MICRO-ORGANISMS IN FOODS AND FOOD PRESERVATION

by Harry E. Goresline [1]

BACTERIA, yeasts, and molds cause enormous losses in the food industries every year, attacking and spoiling practically every kind of food. Preventing this loss is one of the most important problems in our modern economy. It can be done only by using correct methods and continual care. In this brief account, the author tells how such spoilage occurs and outlines what is done to prevent it. He also describes the use of micro-organisms for making many products, including such everyday foods as bread and cheese.

THE MICRO-ORGANISMS that act on foods may be divided into two general groups: (1) Those bringing about spoilage and deterioration, and (2) those employed by man as a means of preservation.

Bacteria, yeasts, and molds are microscopic forms of plant life that utilize the soluble constituents of food in their life processes, or that secrete enzymes that bring about decomposition of food tissue, which renders many of the constituents soluble and available to the micro-organisms. These processes are going on in nature continuously, and they account for a large proportion of the decomposition of organic matter to material which increases the fertility of the soil. The decay of leaves, wood, grass, etc. is brought about by these minute forms of life.

Bacteria, yeasts, and molds cause enormous losses in the food industries. Since these micro-organisms are everywhere in nature, they are present on the surface of nearly all fresh food products. As long as the plant or animal is alive and in good condition it has the ability to prevent the action of the micro-organisms on its tissues, but if the healthy condition of the organism is lowered or the plant or animal is killed, then the micro-organisms gain access to the tissue and decomposition results.

For example, an apple hanging on the tree is ordinarily free of decay although bacteria, yeasts, and molds are present on its surface. Like most fruits it has a waxy coating, which protects it from invasion, but

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once this is removed or the surface broken or bruised the micro-organisms gain access and begin to destroy the tissue. When this apple is picked and placed in storage certain natural changes begin that soften and mellow it and bring it to the stage called ripe. If the apple is left in storage long enough, or has been bruised, its resistance to the invasion of micro-organisms will be lowered to the point where some form of rot will set in. This invasion of the tissue is generally made by some form of mold, which, by enzymatic action, softens the tissue and makes it relatively easy for bacteria and yeasts to gain entry. Within a very short time the apple is reduced to a dark, soft, mushy mass of soluble material. It is by this process that nature prevents the accumulation of insoluble organic material that would otherwise clutter up the earth.

PROTECTION AND STORAGE OF FOODS

FRUIT

In common with other forms of life, micro-organisms grow best under certain conditions of acidity, oxygen supply, and carbohydrate and nitrogen metabolism. Since most fruits are acid, they are attacked principally by molds and yeasts, which are acid-tolerant and grow best under acid conditions. Bacterial spoilage of fruit is of secondary importance. Pectin, starch, and other carbohydrates are broken down by these micro-organisms, and the fruit becomes soft, unsightly, and unfit for consumption. Even in the early stages of the decomposition, it becomes unpalatable.

A number of methods have been devised to prevent spoilage of fruit in storage. Cold storage is used almost universally for the preservation of fruit and fruit products. Low temperatures retard the natural processes in the fruit and retard the growth of micro-organisms. Waxy or fungicidal coatings are applied to the surface of fruits, especially citrus fruits, and fungicidal wrappings have also been used on various kinds of fruits.

FRUIT JUICES

Freshly pressed fruit juices contain many micro-organisms that quickly multiply unless some preservation process is employed. The surface of the juice generally becomes covered with a white to gray wrinkled scum of mycoderma, which destroys the fruit acids and the sugars and gives rise to musty flavors. Since the scum must have access to oxygen in order to grow, one method of preventing this surface growth is to seal the juice from the air. A cottony type of mold also may form on the surface of fruit juices that are not sealed from the air.

Yeasts multiply quickly in fresh fruit juices and convert the sugars to alcohol and carbon dioxide. Under controlled conditions the juices are converted into wines by this process, but in open containers a large amount of acetic acid is formed. This fermentation and acetification make fruit juices unfit for consumption in a short time. The preservation of the juices may be accomplished by pasteurization, filtering to remove all germs, or freezing. The process most universally employed is pasteurization, in which the juice is either heated in bulk and bottled hot, or heated in the bottle. The temperature and method

employed are different for each juice owing to the differences in acidity, sugar content, and initial contamination with micro-organisms. Freezing prevents fermentation, but this process starts as soon as the juice is thawed.

VEGETABLES

Fresh vegetables differ in composition and character from fruits, and naturally the flora of the surface and manner of spoilage are somewhat different. Most vegetables are nonacid, and many types of bacteria and other micro-organisms will grow on the surface and in the tissue that will not grow on fruits. Bacteria and molds growing on vegetables break down the pectic material, and the tissue becomes soft and watery through loss of structure. If piled together, most vegetables undergo a sweat with a considerable rise in temperature. This steamy, warm environment is ideal for the growth of many micro-organisms and spoilage of the product takes place in a few hours. Fresh vegetables should be handled rapidly, kept as cool as possible, and not placed in large containers or piles. Ample circulation of air should be afforded in any storage place.

Certain bacteria convert the soluble sugars present in the vegetables to lactic acid, which gives the product a sour smell and taste. This souring takes place in fresh and cooked vegetables, as well as in thawed frozen products, and should be used as one criterion in judging when material is fit for consumption.

FROZEN FOODS

In the last few years the increased production and consumption of frozen foods, including ice cream, meat, fish, poultry, eggs, fruits, and vegetables, has renewed interest in the action of micro-organisms at low temperatures. Thirty-two degrees Fahrenheit has not proved sufficiently low to prevent growth over prolonged storage periods of many bacteria, yeasts, and molds capable of bringing about changes in appearance, flavor, texture, and general usability of the stored foods. Storage at temperatures above 15° F. is not considered safe from the standpoint of microbial spoilage, nor is this temperature sufficiently low to prevent undesirable enzymatic changes in certain products. The rate of destruction of microbes and the predominating forms surviving are determined by such factors as rate of freezing, the nature of the product, acidity, size and type of container, airtightness of the pack, subfreezing storage temperature, length of storage, original contamination, etc. Less resistant microbial forms are destroyed during the first intervals of freezing. Thereafter the rate of destruction is slow. Some microbial forms may remain viable for several years.

Most spoilage encountered in the frozen-food industry is due to improper handling of the product prior to freezing or after it is thawed. Vegetables are scalded (blanched) before being frozen to inactivate the enzymes present in the tissue, and during this process many micro-organisms are killed by the heat. If vegetables are held for a time before scalding or freezing, there is danger of the growth of micro-organisms that will produce lactic acid, musty flavors, softening of the tissue, and general loss of quality. Frozen-food products are not sterile, but their microbial content may be kept low by sanitary preparation and handling, by the maintenance of subfreezing temperatures

below which microbial growth is known not to take place, and by immediate use of the product after thawing.

As soon as the frozen food is thawed and left at room temperature the micro-organisms start to grow. Owing to the partial cooking of such vegetables during the scalding process, the tissue is softer than that of fresh vegetables and the product will sour in a very few hours unless it is kept cold.

Fruits are generally packed in sirup or dry sugar just before they are frozen. Yeast growth starts quickly both in material to be frozen and in that which has been thawed. Mold growth is to be expected on portions exposed to the air, and the combined action of the micro-organisms and the oxygen of the air give rise to darkening and to off flavors and odors in unfrozen material.

Fish to be frozen should be handled rapidly, and only freshly caught fish should be used, for decomposition sets in rapidly. Even though they may look fairly acceptable in the frozen state, products of low initial quality will have undesirable odors and flavors when thawed.

To secure and maintain high quality in frozen food it is necessary to start with high-grade material, handle it rapidly under sanitary conditions, store and transport at proper freezing temperatures, and use it within a short time after thawing.

CANNED FOODS

In the canning process foods are packed in hermetically sealed containers, and the enzymes are inactivated and the spoilage micro-organisms killed by the action of heat. When improper processing is employed certain micro-organisms survive and multiply in the product. Certain types of bacteria produce gas that swells the ends of the cans. Other types produce acid without producing gas; this type of spoilage is referred to as "flat sour." Canned food that shows evidence of spoilage or has an off odor or flavor should be discarded.

Molds do not grow in the absence of air, but yeasts may ferment fruits that are improperly processed and cause spoilage. Yeast fermentation produces carbon dioxide and swells the cans. The time and temperature of processing have been worked out in commercial practice for the various food products until there is relatively little spoilage.

EGGS

Much of the spoilage and deterioration encountered in fresh, stored and processed eggs are due to micro-organisms. The presence of large numbers of micro-organisms is an indication of improper handling and often of unsanitary conditions. A certain percentage of eggs contain bacteria at the time they are laid, but most eggs are sterile. The white of the egg contains a product known as lysozyme, which kills bacteria and which no doubt accounts for much of the freedom from contamination.

If the flock is handled in such a way as to produce a large percentage of "dirties," or the eggs are subjected to improper treatment, a much higher loss from bacterial spoilage is to be expected. The principal types of bad eggs found during and after storage are green whites, digested whites, white rots, and black rots. As a rule these types show decided chemical decomposition and are heavily infected

with bacteria. Owing to their high nitrogen and sulfur content, eggs have very bad odors and flavors when decomposed by bacteria. Musty eggs also are caused by bacterial growth. In commercial practice nearly all infected eggs are detected by candling so that few bad eggs reach the consumer.

The molding of the surface of eggs in storage gives them an unsightly appearance, but this trouble can be avoided by proper handling. If the humidity is properly controlled and contaminated cases and packing materials are eliminated, very little trouble should be encountered. Such molding does not affect the food value of the egg unless it is allowed to remain in storage for a considerable length of time, in which case the mold will penetrate the shell and cause darkening.

Rigid sanitary measures are essential in egg-breaking plants if quality products are to be produced. Great care should be exercised in breaking to eliminate all bad eggs, since whole batches can become infected by one musty egg accidentally included through careless inspection. This musty flavor or odor is very penetrating, and every precaution should be employed to keep such materials out of the commercial pack. The eggs should be broken separately, examined, and smelled before being added to the main batch in the mixer.

Speed is essential in handling eggs to be frozen. The fresh eggs should be kept in cold storage until ready for breaking. As soon as they are broken they should be churned, poured into the final containers, and frozen as rapidly as possible. If any chance is given for bacteria to multiply in the egg mass there is likelihood of the production of off flavors and odors and of general loss of quality.

MILK

Milk is a highly perishable article of food, chiefly because it is an ideal medium for the growth of micro-organisms. The souring of milk is a well-known example of this activity. Certain bacteria convert the milk sugar to lactic acid, and under ordinary conditions at room temperature this process is carried on very rapidly. When a certain acidity has been reached the casein is converted to its insoluble state and sets in the form of curd. Bacteria of the *Bacillus subtilis* type produce a rennetlike enzyme which forms sweet curdling of milk, but later the curd is more or less completely digested. The growth of undesirable micro-organisms often gives rise to very objectionable odors, soapy or bitter flavors, and various abnormal colors, or they may produce gums in the milk. Yeasts may grow in cream and cause it to "gas" or become frothy. Pasteurization is generally employed to kill the bacteria, and it greatly prolongs the time that milk may be kept in wholesome and palatable condition. Cold storage should be used wherever possible to retard the growth of the micro-organisms in milk, and needless to say, every sanitary precaution should be taken in handling.

MEAT

If meats are handled rapidly under sanitary conditions and the proper cold-storage methods are employed, relatively little microbiological spoilage should occur. A bacterial infection next to the bone known as "ham souring" or "bone souring," which has caused consider-

able difficulty, is due without doubt to slow withdrawal of animal heat or to improper penetration of brine. Injuries to the bone and tissue during slaughter may play an important role. Beef souring is also sometimes encountered. Under certain conditions of humidity, long cold storage, and contamination in handling, fresh meat may become covered with a growth of mold, but this is of little consequence unless it affects the appearance of the product. Under conditions of improper handling and storage, bacteria and molds may produce putrefaction and thus render the product unfit for human consumption. Salting, smoking, drying, and freezing are employed to prevent bacterial action, retard enzyme activity, and reduce possibility of rancidity.

CARBOHYDRATE MATERIALS

Bacteria, yeasts, and molds seldom develop in sugar, starch, or sirups, because of lack of moisture. However, certain types of food-spoilage bacteria sometimes occur in carbohydrates, and when the carbohydrates are added to canned foods they may cause spoilage unless extreme care is taken to safeguard the keeping quality. This group of bacteria is known as "thermophilic," which means "heat loving." The optimum temperature for growth is about 131° F., which is well above the temperatures tolerated by most forms of bacteria. The spores of this group are highly resistant to heat and are not easily killed during the normal processing of food products. Spoilage of processed foods by this group of bacteria usually results from undercooling after processing or from storage in too warm places.

The manufacturers of sugar are cooperating with the food industry by eliminating food-spoilage bacteria from sugar. Yeasts and molds do not survive processes now used in manufacturing sugar and sirup. If present they are the result of contamination in handling and storage.

Some trouble is encountered in the action of yeasts in candy and other confections. These yeasts have the ability to grow in sugar of very high concentration. The pressure of the carbon dioxide they produce causes the candy to burst open or foam.

Beverages of the soft-drink type constitute an important item of the Nation's food bill, and several hundred tons of energy-giving sugar and other ingredients are used each year in their manufacture.

The presence of sugar often makes a product a potential medium for the growth of bacteria, yeasts, and molds, and unless measures are taken to safeguard against their entrance, spoilage often results. Yeasts and bacteria are more often the cause of spoilage of beverages than are molds. Spoilage evidenced by cloudiness and by the accumulation of a sediment at the bottom of the bottle occurs more often in the winter than in summer, owing to slower turn-over of the stock. Continued improvements in bottle-washing methods, preparation and handling of ingredients, and automatic bottling machinery have resulted in the manufacture of beverages relatively free from spoilage.

FOOD PRESERVATION AND PROCESSING BY THE USE OF MICRO-ORGANISMS

So much emphasis is placed on the role of micro-organisms in food spoilage that the importance of their use in food preservation is often overlooked. Yet a number of large industries rely on fermentation

under controlled conditions to preserve food products or to alter their character, and such methods are among the oldest employed by man for the preservation of food.

WINE AND BEER

Without doubt the first use man made of micro-organisms was in the conversion of the juice of grapes and other fruits to wine. This natural process, which prolonged the length of time a fruit product could be kept, was employed wherever fruit was available. Over 100,000,000 gallons of wine is now being produced every year in the United States.

Yeasts are naturally present on the stems and skins of grapes and on most other fruits as well. When the berries are crushed, the yeasts multiply rapidly in the juice, forming carbon dixoide and alcohol from the sugar. If the proper control is exercised over the fermentation, almost all other micro-organisms can be prevented from growing in the material. Most scum or surface-growing forms can be eliminated by sealing the product from the air and allowing the carbon dioxide formed by the yeast fermentation to sweep all of the oxygen out of the container. In making champagne, the carbon dioxide is retained in the liquid by keeping the container stoppered; a pressure of as much as 120 pounds per square inch is developed.

In order to insure a good clean fermentation, most wineries inoculate the must or juice with a pure culture of wine yeast, which gets a head start on the other micro-organisms and prevents an undesirable type of fermentation. Most wine yeasts grow well in acid solutions and at temperatures slightly below the optimum for the growth of most bacteria. Where low temperatures are not available treatment with sulfur dioxide or pasteurization of the must is often employed. Yeasts are tolerant of concentrations of sulfur dioxide that will kill most spoilage organisms.

When all of the sugar of the must has been converted to alcohol, the yeasts die for lack of food and because of the killing action of the alcohol. Light wines contain up to 14 percent of alcohol by volume, but 16 or 17 percent may be obtained by natural fermentation when the juice has a very high sugar content. By special methods of feeding the yeast an alcohol content as high as 21 percent has been attained. Wines stored in casks should be sealed from the air to prevent spoilage, and spoilage organisms in bottled wines can be killed by pasteurization.

Beer is made by a yeast fermentation of malted cereal grain extracts. The sugars are converted to carbon dioxide and alcohol as in the wine fermentation, but the percentage of alcohol produced in beer is very much lower. In the case of beer the carbon dioxide is retained in the product under considerable pressure. This not only adds to the palatability but aids in the preservation of the product. Since the acidity of the beer is relatively low there is danger of souring by the action of the lactic acid bacteria unless the proper precautions are taken. Most present-day beer is pasteurized in order to insure its keeping quality in the bottle or can.

VINEGAR

The first step in any vinegar process is the production of alcohol as in making wine or beer. Cider vinegar is produced from fermented

cider, while white or distilled vinegar may be made from the alcohol distilled from fermented mashes, molasses, or other saccharine materials. After fermentation, the alcohol is converted to acetic acid by an oxidation process carried on by acetic acid bacteria. Whereas the yeast fermentation is carried out in the absence of air, the conversion of the alcohol to acetic acid can be carried out only in the presence of air. In the old barrel method the acetic acid bacteria are allowed to grow on the surface of the alcohol solution, while in the generator process the alcoholic solution is allowed to trickle down through towers filled with shavings, pumice, rattan, or other filling material. Millions of gallons of vinegar are produced each year by this use of micro-organisms in these two relatively simple processes.

BREAD AND YEAST

Leavened bread has been an article of diet for centuries. A culture of yeast is allowed to grow in a dough made of flour and water. As it grows the yeast produces carbon dioxide, which causes the dough to rise or become light. In addition, flavors are produced in the bread by the yeast or certain types of bacteria. In certain breads the growth of lactic acid bacteria is encouraged and characteristic flavors are obtained. When the bread is baked the alcohol produced by the fermentation is driven off and the micro-organisms are destroyed. Under abnormal conditions bread may become ropy, moldy, or highly pigmented by the growth of micro-organisms.

The yeast used in bread making, or bakers' yeast, is not the same as those types used in making wine or beer. It is manufactured on a large scale, and a high yield of yeast is obtained by a process that suppresses the formation of alcohol. The use of this type of yeast as a food for man and a feed for animals has built up a large industry with the sole function of growing and harvesting a yeast crop. Yeasts of this general type are the only micro-organisms that man eats as such, and they are consumed for their vitamin and mineral content.

FERMENTED FOODS

The ability of certain bacteria to form lactic acid from sugars is utilized in the preparation of so-called "fermented foods." These include pickles, sauerkraut, olives, and animal feeds on the order of silage. In these processes the sugars are converted into lactic acid. The preservation is of a twofold nature, since (1) the increased acidity exerts a selective action that inhibits the spoilage micro-organisms, and (2) most of the food for bacteria has been used up in the process of fermentation, so that there is no further material to encourage large microbial populations.

Since these lactic acid bacteria are tolerant of salt, and since salt exerts a curing action, it is employed in almost all fermented foods. Cucumbers are fermented in brines strong enough to discourage most spoilage micro-organisms, the salt and acid being soaked out before the product is used as food. This general process is also used in the production of pickled olives. In the case of sauerkraut, the salt concentration is only about 2½ percent, and the product is consumed in its final fermented form. The pleasant acid flavor of sauerkraut is the result of the bacterial activity. The process in all three cases

should be carried out in the absence of air if possible in order to prevent scum formation. In 1937 the production of pickles took almost 8,000,000 bushels of cucumbers, of sauerkraut 127,000 tons of cabbage, and 25,000 tons of olives were pickled, a total farm value of over $7,800,000 for the material used in the making of these fermented foods.

The utilization of micro-organisms in the production of silage is quite similar except that very little, if any, salt is used. The process is described in Losses in Making Hay and Silage (p. 992).

MILK PRODUCTS.

Micro-organisms are used extensively in the manufacture of cheese, butter, and fermented milk products. Various types of micro-organisms and various procedures are employed to produce different products and flavors. Bacteria are employed to sour milk for cheese making, and the growth of other bacteria is encouraged in pressed cheese to produce ripening. This is brought about by bacterial digestion of the curd, resulting in the development of certain flavors. Types of cheese such as Camembert, Brie, and Roquefort are produced by the action of molds, and specific flavors are produced by their growth.

Sour-cream butter is made by churning cream that has been ripened by bacterial action with a resultant production of lactic acid. The fat globules are more easily coalesced during the churning, and they take up certain desirable flavors that were produced by the bacteria during the fermentation process. Undesirable micro-organisms may produce bitter and off flavors in the cream unless proper handling methods are employed, such as pasteurization, cooling, and the use of starters.

Micro-organisms are used in the production of various sour-milk drinks, such as culture buttermilk, acidophilus and bulgaricus milks, kefir, and koumiss. The latter two are produced by the combined action of yeasts and bacteria and contain an appreciable amount of alcohol.