Illinois showed that ground beef packaged in saran film with low oxygen permeability still had good flavor after 10 days at 30° F. The use of saran, which excluded oxygen, provided a means for controlling psychrophilic bacteria. These are the bacteria that grow well under refrigeration and are commonly associated with fresh-meat spoilage.

Ground beef packaged in opaque oxygen-barrier films in vacuum packs is now seen increasingly in today’s supermarkets.

Cured meats, in contrast to fresh meats, retain their bright pink and red colors better in an oxygen impermeable package than in one that is oxygen permeable.

Therefore, cured meats can be vacuum packed in impermeable transparent films to provide better protection from discoloration.

The cardinal principle for packaging cured, smoked, and table-ready meats for retailing is to exclude both oxygen and light, since both accelerate color deterioration.

Lighting in a refrigerated display case readily fades the color of sliced cured, smoked, and table-ready meats—ham, bacon, bologna, and luncheon meats—when they are packaged in semimoistureproof cellophane, an air-permeable film. Exposure to light for as short a time as 4 hours may cause objectionable fading.

Opaque labels are essential, therefore, on the side of cured meat packages exposed to light, if the films are air permeable.

Remarkable progress has been made recently in developing combination packages of three or more materials laminated together—useful for vacuum and nitrogen backfilled packages. Four-ounce flexible packages of dried beef are often this type, which may be a combination of cellophane, aluminum foil, and polyethylene.

After the package is filled, air is evacuated and then the package is backfilled with nitrogen to retain looseness of the slices and to protect the product from oxidation. This package protects both color and flavor better than cellophane-overwrapped window cartons.

Hotdog producers use many types of films and film laminates, providing different amounts of protection. A billion and a half 1-pound packages of hotdogs or frankfurters are produced yearly—big business indeed. The amount of film required, 11 inches wide, would reach around the world 11 times.

For best protection, hotdogs are packed using barrier films like saran, polyester, or nylon which exclude oxygen.

Skintight vacuum packs for bacon now provide better protection than previous window cartons. Good color is retained, and rancidity is retarded, allowing up to 8 weeks of refrigerated shelf life. One such package uses a laminate film of 1-mil (0.001 inch) nylon
and 2-mil polyethylene coated with 0.1 mil of saran and a polyethylene-coated backing board to support the bacon.

Great quantities of fresh poultry are packaged and distributed through supermarkets. Much of this fresh product is shipped from processing plants to stores in wirebound crates lined with waxed kraft paper and with ice mixed with the poultry.

A NEW DEVELOPMENT is to ship pre-chilled fresh poultry in corrugated boxes without ice—commonly known as a dry pack. Fluids from the chilling process are absorbed by special paper toweling liners.

Poultry shipped in these boxes reportedly maintains a fresher appearance because the product is not subjected to skin bleaching by melting ice.

Fresh poultry usually is prepackaged after it reaches the supermarket. Here semimoistureproof films are desired which have fairly high gas permeability. If films are too moistureproof, slime formation is increased. If they are too impermeable to gases, odors that develop within the package may accumulate and become objectionable. These off odors are due to slowly developing bacteria on poultry surfaces, which grow even under refrigeration.

The film also helps maintain the fresh bloom and protects against shrinkage and dehydration. Dehydration results in darkening of the meat.

Cut-up poultry has the same film requirements, but pulpboard trays are added to aid in unitizing and to absorb the moisture "drip" that exudes from cut meat.

FROZEN POULTRY is shipped in corrugated boxes which must be rigid enough to withstand abuse and protect the product. It has, of course, a much longer shelf life than fresh poultry when adequately packaged and kept frozen.

The primary problem in frozen meat and poultry is preventing freezerburn, a type of deterioration caused by dehydration which leaves white or bleached areas. Packages should be moistureproof and skintight to avoid freezerburn; heat-shrinkable films may be used to advantage.

Polyvinylidene chloride and irradiated polyethylene films both allow high shrink and make good contour packages. Removing the air from film packages after the birds are inserted assists in retarding oxidation, which is the cause of rancidity during prolonged freezer storage.

Edible coatings of acetylated monoglycerides have been approved for use on food.

Meat, poultry, and even nut meats which are dipped in these materials lose their moisture slowly.

It is likely that such edible coatings will find commercial use in the future. However, they do not provide as much protection as moistureproof films so they probably will be used in conjunction with other packaging.

OVER A BILLION POUNDS of seafood is marketed annually in the United States either chilled or frozen. All of it is packaged in shipping containers or consumer packages at some time during marketing. Considerable research in this field is done at regional laboratories of the Bureau of Commercial Fisheries, Department of the Interior.

Fresh fish and shellfish spoil as a result of bacterial or enzymatic action. Low temperature is the most important single factor in retarding spoilage. If a temperature of 32° to 35° F. is maintained, fish may remain acceptable for as long as 9 days from the time when they are caught.

Packaging is the second most important factor in extending keeping quality of fresh fish. Bulk containers serve to hold the fish, and crushed ice maintains low temperatures. Metal and wood boxes are widely used.

Water-resistant fiberboard boxes are now employed to some extent because of their good insulating properties. Reportedly, fish can be kept at low temperatures in these boxes with considerably less ice than in conventional wood boxes.
Frozen fish need protective packaging that will prevent moisture loss and oxidation of fats.

The usual consumer package for frozen fish fillets is the waxed carton with a waxed-paper overwrap. To eliminate dehydration during frozen storage, however, packaging materials with very low moisture-vapor transmission rates must be used.

Some plastic wax coatings and plastic films—polyethylene, polyester, and polyvinylidene chloride—or combinations of these materials with paper have excellent moisture-barrier properties. They are finding increased use for packaging fish.

Fatty and moderately fatty fish must be protected against oxidation of the fats.

Rancidity develops as a result of the reaction of the fat with oxygen, which is in the package initially or which migrates through the packaging material. If this occurs, quality declines and consumers are dissatisfied.

Vacuum packaging in shrinkable film bags that prevent transmission of oxygen is one solution. Air is removed from the package and the film shrunk tightly around the product.

Purging the package with nitrogen is another method of removing oxygen before sealing. This method is good where a loose-fitting package is desired.

Another method of protecting fishery products against rancidity consists of coating the unwrapped product with gels prepared from seaweed extract or solutions of corn-sirup solids. These materials provide coatings that resist the penetration of oxygen.

Antioxidants incorporated into packaging materials are also of some value in preventing oxidation, particularly where there is close contact between the package and the product.

The variety of frozen foods now available in supermarkets is immense; all are packaged for protection.

This variety continues to grow rapidly. It includes practically a full range of food types: Meats, fruits, vegetables, beverages, bakery products, dairy products, and desserts. Each comes in a variety of forms and with more and more built-in services to please consumers.

Many kinds of frozen dinners and combination foods are available.

Newer items include frozen packaged salads, and cranberry apple salad with walnuts.

Preservation is primarily through the freezing process with subsequent storage at 0°F. or below. However, good packaging is a physical means of extending the storage life of frozen foods. With no protective packaging, most frozen foods would become unmarketable or unpalatable in a few weeks' time. Wood, metal, glass, paper, and plastic materials have been used successfully.

Packaging protects frozen food from dirt, insects, and micro-organisms before and during storage, as well as during thawing and preparation for cooking. For fruits packed in sirup, waterproof packaging is of prime importance; for obvious reasons leaky cartons must be avoided.

Protective packages are also designed to overcome the conditions of low-temperature storage which desiccate foods and cause freezerburn.

Freezerburn was mentioned earlier but deserves further emphasis because of its importance. It may irreversibly alter the color, texture, flavor, and nutritive value of frozen foods.

The snow or frost that accumulates on coils in a freezer comes from moisture vapor in the air condensing and freezing.

As moisture is removed from circulation, any moist product in the room will give up more water vapor.

Thus there may be a constant loss of water in the form of vapor (sublimation) from the unprotected materials in the storage area.

Moisture-vaporproof packaging materials must be placed around the food to eliminate or minimize yielding of moisture to the freezer coils. If much desiccation occurs, the food develops freezerburn. Visible frost may develop
even within good packages if storage temperature is allowed to fluctuate.

ONE OF THE SIMPLEST protective coatings for frozen foods is to glaze or coat them with ice. Glazing has been widely used in the fishing industry.

More commonly, barrier films, aluminum foil, and special papers provide protection from desiccation. These packaging materials must not impart any odor or flavor to the product. They should also prevent odors from other products stored in the same room from contaminating frozen food. Odors and flavors from fish and smoked meats may migrate into other foods, if not adequately packaged in impermeable materials.

Some new products like frozen chopped onions may lose their desirable aroma if the package is an inadequate barrier. Transparent pouches of saran-coated cellophane laminated to polyethylene make a gas-tight package which provides good aroma protection.

LIGHT CAN BE damaging to the color and flavor of frozen green vegetables like peas, particularly if storage is at temperatures higher than 0°F. Peas held only a week at 20°F in transparent packages in an illuminated display case may become slightly bleached or mottled, and flavor is damaged. Bleaching and flavor loss are severe after 3 or 4 weeks of exposure to light.

The peas absorb radiant energy from the light. This creates a temperature difference within the package, and moisture is lost to surrounding air-spaces and container walls.

Opaque packaging materials, therefore, are desirable. The popular 2-pound transparent polyethylene bags for loose-frozen free-flowing vegetables (pour and store) are satisfactory for retailing under lights if temperatures are maintained at 0°F or below.

AN IMPORTANT PACKAGING innovation, now expanding rapidly, is heat-in-bag or boil-in-bag frozen foods—frozen main dishes and frozen vegetables in sauces. Production was already over 300 million units a year in 1965.

Polyester film laminated to polyethylene is in wide use. This protects the food in both below zero temperatures and in boiling water. The see-through polyester bags of food are simply placed in boiling water, steamer, or electronic oven until cooked.

The consumer is assured of flavor and nutrients being sealed in the package. She need not concern herself with having to clean or scour pans.

COMBINATION PREPARED foods in boilable bags require the package to be an excellent barrier material against water, moisture vapor, gases like oxygen, and grease.

Restaurant owners, hotels, and drive-ins like boil-in-bag frozen foods because orders often can be filled 50 percent faster than by conventional methods and a variety of gourmet meals can be easily provided.

Dozens of frozen prepared foods can be heated simultaneously in the same cooking cauldron. These include broccoli au gratin, lima beans in butter, creole succotash, roast beef with gravy, and chicken a la king. The boilable bags are packed in opaque protective cartons picturing and describing the finished product.

Rigid aluminum foil containers are widely used as containers for frozen dinners, bakery products, and pizzas where baking is required. These foil containers have excellent heat conductivity for rapid baking. They are moisture- and vapor-proof, odorproof, and greaseproof. They may also be coated on the inside if protection from food acids is needed.

FOOD PRESERVATION by canning or heat processing leads all other methods and provides maximum storage life.

It changed the eating habits of modern man. Scurvy and pellagra, dread diseases caused by lack of certain vitamins, are almost unknown wherever canned fruits and vegetables are enjoyed. And canning has proved one of
the greatest laborsaving devices in the American home.

Canning dates back to 1795 when Nicolas Appert, a Frenchman, discovered that food heated in sealed containers was preserved if the container was not reopened and the seal didn’t leak. Scientists in those days did not know the cause of food spoilage but the canning process worked.

Metal cans, glass jars and bottles—these are the commonplace yet fabulous containers that protect our canned foods. Some flexible packages made from lamination of films or film and foil now withstand heat processing temperatures and will be entering the picture. Laminated materials are a combination of two or more materials bonded together by heat and pressure.

Metal cans and glass containers help insure good quality for thousands of different packaged foods. Today’s supermarket shelves are lined with cans, bottles, and jars.

No container comes close to the metal can in total production. Over 48 billion metal cans were produced in 1964. Glass containers are in second place with production now over 27 billion containers annually.

The average American family uses about 600 food cans annually. Americans open about 131 million food cans every day.

Cans and glass containers are an indispensable part of our plentiful food supply. Both are strong and provide exceptional protection. Both withstand the high temperatures needed to sterilize foods and the pressures built up to provide an airtight vacuum container.

The purpose of heat processing is to destroy pathogenic and spoilage organisms that may be present in raw food materials. Sealing the container prevents reinfection of the food. Having a vacuum in containers is one way to remove oxygen.

A vacuum in canned foods helps protect color and flavor of products, assists in retaining vitamins, prevents rancidity due to oxidation, and helps retard corrosion of cans and corrosion of closures on glass containers.

Approximately 4 million tons of metal, mostly steel, go into the manufacture of cans each year and only about $\frac{3}{4}$ of 1 percent is tin. Thus, tin cans are a misnomer.

Thin tin coatings, applied efficiently by modern electrolytic methods, protect the steel from both external and internal corrosion.

In addition, other baked-on organic coatings or “can enamels” are used with the modern sanitary can, preventing interaction between metal and various foods. They aid in preserving the attractiveness of food and the appearance of the can, or may even replace the tin coating.

Products like rhubarb, tomato juice cocktail, and some fish products are noted for their detinning action on tinplate. Therefore, these foods are packed in enamel-lined cans. Highly colored fruits, like cherries and berries, fade when packed in plain cans. Can enamels formulated from oleoresins prevent this fading.

Many vegetables like peas and corn contain sulfur-bearing protein constituents. During processing these compounds break down, yielding sulfur residues that react with tin and iron of the container to produce dark-colored metal sulfides.

These deposits are similar to the tarnish found on silver spoons in contact with eggs. Like this tarnish, “sulfur black” in cans is harmless but nevertheless is objectionable because of its appearance.

Now sulfur-bearing foods are packed in containers with an oleoresinous coating with zinc oxide pigments, which trap the sulfur and prevent discoloration.

Beer and beverage containers have double coatings that prevent flavor changes. Meat cans may have special phenolic coatings with fatty acid amides to prevent the contents from sticking.

Aluminum cans are growing in popularity because of their light weight,
corrosion resistance, and compatibility with certain foods and beverages. Current applications for aluminum cans include beer, soft drinks, frozen fruit juices, dairy products, and canned meats and fish—like sardines and tuna.

The aluminum pull-tab end, an important packaging innovation, has had much to do with increased usage of aluminum cans. The pull-tab end does not contribute to product protection, but it has sales appeal and convenience.

Fiber cans with a fiber body and metal ends and liquid-tight paper containers have a role in protective packaging of items like cocoa, salt, fruit juice, and milk.

The paper milk carton, which first reached the markets in 1934, has expanded to the point that 18 billion were produced in 1964. These are now mostly polyethylene-coated paper cartons, which have gradually replaced wax-coated cartons for both milk and chilled juice.

Use of Glass Containers for food and beverages continues to grow in constant competition with metal cans.

Glass jars are used for most processed baby foods. Glass bottles are excellent containers for milk, soft drinks, soluble coffee, and many other beverages. Glass containers predominate for home canning.

Glass has many characteristics that play a role in providing protection for food. Glass is chemically inert, so it does not react with foods to produce flavor changes. For foods like pickles, ketchup, and mayonnaise, glass containers are ideal.

Glass is almost 100 percent impermeable, nonporous, and odorless. It is transparent, allowing the contents to be inspected for quality. Glass containers are strong so they give good physical protection. And each year they are being made stronger, yet lighter and thinner. They are easy to open and to reseal to store unused portions of the contents.

As with cans, glass containers may have various surface treatments to improve performance. Colored glass can give protection against light rays where required. For example, a Wisconsin dairy showed that amber-colored glass protects milk from the flavor changes which are a result of exposure to the sun.

Returnable bottles for milk, soft drinks, and beer are among the lowest cost containers found in packaging—averaging less than half a cent per trip.

Glass containers are useful packages to food processors only if properly capped or sealed. Good seals are needed to prevent contamination and to prevent transfer of gases.

Currently, many closure types are made from metal, plastic, cork, rubber, and paper. They are continually being improved.

Some provide pilfer-proof seals. Some provide hermetic or airtight seals, and others are nonhermetic.

High utility closures are available with improved gaskets for vacuum-packed foods. These maintain the vacuum, protecting quality and increasing shelf life of the product.

Appreciable growth of aerosol packaging of food is expected, since numerous new propellent gases have been approved by the Food and Drug Administration.

Aerosol packaging until recently was limited to whipped cream and to other toppings. Soon there may be aerosol mayonnaise, honey, ketchup, and fruit purees.

This is more than just convenience packaging. Foods packaged in hermetically sealed containers with a propellent to eject the product are protected from evaporation, from contamination by micro-organisms, and from oxidation. One-way valves permit dispensing food but prevent entrance contamination.

Whipped cream is the most familiar aerosol product and is a food that benefits from aerosol packaging. Leftover hand-whipped cream often deteriorates or is discarded, while aerosol whipped cream may be dispensed in desired portions and the container put back in the refrigerator for future use.
BAKERY PRODUCTS are packaged to protect them both from drying out and from gaining moisture.

Protective packaging is particularly important in keeping the freshness and crispness of crackers and cookies. If the packaging material gives adequate protection against moisture vapor transmission, it can be expected to protect the product from dust, dirt, mold spores, and off odors.

Consumer packages and shipping containers for crackers and cookies also provide structural strength for protection from crushing during marketing. Fragile pastries are protected in overwrapped molded plastic trays, paperboard cartons, or window boxes.

Waxed glassine gives bakery products dependable protection from moisture vapor. Other materials that do the job include waxed paper, glassine, foil, cellophane, polyethylene, and polypropylene.

SUCCESSFUL PACKAGING of potato chips is not simple. Loss of crispness and rancidity are factors limiting shelf life.

Rancidity in potato chips results from the reaction of oil with oxygen in the presence of light or heat. A good oxygen barrier is especially needed to retard rancidity. Recent research shows that a saran-latex coating on glassine bags effectively excludes oxygen, preventing rancidity of chips.

Shelf life of shelled nuts is markedly extended with good packaging.

Nuts packed under vacuum in metal cans are protected for long periods from darkening and flavor changes caused by oxidation and exposure to light. Moisture loss or gain is prevented.

Transparent film bags or pouches also are widely used for packaging shelled nuts. They are less costly and lighter in weight than metal cans, but do not provide as much protection from oxygen, light, moisture, and insects. Consequenly, shelf life is less in film bags than in vacuum cans.

Greater barrier properties have been built into films through coatings and laminations. An adequate shelf life for nut meats in film bags is now possible with these improved films. Replacement of the air in film packages with nitrogen markedly retards rancidity and darkening.

MANY IMPROVEMENTS in convenience packaging of food are seen in our supermarkets.

Convenience packaging involves shape and size of containers that allow easy pouring, serving, carrying, re-closing, and storage in refrigerators.

The trend toward individual servings of mustard, ketchup, cream, sugar, soluble coffee, jelly, salt, and pepper is increasing rapidly. Recent improvements in laminating polyethylene film to foil, cellophane, and other films, which make better barrier packages, open the possibility of marketing many other foods in portion packs.

Many unique films have been created to meet multiple needs of foods.

A new “3-ply” film for bread is made of a thin layer of polypropylene sandwiched between outer layers of polyethylene—yet the entire film is a thousandth of an inch thick.

A new “6-ply” film pouch is available for vacuum packaging foods like fresh shredded Cheddar cheese, dried beef, and soup mixes. This is a lamination of cellophane-polyethylene-cellophane-polyethylene-aluminum foil-polyethylene.

Individual strips of bacon in foil envelopes, which may be dropped in a toaster, may soon be marketed.

THESE ARE JUST a few of many tailor-made packaging developments.

We can be sure the food and container industries will continue to keep abreast of new developments in packaging materials and food processing, and create even better food packaging for the future. This will be done at an economic cost.

We know it’s what’s inside the package that counts. Packaging can’t improve food quality. But with proper storage plus the right package to protect each food from deterioration, waste and spoilage are minimized.