SPOILAGE AND PRESERVATION OF FOOD

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Summary

Although the deterioration of foods is a result of several factors (such as physical, chemical, enzymatic and microbiological changes), the most important cause of spoilage of foods is activity and growth of microorganisms. The kinds and numbers of microorganisms that are present in food depend primarily on the type of food and degree of contamination. Every food has a typical natural microflora. For example,

fruits and vegetables contain mainly yeasts and molds, while meat and eggs are generally spoiled by bacteria. In addition to the natural microflora of foods they may be contaminated with microorganisms during all steps of handling. Whenever the food is handled personally by a human being, there always is the possibility of the addition of human pathogens. Air, dust, water, ingredients may add their quota of contaminants. The kind and number of microorganisms will determine the keeping quality of the food, and the rate of spoilage. Due to their low moisture content, cereal grains and flours made from them are not prone to microbiological spoilage if they are prepared and stored properly. Fruits and vegetables are good media for microorganisms due to their high moisture and sugar content which may be fermented by microorganisms to alcohol and acids. Formation of color compounds and unwanted changes of flavor may occur. In the case of meats, changes of color, surface slime, and, in the most drastic spoilage, decomposition of proteins (putrefaction) are typical signs of spoilage. Souring or acid formation is the main type of milk spoilage. Like meat, fish and other seafood may be spoiled by autolysis, oxidation or most commonly by microorganisms.

Prevention of spoilage and preservation of food, principally requires exclusion of microbial activity. This may be achieved (1) by excluding or removing microorganisms, (2) by hindering of growth and activity of microorganisms and (3) by killing the microorganisms. In commercial practice the killing of microorganisms by high temperature treatment (pasteurization, sterilization) is the most common method. Drying (reduction of water content) is the oldest technology. The traditional sun drying has now been largely substituted by artificial drying with hot air. Preservation by using low temperatures (chilling storage, freezing) reduces the number of microorganisms and at freezing temperatures stops their growth and activity. So freezing assures long term storability at temperatures below freezing point. Chilling only reduces the activity of microorganisms but does not exclude their slow growth and changes caused by them, so the storability is limited. Some chemicals, called preservatives, inhibit (in some cases also kill) the growth and and activity of microorganisms. Stimulated by efforts to increase food safety, the use of such chemicals has declined in recent decades and intensive research is being conducted in order to find natural substitutes of these chemicals that are less harmful to human health.

1. Introduction

Microorganisms are the most important cause but not the only cause of deterioration of food. On the other hand, preservation of foods is primarily connected with prevention or reducing of activity of microorganisms. This article will deal primarily with spoilage of foods by microorganisms on one hand and with hindrance of their activity on the other. The role of food enzymes will be treated only marginally.

1.1. Factors Influencing Microbial Status of Foods

1.1.1. Type of Food

The kind of spoilage of foods by microorganisms (and enzymes) will depend upon the kinds and numbers of these agents present and upon their surrounding environment. Most raw foods contain a variety of bacteria, yeasts and molds. Because of the

particular environmental conditions, only a small proportion of the kinds of microorganisms present will be able to grow rapidly and cause spoilage, usually either a single type of microorganism or sometimes two or three types, which may not have been predominant in the original food. If spoilage by the first organism or organisms is allowed to proceed, one or more other kinds of microorganism are likely to produce secondary spoilage.

The kinds and numbers of microorganisms that are present in food depend primarily on the type of food. Additional factors influencing the microbial status of food are the kind and extent of microbial contamination, previous opportunities for the growth of certain kinds, and pretreatments which the food has received.

Every food raw material has a typical natural microflora. Among the properties of food determining the potential number of microorganisms present in food or at its surface and conditions of their growth, one of the most important is the available moisture content (a_w = water activity). Bacteria need higher water activity than yeasts and molds, consequently foods with low water activity may be contaminated mainly with yeasts and molds. For example, bread is most likely to be spoiled by molds.

The acidity (pH) of the food is also an important factor. Most molds can grow over a wide range of pH. Yeasts are favored by a pH of about 4.0 to 4.5. Most bacteria are favored by a pH near neutrality. Fruit juices generally contain yeasts and molds, while eggs are generally spoiled by bacteria.

1.1.2. Chemical Composition and Physical Structure

Concerning the chemical composition of foods, it may be noted that carbohydrates, particularly sugars, are preferred by microorganisms as energy sources, and only a few kinds of microorganisms can obtain energy from fats. Finally, it should be noted that the inner parts of whole, healthy tissues of living plants and animals are either sterile or at least low in microbial content.

Therefore, unless opportunity has been given for their penetration, spoilage organisms within may be lacking. Often there is a protective covering about the food, such as the shell on eggs, the skin on fowl, the shell on nuts, and the rind or skin on fruits and vegetables. Also, we may have surrounded the food with an artificial coating, e.g. plastic or wax.

1.1.3. Environmental Factors

Of the environmental factors, temperature is one of the most important. Every microorganism has an optimal temperature for growth. Thus avoiding storage at this temperature or near this temperature decreases the rate of spoilage. Some microorganisms (aerobic microorganisms), e.g. molds, require oxygen for growth so they cannot grow under anaerobic conditions.

In addition to their natural microflora, foods may be contaminated with microorganisms during all stages of handling (from field to table). Whenever food is handled directly by

humans, there is always the possibility of the addition of human pathogens. Food items may be contaminated by each other and by pieces of equipment with which they come in contact. Microorganisms may build up in numbers on this equipment, resulting in the constant contamination of the foods. Air, dust, water and ingredients may add their quota of contaminants. The kinds and numbers of contaminating microorganisms will determine the keeping quality of the food, the rate and kind of spoilage likely to take place, and the processing needed for the preservation of food.

1.2.Principles of Prevention of Spoilage.

As mentioned before, the main processes of food spoilage are connected with the activity of microorganisms, thus the prevention of spoilage and the preservation of food demand the exclusion of microbial activity. In principle this may be achieved in the following ways:

- by keeping out or removing microorganisms,
- by hindering growth and activity of microorganisms, and
- by killing microorganisms.

The exclusion of microorganisms or their removal from foods is relatively rarely used in preservation at the commercial scale. In practice only the removal of microorganisms by filtration is used, and this process is limited to clear liquids. This method may be used with fruit juices, beer, soft drinks, water, and wine. Although complete exclusion of microorganisms is not possible at reasonable cost, the maximum reduction of microbial contamination during all stages of food processing is the norm in the food industry.

To hinder the growth and activity of microorganisms, the most widely used methods include reduction of the moisture content (drying) of foods and storage at low temperature (chilling, freezing). Preservation of foods by drying has been practiced for centuries. Drying is usually accomplished by the removal of water, but any method that reduces the amount of available moisture in a food is a form of drying. Thus, addition of salt or sugar is also a method of presevation.

Low temperatures are used to retard chemical reactions and action of food enzymes and to slow or stop growth and activity of microorganisms. Temperatures that are just above freezing maintain foods near their original condition without special pretreatments. Storage time in such a case is limited, because some bacteria, yeasts and molds can grow at low temperatures, although this growth is much slower than at higher temperatures. Freezing and storage in the frozen condition results in a complete stop of growth of microorganisms. Freezing usually results in considerable reduction in the numbers of viable microorganisms in a food, but does not sterilize it. The lethal effect depends upon the kind of microorganism, the temperature during freezing and storage, the length of time in the frozen condition, and the kind of food. Although storage in frozen form completely stops the growth and activity of microorganisms, the frozen food could not be stored for unlimited time because of various chemical reactions catalized by enzymes or caused by environment (e.g. oxidation in the presence of air) that may very slowly continue even in a frozen state. So frozen storage is usually not longer than one year.

Growth of microorganisms and their activity may also be hindered by chemical agents known to specialists as *preservatives.* Preservatives added to inhibit (or eventually kill) microorganisms are numerous and different in their mode of action, specificity, and effectiveness. Some of them, e.g. sugar, are effective because of their physical action, others, such as sodium benzoate, due to their chemical action, and others because of a combination of these actions such as sodium chloride. Some preservatives are incorporated into food, while others are used only to treat outer surfaces. Some are applied to treat wrappers or containers for food, while others are used as gases or vapors around food. Preservatives may be fairly specific in their action against microorganisms. For example, they may be effective against molds or yeasts and less so against bacteria, or vice versa, and they may act against definite groups or species of bacteria or other organisms. A special group of preservatives is the group of antioxidants serving primarily to reduce deteriorative oxidative changes of fats and fat-containing foods. It should be noted that in recent times increasing efforts are being made to reduce the use of synthetic chemical preservatives and to substitute them with natural compounds and preparations. This tendency is supported by food regulations and food laws in different countries and also internationally. Preservation by killing of microorganisms is primarily achieved by use of high temperatures. The heat treatment necessary to kill microorganisms or their spores varies with the kind of organism, its state, and the environment during heating.

Duration of heat treatment depends on the temperature (higher temperature needs shorter time), initial number of microorganisms, type of microorganism (heat resistance) and composition of the food. In the practice of preservation the foods are classified according to their pH into four groups:

- Low-acid foods, with a pH above 5.3 (vegetables, meat etc.)
- Medium-acid foods, with a pH between 5.3 and 4.5 (mainly some vegetables)
- Acid foods, with a pH between 4.5 and 3.7 (tomatoes, fruits)
- High-acid foods, with a pH of 3.7 and below (berries, sauerkraut).

The length of the heat process required for canning increases at higher pH.

In practice, different heat-treatment procedures are used. Pasteurization is a heat-treatment that kills most but not all the microorganisms present and usually involves the application of temperatures below 100 ^{o}C. Pasteurization is used when more rigorous heat-treatment would harm the quality of the product (as with market milk), when one aim is to kill pathogens, and when the main spoilage organisms are not heat resistant. Heating at the boiling temperature of water is primarily used in home canning. Industrial canning is made in sealed containers (tin cans or glass containers) at a temperature of 121 ^{o}C.

Different radiations (ionizing radiation, ultraviolet radiation, X-rays, gamma rays) may also be used in food preservation. The bactericide effect of radiations depends on the dose, the kind of microorganism, the food composition and the presence or absence of oxygen. Finally, it may be mentioned that high, mechanically produced pressures will kill microorganisms and inactivate enzymes.

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Biographical Sketch

Maria King obtained her M.Sc. degree in biochemistry at the Budapest University of Technology and Economics (Budapest, Hungary) in 1983 and a Ph.D. in Biochemistry, Microbiology and Medical Sciences from the Institute for Biotechnology in Berlin (Germany) in 1986. She acted as senior scientist and later as head of the Department for Biochemistry at Central Food Research Institute in Budapest. Since 1996 she has been a consultant in the International Centre for Genetic Engineering and Biotechnology of UNIDO, visiting scientist at the Department of Food Science and Technology at Cornell University and at the Department of Biochemisrtry and Microbiology at Rutgers University. At present she is acting as senior researcher at the Department of Biochemistry and Biophysics at Texas A&M University. Her main fields of her research activity are connected with biochemistry and biotechnology of microorganisms and bioaerosols.