CHAPTER 1

Microbiology of Canned Foods

Basic Considerations on pH Value

One of the most important properties associated with food chemistry and with microbiological food spoilage is the intensity of the acidity, or the pH of the product. This intensity factor, or pH value, is not to be confused with the amount of acid present in the food, but is attributable only to the ionized acid. In order to state this intensity of the acidity in simple numerical terms, the pH scale, a mathematical notation was developed.

pH of foods depends upon many factors, including maturity of product, variety, and growing conditions. For these reasons, the pH of food is usually within a range of values.

pH is defined as the base-ten logarithm of the reciprocal of H+ (hydrogen-ion) concentration (more correctly, H^+ activity) in moles per liter. The neutral point, pH 7.0, is the mid point of a scale from 0 to 14. A pH of zero indicates an extremely acid condition, and pH 14 extremely alkaline.

TABLE 1.1 - The pH Scale

H^+ concentration (moles/liter)			pH
1.0	10^0	[example: 1M HCl]	0
0.1	10^{-1}	[example: 0.1M HCl]	1
0.01	10^{-2}		2
0.001	10^{-3}		3
0.0001	10^{-4}		4
0.00001	10^{-5}		5
0.000001	10^{-6}		6
0.0000001	10^{-7}	[example: pure water]	7

Four points concerning pH follow. The first three are a consequence of the definition of pH, while the fourth is concerned more with the nature of foods.

First, pH is logarithmic. H^+ concentrations progress arithmetically, but each unit increment of pH indicates a tenfold increment in H^+ concentration.

Second, successive increments of pH do not indicate the same increments of H^+ concentration. Therefore, from pH 7 to 6 there is an increase in acidity of ten fold, from 7 to 5 is 100, 7 to 4 is 1000. Simple linear relationships between pH and H^+ concentration can be graphed only by using semilogarithmic graph paper.

Third, the point between whole pH values corresponding to the midpoint of H^+ concentration occurs at pH 0.3, not 0.5. For example, the midpoint of H^+ concentration between pH 4 and 5 corresponds to pH 4.3.

Fourth, most foods have an inherent buffer capacity, i.e., an ability to resist change in pH. This buffer capacity is important in acidification and pH control. Weak acids and their salts in solution establish an equilibrium which resists changes in pH when more acidic or alkaline ingredients are added. The sodium salts of acids, such as acetic, citric, or phosphoric, can be added to buffer foods.

The pH can be measured using colorimetric or electrometric methods. In colorimetric methods, dyes that change color over a limited range of pH values are used; the color change developed after adding indicator solution to a food is then compared to a standard to determine pH. Indicator or pH paper is a type of colorimetric method where dye has been added to strips of paper. Colorimetric methods are used only to obtain approximate pH values and should not be used in foods with pH higher than 4.0. The most common and reliable method to determine the pH of canned foods is an electrometric method using a pH meter. This instrument measures the electrical potential developed between a glass and a reference electrode when imersed in a solution or food; this potential is converted to pH value and read from an analog or digital meter (FPI, 1988).

Influence of pH on Food Microbiology and Spoilage

While different species of microorganisms are characterized by a specific pH value for optimum growth, other chemical and physical characteristics of food are factors that affect the growth rate of bacteria, yeasts, and molds. One important effect of pH is its influence upon resistance of bacteria to heat: the lower the pH value, i.e., the higher the acid intensity, the lower the resistance of bacteria and bacterial spores to heat at a given temperature. When there are several species of bacteria, yeasts, and molds in a food, the pH value of the food is one of the most important factors determining which of those types of microorganisms will multiply faster, and within the types, the species that will prevail. That characteristic of pH is important, both in industrial fermentations and in food spoilage considerations.

TABLE 1.2 - Mean pH Values of Selected Foods

pH value	
2.3	Lemon juice (2.3), Cranberry sauce (2.3)
3.0	
	Rhubarb (3.1)
	Applesauce (3.4), Cherries, RSP (3.4)
	Berries (3.0-3.9), Sauerkraut (3.5)
	Peaches (3.7), Orange juce (3.7)
	Apricots (3.8)
4.0	
	Cabbage, red (4.2), Pears (4.2)
	Tomatoes (4.3)
	Onions (4.4)
4.6	Ravioli (4.6)
	Pimientos (4.7)
	Spaghetti in tomato sauce (4.9)
5.0	Figs (5.0)
	Carrots (5.2)
	Green beans (5.3), Beans with pork (5.3)
	Asparagus (5.5), Potatoes (5.5)
	Lima beans (5.9), Tuna (5.9), Tamales (5.9)
6.0	Codfish (6.0), Sardines (6.0), Beef (6.0)
	Pork (6.1), Evaporated milk (6.1)
	Frankfurters (6.2), Chicken (6.2)
	Corn (6.3)
	Salmon (6.4)
	Crabmeat (6.8), Milk (6.8)
	Ripe olives (6.9)
7.0	Hominy (7.0)

Effect of Temperature on Growth of Microorganisms

In actively growing stages, most microorganisms are readily killed by exposure to temperatures near the boiling point of water; bacterial spores, however, are more heat resistant than their vegetative cells.

Bacteria can be classified according to temperature requirements for growth. Bacteria growing at temperatures between 68–113°F (20–45°C), with optima between 86–104°F (30–40°C), are called *mesophiles*. Other species of bacteria are referred to as *psychrotrophs*, with optimum growth temperatures between 68–86°F (20–30°C) and growing well at or below 45°F (7°C). Those that grow well at and above 113°F (45°C), with optima between 131–149°F (55–65°C), are *thermophiles*. Thermophiles may grow slowly up to 170°F (77°C) (Jay, 1992).

There is an important difference between the optimum temperatures for growth of bacteria and their resistance to heat. Highly heat resistant bacteria are called thermoduric. Mesophilic organisms can be thermoduric due to the high heat resistance of their spores, as can the spores of thermophilic bacteria.

Foods have associated microfloras; certain microorganisms are usually found in certain food groups. These organisms gain entrance into the food during the canning operation, either from the soil, from ingredients, or from equipment. On the basis of acidity classification of foods, it is possible to make general statements relative to the microorganisms which are potentially capable of producing spoilage in canned foods.

pH and Growth of *Clostridium botulinum*

For years, laboratories connected with the canning industry and others have studied *Clostridium botulinum*, its heat-resistance and processing recommendations for low-acid foods. While studying the growth requirements for *Clostridium botulinum*, it was found that the dividing line of acidity between products in which the organism would grow, and those in which it would not grow, was about pH 4.6; below this level, growth of the organism in a favorable medium is inhibited. Under other conditions, such as one in which nutrient value is low, growth may be inhibited, regardless of pH. As a practical matter, this means that products of pH levels higher than pH 4.6 must be processed under steam pressure, at temperatures considerably higher than 212°F (100°C), usually higher than 240°F (116°C), in order to insure destruction of spores, while products at pH 4.6 or lower may be safely processed in an open bath at 212°F (100°C).

Acidity Classification of Canned Foods

Low-Acid Foods. Because *C. botulinum* will not grow at pH levels of 4.6 or below, foods in which it will grow have been categorized as "low-acid foods". Low-acid foods are defined as "any commercially processed food with a finished equilibrium pH value greater than 4.6 and a water activity greater than 0.85, but not including alcoholic beverages, and shall also include any normally low-acid vegetables or vegetable products in which, for the purpose of thermal processing, the pH value is reduced by acidification."

Meat, fish, poultry, dairy products, and vegetables, except tomatoes, generally fall into a pH range of 5.0 to 6.8 (see Table 1.2). While low in acid, they do fall in the acid range of pH values. Figs and pimientos, as well as some manufactured foods such as pasta products, have pH values between 4.6 and 5.0.

High-Acid Foods. Foods with pH values of 4.6 to 3.7 are classified as acid foods; examples include tomatoes, onions and pears. "High-acid foods" have pH values below 3.7 and include fruits, rhubarb, berries, and fermented foods, such as pickles and sauerkraut.

Acidified Foods. U.S. federal regulations define acidified foods as those low-acid foods which have had their pH reduced to 4.6 or lower by the addition of acids or acid foods. Vinegar, or any safe and suitable organic acid or acid food, can be used for this purpose.

Acidification is one means of preserving food products; in addition to preventing bacterial growth, acidification helps maintain a desired product quality. Puddings, cucumbers, artichokes, cauliflower, peppers and fish are examples of low-acid foods which are normally acidified. The addition of an acid or an acid food to such products is a method of preservation designed to prevent bacteria of public health significance from growing. If acidification is not adequately controlled at a pH of 4.6 or below, *Clostridium botulinum*, a toxin-producing micro-organism, can grow in the food.

In the U.S., all operating personnel concerned with the acidification of foods must be supervised by a person who has attended a school approved by the Commissioner of the U.S. Food and Drug Administration. This school presents instructions on pH and the critical factors to be considered in the acidification of foods.

BOTULISM

Botulism is an intoxication caused by a toxin produced in foods by the microorganism called *Clostridium botulinum*. This organism is a rod-shaped, spore forming bacillus. It originates in the soil in all parts of the world. *C. botulinum* is an anaerobic bacterium; it does not grow in the presence of free oxygen, nor on surfaces which support the growth of many other types of bacteria. This bacterium produces an exotoxin which is the most deadly neuro-paralytic toxin known.

Six types of *C. botulinum* have been described and are well known, i.e., Types A, B, C, D, E, and F. Each type produces a specific and somewhat different exotoxin, but each toxin causes similar symptoms. Anti-toxins or serums are specific to the particular type of toxin, but polyvalent vaccines are available. Intoxication is caused by ingestion of the exotoxin produced by the organism *C. botulinum*; it is not caused by the organism itself. The toxins are inactivated by heat in 10 minutes at 212°F (100°C). Types A, C and D are proteolytic, that is, they produce an extremely foul and putrid odor, while Types B and E do not produce this odor. According to Rhodehamel et. al. (1992), Type A was responsible for 60.1% of the confirmed outbreaks in the U.S. since 1978; Type B for 18.5% and Type E for 17.9%

Botulism occurs throughout the world because *C. botulinum* is widely distributed in nature and occurs in both cultivated and forest soils, bottom sediments of streams, lakes, and coastal waters, the intestinal tracts of fish and mammals, and gills and viscera of crabs and other shellfish. Canned vegetables, sausages, meat products and seafood products have been the most frequent vehicle for human botulism.

The types of foods involved in botulism vary according to food preservation and eating habits in different regions. Since any low-acid food can support growth and toxin formation, botulinum toxin has been found in a considerable variety of foods, including canned corn, peppers, green beans, beets, asparagus, mushrooms, ripe olives, spinach, tuna fish, salmon, chicken, chicken livers and liver pate, and in luncheon meats, ham, sausage, lobster, smoked fish, and stuffed eggplant. High acid foods, such as fruits, tomato products, sauerkraut, vinegared foods, etc., are not susceptible unless some form of spoilage has resulted in removal of sufficient acid, thus permiting growth of *C. botulinum*.

Methods of Commercial Control of Botulism

The canning industry employs standardized processes for treating foods insuring that the probability of survival of *C. botulinum* spores is very remote. These processes, which take into account the consistency and chemical nature of the product and the size of the can, are standardized so that the chance of spoilage due to inadequate processing is almost zero; only through recontamination after heating, due to container leakage, is it likely that a significant degree of spoilage could occur. Additional safety is provided by proper sanitary control, specified in U.S. FDA's Good Manufacturing Practice Regulations (21 CFR 110, 113 & 114), which serves to reduce the original bacterial load. The FDA-National Food Processors Association "Better Process Control" schools ensure education of retort operators and seam inspectors.

Whenever there is a question about product safety, cans should be discarded if they show even slightly bulging ends or any other evidence of spoilage, such as souring, gas formation, discoloration, or leaks. These recommendations do not apply to those commercially pressurized canned products, such as canned soft drinks, beer, and coffee; botulism bacteria cannot grow in these products.

Food cans or jars showing bulging lids should be suspected of potential botulism. Under no circumstance should the contents of these containers be tasted; they should be discarded where animals cannot gain access to them.

C. botulinum is a gas producing organism, but it is not a prolific gas former. Cans of food in which there are living organisms do not usually produce a "hard swell"; normally, the type of swell formed is a "soft swell" or a "springer"; in some cases, cans may not swell at all. The optimum growth temperature of the botulism organism for the development of toxin is from 65–85°F (18–29°C). Five to ten percent salt content in products such as salt-cured meats and fish will prevent the growth of *C. botulinum*.

Botulism Outbreaks

Most outbreaks of botulism are dramatic; symptoms appear suddenly within 8 to 72 hours after ingesting the toxin and progress rapidly. Typical symptoms involve the nervous system and result in double vision, difficulty in swallowing, impaired speech, difficulty in breathing, and paralysis of the extremities. Death usually results from paralysis of the respiratory muscles and asphyxia. Some botulism victims show symptoms of nausea, vomiting and constipation.

The illness is difficult to diagnose because at the onset, the symptoms of botulism are often confused with those of other diseases and few physicians are familiar with the diagnostic techniques. By the time the illness is recognized, it is usually too late for therapy; in botulism, the only therapy known is an early administration of anti-toxin serum. Mortality varies with different outbreaks, but the average in the U.S. for the 1971–1989 period was 11% (McClure et. al., 1994), down from about 60% until 1945.

Between 1971 and 1989, home-preserved foods accounted for 92% of the outbreaks of botulism in the United States, while only 8% was attributed to commercial foods. 63 fatal cases were recorded for that period. Of 222 outbreaks studied, 16% were related to meats, 17% to fish, 59% to fruits and vegetables and 9% to other products (McClure et. al., 1994).

Botulism is usually associated with foods that have been given an inadequate or minimal preservation treatment, held for some time non-refrigerated, and consumed without appropriate heating. The growth of *C. botulinum* in foods frequently, but not always, produces a foul, putrid odor that serves as a warning to the consumer. Signs of spoilage, however, have not prevented botulism, because the degree of tolerance to disagreeable odors or off-flavors varies among individuals; in green beans or in foods that are smoked, heavily spiced, or fermented, the off-odor may be difficult to recognize. Because botulinum spores are killed by heat, the culprit in home canning is under-sterilization, either by not using a high enough temperature, or by processing for too short a time, or a combination of these conditions.

From 1926 to 1982, eight deaths were reported from consumption of foods commercially canned in the United States; details appear in Table 1.3. These eight fatalities occurred over a period during which consumers ate the contents of nearly 900 billion containers of canned food. This record supports the fact that properly processed canned foods are safe. The few exceptions, however, were so tragic in their occurrence and consequences that increased effort and diligence by the canner in preventing botulism outbreaks are mandatory. Adherence to the Good Manufacturing Practice regulations and good plant sanitation in processing low-acid canned foods constitute a safeguard against botulism outbreaks.

TABLE 1.3 - Human Botulism Outbreaks Involving U.S. Commercially Canned Foods in Metal Containers, 1940-1982[a]

Year	Product	Out-breaks	Cases[b]	Death[e]	Toxin Type	Cause of Outbreak
1941	Mushroom sauce (single can)	1	3	1	E	Suspected leakage
1963	Tuna fish	1	3	2	E	Alleged leakage[c]
1971	Vichyssoise soup	1	2	1	A	Under-processing[d]
1974	Beef stew (single can)	1	2	1	A	Unknown - can possibly missed retort
1978	Salmon (single can)	1	4	2	E	Leakage - can damaged after processing
1982	Salmon (single can)	1	2	1	E	Leakage - malfunctioning can reformer
1982	Peeled whole tomatoes (single can)	1	1	0	A	Unknown - no evidence of container leakage

[a]No botulism outbreak is recorded from 1926 to 1939 in commercially canned foods in metal containers.

[b]Number of persóns afflicted.

[c]21 additional cans recovered by FDA reportedly showed *C. botulinum*; container evaluation was not definitive.

[d]Four additional cans (swollen) of the same code showed type A toxin.

[e]No known deaths in 1981-1985 involving U.S. commercially canned foods.

(Table adapted from: J. M. Dryer, *et al.*, Journal of Food Protection 47(10):801-816, 1984.)

Table 1.4 shows recent cases of reported botulism around the world from commercially prepared foods, including foods from restaurants.

TABLE 1.4 - Worldwide Botulism Outbreaks, 1973-1991

Year	Product	Country	Cases (Type)	Deaths	Cause
1973	Bottled mushrooms	Canada	1 (B)	0	Inadequate acidification
1977	Canned peppers	USA	59 (B)	0	Underprocessing
1978	Canned salmon	UK	4 (E)	2	Post-process leakage
1981	Kapchunka (salt-cured, air-dried uneviscerated whitefish)	USA	1 (B-np)	0	Poorly controlled salting process
1982	Canned salmon	Belgium	2 (E)	1	Post-process leakage
1982	Bologna sauce	Madagascar	60 (E)	30	Inadequate preservation
1982	Beef pot pie	USA	1 (A)	0	–
1983	Sauteed onions	USA	28 (A)	1	Temperature abuse
1984	Karashi-renkon (vacuum packed, deep-fried, lotus root)	Japan	36 (A)	11	Underprocessing/ temperature abuse
1985	Chopped garlic in oil (bottled, no preservatives)	Canada	36 (B)	0	Temperature abuse
1985	Kapchunka	USA	2 (E)	2	Poorly controlled salting process
1986	Bottled peanuts	Taiwan	9 (A)	2	Underprocessing
1987	Kapchunka	USA and Israel	8 (E)	1	Poorly controlled salting process
1987	Kosher airline meal (meat, shelf-stable, from Switzerland)	UK	1 (A)	0	Underprocessing/ temperature abuse
1989	Hazelnut yogurt	UK	27 (B)	1	Inadequately reduced a_w
1989	Chopped garlic in oil (bottled, no preservatives)	USA	3 (A)	0	Temperature abuse
1991	Faseikh (uneviscerated fish)	Egypt	91 (E)	18	Poorly controlled fermentation/salting

Table adapted from McClure et. al. (1994) and Rhodehamel et. al. (1992)

SPOILAGE OF CANNED FOODS – CHARACTERISTICS OF CANNED FOOD SPOILAGE MICROORGANISMS

Low-Acid Canned Foods

Flat sour producing thermophilic bacteria. Aerobic and facultative anaerobic. Spores highly heat resistant. Occur more in canned vegetables and in products high in starch content for which quality considerations necessitate a minimum of heat processing. Produce acid, but not gas. Cans do not swell. Type species: *Bacillus stearothermophilus.*

Thermophilic anaerobic bacteria. Very heat resistant. Obligate anaerobic. Gas and acid producers. Cans swell. Type species: *Clostridium thermosaccharolyticum.*

"Sulfide spoilage" thermophilic bacteria. "Sulfur stinkers." Food turns dark due to production of H_2S and formation of sulfide with iron containers. Cans usually remain flat due to solubility of H_2S in water. Type species: *Desulfotomaculum nigrificans.*

Putrefactive anaerobic bacteria. Mesophilic, spore-formers and gas-formers. Type species: *C. botulinum, C. butiricum,* etc. Destruction of spores of *C. botulinum* is minimum standard for processing low acid foods. Most species of this group are more heat resistant than *C. botulinum.*

Aerobic mesophilic spore-formers. As a group, they are less important than putrefactive anaerobes, due to (a) vacuum in canned foods which inhibits their growth, and to (b) inability to produce marked changes in foods. However, some species of this group have shown considerable heat resistance. Several species of *Bacillus* belong to this group.

Yeasts, molds, and non-spore-forming bacteria. Spoilage by these microorganisms is not common in low acid canned foods. Their presence would indicate: (a) gross understerilization; or (b) contamination due to defective seam. These organisms are readily controlled by relatively short processes at temperatures below 212°F (100°C).

Acid Foods

Spore-forming bacteria. Among the most important are: (a) *Bacillus coagulans,* which is aerobic, not very heat resistant, thermophilic, produces "flat sour;" (b) *C. pasteurianum,* which is spore-former, anaerobic, saccharolytic, gas-producing.

Non-sporing bacteria. Lactic acid producing bacteria: *Lactobacillus* and *Leuconostoc* sp. Some are gas producing and develop best under conditions of reduced oxygen tension.

Yeasts. Due to their very low heat resistance, yeasts cause spoilage in canned foods only in cases of gross under-processing or can leakage.

Molds. Generally molds are of little importance in all canned foods. However, there are exceptions in *Byssochlamys, Neosartorya* and *Talaromyces,* which are molds that produce heat resistant ascospores; they can spoil canned fruit products sometimes with gas production. Heat resistance: 30 minutes at 190°F (88°C), or 16 minutes at 212°F (100°C). These molds are unusually heat resistant in comparison to other molds. For *Byssochlamys fulva,* a D value between one and 12 minutes at 194°F (90°C) with z value of 6–7°C are reported to be practical working values (Jay, 1992).

Autosterilization: This term is used to explain absence of viable bacteria in cultures and plates made from the contents of cans which have evidence of spoilage by microbial action. This condition may result from the death of bacteria which caused the spoilage from accumulation of products of metabolism; it is especially possible in flat sour spoilage of vegetables. When characteristics of bacterial spoilage are evident, plates and cultures remain sterile because of the death of bacteria which caused the spoilage.

TABLE 1.5 - Spoilage Manifestations in Low-Acid Products

Type of Organism	Classification	Manifestations
Flat sour bacteria	Can flat Product	Possible loss of vacuum on storage. Appearance not usually altered. pH markedly lowered, sour. May have slightly abnormal odor. Sometimes cloudy liquor.
Thermophilic anaerobe bacteria	Can swells Product	May burst. Fermented, sour, cheesy or butyric odor.
Sulfide spoilage bacteria	Can flat Product	H_2S gas absorbed by product. Usually blackened. "Rotten egg" odor.
Putrefactive anaerobe bacteria	Can swells Product	May burst. May be partially digested. pH slightly above normal. Typical putrid odor.
Aerobic sporeformers (odd types)	Can flat	Usually no swelling, except in cured meats when nitrate and sugar present. Coagulated evaporated milk, black beets.

TABLE 1.6 - Spoilage Manifestations in Acid Products

Type of Organism	Classification	Manifestations
Bacillus thermoacidurans (flat sour, tomato juice)	Can flat Product	Little change in vacuum. Slight pH change. Off-odor.
Butyric anaerobes (tomatoes, tomato juice)	Can swells Product	May burst. Fermented, butyric odor.
Non-sporeformer bacteria (mostly lactic types)	Can swells Product	Usually burst, but swelling may be arrested. Acid odor.

TABLE 1.7 - Laboratory Diagnosis of Bacterial Spoilage

	Underprocessed	Leakage
Can	Flat or swelled. Seams generally normal.	Swelled; may show defects*.
Product Appearance	Sloppy or fermented.	Frothy fermentation; viscous.
Odor	Normal, sour or putrid, but generally consistent from can to can.	Sour, fecal; generally varying from can to can.
pH	Usually fairly constant.	Wide variation.
Microscopic and Cultural	Cultures show spore-forming rods only. Growth at 98°F and/or 131°F. May be characteristic on special media, e.g., acid agar for tomato juice. If product misses retort completely, rods, cocci, yeast, or molds or any combination of these may be present.	Mixed cultures, generally rods and cocci. Growth only at usual temperatures.
History	Spoilage usually confined to certain portions of pack. In acid products, diagnosis may be less clearly defined; similar organisms may be involved in understerilization and leakage.	Spoilage scattered.

*Leakage may not be due to can defects but to other factors such as contamination of cooling water or rough handling, e.g., can unscramblers, rough conveyor system.

TYPES OF SPOILAGE OF CANNED FOODS

Swells

Swells are caused by gas production by microorganisms, either from lack of sterilization, or by contamination through a leak. When significant numbers of cans swell soon after processing, there is no evidence of leakage, and the general run have a good vacuum, it is very safe to conclude that the cause is under-sterilization. If one organism greatly predominates, grows under anaerobic conditions, and is spore bearing, lack of sterilization is probably confirmed. Cans from the same lot, if placed in a warm temperature, generally develop some swells. Swells caused by under-processing generally develop within two to fourteen days if the warehouse temperature is warm, but may be delayed for some months if held cold. The development of swells may be slow in some heavy products like sweet potatoes, squash, pumpkin, heavy cream-style corn, and tightly packed spinach, so that time must be considered in connection with other factors.

There is an important biological differentiation between spoilage from under-sterilization and from leakage in the case of low-acid foods. When spoilage occurs from under-sterilization, it is usually caused by a single spore-forming type. Where leakage has occured, mixed cultures of non-sporing bacteria which could not have survived the process, but must have entered the can after process, are found. This differentiation does not exist in a clean-cut way in the case of the acid products, because the aciduric organisms which cause spoilage may have been present in the product at the time of canning, or may have entered subsequent to the process. Cause of spoilage may be identified by observations of whether it occurred from one, or a few, or many bacterial types; in the latter instance, leakage is indicated.

Swells may be so mild that the ends of the can are barely destended or so strong that cans burst. The major gas present is carbon dioxide, although it may be mixed with other malodorous gases such as H_2S. The product is most often offensive, sour, and frequently discolored. The term "puffer" has the same significance as "swell" and is used more among meat canners than among canners of fruits or vegetables.

Swells are usually caused by holding the process to minimum time or temperature, and changes in fill or product consistency, all factors requiring consideration

The words "flipper," "springer," "swell," etc., are rather loosely used by the canning trade. The National Food Processors Association's definitions: "Flippers" are cans, the ends of which are flat, but one end of which is forced out when the can is knocked against a hard surface. Such cans have no vacuum and the ends may come out if cases are dropped during loading or shipping. A "springer" is a can, one or both ends of which are slightly bulged, but the interior pressure of which is not sufficient to prevent forcing one or both ends to their normal position by means of pressure with the fingers. A "swell" is a can, both ends of which are bulged and cannot be forced into their normal position with the fingers.

The contents of a can spoiled by micro-organisms passes through various stages. First, enough gas is produced to relieve the vacuum in the can; at this stage the can may be a "flipper". When slightly more gas is produced, the can may become a "springer", and later become a "swell". If the interior pressure is produced by hydrogen developing from the action of acid in the product on container metal, the same thing occurs. Although this rarely occurs, sufficient hydrogen may be produced causing cans to burst. Cans of fruits frequently contain sufficient hydrogen to become hard swells. Hydrogen swells can generally be differentiated from bacterial swells, since bacterial swells develop within about 15 days at warm warehouse temperatures, while hydrogen swells do not become apparent until months after packing.

"Springers" from overfilling occur infrequently. "Springers" caused by insufficient vacuum may occur in foods packed in a cool climate without proper exhaustion and develop when these foods are sent to a warm climate or to a high altitude; they may develop at the same location during the summer of the following season. "Springers" caused by attack of the food material upon the metal are a problem. These usually develop slowly over weeks or months, but may be hastened by storage in a warm place. Those products most apt to cause "springers" are apples, cider, strawberries, sour cherries, loganberries and other seed berries. When a "springer" is punctured, the gas emitted is hydrogen; it will burn if lighted; there is no objectionable odor; the product is generally normal or may be somewhat bleached in appearance. Flavor may be astringent because of iron present; no bacteria are present; the product is sound, but may not sold.

Pinholing

Pinholing is caused by the same conditions that create hydrogen springers, but the effect is localized. Points usually develop where metal has been fractured by the die on a double seamer.

Flat Sours

A "flat sour" is caused by under-processing or under-cooling. The organisms present develop without the production of gas, but some amount of acid is produced, hence the name, flat sours. An exception - hominy - develops a sweetish taste. The "flat sour" condition is caused by heat-resistant, thermophilic, spore-forming bacteria.

Flat sours generally occur when low-acid foods, like vegetables and meats, are warehoused while still hot. If cans are cooled after the sterilization process, thermophilic bacteria that may have survived sterilization do not have enough time to grow and cause spoilage. While there is nothing in the external appearance of the can to indicate that anything is wrong, shaking may disclose a liquid consistency with products like cream-style corn. If the cans are placed in warm water, the ends of those which contain flat sour material will usually be forced out faster than those containing sound food; the reverse will occur on cooling. This fact provides a means by which bad cans may be separated from good ones. Flat sours occur in the interior of stacks of canned food rather than in outer rows. Adequate process, prompt cooling, and good sanitary conditions prevent "flat sour" production. Thorough washing of raw products to eliminate soil and prevention of recontamination of product with soil or other sources of thermophilic bacteria during the canning operations is important.

Stack Burning

Stack burning results if cans are stored while too warm; the contents soften, sometimes to the point of becoming soupy, darken in color, and acquire a disagreeable flavor. The inside of the cans look galvanized or of a dull color. Stack burning probably occurs more often in tomatoes than in any other product, partly because tomatoes will not resist heat as well as most products and because they are packed in large quantities and stored at once without narrow ventilating aisles between double tiers. Stack burn causes peas to become mushy and acquire a scorched taste with the liquor dark and starchy; other fruits and vegetables behave similarly. Stack burning, like "flat sours," occurs on the inside of stacks and not in outer rows.

Food Discoloration

Discoloration may be caused by various metals, by exposure to high or prolonged temperature, or by bacterial action.Discoloration caused by metals may occur from contamination before foods are placed in a can or by reaction between the food material and the container. Discoloration from metals is well illustrated by the blue-gray coloration in corn when the machinery is first started in operation. Contact with copper at any point along the preparation line, particularly at the filling machine, causes darkening of grains and liquor. Blackening of peas is similarly caused; free copper should be eliminated from the equipment by tinning exposed parts or by other means. Blackening of hominy, however, is most often caused by failure to remove the bleaching material rather than by machinery.

The effect of iron upon fruits is such that iron should be minimally used in the preparatory apparatus; fruit juices are so sensitive to metals that their preparation is best carried out in glass lined kettles, stainless steel or aluminum; preparation tables should also be of such material. Tin bleaches fruit juices.

Black Stains

Discoloration caused by food container interaction during processing is a serious problem. The temperature of the processing breaks up sulfur compounds in proteins, which combine with iron, forming black iron sulfide; this is especially objectionable in corn. A black deposit formed in the headspace of the can becomes detached and mixes with the corn; it is avoided by the use of special enamel lined cans which prevent iron exposure. Black stains may occur in canned shrimp, lobsters, crabs, white meats from fish, meats from slaughter houses, pears and light colored fruit. While it produces no harm, except the objectionable appearance, it is eliminated by the use of enamel lined cans known as "C" enamel and developed for this purpose.

The bleaching effect upon foods, especially those which are highly colored, is largely overcome by the use of inside enameled tins. "R" enamel is used with highly colored fruits and other foods that are bleached by the tin.

Heat discoloration usually results in darkening, though in the case of pears, a distinct pink color results. Dark discolorations are caused by leaks. Discoloration from bacterial decomposition is unusual, but occurs in peas, beans, corn, and fish products; it is invariably a blackening.

Glass-Like Deposits in Canned Foods

Canned food consumers occasionally complain of yellow crystals in asparagus, green beans, and onions, of white transparent crystals in grape products, and of crystals resembling particles of glass in canned crab meat, shrimp, and salmon. These crystals are completely harmless and are formed by certain natural components of the food becoming too concentrated in a particular spot and then precipitating out of solution into this form of crystal (struvite).

The addition of substances known as "chelating agents" is recommended to prevent the formation of these glass-like crystals in canned seafood products; laws and regulations that apply to the manufacture of these products must be checked before use of these additives.

Off Flavors

Foreign flavors are most often acquired before foods are placed in cans. While vegetables may acquire an acid taste caused by incipient fermentation, they may also develop a bitterness due to changes in structure. While this is more noticeable in asparagus than in any other product, it is not infrequent in corn and snap beans. Fruits, especially peaches and apricots, acquire a flavor from standing too long in pine lug boxes. It is difficult to describe, but is referred to as piney, a slight suggestion of wood, turpentine, and resin. Fruits which stand in cold storage take on a musty taste, even though there is no evidence of mold. Standing in a closed, unventilated room, they develop a peculiar flavor believed caused by the action of carbon dioxide.

SPOILAGE BY RECONTAMINATION

The assumption that the heat sterilization given canned foods killed all bacteria that might be present, regardless of kind or number, must be modified since certain types of bacteria are very resistant to heat; the presence of any considerable number of such bacteria renders successful processing very difficult. Certain types of equipment, or lack of proper control measures, may permit such bacteria to multiply and become a spoilage hazard. The following statement on spoilage by recontamination is taken from the Appendix to Bulletin 26-L (1982) of the National Food Processors Association.

Precautions For Handling Filled and Sealed Containers

Installation of labor-saving devices for handling filled containers introduces certain hazards. If these are not minimized, some spoilage may result from post process contamination, even with the best possible double seam construction. Before the containers are thoroughly cooled, seams are slightly expanded and the compound lining is somewhat soft or plastic. Rough handling of containers in this condition may result in contamination by spoilage organisms. In addition to these seam considerations, precautions must be taken in handling containers before they are thoroughly cool and dry to prevent dents on or near the double seams. When filled containers are handled automatically at high speeds, seam deformation may be more significant as a spoilage factor than under slow speed, low-impact conditions. The three main factors in spoilage resulting from post-processing container handling operations are:

1. Condition of container double seams,
2. Presence of bacterial contamination in cooling water or on wet container runways, and
3. Container abuse due to poor operation or adjustment of the filled container handling equipment.

The following recommendations will minimize the potential for spoilage by recontamination after processing:

1. Inspect can seams periodically to insure that they are properly formed. Inspection must include both visual and teardown examinations. Observations and any corrective actions must be recorded.

2. Do not allow containers to drop into crates from closing machine discharge tables without cushioning their fall.
3. Do not overfill retort crates. Containers in overfilled crates could be crushed by crate bales or by crates above them in the retort.
4. Prevent sharp impacts between filled crates or against protruding points during transfer by overhead monorail or on dollies.
5. Operate crate dumps smoothly to prevent impact denting.
6. Apply an appropriate and sufficient quantity of germicide to cooling water to assure its sanitary quality. For example, chlorinate or otherwise sanitize all cooling water to a point where there is measurable residual (0.5 ppm free chlorine recommended when chlorine used) at the point of cooling water discharge.
7. In pressure cooling, maintain adequate retort pressure for a sufficient time to prevent permanent distortion of can ends.
8. Inspect the container handling system periodically from the closing machine to the caser. Where rough handling of the container is apparent, smooth out the operation to minimize seam damage.
9. Dry the containers after cooling and before discharge into the container handling system.
10. When containers are handled on belt conveyors, lowerators or belt elevators, construct these units so as to minimize contact by the belt with the double seam. Cans should not be rolled on double seams.
11. Replace all worn and frayed belting, can retarders, and/or cushions with new non-porous material.
12. All tracks and belts, which come into contact with can seams, should be thoroughly scrubbed and sanitized at intervals frequent enough to prevent bacterial buildup.

GENERAL SOURCES AND CONTROL OF SPOILAGE DUE TO CONTAMINATION

Process efficiency depends in large measure upon type and number of microorganisms in the product at the time of processing. All processes for low-acid canned foods recommended in National Food Processors Association Bulletin 26-L, 12th Edition, are designed to provide commercial sterility. These processes are not necessarily adequate in cases of extreme contamination by spoilage bacteria.

Bacterial contamination of product must be minimized by employing comprehensive sanitation and inspection programs, which are an integral part of a plant's operation.

Factory surveys to identify contamination sources, and to develop means for their elimination, have been conducted since 1926. These surveys have shown that major sources of contamination are often located within the processing plant. Heat resistant spoilage organisms are brought to the plant on the raw product. Even though preliminary washing operations are largely sufficient to reduce initial contamination to a level which will not result in spoilage, residual spoilage organisms may become established in processing equipment and increase to a point where they may constitute a spoilage hazard. With some products, such as asparagus and mushrooms, soil-borne contamination of the raw product may be a direct cause of spoilage.

While factory studies have centered chiefly upon asparagus, corn, mushrooms, peas, pumpkin, and spinach processing, facts uncovered in these studies are applicable to other products. Accordingly, adoption of the following information should serve to control contamination to a degree that insures effectiveness of the processes presented in Bulletin 26-L, 12th Ed., 1982.

Wooden Equipment

In general, the use of wood in processing equipment is not recommended. Bacteria may become "seeded" in the pores, and once established, may contaminate food materials to such an extent that spoilage occurs with a process that has been satisfactory for years. Any wooden equipment or other porous material which food materials contact, such as brine and hot water tanks, conveyors, blanchers, inspection or filling tables, and even small items such as paddles and rollers, may be carriers of contamination. For example, wooden tanks used for storage of hot water for general plant purposes may contaminate a whole processing system. At the beginning of a day's run, wooden brine tanks may supply large numbers of organisms to the product; their number decreases markedly during steady operation due to dilution, only to build up again during a shutdown. Since wood is porous, it retains bacteria and protects them from scrubbing and other cleaning processes. "Seeding" may be prevented to a considerable degree by constant cleaning. In spite of all precautions, there is no practical treatment which will rid wood of established organisms.

Pumps, Pipes, Extractors, Cyclones, etc.

Pumps, pipes, extractors, cyclones, etc., should be selected from the standpoint of ease in cleaning. Since such equipment might hold food material, this serves as a medium for bacterial growth, permitting high numbers of organisms to seriously contaminate the first part of the next day's pack. After use, all such equipment should be thoroughly cleaned, cooled with water, and kept cool until its next use; it should be flushed with water again immediately before use.

During cleaning, care should be exercised to force steam through the perforations of steam distribution pipes, which are submerged in food or brine during operation, to insure that all perforations are open.

Pipe systems carrying product should be thoroughly cleaned at least at the end of the day's pack. More frequent cleanings are necessary if transport pipes are normally operated partially full. "Dead ends" should be eliminated; if unavoidable, they should have drains to accommodate flushing at frequent intervals. All cleaning operations should be inspected to insure effectiveness.

Blanchers

Blanching by heat, when required in the preparation of food, should be accomplished by heating food to the required temperature, holding it at this temperature for the required time, and then either rapidly cooling the food, or processing without delay. Thermophilic growth and contamination in blanchers should be minimized by the use of adequate temperatures and by proper cleaning followed by cold water rinsing. If blanched food is washed before filling, potable water should be used.

Fluming

Flumes, such as those used for conveying peas and whole kernel corn, may become sources of bacterial contamination. Water temperatures in the range of 100–180°F (38–82°C) should be avoided, since this may provide a favorable condition for the growth of thermophilic spoilage bacteria. The reuse of hot flume water may aggravate contamination; it is advisable to use only cold water for fluming purposes.

Fillers

Filling machines used with low-acid products may become contaminated with spoilage bacteria, especially when the filler is maintained at temperatures within thermophilic growth range. This might occur during operation from contact with a heated product, or during shutdown periods from leakage of steam supply valves.

Fillers should be dismantled and cleaned as frequently as practicable. After the day's cleanup, fillers should be flushed with cold water with all machinery in motion to chill the equipment. During the overnight shutdown, fillers should be left clean, cold, and empty. If a filler operates at temperatures within the thermophilic range during actual packing operations, it should be emptied of its product every 4 hours and thoroughly flushed with water while all machinery is kept in motion.

Canning Ingredients

Ingredients commonly used in canning, such as sugar, starch, flour, spices and dried milk, may be carriers of spoilage organisms. Before such raw materials and ingredients which are susceptible to microbiological contamination are used, it must be insured that they are suitable for use in processing low-acid foods. A supplier's guarantee of suitability by microbiological examination, or by other acceptable means, serves as a guarantee that standards are met.

SPECIFIC SOURCES OF SPOILAGE DUE TO CONTAMINATION

In addition to the preceding general information on contamination sources, specific information on individual products follows.

Corn

Cream Style

a. Preheating systems, mixing and blending tanks. Increasing use of mixing and blending equipment in which hot corn is handled has demonstrated further need for contamination control. Such equipment, operated at 180°F (82°C) or higher, does not act as a breeding point for spoilage bacteria, but if operated in the range of 100–180°F (38–82°C), there is opportunity for development of thermophilic organisms. This usually occurs overnight and during shutdowns; spores which develop during those times may contaminate the subsequent run. While it is best to hold the tanks empty overnight, they must be held full of cold water to insure that there are no leaky steam valves in the line which might tend to warm the equipment. During cleaning, perforated steam supply pipes should be blown out; they may hold food material that could serve as a bacterial medium. Flushing and cooling may be conveniently accomplished by connecting a cold water line into the steam supply line adjacent to the mixer and blending tank.

b. Circulating systems. Product circulating pipes should be thoroughly cleaned at the end of a day's production. There may be occasions when more frequent cleanings are necessary, for example, if all pipe sections within the system are not completely full during operation.

Whole Kernel

With this product, special care is required to prevent contact with wooden equipment. After cutting, corn should be given an effective wash; failure to wash cut corn properly may result in spoilage. Warm water in flotation washers should be avoided, since such practice may lead to rapid development of spoilage bacteria.

Peas, Beans, etc.

Earlier recommendations are particularly important to control blancher contamination of peas; these recommendations also apply to other products blanched in a conventional pea blancher, such as lima, green and wax beans.

Pumpkin

Procedures in pumpkin canning are not standardized. The following suggestions are based upon a study of systems used by a majority of pumpkin canners. Consideration of contamination sources focuses first on wilting equipment.

(1) Wooden Box or Tower Wilters. Wooden equipment is objectionable, but it may be lined with metal, if this is practicable, and the interior sealed so that product leakage through holes or seams into the wood does not occur.

(2) Continuous Metal or Wooden Box Wilters. Both metal and wooden boxes used as continuous wilters may be sources of contamination; they are difficult to clean and cool.

(3) Continuous Conveyor Presses. There are several variations of this type of equipment; pumpkin from the wilter is dropped into a hopper and carried between two moving belts; the distance between belts gradually decreases toward the outlet end, and pressure exerted squeezes juice from the pumpkin. These presses are mechanically complicated and their parts vary in temperature; where temperature is favorable to thermophilic growth, there may be some bacterial development. Some control may be maintained by spraying the press "aprons" with cold water. For contamination control, a screw type press is preferred; this equipment forces pumpkin through a tapering perforated screen and during operation, the temperature of all parts is so high (180-200°F) (82-93°C) that no bacterial growth is possible. The screw press is readily accessible for cleaning.

(4) Concentration of Pumpkin Juice. The juice from the press is discarded, but, in some cases, it is concentrated and added back to the pumpkin at the finisher. This system is satisfactory, if general packing procedure keeps contamination at a low level, but the contamination level is increased as the volume of juice is reduced by evaporation, and any contamination present is returned to the product.

Spinach

(1) Washers. Spinach washers include "immersion", "spray-rotary" and "spray-belt" types; they are used individually, or in combination; the washer's primary function is to remove grit and adhering soil, along with any soil-borne bacteria. In all types of washers, efficiency is determined, at least in part, by the amount of water used. Since thorough washing is of primary importance, a large volume of water is usually required. Washers should not be overloaded with product, because this limits efficiency. If both immersion and spray types are used in the same

line, better results are achieved if the immersion washer is placed before the spray washer. The first washing should always be done with cold water, since warm water may lead to an increase in bacterial numbers. Equipment could become contaminated. Water from a single washer should not be recirculated.

(2) Blanchers. Blanching equipment may be a thermophilic spoilage bacteria source; to minimize spoilage hazards here, washing and cooling treatments previously discussed should be applied. Occasionally, rotary drum blanchers are used, but since this equipment is difficult to clean, spoilage organisms may develop; their use is not recommended. Makeup water should be added to blanchers at a reasonably rapid rate.

Both rotary drum blanchers and tubular blancher systems may become contaminated with thermophilic spoilage bacteria. Contamination, which occurs during shutdown periods, can be minimized by prompt cooling of the blanchers after use, thorough cleaning, elimination of steam leaks, and flushing of the blancher system before its next use. However, thermophilic contamination may occur during operation of either type of blancher system.

In rotary drum blanchers, contaminating bacteria can grow on inner surfaces above the water line, where temperatures are reduced by cool air drawn into blanchers under loose fitting doors and other openings. Any blancher surface where the temperature ranges between 100–180°F (38–82°C) can serve as a site of bacterial growth. From these surfaces, heat resistant spores are washed by condensate into blanch water and contaminate the product.

To prevent contamination in rotary drum blanchers, inner surface temperatures should be elevated above 180°F (82°C); blancher doors should be closed and fastened at all times during operation; bent doors, or doors similarly in disrepair, should be repaired. Entry of cool air should be prevented; vent stacks should be eliminated from the blancher shell. Since the coldest sections within a drum blancher are at the feed end, a spray or steam jet, inserted at the upper edge of the feed end to deliver steam or hot water (190°F (88°C) or higher) over inside surfaces, is useful in preventing contamination. During operation, blanch water temperature should be as high as practicable (at least 180°F (82°C)); reels should be kept in continuous motion while blanchers are being heated or held at operating temperature; a continuous water overflow from the blancher should be maintained during operation.

In tubular blanching systems, a large percentage of flat sour spore contamination occurs in the de-watering reel into which product is discharged from the blanchers. Thermophilic bacteria grow on the screen mesh and splash board surfaces around the reel and underneath the pan; bacterial spores are added to product as it passes through the reel; they may also be washed into the water and recirculated in the blancher. Such contamination can be reduced if water sprays are installed to wash reel surfaces. This water may be chlorinated; cold water is desirable to lower product temperature before it enters the quality grader.

Sprays should also be provided to wash down inner surfaces of splash boards or canopy surrounding the reel. Tests indicate that cold water sprays are effective in reducing flat sour contamination. Foam accumulating on tanks supplying recovered water to tubular blanchers can be the growth site for thermophilic spoilage bacteria; a large, broad overflow should skim the tank's surface; top sprays delivering streams of water at a flat angle prevent foam formation; they also help to skim the tank.

It is important to wash product thoroughly after blanching; adequate washing removes large numbers of spoilage bacteria, but it cannot remove all bacteria added by heavy contamination. Cold water washing reduces product temperature, which helps to minimize slime growth and prevents undesirable temperature increases further down the processing line.

Blancher water should be dumped as often as practicable, since bacterial spores in the water increase with time and use; drain and water supply pipes should be of sufficient size to permit rapid draining and refilling.

SOURCES OF CONTAMINATION OF VEGETABLES IN GENERAL

Vegetables, as received at the processing factory, usually contain large numbers of viable microorganisms; counts in the millions per gram are not uncommon. While growing field soil is a principal source of contamination, organisms can also originate from the surfaces of harvesters and from the containers used to transport product to the factory.

Actual growth of microorganisms can be responsible for high counts if a vegetable is held for an extended period after harvest, especially when the weather is hot. This cause of high counts can be avoided by proper harvest scheduling.

Usually, the initial wash that is given vegetables only removes a portion of the microorganisms and soil; as a result, microbial populations remain high until a vegetable is blanched. Thus, blanching also serves as a cleaning step, though not usually considered one.

With frozen vegetables, most viable microorganisms in the final product are introduced at processing stages following the blanch. Equipment such as cutters and slicers are often significant sources of contamination, because they are difficult to clean. Belts can be a problem, although many factories prevent growth on them by continuous cleaning with chlorinated water sprays.

Number of Microorganisms

Predominant types. Bacteria greatly outnumber viable yeasts and molds that are present on low-acid vegetables (yeasts outnumber the molds). These data indicate that, if there is a buildup of slime on processing equipment, bacteria would be responsible.

A wide variety of bacteria make up the microflora that are enumerated by aerobic plate counts. The most numerous group is the catalase negative cocci; they increase in numbers as the processing season progresses and may make up 90% or more of the organisms on vegetables, such as corn, which are processed later in the summer.

Fecal indicators. Coliforms and enterococci are present on vegetables as received from the growing field and can be recovered at most stages of processing. It is believed that their presence has no special sanitary significance: they merely make up a part of the processing line microflora, along with lactic acid bacteria and other organisms. *Escherichia coli*, on the other hand, is rarely found and its presence may indicate a problem.

Geotrichum candidum. If this mold is found in processed fruits and vegetables, it is evidence of insanitary processing conditions. While the presence of *Geotrichum* (machinery mold) in certain canned fruits and tomatoes appears to be well explained, the significance of low counts in low-acid vegetables is less well understood. For example, yeast and mold growth on the surfaces of soiled vegetable processing equipment would be expected to parallel that of bacteria, the predominant organism, but no correlation between the incidence of *Geotrichum* and the numbers of bacteria has been found. *Geotrichum*-positive samples did not yield higher viable counts than those that were negative for the mold.

MICROBIOLOGICAL STANDARDS FOR INGREDIENTS

In the analysis of ingredients, a wide variety of thermophilic and mesophilic bacteria are encountered. Relatively few of the mesophilic bacteria, however, are considered significant from the standpoint of food spoilage. In general, yeasts, molds and thermophilic bacteria are the significant spoilage types of organisms.

The types of thermophilic, low-acid, food spoilage, spore-forming bacteria which may be found are characterized into three groups: those which produce flat sour spoilage, i.e., *Bacillus stearothermophilus*; those which produce gas, but not hydrogen sulfide, i.e., the thermophilic anaerobe *Clostridium* *thermosaccharolyticum;* and the thermophilic anaerobes which produce hydrogen sulfide spoilage, i.e., *Desulfotomaculum nigrificans.*

In general, there are no microbial standards by which the suitability of ingredients for use in canning may be measured. An exception to this are the standards suggested by the National Food Processors Association for thermophilic spore contamination of sugar and starch to be used in low-acid, heat processed canned foods. Those standards follow.

STANDARDS FOR SUGARS AND SYRUPS

Sugars

Granulated sugar, as well as starch, bought under American Bottlers of Carbonated Beverage Association or National Food Processors Association specifications, meets standards for low thermophile count.

1. Standards for thermophilic spore count "for five samples examined, there shall be a maximum of not more than 150 spores per 10 grams of sugar".
2. Flat sour spores "for five samples examined, there shall be a maximum of not more than 75 spores and an average of not more than 50 spores per 10 grams of sugar".
3. Thermophilic anaerobic spores "shall be present in not more than three (60%) of the five samples of starch and in any one sample to the extent of not more than four (65+%) of six tubes inoculated by the standard procedure.
4. Sulfide spoilage spores shall be present in not more than two of the five samples and in any one sample of starch to the extent of not more than two of the five samples and in any one sample of starch to the extent of not more than five colonies per 10 grams. This is equivalent to two colonies in six tubes.

Because NFPA is primarily concerned with canning operations, standards emphasize thermophilic type bacteria; yeast and molds would be killed in the canning process.

Since the process for producing crystalline dextrose at the crystallization step is very similar to that of producing granulated sucrose, the microbiological background is similar. Dextrose producers can routinely meet NFPA and NSDA standards set for sucrose.

Crystalline sugars, in their normal dry state in bags or in other suitable containers, are microbiologically stable if kept dry; low levels of moisture preclude growth of microorganisms.

Syrups

Syrups present a somewhat different microbiological situation than dry sugars; moisture content and wide variety creates a complex situation. The higher the solids content of a syrup, the less tendency there is to microbiological spoilage; conversely, the lower the solids, the greater susceptibility to mold growth. Of course, there are exceptions to these general rules. Osmotic pressure is the explanation for this differential behavior of microbes in syrups.

Corn syrups are produced in a wide range of types; they can vary from a high of 95 dextrose equivalence (D.E.) plus to a low of 20 D.E. Syrups derived from corn below 20 D.E. are designated malto-dextrin syrup. Solids content of all of these corn syrups can vary on a commercial basis from 70–84% solids, depending on handling characteristics and crystallization tendencies. These syrups have a low microbiological profile if handled properly in transit and in plant storage facilities.

Corn syrups are often purchased with a microbiological specification; a typical requirement would be a total plate count of 1,000 per gram maximum and with yeast and molds at 100 per gram maximum for each. Product used by bottlers would require the same NSDA levels as dry sugar and canners would apply NFPA specifications for thermophiles.

Syrups derived from sucrose fall into three general types: liquid sucrose, invert syrups, and molasses. Invert syrup differs from liquid sucrose in that a portion of up to 50% of sucrose is hydrolyzed to dextrose and levulose to allow a higher solids syrup to be produced. This higher solids content gives the syrup better protection against most microorganisms.

Liquid sucrose and invert syrups are produced at low counts and routinely meet requirements for NSDA and NFPA specs. If proper handling facilities are available, these syrups have excellent storage life.

Molasses, a byproduct, can have wide variations in microbiological background. If a good food grade type molasses is purchased, no microbiological problems should be experienced.

Honey is a natural syrup worthy of consideration; even though no particular precautions are taken, honey is generally free of microbiological problems. When a rare fermentation problem is encountered with honey, it is usually attributed to a *Zygosaccharomyces* or *Torula* type yeast.

In the production of table or fountain syrups, classified as mixed syrups, a pasteurization step is usually carried out. This involves heating to 190°F (88°C) and packaging at this temperature. Containers are then inverted to heat the top of the container. Low levels of potassium sorbate or sodium benzoate may be added to protect the syrup after opening.

Some mixed syrups are cold packed; in these instances, the component ingredients must be relatively "clean" and great care exercised to avoid contamination during processing. It is imperative that an inhibitor is used in this type of operation. Even with this protection, these types of syrups can occasionally ferment.

Bulk handling systems for all types of syrups have certain basic requirements. Tanks can be of mild steel with a suitable food grade epoxy coating, stainless steel or fiber glass construction. These tanks should have an air filter-blower system to assure proper air flow over the head space in the tank, or condensation can occur, diluting the syrup at the surface and making it more susceptible to microbial activity, usually yeasts. Once started, a fermentation of this sort will spread throughout the tank.

With syrups at lower solids levels, such as 67–75% solids, it is strongly recommended that incoming air to the tank be passed over an ultraviolet lamp to give further protection. Samples of sugars and syrups should be analyzed occasionally.

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