Consortium for Educational Communication

Module

on

Spoilage And Quality Changes In Canned Foods

By

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TEXT

Appearance of the unopened cans

Normally the ends of a can of food are termed flat, which means that they are actually slight concave and a partial vacuum exists in the container. If pressure develops inside, the can goes through a series of distortions as a result of increasing pressures and is called successively a flipper, springer, soft swell or hard swell.

Flipper: This is due to the mild positive pressure resulted inside the can due to overfilling or under exhausting. The can may be of normal appearance but the end if struck sharply against a solid or table top it becomes convex but it can be pushed back to its normal condition by a little pressure.

Springer: The one end of the can becomes bulged and on pressing or pushing, the other end bulges in the places of preveious one and a can in this condition is known as “Springer”. Springer may be due to the initial stage of hydrogen swell or by over filling the cans or by insufficient exhausting. Product is fit for consumption.

Soft swell: The ends of can are slightly bulged due to the formation of gas within the can as a result of decomposition caused by microbial or chemical activity. The end of the swell can remain convex and spring back to this position if pressed inward.

Hard Swell: A hard swell has such high gas pressure from within that the ends are too hard to dent by hand. Often the high gas pressures distort or buckle the ends or side seam of the cans.

Breather: If the pressure guage shows no vacuum inside a can it is called as “Breather”. An air may pass in and out due to presence of small leak.

Chemical spoilage

The chemical spoilage in most cases is due to production of hydrogen gas produced in can because of action of acid of food on iron of can. This spoilage is termed as Hydrogen swell. It occurs due to following factors:

a) Increased storage temperature.

b) Increased acidity of food

c) Improper exhaust

d) Presence of soluble sulfur and phosphorous compounds

e) Improper timing and lacquering of can at internal surfaces

Biological spoilage

The cause of biological spoilage is microbial activity. The microbial spoilage of canned food is classified as caused by thermophilic bacteria and mesophilic organisms. Most common spoilages of microbial origin are known as flat sour spoilage, Thermophilic anaerobic (TA) spoilage and putrefaction. These different types are briefly described here. In heat treated cans, the growth of microorganisms occur due to:

Leakage of can

It occurs because of manufacturing defects, punctures or rough handling. Bacteria are introduced into can by either in holes or improper seams. In this type, the microorganisms are not usually heat resistant and wide array of organisms had been found to cause spoilage as it is post processing contamination. Microbes may also get entry into can due to cold water, used to cool cans after heat treatment. Leakage may also be responsible for release of vacuum, which can favor the growth of microorganisms. Presence of low heat resistance organisms usually indicates leakage of can.

Under processing

It includes sub-optimal heat treatment, faulty retort operations, excessive microbial load and contamination in product, change in consistency of the product.

Spoilage by thermophilic spore forming bacteria

Spoilage by these types of bacteria is most prevalent in under processed heat treated canned foods. Their spores survive the heat treatment and undergo vegetative cell formation and subsequent growth in canned conditions. Major spoilages by these organisms are:

Flat sour spoilage

This is caused by souring bacteria. One characteristic of this spoilage is that ends of can remain flat during souring. Because of this condition, the detection of spoilage from outside is not possible thereby culturing of contents become necessary to detect the type of organisms. Main organisms involved are *Bacillus,* while it occurs more frequently in low acid foods. *Bacillus* spp. has ability to produce acid without gas formation.

TA spoilage

This type of spoilage is caused by thermophilic anaerobe not producing hydrogen sulfide. *Clostridium thermosaccharolyticum* is the main organism involved. It produces acid and gas in foods. Spoiled food produces sour or cheesy smell.

Sulfur stinker spoilage

This type of spoilage occurs in low acid foods and primarily *Desulfotomaculum nigrificans* is involved. The spores of these organisms are destroyed at optimal heat treatment, thus presence of this organism usually indicates under processing in terms of heat treatment. It produces hydrogen sulfide which produce typical odour.

Spoilage by mesophillic spore formers

Bacillus and Clostridium are involved in this type of spoilage which is usually indicative of under spoilage.

Spoilage by non-Spore formers

Presence of non spore formers in cans indicate post processing contamination. The organisms whose vegetative cells are heat resistant are more readily found. Following organisms are more prominent: *Enterococcus, Streptococcus thermophilus, Micrococcus, Lactobacillu, Leuconostoc, Microbacterium.* Presence of these organisms indicates leakage of container. Cooling water is one of the important source of contamination, thus coilforms also gain entry into the can through leakage.

Spoilage by Fungi

Yeasts

Yeasts and their spores are not thermo tolerant, thus they are not found in suitably heat treated cans. Their presence indicates under processing or post pasteurization contamination through leakage. Fermentative yeasts are more prominent and they produce carbon dioxide, thus causing swelling of cans. Film yeasts too can grow on the surface of the food products.

Molds

Among molds, *Aspergilus* and *Penicillium* are most spoiling organisms. These can grow at high sugar concentration. Acidification is considered method of preventing growth of molds. Some of the molds are resistant to heat. Molds are more common in home canned foods where heating as well as sealing is not under total aseptic conditions.

Quality of Canned Foods

Plant Origin Foods

The purpose of heat sterilization is to extend the shelf life of foods while minimizing the changes in nutritive value and eating quality. Differences between the heating characteristics of microorganisms, enzymes, and sensory or nutritional components of foods are exploited to optimize processes for the retention of nutritional and sensory qualities. This is achieved in practice by a reduction in size or cross-sectional area of containers, agitation during processing, or aseptic processing. The extent of thermal processing, which a food receives, is dependent upon the composition and physical characteristics of the product and is the result of a combination of time and temperature. Physicochemical changes occurring during processing and storage are the factors that determine the product quality in terms of both its sensory properties and its provision of nutrients to the consumer.

Sensory Quality

The heat process itself has a major effect upon the quality of a food product and is responsible for a range of changes taking place. Starch gelatinization and structural protein denaturation have a direct influence on the texture of a food. Heat-induced reactions such as the Maillard reaction affect the color and flavor as well as the nutritional status of the food. In general, changes that occur before the heat process are less important than those during or after processing since it is the manipulative and thermal procedures of food production that have the greatest effect on tissue damage and the resultant mixing of cell contents from different materials.

Texture

The tissue damage that occurs during the heat process of plant material is of two types. These are destruction or damage to the semipermeable cell membranes, and disruption of the intercellular structures with resultant cell separation. The effects of these types of tissue damage are a loss in cell turgor and cellular adhesion, which give rise to loss of crispness and softening of the heat-processed product. Other major influences on the texture of heated foods arise from the denaturation of proteins. Even on relatively mild heating, conformational change affecting the tertiary structure of protein can be observed. Denaturation of the proteins may follow. The hydrogen bonds maintaining the secondary and higher structure of protein rupture and predominantly random coil configuration occur. This leads to considerable changes in chemical and physical properties of proteins due to losses in solubility, elasticity, and flexibility. This mechanism also causes enzyme inactivation and breakdown of proteinaceous toxins and antinutrients. They cause turbidity leading to either a precipitate or gel, which will greatly alter their water-holding capacity and also lead to increased thermal stability. In fruits and vegetables, softening is caused by hydrolysis of pectic materials, gelatinization of starches and partial solubilization of hemicelluloses, combined with a loss of cell turgor. Calcium salts may be added to blanching water or to brine or syrup, to form insoluble calcium pectate and thus increase the firmness of the canned product. Different salts are needed for different types of fruit (for example, calcium hydroxide for cherries, calcium chloride for tomatoes, and calcium lactate for apples) owing to differences in the proportion of demethylated pectin in each product.

Color

The color of a food product is determined by the state and stability of any natural or added pigments, and development of any coloration during processing and storage. Natural pigments are generally unstable compounds that are broken down on heating but whose stability is dependent upon many factors. In fruits and vegetables, chlorophyll is converted into pheophytin, carotenoids are isomerized from 5, 6-epoxides to less intensely colored 5, 8-epoxides, and anthocyanins are degraded to brown pigments. Anthocyanins are fairly heat-stable compounds but take part in a wide range of reactions, e.g., with ascorbic acid, sugar breakdown products, such as hydroxymethyl furfural, and other reactive phenolics, which bring about their breakdown. Factors that accelerate degradation include high levels of oxygen in the product and storage temperature. Conversely, anthocyanins can be undesirable in a product and can be produced on thermal treatment of lencoanthocyanidin. They give rise to defects such as very dark broad beans and red gooseberries. Other problems can occur with anthocyanin pigments due to the formation of metal complexes, for example, the bluing of red fruits and the pinking of pears when exposed to tin. The flavonoid rutin, present in asparagus, can also form a complex with iron causing dark discoloration in lacquered cans where iron dissolution can occur and in which the colorless tin complex is not formed. Carotenoids are mostly fat soluble and are responsible for yellow, orange, and red coloration. They are unsaturated compounds and are therefore susceptible to oxidation, giving rise to off-flavor and bleaching. In addition, two types of isomerization can occur, namely, *cis–trans* isomerization and epoxide isomerization, which can give rise to lightening of the color. The temperature of storage is considered to have a greater effect on the isomerization than on the heat process itself. The two major groups of porphyrin- based pigments are chlorophyll and the heme compounds, both of which are very sensitive to heat. On processing, chlorophyll is converted into pheophytin with an associated loss of green color. Several approaches have been taken to try to reduce the color loss such as adjusting the pH and the use of HTST treatments. In the latter case, although improvements were observed after processing these were lost during storage. Betalins are water-soluble pigments, which are susceptible to oxidation and loss of red color. Browning of heat-preserved beetroot products is an example where residual oxygen in the product or headspace causes the appearance of a chocolate brown color. Heat processing itself in the presence of oxygen has a major effect on the end product quality, and this is demonstrated by the comparison of products packed in plain tin-plate cans with the identical material processed in lacquered cans or glass jars. In the plain tin-plate container, dissolution of the tin during processing removes a major proportion of oxygen from the pack and little is available to react with the food. Some products such as pale fruits, tomatoes and tomato formulations, mushrooms, and milk products are particularly susceptible to such heat-induced oxidative changes. It has been demonstrated that a brownish color develops in beans dipped in tomato sauce packed in different container types. Ascorbic acid is often used as an antioxidant and can be effective in improving color in certain products, e.g., mushrooms. It can be degraded to produce reactive compounds, which further react to form brown pigments.

Flavor

Generally, heat preservation does not significantly alter the basic flavors of sweetness, bitterness, acid, or salt. In fruits and vegetables, changes are due to complex reactions, which involve the degradation, recombination, and volatilization of aldehydes, ketones, sugars, lactones, amino acids, and organic acids. Major changes can occur in the volatile flavor components. One of the most important sources of volatile is lipid oxidation or oxidative rancidity. Three stages are involved: (i) initiation; (ii) propagation in which highly reactive hydroperoxides are formed, and (iii) termination. The initial uptake of oxygen is in the presence of catalyst, such as metal ions or metalloproteins, but can also be brought about by heat or light. The reaction does, however, have low activation energy (4–5 kcal/mol). The hydroperoxides formed take part in secondary reactions to give rise to a range of volatiles including aldehydes, ketones, and alcohols and it produces typical rancid or stale off-flavors. Volatile flavor compounds are also produced via the Maillard reaction. Since the first scheme for the reaction was put forward, a great deal of research has been undertaken The reaction occurs during heating and extended storage, is influenced by water activity, with an optimum for flavor generation at intermediate values of around 30% water, and is accelerated by high pH and buffers such as phosphates and citrates. The first stage of the reaction is fairly well defined and involves the condensation between carbonyl groups of the reducing carbohydrates and the free amino acids or protein, and rearrangement to produce amatory compounds. This leads to a loss of protein nutritional quality but does not affect the sensory properties significantly. The second stage is very complex and gives rise to numerous products, many of them volatile and is responsible for many characteristic flavors and offflavors in food materials. Loss of volatile constituents can also present problems in heat-preserved foods. The breakdown of essential oils in citrus products can result from oxidation. Packaging can also have a direct influence on volatile scalping.

Nutrients

Both physical and chemical reactions occur in heat-preserved foods, which influence nutritive value. Physical factors such as the loss of soluble nutrients, or leaching, can be significant for products in which there is a carrying liquid discarded before consumption.

Chemical reactions include heat damage to labile nutrients such as vitamins. One of the most fundamental changes, which can occur in a heat-preserved product, is the movement of water and solids within the food material during processing, storage, and reheating. In a formulated product or a product in which the entire pack contents are consumed, such changes can be largely disregarded, from the nutritional point of view, in that they do not alter the total amount of the nutrients consumed. Products that are packed in liquor, which is discarded before consumption, often exhibit dilution, dehydration, or loss of total solid materials from the edible portion. Sterilized soya-meat products may show an increase in nutritional value owing to an unidentified factor that decreases the stability of the trypsin inhibitor in soybeans.

Proteins: Heat preservation can lead to both desirable and undesirable changes in the nutritive quality of proteins. They are susceptible not only to heat but also to oxidation, alkaline environment, and to reaction with other food constituents such as reducing sugars and lipid oxidative products. The total amount of crude protein, generally, appears relatively unchanged due to heat processing but can suffer from leaching into the liquid component of some products. The crude protein levels, however, appear to be stable during subsequent storage of canned vegetables. The changes occurring are associated with tertiary structure, functionality, chemical changes related to digestibility, and amino acid availability. Canning of potatoes also leads to loss of amino acids though this has been shown to vary depending on the specific gravity of the potato. Lysine is again particularly vulnerable with a reduction in its availability of about 40%. Some of the losses found in canned potatoes may be due to the leaching of the protein into the brine, although the major cause of loss of amino acids on heat preservation is the Maillard reaction. Soybeans and many other legumes also undergo improved protein digestibility and bioavailability, especially of the sulfur-containing amino acids on heating due to inactivation of trypsin inhibitors and unfolding of the major seed globulins.

Vitamins*:* The effect of heat preservation on vitamins is generally detrimental although mild heating conditions can have beneficial effects on the bioavailability of certain vitamins, particularly biotin and niacin. This is due to enzyme inactivation and the inactivation of binding agents. The stability of vitamins varies under different conditions with vitamin C and thiamin being most susceptible to degradation through heating. The fat-soluble vitamins are the more stable of the two sets, although these can be degraded by oxidation especially when heated. Loss of water-soluble vitamins during processing can be considerably higher. Vitamin C is the most labile of the vitamins and can be lost during storage of the fresh material, food preparation, washing, and blanching as well as by degradation on heating and leaching into carrying liquor during the process. Studies on garden peas and carrots have shown that as much vitamin C can be lost on storage of the fresh produce for 7 days prior to cooking as that lost on canning. Much of the vitamin C lost during canning is leached into the canning liquor. Thiamin is the most heat sensitive of the B vitamins especially under alkaline conditions, and it is also susceptible to leaching during any washing or blanching stages. Thiamin, however, is less labile than vitamin C and retention of 60%–90% is usual in canning. Folic acid and pyridoxine are also susceptible to degradation by heating and in the case of folic acid by oxidation. Canning of potatoes can lead to loss of vitamins up to 30%. Both Riboflavin and niacin are relatively stable on heat preservation although riboflavin is very sensitive to light and will undergo degradation in the presence of both heat and light together. Heat-preserved foods often require less cooking than fresh foods, and the differences in the vitamin content between the fresh and the processed food at the point of consumption can often be negligible. In canned fruits and vegetables, significant losses may occur in all water-soluble vitamins, particularly ascorbic acid/vitamin C.

Minerals*:* Minerals are generally stable to most of the conditions encountered in heat preservations i.e., heat, air, oxygen, acid, or alkaline. Losses of minerals, however, can occur during processing, especially of vegetables, due to leaching into canning liquor. Conversely, certain minerals, for instance, sodium and calcium can be taken up by the food from the cooking or canning liquids. Comparisons between fresh and canned vegetables have shown higher ash content in canned products in all cases. This is due to the uptake of sodium and to lesser extent of calcium from the brine. Between 15% and 50% of potassium can be lost primarily by leaching on the canning of vegetables. Slight leaching of zinc and negligible changes in iron content occurs during processing. Heating has been seen to increase the bioavailability of iron in spinach and the presence of fructose also leads to an increased iron bioavailability.

Carbohydrates: Carbohydrates are less susceptible than most other food compounds to chemical changes during heat preservation. The levels of total and available carbohydrates in vegetables have been found to be very stable on canning and subsequent storage of the canned vegetables. However, there are some effects of heat on various carbohydrates. The effect of sugar on protein and iron bioavailability, and the relationship between starch, texture, and palatability are more important. Gelatinization of the starch also aids digestibility of foods. A good example of this is the potato, which in raw state is largely indigestible. The exact effect of heat preservation on various types and constituents of dietary fiber has not been fully investigated. Cellulose, the main constituent of dietary fiber, hemicelluloses, and pectins are together responsible for structure and texture in plant foods and can be disrupted by heating, which leads to a softening of the food and increased palatability as discussed earlier, generally, without any loss in the physiological value of the dietary fiber. **Lipids***:* Lipids, especially the unsaturated lipids, are prone to oxidation when heated in the presence of air or oxygen, resulting in losses in nutritional value of the food product. Although the major effect of lipid oxidation is in the flavors of foods, oxidation can lead to a conversion of the natural *cis*-fatty acids to *trans*-fatty acids. The digestion and absorption of *trans*-fatty acids is comparable to that of the *cis*-fatty acids and their nutritional value as an energy source is not affected. However, *trans*-fatty acids do not generally possess essential fatty acid activity, i.e., as precursors of prostaglandins and thromboxanes. This activity is dependent on a *cis* 9, *cis* 12 methylene interrupted double bond system, but provided that sufficient linoleic acid is consumed, the *trans*-fatty acids do not appear to inhibit essential fatty acid metabolism. The oxidation of lipids has also been implicated, as previously noted, in the loss of protein quality and can inhibit the activity of the fat-soluble vitamins A, D, and E as well as vitamins C and foliate. The oxidation of fats in processed foods, however, can be controlled by the exclusion or minimization of oxygen and the use of antioxidants. The effects of heat preservation on the nutritional value of fats can therefore generally be considered as negligible.

Animal Origin Foods

Color

The time–temperature combinations used in canning have a substantial effect on most naturally occurring pigments in meat foods. The red oxymyoglobin pigment is converted into brown metmyoglobin, and purplish myoglobin is converted into red-brown myohemichromogen. Maillard browning and caramelization also contribute to the color of sterilized meats. However, this is an acceptable change in cooked meats. Sodium nitrite and sodium nitrate are added to some meat products to reduce the risk of growth of *C. botulinum*. The resulting red-pink coloration is due to nitric oxide myoglobin and metmyoglobin nitrite. Loss of color is often corrected using permitted synthetic colors.

Flavor and Aroma

In canned meats, there are complex changes (for example, pyrolysis, deamination and decarboxylation of amino acids, degradation, Maillard reactions and caramelization of carbohydrates to furfural and hydroxymethyl furfural, and oxidation and decarboxylation of lipids). Interactions between these components produce more than 600 flavor compounds. Other volatiles have been identified as having a significant effect on the flavor of foods, and perhaps one of the most dramatic is the development of "catty taint." This is an extremely unpleasant and potent odor produced by the reaction of unsaturated ketones, notably mesityl oxide, with natural sulfur-containing components of the food. Heating is essential in the formation of the taint and incidents have been widespread due to the diverse availability of the unsaturated ketones. Examples include processed meat products using meat from cold store, painted with a material containing mesityl oxide as a solvent contaminant, canned ox tongues, which had been hung on hooks coated with a protective oil, and pork packed in cans with a side seam lacquer, which had been dissolved in impure solvent.

Texture

In canned meats, changes in texture are caused by coagulation and a loss of water-holding capacity of proteins, which produces shrinkage and stiffening of muscle tissues. Softening is caused by hydrolysis of collagen, solubilization of the resulting gelatin, and melting and dispersion of fats through the product. Polyphosphates are added to some products to bind water. This increases the tenderness of the product and reduces shrinkage. Small changes in the viscosity of milk are caused by modification of K-casein, leading to an increased sensitivity to calcium precipitation and coagulation.

Nutrients

Canning causes the hydrolysis of carbohydrates and lipids, but these nutrients remain available and the nutritive value of the food is not affected. Proteins are coagulated, and in canned meats, losses of amino acids are 10%–20%. Reductions in lysine content are proportional to the severity of heating, but rarely exceed 25%. The loss of tryptophan and to a lesser extent, methionine, reduces the biological value of the proteins by 6%–9%. Vitamin losses are mostly confined to thiamin (50%–75%) and pantothenic acid (20%–35%). However, there are large variations owing to differences in the types of food, the presence of residual oxygen in the container, and methods of preparation (peeling and slicing) or blanching. In some foods, vitamins are transferred into the brine or syrup, which is also consumed. There is thus a smaller nutritional loss. Heat sterilization of meat leads to a reduction in digestibility of the meat proteins and damage of amino acids, especially the essential sulfur-containing amino acids and lysine, with 10%–15% losses in beef. The heat preservation on the quality of foods has two important effects. (i) Many of the changes (sensory or nutritional) that occur during the thermal process are not restricted to heat-preserved foods. In many instances, the process replaces the conventional cooking, which the food receives prior to consumption. Reheating the heat-preserved food is a relatively mild treatment, which does not significantly affect the quality. (ii) heat preserved foods provide the consumer a wider choice of sensory experience and nutritional requirements without constraint of seasonality and the burden of preparation.