

**Shelf Stability:  
A Question of Quality**

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**U**ntil refrigeration became the norm, in this country at least, creating shelf-stable foods was the only way to assure a consistent, somewhat variable food supply throughout the year. Those with sufficient means could always butcher a herd animal or go out and hunt something down, but that still caused problems. Unless the weather cooperated and provided a deep freeze or one invited 20 or 30 close friends for lunch, most of the food provided by larger meat animals would go to waste. Not to mention the various unsavory results of not following the rest of the food guide pyramid.

  So our ancestors dried and smoked and fermented and salted their food to provide a year-round supply. The discovery that heating foods in closed containers preserved the food for long periods of time provided a major breakthrough at the turn of the 19th century. And though the safety and technology of shelf stable food has vastly improved since those days, critics would say the quality has not kept pace.

  While some shelf-stable foods leave room for improvement, current technology provides the answers to many of the problems facing those who design these types of products. Some of the problems are easier to solve than others. But, as consumers demand more for their food dollar, the convenience of room temperature storage must share the stage with high quality and a satisfying eating experience.

  In order to qualify as shelf stable, a product must be safe for consumption and maintain an acceptable quality when stored at room temperature. Typically, they are low- or intermediate-moisture products or high-moisture products whose formulation, processing and/or packaging render them commercially sterile and impervious to microbial growth. While hosts on the late night shows joke about 10-year-old Twinkies, they don't really fall under the shelf stable umbrella -- the official shelf life is only one week according to the manufacturer.

***The bad actors***

  Four major agents contribute to the deterioration of foods: enzymatic, microbial, chemical and physical phenomena. The first step in designing a shelf-stable product is to address each of these through formulation or processing. Unfortunately, sometimes the cure is almost as bad as the disease. That is why food product designers need to look closely at the options and decide which have the best result from all aspects -- safety, storage and quality.

  Enzymatic activity can produce proteolysis, oxidation and browning, among other undesirable reactions. The optimum reaction rates occur at temperatures slightly elevated from ambient room temperature storage. Fortunately, enzymes are inactivated by heat: approximately two minutes at 200°F moist heat denatures the molecule. Luckily, since technology hasn't provided any alternative, this heat treatment is fairly benign to the finished product quality. Many shelf stable food products go through some kind of heating sufficient to inactivate the enzyme without a special step, such as cooking, baking or retorting.

  Microbial activity can take two forms: food spoilage and food safety. While spoilage refers to the deterioration of the aesthetic properties of the food -- flavor, appearance, texture and odor -- food borne pathogens and the toxins they produce can cause illness or death.

  In shelf-stable products, microbial problems can be controlled by the formulation, the process or a combination of the two. In many foods these are the solutions that provide a whole new set of problems when maintaining organoleptic quality becomes an issue.

  Chemical reactions create a number of results affecting the quality of shelf-stable products. The most universal problem is oxidation and its many undesirable consequences: off flavors, nutrient loss, changes in appearance, etc. However, oxidation is not the only reaction of concern. Things like ingredient interactions, esterifications, browning reactions and staling also decrease the desirability of foods.

  Physical effects will affect the quality of many products over time. Evaporation, moisture migration, and emulsion instability can make a good product go bad during storage. Texture and appearance degrade over time.

***Preservation practices***

  Protection from microbial spoilage is still the most important facet of developing shelf-stable foods. The objective is to create conditions where microorganisms are unable to grow or, better yet, are destroyed.

  One of the most important criteria from a microbial standpoint is water activity (Aw). This indicates the amount of free water available that microorganisms can utilize. Aw is defined as the equilibrium relative humidity (ERM) divided by 100. Reducing the water activity below 0.6 effectively curbs microbial growth.

  Lowering the moisture level is the simplest way to reduce the water activity. This involves removing the water through a drying process. These methods typically incorporate heat and often result in decreased quality. Sometimes the process is a means to the end, like baking or frying, and heat actually improves the product. But, even these methods can drive off important flavor volatiles incorporated before the heat process.

  If a product requires a higher moisture to deliver certain textual qualities, the free water can be chemically bound by the addition of solutes, usually sugars or sodium chloride. Water activity cannot be significantly changed by the addition of gums and starches. They merely physically bind the water. While certain products may chemically bind small amounts of water, and there is some disagreement about this, these products are not designed to affect the water activity.

  "Water activity means chemically bound water," explains James Carr Ph.D., technical director, Sanofi BioIndustries, Inc., Waukesha, WI. "There you're talking about smaller molecules that actually associate with the water and form bonds. When you use gums and starches, the product may look dry, but the water is only immobilized in the physical sense -- it is still available for microbes to grow on and chemical reactions to take place. The molecular weight of hydrocolloids is around 100,000 and in a given weight you will not have that many molecules to affect the water activity."

  "People have wanted to use carrageenan to reduce Aw in various products," Carr relates. "I recommend they switch from sugar to dextrose or change other solutes in the system to lower the Aw.

  When designing a sugar system for a food product with a lowered Aw, focus on the types of sweeteners used. A monosaccharide like fructose will have a greater impact than a disaccharide like sucrose. The higher D.E. (dextrose equivalent) corn sweeteners bind more free water than the low D.E. types. At the same time, a product designer has to consider the sweetness level or textural effects contributed by the sugar system and how it affects the finished product.

  Other options for reducing water activity include using a humectant, such as propylene glycol or glycerin, or an ingredient like fat that provides the perception of moistness. In the current reduced-fat environment, fats and oils are not a popular option. Additionally, most fat replacement technologies use some kind of water based system. This increases the amount of physically bound, chemically free water, making it very difficult to maintain a low Aw.

  Salt can be an effective agent for lowering the water activity of a food product. Because Aw is related to the size of the molecule, sodium chloride at molecular weight 58.4 is a much more potent agent than sugar (molecular weight 342) on a per weight basis. Because of its flavor, the high usage levels of salt are restricted to products where the flavor is acceptable, like semi-dry processed meats. Six percent salt will make a meat product shelf stable. Since salt levels like this are not acceptable in most products, added salt is probably best incorporated as one part of a total Aw reduction strategy. Other factors, such as pH, could lower the level of salt required.

  Acidic conditions help to curtail microbial growth. A limited number of microorganisms grow in acid (pH 4.5-3.7) and high acid (3.7-2.3) foods. Clostridium botulinum will not grow in this range. Additionally, spoilage organisms that grow in foods under pH 4.5 tend to be more susceptible to heat. This can provide a number of formulation opportunities as long as an acid flavor character fits the product.

  Increasing the acidity can be achieved with standard acidulants such as acetic acid, citric acid, and phosphoric acid or by the addition of naturally acidic products like lemon juice. Each will contribute a distinctive flavor that can influence its choice in a particular application. For instance, phosphoric acid contributes a flat, harsh, sour note. Malic acid produces an acidic flavor that builds and then gradually diminishes and complements fruit flavors.

  A number of chemical agents exist that act as preservatives or inhibitory agents to microbial growth. The most commonly used preservatives consist of certain organic acids and their salts, such as parabens, sorbic acid or potassium sorbate, benzoates and propionates. They each have an optimum pH range for effectiveness and may work best against different microorganisms. Benzoates, for example, work best in the acid range, while parabens should be used when the product is in the neutral range.

  Various chemicals act as disinfectants or fumigants, such as chlorine, hydrogen peroxide and ethylene oxide. These act as sanitizers and are not added as ingredients but they may find their way into the finished product.

  "We didn't have UHT aseptic products like juice boxes in this country until nearly a decade after the process was commercialized," notes Phil Katz, president of Herbert H. Shuster, Inc., Quincy, MA. "There was no way to reduce the residuals from the hydrogen peroxide used to sanitize the packaging surface. They finally set a limit and approved residuals up to that limit."

***Now you're cooking***

  High-heat processes, such as retorting or pasteurization, destroy vegetative cells and spores, as well as certain toxins produced by pathogens. The heat treatment required for commercial sterilization depends on a number of factors: the type and number of organisms present, pH and presence of solutes (such as sugar and salt).

  There is a time/temperature relationship -- the higher the temperature, the shorter the time required. Thus coupling HTST, (High Temperature Short Time) and UHT (Ultra High Temperature) technologies with aseptic packaging techniques generates shelf-stable products.

  At the same time heat is destroying the microflora in a shelf stable product, it is wreaking havoc on its organoleptic qualities. Depending on the product and the ingredients used, high heat results in loss of flavor, changes in color and modification of texture.

  "Any highly volatile flavor compound dissipates when heated," notes Terry Emmel, manager of flavor development for McCormick & Co., Hunt Valley, MD. "When adding flavor ingredients, the choice of solvents also influences the stability. Vegetable oils exhibit a fixative effect, as opposed to an alcohol or volatile ester."

  There are two ways to help maintain the proper flavor profile in products subjected to heat: encapsulation with a protective material, such as a protein, and the use of processed or precursor flavors. These latter two types of flavors, usually Maillard reaction products, result from the application of heat. The processed flavors have undergone high heat during manufacture and are stable under high-heat conditions. Precursor flavors form during the retort process producing the desired effect in the finished product. (See "New Ways to Deliver Flavor," New Technologies department, June 1994, **Food Product Design**.)

  In addition to the loss of flavor, undesirable compounds may form under high temperatures. Brown and cooked notes, while pleasant in meat and baked products, are out of place in many others.

  "The average U.S. consumer just won't drink a UHT aseptic package of milk," says Katz. "They're not used to the cooked flavor. The milk products with added flavor adjuncts aren't completely successful in covering up the taste. Even juice in aseptic boxes has a cooked flavor when compared with frozen concentrate."

  As with flavor, the effect of heat on color is a double-edged sword. Browning reactions, including caramelization and Maillard browning, can impart a desirable color to a gravy, but not to a tomato sauce. Heating natural pigments like carotenoids and chlorophyll alters them. But, heating chlorophyll-containing vegetables in an alkaline environment helps to maintain the green tint.

  High heat usually affects the texture negatively, too. While it has a tenderizing effect on many products, exposure to elevated temperatures for long periods of time often changes tender to mushy. Certain stabilizers and thickeners break down under these conditions. But the heat stability of these products is only one aspect to the selection of the correct stabilizing system for shelf-stable foods. These ingredients have a tremendous effect on the overall quality of the finished product and will be discussed in more detail later in this feature story.

  Nutrient losses in thermally processed foods can be a problem. Some are heat-sensitive, especially thiamin, incurring significant losses when exposed to heat. There is a time/temperature relationship so the nutrient loss is highest in retorted products. Acid foods retain more thiamin because this vitamin exhibits increased stability in the presence of acid. Also, acidic foods require a less severe heat treatment to achieve shelf stability.

  In the case of high-acid, high solids products, hot filling is all that is required to produce microbial stability at room temperature storage conditions. If the product can be acidified to 4.5 or below, it will only need minimal heat processing, i.e. boiling, resulting in minimal heat promoted deterioration.

  "We're seeing a lot of activity in shelf-stable products on the high acid end," discloses Katz. "They are more economical to produce because of the lower heat requirements. The pH of many cooking sauces and products of that nature are adjusted so they are shelf stable, but the flavor profiles are being modified. The acidity is masked or 'buffered' from a flavor standpoint. It's not a chemical buffering -- you need the pH from a microbial perspective and to reduce the amount of heat processing required."

  "Starch and gum technology has created some ingredients that can mask the sharpness or bite from the acidity," continues Katz. "The sweetness level can also counteract the acid and so can certain flavors -- the vanillins, the maltols, the sugar alcohols. Increasing the spice profile often helps. Getting away from the hard acids improves the flavor. More natural acidifiers, like lemon and lime juice, tend to taste less harsh."

***Flash Gordon and preservation***

  Once hailed as the wave of the future, irradiation to produce shelf stable foods has not met with wide commercial success. In the United States, irradiation has only been approved by the FDA and FSIS for a limited number of products: poultry, spices (including herbs and vegetable seasonings), some fresh produce and pork for trichina control. The maximum dosages of gamma radiation are relatively low -- not in the ranges required for commercial sterilization. It's approved function is the reduction of the microbial load and the destruction of insects. For example, the highest approved dosage limit is for spices at 30 kGy (kilogray). Generally, at least 40 kGy is required for sterilization.

  "I don't see a great demand for shelf-stable irradiated foods for the general public in the near future," predicts Michelle Marcotte, senior market development specialist, food irradiation application, Nordion International, Inc., Kanata, Ontario, Canada. "Products have to go through the FDA for clearances. This is not impossible, but it takes both time and money to generate the information that the FDA requires. I've had informal discussions with food manufacturers about things like shelf-stable cheese sauces in a pouch, but without clearances in place it won't go very far."

  Irradiation does exhibit some interesting possibilities. Although an irradiated product still would have to be heated to inactivate the enzymes, the resulting products tend to exhibit superior organoleptic qualities to a comparable retort product. According to Charles Bourland, Ph.D., subsystem manager for space station, flight crew support division, Johnson Space Center, Houston, the texture of beef steaks is neither mushy or tough, but is similar to that seen with conventional cooking. NASA has been granted temporary approval for irradiated beef steaks for use in the shuttle program. There also have been experimental products made for hospital patients with special dietary needs. (See Sidebar: Shelf Stable Irradiation : Special Cases.)

  Rather than treating the product stream or individual packages, irradiated product is treated by the case or pallet. The packaging for shelf stable irradiated foods has the same requirements as any other shelf stable product, with one caveat. The inner layer has to be compatible with the process to eliminate and migration of any packaging components to the food. According to Marcotte, polyethylene, a common component of retort pouches, is inert to the irradiation process.

  While the FDA has taken the position that the approved uses present no hazard to the consuming public, opponents of irradiated foods claim an array of potential hazards. These include carcinogenic and mutagenic effects of consumption, chromosome damage, formation of toxic compounds such as benzene, formation of free radicals, mutation of exposed microorganisms and the formation of "unique" radiolytic compounds (those not naturally found in irradiated foods). The FDA reviewed these claims and reaffirmed its position on irradiation safety. Details can be found in the Federal Register (53 FR 53176).

  "Irradiation is going to be a hard sell in this country because of the consumer perception," predicts Katz. "Personally, I worked with the government and tasted irradiated foods every day for three and a half years and I don't glow in the dark. But there are some real benefits that have come out of the work -- lowering the bacterial load on high-fat spices and meat, reducing the maturing of fruits and vegetables. We did some work with refrigerated salads and achieved unbelievably low counts after six to eight weeks of storage. But by then, the moisture had migrated out of the vegetables, rendering the product inedible from a quality standpoint."

  While food sterilized by this process has been favorably compared to that produced by retort methods, it does not mean that the products mimic fresh foods. While some vitamin loss occurs, researchers compare the levels to those maintained in conventional heat sterilization. The levels vary with the treatment and product, but reduction of thiamin and vitamin C occurs the most often. Vitamin retention improves when the food is treated and held at low temperatures and atmospheric oxygen is excluded. Fresh fruits and vegetables can become discolored and soften. Certain foods, especially dairy products, acquire off-odors and flavors.

***Chemical culprits***

  When a food product is exposed to oxygen in the air, oxidative chemical reactions often occur. Oxygen attacks the structure of a molecule and the result is generally not positive: oxidative rancidity of lipids, destruction of oxygen-sensitive vitamins, such as ascorbic acid, and color changes are a few of the outcomes.

  Oxidative rancidity of lipids occurs when oxygen reacts with an unsaturated bond in the fat to form a free radical. This initiates a chain reaction, resulting in the formation of aldehydes, ketones, fatty acids and alcohols that produce the off-flavors and odors that characterize fat rancidity. Antioxidants interfere with this reaction by donating a hydrogen to the fat or peroxide free radical creating a stable compound that no longer continues the reaction.

  A number of conditions catalyze this reaction: heat, light and the presence of metal ions such as copper and iron. Product moisture and pH, as well as the degree of fat saturation, also influence oxidation. The less saturation, the more the risk of oxidative rancidity. Synergists such as citric acid, ascorbic acid and EDTA can often increase fat stability when used in combination with antioxidants.

  Antioxidants do not prevent or reverse oxidation according to Gary Shap, development chemist, Henkel Corp., LaGrange, IL. "You want to add an antioxidant as early in the process as possible to protect the product, especially if you are subjecting it to a high temperature process."

  Several antioxidants exist to help fight rancidity. The choice depends on a number of factors: the product substrate, the process, especially those involving heat, and regulatory considerations.

  "Oxidation is a very complex reaction," notes Connie Sandusky, Ph.D., technical sales, Kalsec, Inc., Kalamazoo, MI. "Different oxidation inhibitors work differently in different substrates -- there's not a generic one that works for every oil and every product."

  The most commonly used synthetic anti oxidants include butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT), tertiary butylhydroquinone (TBHQ) and propyl gallate. The FDA and USDA restrict the usage levels of these products. This varies with the antioxidant and the product. Each works best under a certain set of conditions. BHA and BHT are more effective in animal fats than vegetable oils and work in synergy with each other. TBHQ works well in both animal and vegetable fats and is suitable for frying applications. Propyl gallate stabilizes vegetable oil and provides a synergistic effect with BHA and BHT, but is heat sensitive.

  A number of other ingredients exhibit antioxidant properties. These are often considered "natural" antioxidants and may perform other functions, such as flavoring foods. Because of the positive label impact, they are rising in popularity.

  Mixed tocopherols provide effective antioxidant properties in many foods, especially animal fats and nut oils. These compounds occur naturally in vegetable oils and are made up of a mixture of related compounds including vitamin E. They exhibit increased solubility and decreased volatility over the synthetics due to a long hydrocarbon side chain in their structure. This makes them stable in high heat conditions.

  According to Shap, in addition to its heat stability, mixed tocopherols provide three main benefits over synthetics: natural labeling, worldwide regulatory approval and unrestricted usage levels in foods regulated by the FDA.

  "Depending on the application, mixed tocopherols may or may not work as well as the synthetics in preventing the onset of rancidity at equivalent usage levels," Shap explains. "But the big advantage is that you're not regulated to a 200 ppm usage level limit. If you can get the required shelf life at 400 or 500 ppm with mixed tocopherols, you are legally allowed to go that high."

  Some spices contain significant amounts of naturally occurring compounds with antioxidant properties, especially rosemary and sage. Commercial blends of these products sometimes contain other ingredients that enhance their antioxidant properties. Spice extractives are labeled, "natural flavor" and the other ingredients are labeled separately. While these types of products may contribute characteristic flavors to food products, the flavor intensity can be tailored to the individual application. Removal of color pigments decolorizes the blends.

  While oxidation is the main culprit for degenerative reactions over shelf life, other reactions may come into play. These kinds of reactions are often dependent on the product matrix.

  "When adding flavors, you have to consider volatility, oxidation and binding of flavors to other ingredients," warns Ernst Graf, manager of food science, Tastemaker, Cincinnati. "When you use certain fat replacers, they may physically bind the flavor. Some of the aldehydes may insert themselves into the helix of a starch. You may be able to extract them analytically, but they're not available for taste perception."

  Engineering a flavor so that is compatible with the intended use and storage conditions is crucial.

  "Certain flavor compounds have a tendency to modify over time -- they're just not stable," reports McCormick's Emmel. "Often, when products change color, they are giving a visual cue that the product is changing. Some compounds can go through chemical reactions, that although they may be subtle, can produce off-characters."

  "Esterification reactions are the most common," he continues. "When there is an acid and an alcohol in a product together, they can combine to form esters. With storage, your cheese flavor develops a fruity character. If the ingredients lend themselves to polymerization, they tend to lose their character and eventually they may taste like plastic. These are the kinds of things you have to consider in flavoring shelf-stable products."

***A stabilizing influence***

  If all these considerations weren't complex enough, physical forces can render a product unacceptable. Gravity, oil or moisture migration, evaporation and the like change the character of the product as it ages.

  Many shelf-stable products -- soups, sauces and dressings -- contain a mixture of fat and water. These are usually in the form of an emulsion so that the product delivers a consistent flavor, texture and appearance. Emulsions consist of tiny droplets dispersed in a continuous phase, either oil-in-water or water-in-oil.

  Both heat and the effects of gravity over storage can cause emulsions to break down. The droplets can coalesce and become two separate oil and water phases. They may flocculate and become unevenly distributed through the product. They may even invert and change from water-in-oil to oil-in-water. Emulsifiers exhibit both hydrophilic and lipophilic tendencies which prevent these problems. This allows the emulsifiers to converge on the interface between the two immiscible phases and form a stabilizing film.

  The application strongly influences the choice of emulsifiers. Emulsifiers exhibit varying hydrophilic and lipophilic properties referred to as hydrophilic/lipophilic balance (HLB). Those with a low HLB, such as mono- and diglycerides, show an affinity for fat and work best in water-in-oil emulsions.

  Thickening a product or forming a gel network also act to keep different phases from separating. Functional polysaccharides or hydrocolloids provide a food product designer with an entire arsenal of ingredients to improve the texture, viscosity, mouthfeel, flavor and appearance of shelf stable foods. They are added to everything from low- or intermediate moisture foods to help provide a moist texture to highly aqueous systems like sauces to provide body and texture. They can also suspend solids or particulates and keep them uniformly distributed during both manufacturing and storage.

  "In general, you want to add hydrocolloids for shelf-stable products to thicken or gel or stabilize a product for both the process and the finished product," Carr advises. "You may have to thicken a product to help it run through the process better or to get a particular mouthfeel. You may need to stabilize it during the process to keep ingredients evenly distributed during filling or to maintain the distribution for the shelf life thereafter."

  Hydrocolloids modify products by acting as thickeners or gelling agents. Although the line between these two is somewhat blurred, simply stated, gelation means that an actual network of molecules has been formed rather than just swelling from water absorption. A fairly wide array of choices exist that can function in shelf-stable products: starch, agar, algin, carrageenan, cellulose gels, gellan gum, konjac, locust bean gum, methyl cellulose, pectin and xanthan gum.

  "Each can provide certain benefits and functions," notes Sanah Atassi, marketing segment manager, FMC Corp., Food Ingredients Div., Philadelphia. "In a lot of cases, the optimal characteristics will be provided by a combination of things. There are times that one ingredient works great by itself, but especially in low-fat systems, the combined systems really perform the best. This can be a challenge, but as a supplier, we've found that often the way to maximize an ingredient is to use it in conjunction with something else."

  Many of these ingredients work under particular conditions, so the first step is outlining the product characteristics and process conditions. Many of these influence which hydrocolloid should be added and how well they function in a given application.

* Process conditions: Mixing procedures and equipment, temperature, time, agitation, pumping and filling viscosities.
* Formulation attributes: pH, ions, and particulates.
* Finished product characteristics: Clarity or opacity, mouthfeel, cling, microwave or heat stability, and flavor delivery.

  While we can't exhaustively cover the subject in the space allotted, we'll look at some specific examples.

  Retort products. Because of the harsh temperature requirements for these products, the stabilizer needs to stand up to long-term exposure to elevated temperatures. Because they require retorting, the pH is in the low or medium acid ranges. This category contains products like cream sauces and gravies, soups and stews, noodle dishes, meats and main dishes. Most of these require an additional heating step before consumption, either conventional or microwave.

  "Retort products require something that is resistant to breakdown through the retort heat cycle, as well as at the localized hot pockets you get during microwaving," recommends James Zallie, manager, marketing for National Starch and Chemical, Bridgewater, NJ. "There are a wide variety of modified starches that can cook out under the conditions required to make them commercially sterile, and then tolerate microwave heating."

  Many gums can withstand high heat encountered in retorting, especially at neutral pHs. Suppliers particularly recommend xanthan gum, cellulose gums and konjac for these applications.

  "Xanthan gum provides hot viscosity to a number of retort products," Carr explains. "If you have an emulsion, you need to stabilize it so it doesn't break down under high heat. You can often use xanthan in combination with starch to reduce the masking effects or starchy mouthfeel produced at high starch levels."

  Cellulose gel (microcrystalline cellulose) or carrageenan can suspend particulates and prevent oil coalescing and "fat capping" in retort products. As long as you add xanthan gum as a protective colloid in acidic conditions, colloidal forms of cellulose gel will not break down under high heat. The choice also depends on the process requirements.

  "If your process requires a low process viscosity and a low hot viscosity, you should consider carrageenan," Atassi recommends. "If you need to maintain suspension of particulates during filling, you don't want any heat thinning. Cellulose gel would be a good choice then."

  Konjac is extremely stable under retort conditions. It can form either a viscous aqueous sol or a heat-stable gel, depending on the system, so it is necessary to tailor the formula for the appropriate result. Interaction with other hydrocolloids, heat and pH affect the final gel or thickening characteristics. Atassi reports excellent results in cream soups. It has a synergistic effect with starch, increasing viscosity without producing a starchy mouthfeel.

***UHT and HTST processes***

  Again the stabilizers have to be heat stable, but since the duration of heating is much shorter, the effect is minimized. However, holding times required for certain aseptic processes may extend the time the product is subjected to high temperatures.

  "If you are processing something through a tubular heat exchanger, you need something that remains fluid during the process so that you don't plug the line, blow a gasket or experience 'burn-on,' " Zallie notes. "There are some highly inhibited starches that have slow gelatinization profiles suitable for products undergoing this kind of process. They have low hot viscosity for better heat transfer, but still provide a bodying effect after cooling."

  Dairy products typically use carrageenan to provide body and suspend particulates such as cocoa. Because it thins out with heating, it reduces the heat processing time. This results in products with better flavors, according to Atassi. When it cools, the viscosity returns.

  Aseptically packaged chocolate milk has a much longer shelf life than its refrigerated counterpart, making stabilization difficult.

  "You have to choose a carrageenan system that will stabilize against separation, but also avoids gelation during storage," says Carr. "The carrageenan must form a weak network in order to hold up the insoluble cocoa particles. It's almost imperceptible -- only 200 to 300 ppm carrageenan. While you actually have a network at that level between the casein and carrageenan molecules, you can still pour the product.

  Hot pack/cold pack. These products undergo moderate to no heating. This category contains products like acid sauces, high solids fruit products and salad dressing. In order to avoid retort conditions, they must have a high pH. Therefore, the stabilizer must be able to withstand acid conditions, sometimes in the presence of heat.

  One product line gaining popularity in this category is the shelf-stable water dessert gels. These need to maintain a gelatin-like consistency at room temperature storage and avoid syneresis during storage. Carrageenan, locust bean, gellan gum and konjac give the required properties.

  "You can blend carrageenans to get the exact texture you want," asserts Atassi. "You can match the texture of gelatin, or make it tougher or softer, but the product doesn't require refrigeration- to maintain a gel. Once the gel network is in place, carrageenan or konjac will be resistant to acid."

  A variation on this technology is the drinkable dessert gel. According to Carr, the gel network is partially broken or weak so that a slight amount of shear causes the product to flow.

  Acidic sauces and dressing also fall into this group. For these products starch, xanthan gum and propylene glycol alginate (PGA) are often used. These products maintain a consistent viscosity over time The PGA the texture produced by xanthan gum, making it shorter and smoother. If clarity is required, as in an oil and vinegar style dressing, carrageenan can be added to the list. And if the product being formulated is reduced or nonfat, you may add mouthfeel considerations and additional ingredients like cellulose gum to the matrix.

  "With a low-fat system, you not only need to suspend particulates and maintain emulsions, you have to replace the mouthfeel and rheology provided by the fat and structure the water," explains Atassi.

  Baked products. The hydrocolloids can also make significant contributions to the stability of baked goods, especially reduced fat products. Typically, the hydrocolloids used bind moisture in either the baked products themselves or in the icings and fillings used in conjunction with them. They can retard staling and maintain a softer texture. They act as stabilizers minimizing moisture migration or keeping fillings and icings from drying out.

  The idea behind shelf-stable food is simple: make a product that maintains its characteristics for an extended storage period at room temperature.

  Today's technology makes that goal a reality. But if the product is going to survive in the marketplace, the characteristics that it maintains better make the customer come back for more.

***Packaging Films: A Quick Snapshot***

  One additional and very important aspect of shelf-stable product design should not be overlooked -- its packaging. Flexible films are used in a number of areas, from snack foods to retort pouches. As with the formulation and processing the solutions are numerous and related to the product and process. To put it as succinctly as possible, the package should be designed to keep the good stuff in and the bad stuff out. The secret is to determine what exactly it is that needs to be kept in or out. In most cases, the packaging technology is there, but often it's a matter of cost.

  "Economics is one of the problems with products in retort pouches," notes John Holovach, technical services manager, new product development, Toray Plastics America, Inc., North Kingstown, Rl. "Some of the packaging materials cost more than the product and consumers are not willing to pay for the added expense."

  From a product designer's perspective, it's best to start out with a list of things from which the product needs to be protected, giving the packaging experts as much information as possible. If it is a low fat product, maintaining moisture is critical. If the product is high in fat, it will likely need an oxygen barrier. If you used annatto, to get away from using certified "artificial" colors, clear packaging will not work. Some products may require nitrogen flushing or other modified atmosphere methods for improved shelf life.

  "The food industry continues to require higher barrier packaging," maintains Holovach. "Currently, vapor transmission is the biggest barrier requirement. But with products like potato chips oxygen permeability is critical. Smaller products, low-fat products, these are much more sensitive to moisture transmission."

  Holovach continues: "Initially, everyone looked at what the material spec sheets said in terms of what they could expect from a package. Now there is a lot more sophistication in the evaluation process -- they're looking at the finished package. After a film goes through the flexing and handling through the converting operation, the packaging operation, shipping and handling by the consumer, it's critical that the package maintains its integrity. That's what a lot of the new technology is focusing on."

  Along with increased barrier properties and the maintenance of these in the finished package, Holovach cites one additional important trend that is making headway: reduction in the amount of materials used. This in an economic and an environmental issue.

  There is currently a lot of excitement in the packaging industry over clear metallization -- materials such as silicon oxide coating. While there are some products available, the cost bars their wide use. And while clarity may be an attractive property from an appearance standpoint, letting the light in may not be the best way to extend the shelf life of some products.

***Shelf-Stable Irradiation: Special Cases***

  While irradiated shelf-stable foods have yet to gain permanent approval in the United States, several applications use the technology on a test or temporary basis. For these applications, irradiation provides a number of benefits not seen in conventional processing methods.

  NASA has filed a petition with the FDA to obtain permanent approval for irradiated shelf-stable beef steak for use on space flights. Currently, they are proceeding with the program under official interim approval.

  During the course of the space program, American astronauts have been provided with irradiated ham, beef, smoked turkey, corned beef, bread and breakfast rolls. According to Charles Bourland, Ph.D., subsystem manager for space station, flight crew support division, Johnson Space Center, Houston, extended duration space missions demand a more palatable diet with strict nutritional specifications. Irradiation offers one solution to the design of these food systems by increasing the shelf life of selected products and reducing the requirement for costly refrigeration systems in flight.

  "We're currently obtaining our irradiated meat through the U.S. Army Natick Center," Bourland explains. "The actual irradiation is done at Vindicator, Inc., in Florida. The meat is first cooked to an internal temperature of about 150°F, packaged in a regular retort pouch, frozen and then irradiated. The finished product quality is outstanding. The astronauts prefer it over retorted meat."

  Studies indicate that freezing products prior to irradiation helps to minimize nutrient loss. Irradiation was shown to be no more destructive to vitamins and other nutrients including proteins, fats and carbohydrates than traditional methods.

  "Nutrient changes are somewhat product dependent," notes Michelle Marcotte, senior market development specialist, food irradiation application, Nordion International, Kanata, Ontario, Canada. "One of the more sensitive vitamins is thiamine, which is present in high levels in meats -- especially pork. There would be a significant reduction in thiamine in the dose range required for shelf stability. But because thiamine is heat labile and water-soluble, you will see significant losses in this particular nutrient with traditional heating processes."

  "As you're asking for clearances from the FDA," Marcotte adds, "you have to include the nutrient value of the product. The space program has to monitor the nutrient content of foods very carefully, because, in a sense, they're all study subjects while up in space."

  Marcotte also refers to research conducted on irradiated foods for people with special dietary needs, including those patients with bone marrow transplants and immune deficiencies. Organisms normally benign to the human body can have serious consequences if consumed by these people.

  Often, due to side effects of the treatment program, these patients have trouble getting sufficient nutrition. Traditional sterilization methods adversely affect the palatability of their food, and the patients will often reject it. The products resulting from irradiation sterilization more closely resemble normal products and are more widely accepted and consumed.