FREEZING OF PRODUCTS

Introduction to freezing

Freezing of food and food products is one of the oldest and most widely used methods of food preservation, which allows preservation of taste, texture, and nutritional value in foods. The freezing process is a combination of the beneficial effects of low temperatures at which microorganisms cannot grow, chemical reactions are reduced, and cellular metabolic reactions are delayed.

1. The importance of freezing as a preservation method

Freezing preservation retains the quality of agricultural products over long storage periods. As a method of long-term preservation for fruits and vegetables, freezing is generally regarded as superior to canning and dehydration, with respect to retention in sensory attributes and nutritive properties. The safety and nutrition quality of frozen products are emphasized when high quality raw materials are used, good manufacturing practices are employed in the preservation process, and the products are kept in accordance with specified temperatures.

1.1.The need for freezing and frozen storage

Freezing has been successfully employed for the long-term preservation of many foods, providing a significantly extended shelf life. The process involves lowering the product temperature generally to -18 °C or below. The physical state of food material is changed when energy is removed by cooling below freezing temperature. The extreme cold simply retards the growth of microorganisms and slows down the chemical changes that affect quality or cause food to spoil. Competing with new technologies of minimal processing of foods, industrial freezing is the most satisfactory method for preserving quality during long storage periods. When compared in terms of energy use, cost, and product quality, freezing requires the shortest processing time. Any other conventional method of preservation focused on fruits and vegetables, including dehydration and canning, requires less energy when compared with energy consumption in the freezing process and storage. However, when the overall cost is estimated, freezing costs can be kept as low as any other method of food preservation.

1.2.Current status of frozen food industry in U.S. and other countries

The frozen food market is one of the largest and most dynamic sectors of the food industry. In spite of considerable competition between the frozen food industry and other sectors, extensive quantities of frozen foods are being consumed all over the world. The industry has recently grown to a value of over US$ 75 billion in the U.S. and Europe combined. This number has reached US$ 27.3 billion in 2001 for total retail sales of frozen foods in the U.S. alone. In Europe, based on U.S. currency, frozen food consumption also reached 11.1 million tons in 13 countries in the year 2000

2. Advantages of freezing technology in developing countries

Developed countries, mostly the U.S., dominate the international trade of fruits and vegetables. The U.S. is ranked number one as both importer and exporter, accounting for the highest percent of fresh produce in world trade. However, many developing countries still lead in the export of fresh exotic fruits and vegetables to developed countries.
For developing countries, the application of freezing preservation is favorable with several main considerations. From a technical point of view, the freezing process is one of the most convenient and easiest of food preservation methods, compared with other commercial preservation techniques. The availability of different types of equipment for several different food products results in a flexible process in which degradation of initial food quality is minimal with proper application procedures. As mentioned earlier, the high capital investment of the freezing industry usually plays an important role in terms of economic feasibility of the process in developing countries. As for cost distribution, the freezing process and storage in terms of energy consumption constitute approximately 10 percent of the total. Depending on the government regulations, especially in developing countries, energy cost for producers can be subsidized by means of lowering the unit price or reducing the tax percentage in order to enhance production. Therefore, in determining the economical convenience of the process, the cost related to energy consumption should be considered.

2.1.Increasing consumer demand in developing countries due to modernization

The proportion of fresh food preserved by freezing is highly related to the degree of economic development in a society. As countries become wealthier, their demand for high-valued commodities increases, primarily due to the effect of income on the consumption of high-valued commodities in developing countries. The commodities preserved by freezing are usually the most perishable ones, which also have the highest price. Therefore, the demand for these commodities is less in developing areas. Besides, the need for adequate technology for freezing process is the major drawback of developing countries in competing with industrialized countries. The frozen food industry requires accompanying developments and facilities for transporting, storing, and marketing their products from the processing plant to the consumer. Thus, a large amount of capital investment is needed for these types of facilities. For developing countries, especially in rural or semi-rural areas, the frozen food industry has therefore not been developed significantly compared to other countries. In recent years, due to the changing consumer profile, the frozen food industry has changed significantly. The major trend in consumer behavior documented over the last half century has been the increase in the number of working women and the decline in the family size. These two factors resulted in a reduction in time spent preparing food.

The entry of more women into the workforce also led to improvements in kitchen appliances and increased the variability of ready-to-eat or frozen foods available in the market. Besides, the increased usage of microwave ovens, affecting food habits in general and the frozen food market in particular, as well as allowing rapid preparation of meals and greater flexibility in meal preparation. The frozen food industry is now only limited by imagination, an output of which increases continuously to supply the increasing demand for frozen products and variability.

3. Market share of frozen fruits and vegetables

Today in modern society, frozen fruits and vegetables constitute a large and important food group among other frozen food products. The historical development of commercial freezing systems designed for special food commodities helped shape the frozen food market. Technological innovations as early as 1869 led to the commercial development and marketing of some frozen foods. Early products saw limited distribution through retail establishments due to insufficient supply of mechanical refrigeration. Retail distribution of frozen foods gained importance with the development of commercially frozen vegetables in 1929.

The frozen vegetable industry mostly grew after the development of scientific methods for blanching and processing in the 1940s. Only after the achievement of success in stopping enzymatic degradation, did frozen vegetables gain a strong retail and institutional appeal. Today, market studies indicate that considering overall consumption of frozen foods, frozen vegetables constitute a very significant proportion of world frozen-food categories in Austria, Denmark, Finland, France, Germany, Italy, Netherlands, Norway, Sweden, Switzerland, UK, and the USA.

Commercialization history of frozen fruits is older than frozen vegetables.

The commercial freezing of small fruits and berries began in the eastern part of the U.S. in about 1905. The main advantage of freezing preservation of fruits is the extended usage of frozen fruits during off-season. Additionally, frozen fruits can be transported to remote markets that could not be accessed with fresh fruit. Also, freezing preservation makes year-round further processing of fruit products possible, such as jams, juice, and syrups from frozen whole fruit, slices, or pulps. In summary, the preservation of fruits by freezing has clearly become one the most important preservation methods.

4. Future trends in freezing technology

The frozen food industry is highly based in modern science and technology. Starting with the first historical development in freezing preservation of foods, today, a combination of several factors influences the commercialization and usage of freezing technology. The future growth of frozen foods will mostly be affected by economical and technological factors. Growth in population, personal incomes, relative cost of other forms of foods, changes in tastes and preferences, and technological advances in freezing methods are some of the factors concerned with the future of freezing technology.

Population growth and increasing demand for food has generated the need for commercial production of food commodities in large-scale operations. Thus, availability of proper equipment suitable for continuous processing would be valuable for freezing preservation methods. In addition depending on personal incomes, relative cost of frozen products is one of the most important of economical factors. Producing the highest quality at the lowest cost possible is highly dependent on the technology used. As a result, developments in freezing technology in recent years have mostly been characterized by the improvements in mechanical handling and process control to increase freezing rate and reduce cost.

Today an increasing demand for frozen foods already exits and further expansion of the industry is primarily dependent on the ability of food processors to develop higher qualities in both process techniques and products. Improvements can only be achieved by focusing on new technologies and investigating poorly understood factors that influence the quality of frozen food products. Improvements in new and convenient forms of foods, as well as more information on

relative cost and nutritive values of frozen foods, will contribute toward continued growth of the industry.

5. General recommendations on the freezing process

Freezing is a widely used method of food preservation based on several advantages in terms of retention of food quality and ease of process. Beginning with the earliest history of freezing, the technology has been highly affected over the years by the developments and improvements in freezing techniques. In order to understand and handle the concepts associated with freezing of foods, it is necessary to examine the fundamental factors governing the freezing process.

5.1.Freezing technology

Freezing has long been used as a method of preservation, and history reveals it was mostly shaped by the technological developments in the process. A small quantity of ice produced without using a “natural cold” in 1755 was regarded as the first milestone in the freezing process. Firstly, ice-salt systems were used to preserve fish and later on, by the late 1800’s, freezing was introduced into large-scale operations as a method of commercial preservation. Meat, fish, and butter, the main products preserved in this early example, were frozen in storage chambers and handled as bulk commodities.

In the following years, scientists and researchers continuously worked to achieve success with commercial freezing trials on several food commodities. Among these commodities, fruits were one of the most important since freezing during the peak growing season had the advantage of preserving fruit for later processing into jams, jellies, ice cream, pies, and other bakery foods. Although commercial freezing of small fruits and berries first began around 1905 in the eastern part of the United States, the commercial freezing of vegetables is much more recent. Starting from 1917, only private firms conducted trials on freezing vegetables, but achieving good quality in frozen vegetables was not possible without pre-treatments due to the enzymatic deterioration. In 1929, the necessity of blanching to inactivate enzymes before freezing was concluded by several researchers to avoid deterioration and off-flavours caused by enzymatic degradation.

The modern freezing industry began in 1928 with the development of double-belt contact freezers by a technologist named Clarence Birdseye. After the revolution in the quick freezing process and equipment, the industry became more flexible, especially with the usage of multi-plate freezers. The earlier methods achieved successful freezing of fish and poultry, however with the new quick freezing system, packaged foods could be frozen between two metal belts as they moved through a freezing tunnel. This improvement was a great advantage in the commercial large-scale freezing of fruits and vegetables. Furthermore, quick-freezing of consumer-size packages helped frozen vegetables to be accepted rapidly in late 1930s.

Today, freezing is the only large-scale method that bridges the seasons, as well as variations in supply and demand of raw materials such as meat, fish, butter, fruits, and vegetables. Besides, it makes possible movement of large quantities of food over geographical distances. It is important to control the freezing process, including the pre-freezing preparation and post-freezing storage

of the product, in order to achieve high-quality product. Therefore, the theory of the freezing process and the parameters involved should be understood clearly.

5.2.Freezing process

The freezing process mainly consists of thermodynamic and kinetic factors, which can dominate each other at a particular stage in the freezing. The material to be frozen first cools down to the temperature at which nucleation starts. Before ice can form, a nucleus, or a seed, is required upon which the crystal can grow; the process of producing this seed is defined as nucleation. Once the first crystal appears in the solution, a phase change occurs from liquid to solid with further crystal growth. Therefore, nucleation serves as the initial process of freezing, and can be considered as the critical step that results in a complete phase change

6. Recommendations for final product quality

The quality of frozen products and consumer acceptance can be enhanced by optimizing process conditions such as rate of freezing, quality of raw materials, and storage conditions details. However, important factors can be grouped in a less confusing way based on conclusions drawn from the aspects related to quality deterioration. These groups are sensory quality, including the physical and chemical aspects of quality deterioration, microbiological quality, and nutritive quality of frozen products.

a. Sensory quality

The main components of the overall sensation of flavor are taste and aroma. The receptors on the tongue are responsible of perceiving flavors, while aroma generally contributes to total flavor. The analysis used to determine the effects of freezing process, frozen storage, and thawing on product flavor is largely based on the changes produced in chemical compounds. Sensory quality of frozen products is commonly determined based on texture, which includes both the properties perceived by sensation in mouth and appearance. Therefore, a good understanding of the physical aspects of freezing will help improve the product’s quality retention during the freezing process.

b. Texture

Most fruits and vegetables are over 90 percent water of total weight. The water and dissolved solutes inside the rigid plant cell walls give support to the plant structure, and texture to the fruit or vegetable tissue. In the process of freezing, when water in the cells freezes, an expansion occurs and ice crystals cause the cell walls to rupture. Consequently, the texture of the produce is generally much softer after thawing when compared to non-frozen produce.

c. Hygienic and sanitary quality: legal standards

Despite a general increase in microbiological outbreaks in processed foods, frozen foods have demonstrated a good food safety record. The confidence in frozen foods largely depends on the microbiological quality of the raw materials prior to usage, the efficiency of processing, and finally the efficiency of consumers in following specified product instructions.

d. Microbiological aspects of freezing

Microorganisms differ significantly in their sensitivity to freezing, thus the main concern about the microbiological aspects of freezing is the growth of organisms during thawing rather than during freezing. In general, the freezing process does not significantly destroy the microorganisms that may be present in fruits and vegetables. The blanching process prior to freezing destroys some microorganisms and there is a gradual decline in the number of microorganisms during freezer storage.
However, a sufficient number of survivors are still present that can multiply and cause spoilage of the product during thawing. Fluctuation in storage temperature is one of the main reasons for microbial deterioration of frozen products during storage. Thus, a careful inspection of frozen products is essential to ensure proper freezing storage with constant temperatures.

e. Legal standards

Several agencies exist that establish regulatory standards for frozen fruits and vegetables based on import-export regulations of countries around the world. Some of the general regulations for consideration in the freezing of fruits and vegetables as summarized by the Canadian Food Inspection Agency Liaison are as follows:

For frozen fruit products
a. Shall be prepared from fresh or previously frozen fruit that is preserved by freezing.
b. Shall be packed
(i) with or without a sweetening ingredient in dry form, or
(ii) in a packing medium consisting of
a. Water, with or without a sweetening ingredient, or
b. One or more fruit juices, concentrated fruit juices, reconstituted fruit juices, fruit purees or fruit nectars, with or without a sweetening ingredient.
c. May contain citric acid or ascorbic acid, in accordance with good manufacturing practice.
d. May contain any other substance, the addition of which to frozen fruit is in
accordance with good manufacturing practice, and is generally recognized as safe.

For frozen vegetable products
a. Shall be prepared from fresh vegetables, or as a mixture of frozen vegetables, that are preserved by freezing.
b. May contain salt.
c. May contain any other substance, the addition of which to frozen vegetables is in
accordance with good manufacturing practice, and is generally recognized as safe.

f. Nutritional quality: energy contribution

For any type of food preservation method, the retention of nutritional components is a concern, but freezing is probably the least destructive when properly done.Fruits and vegetables are important sources of vitamin C, folate, and minerals. Colored fruits and vegetables are a rich source of carotenoids. The freezing process itself has no effect on nutrients, but during blanching (prior to freezing) water-soluble nutrients may be leached-out during the process.

Conclusion

Freezing of food and food products is one of the oldest and most widely used methods of food preservation, which allows preservation of taste, texture, and nutritional value in foods better than any other method. The freezing process is a combination of the beneficial effects of low temperatures at which microorganisms cannot grow, chemical reactions are reduced, and cellular metabolic reactions are delayed.

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