e-planet **15** (1): 12-20 (June 2017)

Canned Foods: Their preservation methods and Public health implications

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Date of receipt: 24.01.2017 Date of acceptance: 30.06.2017

ABSTRACT

Food spoilage is a complex process and excessive amounts of food are lost due to spoilage even with modern day preservation techniques. Canning is a method where food can be prevented from spoilage by storing it in a container that are hermetically sealed and then sterilize by heat which destroys most, if not all the microorganisms. However, heated canned foods may undergo spoilage either due to chemical or biological spoilage. Most common types of spoilage encountered in canned foods are flat sour, Thermophilic Anaerobes (T.A.) spoilage, stinker spoilage and hydrogen swells. Food spoilage bacteria are classified according to their oxygen requirement as obligate aerobe, facultative anaerobe and obligate anaerobe, non spore forming bacteria, yeast, mold etc. In addition to this canned food can be source of deadly bisophenol poisoning and histamine poisoning. Canned foods can be prevented from spoilage as long as they are remain intact and preserved in best possible way in cool and dry environment.

Key words: Canned food, food spoilage, thermophilic anaerobes

INTRODUCTION

Food preservation is pre requisite for protecting the food from spoilage thus prolonging its shelf life. One method of preserving food is by canning. Canning is the process of applying heat to food that's sealed in a jar in order to destroy any microorganisms that can cause food spoilage. Proper canning techniques stop this spoilage by heating the food for a specific period of time and killing these unwanted microorganisms. During the canning process, air is driven from the jar and a vacuum is formed as the jar cools and sealed. In other word, it is a method where food can be prevented from spoilage by storing it in a container that are hermetically sealed and then sterilized by heat which destroys most, if not all the microorganisms (FDA, 2001). The type of heat treat¬ment will however, depend on the nature of the food material and varies from pasteurization for milk, juices and other liquids to sterilization by steam under pressure for canned vegetables or soups (Fellows, 1999). At milder heat treatment a number of heat resistant organisms survive and these may subsequently grow and cause spoilage if conditions are favorable. Following heating, the canned food is then stored at a low temperature. Some foods which are processed at high temperatures can be stored at room temperature.

BENEFITS OF CANNED FOODS

Impact on the environment

Canned foods in general are very environment friendly because the metal cans are endlessly recyclable (Fig.1). In fact, food cans are the most recycled package today. Their recycling rate is more than two-and-a-half times higher than that of most other packaging

options. Additionally, cans are made with more recycled content than most package types, which reduce the demand for new natural resources (SRIS, 2010).

Impact on reduction of waste and costs

Because fruits and vegetables are picked fresh and immediately processed to seal in freshness and flavor, canned fruits and vegetables are a product one can feel good about using at any time. According to a recent study, Americans waste approximately 15 % to 20 % of fresh fruits and vegetables every year (Buzby et al., 2011). Canned meats and fish, such as chicken and tuna, are available in portion-controlled containers and can be enjoyed anytime, anywhere without requiring prior refrigeration. Consumers can cut costs two ways by eating canned foods: eliminating the waste of unconsumed fresh produce or spoiled meat and paying less for canned products at the grocery store.

Impact on convenience

Can foods are loved by many individuals and their family members as these are nutritious, convenient and help in easy preparation of a meal. For the people doing job in food industry, canned foods are easy to demo as few materials are required for the purpose and no cooktop are needed. Moreover, it is great for supermarket tours as it brings people to the middle of the stores, makes them feel good about shopping the aisles.

METHODS OF FOOD PRESERVATION BY CANNING AND FOOD SAFETY

Canned foods must be heated, for safety purpose, to a high enough temperature for a long enough time to destroy enzymes, yeasts, moulds and bacteria that cause food spoilage. Moreover, the canned food must be tightly sealed thereby organisms in the air cannot enter and cause spoilage. The time and temperature needed to destroy organisms in different foods varies. The temperature of boiling water, 212°F, is effective in killing organisms in acid foods. In low-acid foods a much higher temperature, 240°F, is needed to make the food safe to eat and to maintain good quality. To obtain a temperature of 240° F, a pressure canner must be used. The exact times given in a circular for processing fruits and vegetables are based on work by the Consumer and Food Economics Research Institute, Agricultural Research Service, U.S. Department of Agriculture (University of Illinois Circular 1112). As per the circular, failure to use the proper temperature for the length of time required for the food being canned can result in disaster.

Pressure canning

The equipment used in this method is called pressure canner and usually used for processing all common vegetables except tomatoes and pickles. Moreover, it is used for other low-acid foods, such as meat, poultry and fish. For safe use of the pressure canner, the safety valve must be checked properly. The pet-cock opening can be cleaned by drawing a string or narrow strip of cloth through it. The dial pressure gauge should be checked each year before the canning season. One can see a county extension adviser, dealer, or manufacturer about checking it. The weighted gauge needs only to be thoroughly cleaned. The canner kettle must be washed well before using it. The cover can be wiped with a damp, clean cloth; however, it shouldn't be put in water. When using the canner, the manufacturer's directions should be strictly followed (University of Illinois Circular 1112).

Another equipment known as ‘Pressure saucepan’ having an accurate indicator or gauge for controlling pressure at 10 pounds (240° F.) may be used for processing vegetables in pint jars.

Water-bath canning

In this method, high acid foods can be processed safely in equipment called ‘Boiling-water-bath canner’. This type of canners are used for fruits, tomatoes and pickled vegetables. This method sometimes referred to as hot water canning. Any large vessel will do for a boiling-water-bath canner if it meets these requirements: It should be deep enough to have at least 1 inch of water over the top of the jars. The canner should not be overloaded. Jars should not touch one another or touch the sides of the canner. If the pressure canner is deep enough, one can use it as a water bath. The cover can be set in place without fastening it. One must ensure to have the pet cock wide open so that steam escapes and no pressure is built up (University of Illinois Circular 1112).

Home canning with glass jars and closures

Only jars manufactured especially for home canning are used in this method. Processing times are given for half-pint, pint, or quart jars, so one should not use jars larger than those recommended for whatever is being canned. Only jars and lids that are perfect should be used. One cannot have an airtight seal with a defective jar or lid. Jars do not need to be sterilized when food is to be processed in the boiling water bath or in the pressure canner. However, they do need to be clean and hot. If one has a dishwasher, it can be used for this job. Two types of closures for glass jars are used i.e. the two-piece cap and the porcelain-lined zinc cap (University of Illinois Circular 1112). One should make sure to follow the sealing directions for each type of closure.

Porcelain-lined zinc cap

If the porcelain lining is cracked, broken, or loose, or if there is even a slight dent at the seal edge, the cover must be discarded. Opening these jars by thrusting a knife blade into the rubber and prying ruins many good covers. Each time one uses a jar; he should have a new rubber ring of the right size. The rings can be washed in hot sudsy water and then be rinsed well. The wet rubber ring should be fitted on the shoulder of the jar. The jar can be filled leaving the necessary headspace. Any food which might have spilled on the ring or rim should be carefully wiped off. The cap can be screwed on firmly and then it should be turned back 14 inch. As soon as the food has been processed, the seal should be completed by screwing the cap tight (University of Illinois Circular 1112).

Two-piece cap:

The metal lid with sealing compound can be used only once. The lids should be pre treated according to the manufacturer's directions. The jar can be filled, then the rim may be wiped clean. The lid can be put on the jar with the sealing compound next to the glass. The metal band must be screwed down tight. The lid has enough give to let air escape while the food is being processed. It should not be screwed farther after taking the jar from canner. The band may be removed after the contents of the jar are cold, usually after 24 hours (University of Illinois Circular 1112).

Important preliminary steps in canning

i. All the canning equipment needed must be assembled before the canning season begins. It is ensured that all equipment is clean and in good operating condition.

ii. Foods suitable for canning must be selected. It is to be remembered that canning does not improve the quality of a food. For best quality results quality food items such as sound, firm and ripe fruits and young, tender vegetables must be chosen. Care should be taken to sort the food items, so that they will be cooked evenly. In case of fruits, they can be canned quickly while they are fresh, if possible within 2 to 3 hours after they are gathered.

iii. Foods such as fruits and vegetables should be washed thoroughly. When dirts are removed, some of the bacteria that are hardest to kill are removed. Washing should be done in small batches with several changes of water (University of Illinois Circular 1112).

SPOILAGE OF CANNED FOODS

Heated canned foods may undergo spoilage either due to chemical or biological reasons. The most important chemical spoilage of canned foods is the "hydrogen swell" produced as a result of the action of the food acid with the metal can. Such spoilage occurs mostly due to imperfect tinning and lacquering of the interior of the can used for canning acidic foods (Jay et al., 2005). Biological spoilage of canned foods by microorganisms may result either from the survival of organisms after the heat treatment or leakage of the container permitting entrance of microorganisms (Anon., 2013), may be vegetative cells or spore formers depending on the heat treatment. Acid foods are processed at temperatures around 100°C which results in the killing of all vegetative cells of bacteria, yeasts and molds. Only bacterial spores may survive but these do not grow in acid foods. On the other hand, meat, vegetables and milk are processed at lower temperatures. This may eliminate vegetative cells but not the spores, which germinate later and cause spoilage. Here are the terms used in the food industry to describe canned foods with signs of spoilage (Hayes ,1985):

Soft Swell

A can that is bulged on both ends, but not so tightly that the ends can't be pushed in somewhat with a thumb press (Fig. 2).

Hard Swell

A can that is so tightly bulged on both ends that the ends can't be pressed in. A can with a hard swell will generally "buckle" before it bursts (Fig. 3).

Flipper

A can whose end normally looks flat, but "flips out" when struck sharply on one end.

Springer

A can with one end bulged out. With sufficient pressure, this end will flip in, but the other end will flip out.

Leaker

A can with a crack or hole in the container that has caused leakage. Flipper and Springer cans do not always indicate microbial spoilage, but are often an indication of contamination. Soft swells, hard swells and leakers usually do represent microbial spoilage but can sometimes be caused by chemical reactions. Microbial spoilage of canned food occurs when heat processing fails to meet standard requirements. This can occur because of home canning of foods or carelessness in handling the raw materials before canning which results in a high level of contamination that ordinary heat processing may not control. Spoilage can also occur when defective containers permit the entrance of microorganisms after the heat process. Bacteria can cause heat resistant endospores which results in the spoilage of commercially canned foods. The processing of low-acid foods is over particular concern because *Clostridium botulinum* thrives in this environment and causes botulism food poisoning (Sobel, 2005). The risk of botulism is greater with home-canned foods than it is with commercially-canned.

The fact that spoilage in canned vegetables is due to bacteria, has been definitely known since Russel (1895) isolated the causative organisms responsible for an outbreak of spoilage in canned peas in Wisconsin (Wilson and Tanner, 1948). The thermophilic bacteria were factors in spoilage of canned vegetables was not recognized until Barlow investigated spoilage in corn in a canning plant at Gibson city and reported the presence of living thermophilic bacteria which developed only when the cans were improperly cooled and/stored in hot warehouses. He described two types of spoilage due to thermophilic bacteria i.e. Flat sour and T.A. spoilage.

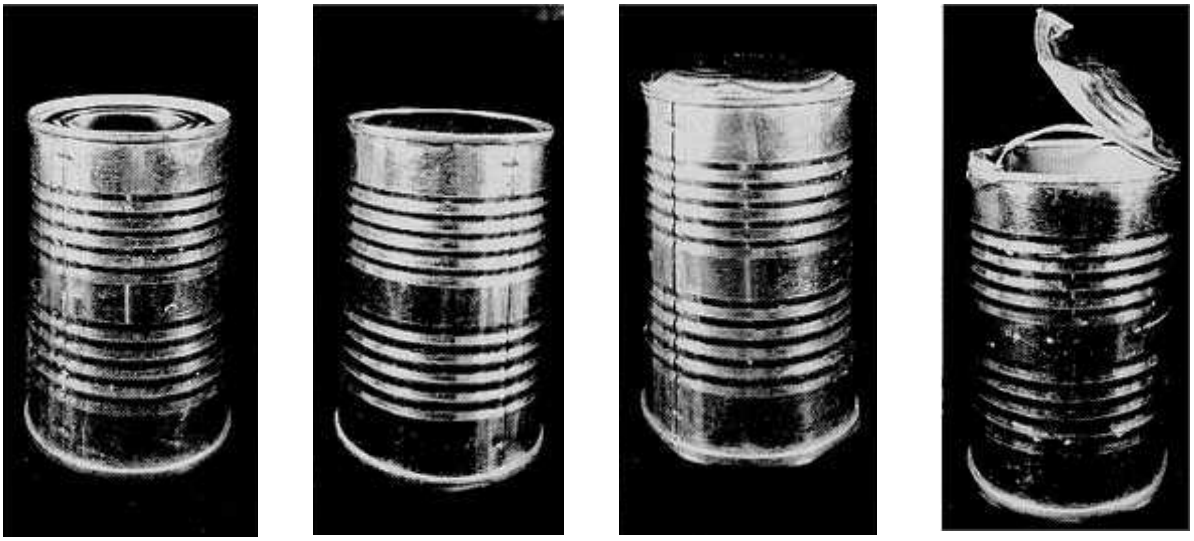

Fig 1-4: Changes in cans as a result of microbial spoilage (Fig.1 Normal Can: the top of the can is indented due to negative pressure (vaccum) inside ; Fig.2 Slightly swollen lid resulting from minimal gas production ; Fig.3 Severe swell due to extensive gas production ; Fig.4 The Can shown in above was dropped and the gas pressure resulted in a violent explosion)

* Source: AFDO, A pocket puide to pan pefect.

There are three types of microbial spoilage: Flat sour, thermophilic anaerobes (T.A.) spoilage and stinker spoilage (Frazier and Westhoff, 2008) which are described below.

Flat sour:

It pertains to spoilage in which acids are formed with no gas production. The ends of the can, therefore, remain flat.

T.A. spoilage:

It is caused by Thermophilic anaerobes that produce acid and gases in low-acid foods. Cans swell and sometimes burst (Fig. 4).

Another spoilage is due to spore former known as Stinker spoilage.

Stinker spoilage:

Here, spore formers cause the spoilage that produce hydrogen sulfide and blackening of the can. The great deformation of the can (Fig. 3) is potentially dangerous and could explode if dropped or hit! Development of spoilage control in canning has necessarily been slow. Conscious, tangible effort in this direction dates back to the first realization by scientifically trained technologists that certain types of bacteria are associated with spoilage of canned foods and that, in the case of nonacid foods, the significant organisms form spores of such high resistance to heat that temperature higher than boiling are necessary for their destruction (Cameron, 1938).

CLASSIFICATION OF FOOD WITH RESPECT TO ACIDITY

Canned foods can be grouped as low acid foods, medium acid foods, acid foods and high acid foods as mentioned in the following table on the basis of acidity (Cameron and Esty, 1940).

Table 1. Grouping of Canned foods on the basis of acidity

Group	Type of Acid Food	pH	Examples of Food
Group I	Low acid foods	>5.3	Vegetables such as peas, corn, beans etc. and meat, fish and poultry.
Group II	Medium acid foods	3.0-5.5	Beets, pumpkin, spinach etc.
Group III	Acid foods	4.5-5.7	Tomatoes, pears etc
Group IV	High acid foods	<3.7	Berries, etc.

* Source: Cameron and Esty, 1940

Except for the dividing line between acid and high-acid foods, this classification serves as well perhaps as any. In practice, it has been found that pH 4.00 is a more realistic dividing line between acid and high-acid foods. Seldom will spore-bearing bacteria grow in heat-processed foods with pH values of 4.0 or lower. Some of the butyric anaerobes and *Bacillus coagulans (B.thermoacidurans)* will grow in laboratory culture or even in foods at pH values as low as 3.7; however, this generally occurs only with very heavy inoculate.

The dividing line between low-acid and acid foods is taken as 4.5 because some strains of *Clostridium botulinum* will grow and produce toxin at pH values as low as about 4.6. Some of the highly heat-resistant saccharolytic anaerobes for example, Clostridium thermosaccharolyticum grow in and cause spoilage of foods in this semi-acid range. Therefore, until more is known of bacterial heat resistance and bacterial growth in the 'semi-acid foods, they perhaps should remain in the low-acid grouping.

CLASSIFICATION OF SPOILAGE BACTERIA

In low-acid and acid foods, the spore-bearing bacteria are of greatest concern from the standpoint of sterilization. With respect to oxygen requirements they may be classified as follows: (1) Obligate aerobes-Bacillus spp., (2) Facultative anaerobes-Bacillus spp., (3) Obligate anaerobes-Clostridium spp.

Obligate Aerobes

This group includes those species that require molecular oxygen for growth. From the standpoint of food sterilization, it is the least important of the

three groups. Under present-day methods of canning, most foods contain very low levels of molecular oxygen, insufficient to support appreciable growth. Beyond this, spores of most obligate aerobes are low in heat resistance compared with spores of a number of organisms in the other two groups. However, as with most things, there are exceptions; in canned cured meat products containing nitrate, the *Bacillus subtilis* and *Bacillus mycoides* group of organisms may at times be of greater economic importance than some other groups of bacteria (FDA, 2001).

Facultative Anaerobes

Spore-bearing bacteria of the facultative anaerobic group carry importance from the standpoint of food sterilization. Of particular importance in low-acid and acid foods are thermophilic spore-bearing bacilli. Of greatest importance in low-acid foods are *Bacillus stearothermophilus* and related species causing flat-sour spoilage (Frazier and Westhoff, 2008) where as in acid foods there are three species of facultative anaerobes-namely, *Bacillus coagulans (B. thermoacidurans)*, *Bacillus macerans* and *Bacillus polymyxa*. Of these, Bacillus coagulans is the more important, particularly in spoilage of tomatoes and tomato products. *Bacillus macerans* and *Bacillus polymyxa* have been isolated as causative organisms in spoilage of some fruits and fruit products.

Obligate Anaerobes

Some species of spore-bearing anaerobes produce spores those are relatively quite heat-resistant. With reference to canned food spoilage these may be classified in two groups, mesophilic and thermophilic. Of the thermophiles, the most important are the saccharolytic organisms, which do not produce hydrogen sulfide. *Clostridium thermosaccharoliticum* is generally considered the type species of this group (Hayes, 1985). These organisms are very saccharolytic, producing large quantities of gas, chiefly carbon dioxide and hydrogen, from a wide variety of carbohydrates. Consequently, they cause spoilage of the "swell" or gaseous type. They often produce a butyric or "cheesy" odor on foods. They generally are of greater importance in the spoilage of semi-acid products (pH 4.5 to 5.0) than are flat-sour types (Yousef and Carolyn, 2000).

Thermophilic spore-bearing anaerobes that produce hydrogen sulfide are responsible for the so-called "sulfur stinker" spoilage of canned foods. *Clostridium nigrificans* is considered the type species of this group (Hayes, 1985). These organisms are proteolytic and hydrogen sulfide is the only gas they produce in great quantity. They are only weak, if at all saccharolytic, because the hydrogen sulfide is soluble in the product, spoiled cans usually remain flat. Many products spoiled by these organisms become black, owing to the interaction of the hydrogen sulfide and iron. Spoilage by these organisms is comparatively rare for two reasons: Incident of their spores in most products is generally low and the spores of most strains are relatively low in heat resistance compared with spores of the saccharolytic thermophilic anaerobes and the flat-sour thermophilic facultative anaerobes. Neither of the above groups is of importance in foods having pH values below about 4.5 (Anon., 2001).

Next in importance, in low-acid foods, to the groups discussed above are spore-bearing mesophilic anaerobes. Because of its public health significance, the toxin-producing organism, C*lostridium botulinum*, should perhaps be considered of greatest importance among organisms of this group (Sobel, 2005). Of the different botulinum types, A, B and E are of greatest significance. Spores of Types A and B are considerably more heat-resistant than spores of Type E and therefore of greatest concern in the sterilization of canned foods. Fortunately, the incidence of the more-resistant strains of P.A.3679 is very low in most foods. For this reason, canning processes designed to assure a high degree of safety with regard to *C. botulinum* are often adequate to prevent economically important spoilage by even the most resistant of these nontoxic putrefactive anaerobes.

In summary, of the mesophilic obligate anaerobes, in spoilage of low-acid and semi-acid foods (pH 4.5 and above) the putrefactive anaerobes, *C. sporogenes* and related species, are of greatest importance. In spoilage of acid foods (pH 4.0 to 4.5) the butyric anaerobes, *C. pasteurianum* and related species, are of greatest importance (Frazier et al., 1987). The temperature range of optimum growth of these organisms is 25^0 to 35^0C [77^0 to 95^0F] (Yousef and Carolyn, 2003).

NON-SPORE-BEARING BACTERIA, YEASTS AND MOLDS

Except when they gain entrance through container leakage, these organisms are of greatest importance in spoilage of high-acid canned foods (pH below 4.0) given relatively mild heat processes-pickles, grapefruit, citric juices, rhubarb, cranberries also in spoilage of concentrated and sweetened products, etc.

Of the non-spore-bearing bacteria, Lactobacillus and Leuconostoc spp. are most important (Potter and Hotchkiss, 1999). A wide variety of yeasts have been found as spoilage agents of number of high-acid foods given mild heat processes. Molds are generally considered significant as spoilage agents in canned foods.

The temperature range of optimum growth for most of these non-spore-bearing bacteria, yeasts and molds is from 20^0 to 35^0C. (68^0 to 95^0F).

ORGANISMS ENTERING VIA CONTAINER LEAKAGE

Microorganisms that enter through leaks during cooling need not necessarily be heat resistant. Because of varied types of bacteria in contaminated cooling water and on can-handling equipment, many different species of bacteria have been associated with leakage spoilage. Usually, though not always, a mixed flora causes leakage spoilage of a container. Commonly found are micrococci, gram-negative rods of the *Pseudomonas*-Achromobacter group and yeasts. It should be recognized that very minute amounts of heavily contaminated water could cause spoilage.

BISPHENOLS IN CANNED FOODS

Bisphenol A (BPA) and Bisphenol F (BPF) are chemical components of resins used to coat some cans (Kawamura et al., 1999). BPA is used to create linings for cans that maintain the integrity of the can, prevent contamination and maintain the safety of the food. More specifically, can linings play an important functional role, safeguarding foods from microbial contamination. And, can coatings prevent perforation defects in the can that would allow bacteria and microorganisms to enter, thereby maintaining the integrity of the can and protecting against food poisoning and food borne illness. In a study by Kawamura et al., 1999 BPF did not leach into food but BPA did. BPA was found in some canned foods like some vegetables but not infant formulae (Kawamura et al., 1999). In fact, the U.S. Food and Drug Administration; World Health Organization; European Food Safety Authority; Health Canada;16 and other global agencies responsible for food products confirmed that BPA in the marketplace today poses no risk to consumers (U.S. Food and Drug Administration, 2012; WHO, 2010; European Food Safety Authority, 2012 and Health Canada, 2012). BPA-lined cans have been effectively safeguarding the global food supply since they were first introduced in the 1960s, without a single incident of food borne illness associated with canned foods since inception.

SCOMBROID POISONING IN CANNED FISH PRODUCTS

Fish such as tuna, mackerel, bonito and saury that contain high levels of free histidine in their muscle are often implicated in scombroid poisoning incidents (Taylor, 1986). Histamine is the causative agent of scombroid poisoning, a food borne chemical hazard mostly seen in canned fish products. Scombroid poisoning is usually a mild illness with a variety of symptoms including rash, urticaria, nausea, vomiting and diarrhea, flushing , tingling and itching of the skin (Russsell and Maretic, 1986).

STORAGE LIFE OF CANNED FOODS

Generally, as long as the container remains intact, canned foods have a long shelf life even at room temperature. If more stringent storage conditions are required for health and safety reasons, then the label must state these storage conditions. As a general rule, the best shelf life will be obtained when canned foods are kept in a cool, dry place. The label of the product for any storage instructions must be checked. If the label has storage instructions, then the food must be stored accordingly at the point-of-purchase. If instructions are not provided on the label, then it should be stored in a cool dry place. Containers should be handled carefully to avoid denting or other damage. Much work has been done on microbiology of spoiled foods but less on the normal sound products which appear on the market (Wilson and Tanner, 1948).

Canned fruits, vegetables and meats are recommended in a variety of food and nutrition policies and initiatives including the 2010 Dietary Guidelines for Americans, Let's Move, the U.S. Thrifty Food Plan, American Heart Association, Academy of Nutrition and Dietetics and the National Heart, Lung and Blood Institute's DASH diet. (Department of Agriculture and U.S. Department of Health and Human Services, 2010; Let's Move, 2010; U.S. Department of Agriculture. 2006; American Heart Association, 2010; Academy of Nutrition and Dietetics, 2010 and U.S. Department of Health and Human Services National Heart, Lung and Blood Institute, 2006). Canned fruits and vegetables are nutritionally similar to fresh and frozen ones, in some cases even better (Miller and Knudson, 2012; Kapica and Weiss, 2012; and Durst and Weaver, 2013).

CONCLUSION

Food spoilage is the deterioration in canned or preserved food that makes the food unsafe for eating. Mold, yeast, bacteria and enzymes are the spoilers. Ingesting spoiled food can cause a wide range of ailments, depending on the type of spoilage and the amount of food consumed. Symptoms vary from mild, flu like aches and pains to more-serious illnesses or even death.

A "hermetically sealed" container for canned food is considered as one that is appropriately constructed/designed and intended to assure no entry of microorganism and thus maintains the commercial sterility of its contents after thermal processing.

Spoilage can be prevented in home canned products by adequately heat processing of food for particular time. The method used for processing depends on whether the food is high acid or low acid. Any practice that does not involve adequate processing is potentially dangerous and should be avoided.

Clostridium botulinum organism which forms spore, in the absence of air, as in a sealed jar and in the presence of low-acid food, germinate and produce gas and a toxin. It is this toxin that causes botulism, a very serious food poisoning. Though the spores formed by the bacterium are very resistant to heat, the toxin they form is easily destroyed by heat. Therefore, as per the Circular 1112 of University of Illinois, in home canning of low-acid foods there are three rules to follow:

i. Always process low-acid foods in a pressure canner at 10 pounds or more pressure for the recommended time.

ii. Boil low-acid home canned foods for at least 10 to 20 minutes before tasting. Corn and spinach should be boiled for 20 minutes.

iii. Destroy all bulging, swollen, or leaking cans of food as well as food from glass jars with bulging lids. Do not taste (University of Illinois Circular 1112).

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