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ONLINE COURSE WARE

PRINCIPLES OF FOOD PRESERVATION

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Module 1

8L

Introduction to Food Preservation

Food preservation is a very popular process used throughout the world and is also one of the oldest technologies discovered by humans. Preservation of food is a procedure of treating and handling food in a way that conserves its value for longer. Maintaining food (salting, cooling, cooking) is beneficial because it stops or greatly slows down spoilage to prevent food borne illnesses. When preserving the values of food, texture and flavor is extremely important. Food has not been well preserved if it becomes dry, hard, or if it does not taste good. Another essential element of food preservation is preventing bacteria, fungi and other micro-organisms from growing. The food becomes unhealthy when micro-organisms are growing on it. Preservation techniques must also destroy enzymes naturally found in a food that cause it to spoil or discolor quickly. Enzymes are delicate because they act as a catalyst for a chemical reaction since they are a necessary component of a special protein. When the temperature of food reaches 150 degrees Fahrenheit (66 degrees Celsius), enzymes are destroyed. All food contains bacteria if not sterilized or sealed. Therefore, sterile food contains no bacteria and prevents spoilage. Two or three hours after milk is left on a kitchen counter, the bacteria will already have spoiled the milk, therefore by putting it in the fridge, it will not eliminate the bacteria already there but slow down the creation of bacteria enough for the milk to stay fresh a week or two. Behind all forms of food preservation, we have discovered there are two main reasons for the process: to slow down the activity of disease-causing bacteria and to kill the bacteria altogether.

When it comes to food preservation, there are many different processes such as: heating to kill or denature organisms, oxidations, use of sulphur dioxide, toxic inhibition, smoking, use of carbon dioxide, vinegar, alcohol, etc. There are also processes like dehydration 'drying', osmotic inhibition (use of syrups), low temperature inactivation, freezing, ultra high water pressure, fresherized, a kind of "cold" pasteurization that prevents food deterioration and unhealthy food caused by naturally occurring pathogens which are killed by the pressure. Through these processes, methods used at home are mentioned.

Preservation Methods

Refrigeration

Preservation methods are forms of preservation that can be used by ordinary citizens. Refrigeration is the most popular form of food preservation. The advantages of refrigeration are that it slows microbial reproduction. The disadvantages are that as time goes by, food starts to lose its nutrients. It takes longer for food to spoil because refrigeration tends to decrease the speed of bacterial action to a crawl. Even though refrigeration has disadvantages, it still remains extremely popular since it's easy and effective.

Canning

Another very popular method is canning. Since 1825, canning has been a way to store food for long periods of time. To kill or weaken any remaining bacteria as a form of pasteurization is the purpose of canning. It involves cooking fruits or vegetables, sealing them in sterile cans or jars, and boiling the containers. Boiling food in the can kills the bacteria and the can is sealed (either before or while the food is boiling) to prevent any new bacteria from getting infected. Once the can is opened , bacteria will begin attacking the food. Therefore, the contents will remain sterile until the container is opened. Various foods, because they have varying degrees of natural protection against spoilage, may require the final step which occurs in a pressure cooker. Similarly to refrigeration, canning has advantages and disadvantages. The advantages are that it destroys microorganisms & autolytic enzymes. The disadvantages are that water-soluble nutrients can be lost into liquid in the can. Another disadvantage, is that boiling food changes the taste and texture of the food as well as its nutritional content but this does not tend to bother people much. Cans come in all shapes and sizes and include jars. Sealable containers can also serve as cans as well as glass jars, foil and plastic pouches and boxes. Canning is also very easy and since it works well, people use it in their daily lives.

Drying

Drying is one of the oldest methods of food preservation. To delay or prevent bacterial growth, it reduces water activity sufficiently. After food is dried, most bacteria die or become completely inactive. The advantages of this method are that it produces a concentrated form of food and retains most nutrients. The disadvantages are that the food can lose some nutrients such as thiamin & vitamin C. So, to retain vitamin C, sulphur dioxide is sometimes added to dried fruits. Some people are uncomfortable with this substance so they don't use it. Instead, they use dehydration to preserve the nutrients. Examples of elements that are easy to dry are soup and milk which can last for years. Normally, drying completely alters the taste and texture of food. People would probably prefer if the taste and texture of food was not altered, but they don't always mind. At a grocery store, you will notice dehydrated products such as : powdered milk, dehydrated potatoes in a box, dried fruits and vegetables, dried meats (like beef jerky), powdered soups and sauces, pasta, and instant rice. Drying is another great example of a food preservation method used throughout the world.

Vacuum Sealing

A less popular method is vacuum sealing. The storage of food in a vacuum environment like an air tight bottle is the purpose of vacuum-packing. hen packaging, it is necessary to have a vacuum and oxygen free atmosphere (a modified atmosphere): low oxygen tension delays growth of facultative anaerobes and inhibits strict aerobes. Vacuum sealing is another effective way to preserve foods.

Freezing

Freezing, similar to refrigeration, is a commonly used process (commercially and domestically) for preserving foods such as prepared foods which, if unprepared, would not have required freezing. Freezing is used to stop bacterial action altogether. The advantages of freezing are that it prevents microbial growth with low temperatures and unavailability of water and it causes bacteria to become completely inactive. Another advantage of freezing is that it has no effect on taste or texture of most meals. Even though freezing changes fruits which become mushy, it has minimal effects on vegetables. The disadvantages are that the food loses some B-Group vitamins and vitamin C, when the blanching of vegetables, prior to freezing, occurs. Freezing is a form of drying that has less effect on a food's taste than normal dehydration does and removes all moisture. In freeze-drying, the frozen food is placed in a strong vacuum and the water in the food turns from ice into vapor (sublimates). Freeze-drying works extremely well on fruits such as apples but is most commonly used to make coffee immediately. Freezing can be used on almost all foods: meats, fruits, vegetables, beverages, etc. Therefore, freezing is also used regularly.

Smoking

Smoking is a method that is quite popular throughout the world. Through the use of smoke, meat, fish and some other foods may be preserved and flavored. The advantages of smoking are that from smoke, you can preserve foods by drying and by incorporating substances, but cancer in regions of the world has been caused by eating a lot of smoked foods. Even though this is a very important disadvantage of smoking, it is still used as a preservation method on a daily basis today.

Adding salt or sugar

Adding salt or sugar is another method of food preservation. Salting, especially meat, is an ancient preservation technique. Sugar preservation, on the other hand, includes the creation of too high osmotic pressure for microbes to survive caused by cooking in high sucrose concentration. The salt draws out moisture and creates an environment inhospitable to bacteria, and sugar is used to preserve fruits: apples, pears, peaches, apricots by adding syrup. Preserved materials can also be cooked in sugar to the point of crystallization. Then, the resultant product is stored dry. The advantages of adding salt or sugar is that it makes water unavailable for microbial growth, and the process does not destroy nutrients. The disadvantages are that it increases the content of salt and sugar in food. Salted meat can last for years if salted in cold weather (so that the meat does not spoil while the salt has time to take effect). The process of salting is briefly described in the following passage from John Steinbeck's "The Grapes of Wrath": "Noah carried the slabs of meat into the kitchen and cut it into small salting blocks, and Ma patted the course salt in, laid it piece by piece in the kegs, careful that no two pieces touched each other. She laid the slabs like bricks, and pounded salt in the spaces" A keg (wooden barrel) full of salt and meat is the technique expressed in the following passage. Today, found widely in the southern part of the United States, salting is used to create salt-cured "country ham", dried beef (which can be bought in jars at most grocery stores), corned beef and pastrami which is made by soaking beef in a 10-percent salt water brine for several weeks. Adding salt or sugar is a very diverse way of preserving food.

High heat processing

Pasteurization and appertization are both forms of high heat processing. Their purpose is the delivery of heat sufficient enough to inactivate target micro-organisms to the desired extent. The advantages of high heat processing are that it stops autolytic enzymes' activity and destroys microorganisms. The disadvantages of this preservation method are that foods may lose nutrients that are sensitive to heat. High heat processing is quite effective and works well on many foods.

Chemical preservatives

Chemical preservatives are another way to preserve foods. The advantages of chemical preservatives are that they prevent growth of microbes, and in addition, the food retains all of its nutrients. Some people are sensitive to some chemical preservatives, as a disadvantage. There are three classes of chemical preservatives that are commonly used in foods: benzoates, sodium benzoate; nitrites, sodium nitrite; and sulphites, sulphur dioxide. Another common preservative is sorbic acid for which you will often see on food labels. All of these chemicals either kill the bacteria or reduce its speed of multiplication. Different types of chemicals are used in ingredients of different foods. Therefore, if left on the kitchen counter, food which includes chemical preservatives will not spoil. Pancake syrup, for example, can sit out because of the ingredients it contains . Using chemical preservatives is a great way of enabling foods to last longer.

Ionizing radiation

Ionizing radiation is used to take out the bacteria from foods. When food is entered in contact with ionizing radiation, it becomes irradiated. High-energy electrons, X-rays, and gamma rays cause ionizing radiation to happen. Food irradiation (radurization, radicidation and radappertization) is the delivery of ionizing radiation. The advantages of ionizing radiation are that it causes foods to sterilize whose flavor would change with heating (spices), and decreases the velocity of sprouting potatoes. Another advantage is that the shelf life of strawberries and mushrooms is expanded by ionizing radiation. The disadvantages are that, since it extends the shelf life of fresh foods, it can lead to greater nutrient losses than if the food was eaten earlier after harvesting. Ionizing radiation is an effective method of food preservation.

Pickling

Pickling is a method of preserving food by placing it or cooking it in a substance that slows down or kills bacteria and other micro-organisms. This material must be utilizable to humans. In the past, pickling was widely used to preserve meats, fruits and vegetables. Today, it is only used to produce "pickles" or pickled cucumbers. The preservative qualities used by pickling are salt combined with acid, such as acetic acid (vinegar). Acid is used because acid environments delay the growth of bacteria in food. To make pickles from cucumbers, the vegetables must be soaked in 10% salt water brine for several days. Then the vegetables are rinsed and stored in vinegar to preserve them for years. Pickling is an excellent method of preservation when preserving pickles or pickled cucumbers, but when it comes to storing other foods, pickling is not useful.

Pasteurizing

Pasteurization is another great way to preserve and clean food. Pasteurization is a compromise. Pasteurization (always liquid) is the process of heating food to a high enough temperature to kill certain but not all bacteria and to disable certain enzymes. In return, effects on taste can be minimized to your preferred quantity. Milk, ice cream, fruit juices, beer and non-carbonated beverages are commonly pasteurized foods. Milk, for example, can be pasteurized by heating it to 145 degrees Fahrenheit (62.8 degrees C) for half an hour or 163 degrees Fahrenheit (72.8 degrees C) for 15 seconds. The product is completely sterilized when ultra high temperature (UHT) pasteurization is used. The temperature of the milk is raised to about 285 degrees Fahrenheit (141 degrees C) for one or two seconds, sterilizing the milk, in UHT pasteurization. A box of rice milk requires no refrigeration because it has been pasteurized. Pasteurization is used often on foods to eliminate all the bacteria.

Fermenting

Fermentation is another effective method of food preservation. Fermentation uses yeast produced alcohol which is a good preservative because it kills bacteria. Fermented grape juice is used to create wine, which can last quite long (decades if necessary) without refrigeration. Normal grape juice, on the other hands, would mold in days. Fermenting is a great way to allow foods to keep their value for longer periods of time.

Carbonating

Carbon dioxide is a form of enriched modified atmosphere in a packaging. When using carbon dioxide as a method of preservation, there is specific inhibition of some micro-organisms. Carbonated water is water in which carbon dioxide gas has been dissolved using pressure. Carbonated water slows down bacterial growth by taking away the oxygen. Carbonated beverages (soft drinks) contain a preservative naturally.

Other methods

Lye is a preservation method since it makes food too alkaline for bacteria to grow. Another method shown is jellying. Foods may be preserved by being cooked in a substance that hardens to form a gel.Such substances include gelatin, agar, maize flour and arrowroot flour. Jugging, modified atmospheres, nitrogen gases, burial in the ground, addition of weak acids, lactic fermentation, ethanol and emulsification are other methods of preservation.

Irradiation

What is food irradiation?

Heat treatments worked but ruined the look of fruits. Treatments used to be done by toxic gases, but now this technique is considered an environmental hazard. The Canadian Food Inspection Agency now reveal food to a controlled amount of energy called "ionizing radiation" in the process of food irradiation. The Canadian Food Inspection Agency and X-rays, gamma rays, and electron beam radiation are the three types of radiation allowed in most places. Nuclear radiation kills bacteria without significantly changing the food containing bacteria.

Why is food irradiated?

Food is irradiated for the effect of when it is processed by heat, refrigeration, freezing. It is irradiated for the same benefits as treated with chemicals to destroy insects, fungi or bacteria. What it destroys causes food to spoil or causes human diseases. Food is irradiated to make it possible to keep food longer and in better condition in warehouses. Hospitals use irradiation to sterilize food for immune-compromised patients. Irradiation destroys disease-causing bacteria. It reduces the incidence of food borne illness. Ionizing radiation penetrates food, killing microorganisms without raising the temperature of the food a lot. One problem is that irradiated food can become contaminated after the treatment. Consequently, the Canadian Food Inspection Agency states proper storage and handling & cooking are very important. Radiated foods are sometimes infested exotic species of fruit fly. They cannot import foods unless the foods are treated first to get rid of flies, eggs, or bacteria. Irradiation is used to kill bacteria, molds and insect pests, reducing the ripening and spoiling of fruits, and at higher doses inducing sterility. Food will be become sterile and can be stored on shelves without refrigeration if the food is sealed in a plastic bag and then is irradiated. Unlike canning, when you irradiate food, you do not change the taste or texture of the food.

Are irradiated foods still nutritious?

Irradiated foods are wholesome and nutritious. Methods of food processing and storing at room temperature a few hours lowers content of some nutrients, such as vitamins. At a low radiation, nutrient losses are not measurable or are not even significant. High radiations are used, to extend shelf-life or control harmful bacteria. The nutritional losses are about the same as cooking and freezing.

Does irradiation make food radioactive?

No. This question comes up often because people have a problem with the words "nuclear radiation". Radioactivity in foods can occur two ways: the contamination of foods with radioactive substances can cause foods to become radioactive, and the penetrating energy in the nuclei of atoms that make the food can make foods radioactive. The irradiation process takes place when the food is passed through an irradiation field. However, the food itself never contacts a radioactive substance. The ionizing radiation used by irradiators is too weak to break down the nucleus of only one atom of a molecule that makes up any kind of food. Irradiated foods will never become radioactive in any way.

Does eating irradiated food present long-term health risks?

Federal government and scientists reviewed hundreds of studies on the effects of food irradiation before concluding that it is generally safe. To make recommendations about poultry irradiation, according to, U.S. Food and Drug Administration scientists reviewed additional relevant studies. Independent scientific committees in Denmark, Sweden, United Kingdom and Canada have reaffirmed the safety of food irradiation. The Canadian Food Inspection Agency says food irradiation received international endorsement from the World Health Organizations and the International Atomic Energy Agency. Extensive research and testing showed that irradiated foods are safe. Health Canada reviewed petitions for new applications of irradiation process to ensure safety of foods listed Food and Drug Regulations as allowed to be irradiated and sold in Canada (Canadian Food Inspection Agency, n.d.). The source, the energy level, and total absorbed dose for identified foods are specified by regulations (Canadian Food Inspection Agency, n.d.). National and international expert bodies have declared food irradiation as wholesome.

Does irradiation destroy all bacteria, resulting in a sterile produce?

At the levels normally used in food processing, irradiation destroys most, but not every microorganism present. Therefore it does not sterilize the food. Consumers should take appropriate precautions, like refrigeration, proper handling and proper cooking, to eliminate all harmful bacteria. After the treatment, disease-causing and food spoiling organisms that have survived start to multiply again if the food is not properly handled. The Canadian Food Inspection Agency (n.d.) also agrees in saying that irradiated food must be handled properly like other foods to prevent re-contamination. The disease-causing organisms in irradiated foods are just as dangerous as in non-irradiated foods. One concern, has been that irradiation does not kill the bacteria that cause botulism. Studies have also shown that in irradiated and non-irradiated foods, spoiling organisms will grow and alert consumers that there is spoilage before botulism bacteria produces toxin. The Canadian

Food Inspection Agency also says that nothing can guarantee food safety. Food irradiation reduces the bacteria and other microorganisms that may be present on food, according to the Canadian Food Inspection Agency.

Does irradiation cause chemical changes in food, producing substances not known to be present in non-irradiated food?

Irradiation produces chemical changes in foods. Substances that appear are called "radio-lytic products", and they are not mysterious to us. They have been scrutinized by scientists in making safety assessments of irradiated foods. Any treatment causes chemical changes in food. For instance, heat treatments, or cooking, produce chemicals are called "thermolytic products". Scientists find the changes in food created by irradiation minor to those created by cooking. The products created by cooking are so significantly changed that consumers can smell and taste them. Only a chemist with extremely sensitive lab equipment may be able to detect radio-lytic products.

According to the Canadian Food Inspection Agency (n.d.), for now, only some foods are approved for irradiation and sale in Canada. Until recently, only irradiated dried spices and enzymes were allowed to be marketed in the United States. Onions, potatoes, wheat, flour, whole wheat flour, whole or ground spices and dehydrated seasonings are now approved to be irradiated (Canadian Food Inspection Agency, n.d.). In January 1992, irradiated strawberries from Florida were sold at the North Miami supermarket. Sales of irradiated products are ongoing in several grocery stores. Poultry irradiation began commercially in 1993. Irradiation of food has been approved in 37 countries for more than 40 products. The irradiation of chicken was approved for some time but it was only recently that the FDA approved irradiation of beef. Irradiation of these meats prevents many forms food of poisoning. Belgium and France are the largest marketers of irradiated food. These countries irradiate 10,000 tons of food per year, and the Netherlands with 20,000 tons of irradiated foods per year ennand, n.d.). Therefore, irradiated foods are not very common in most countries.

How can I tell if food has been irradiated?

Irradiated food cannot be recognized by sight, smell, taste, or feel. Instead these irradiated foods will be labeled with a logo with the words "Treated with Radiation" or "Treated by Irradiation" to prevent one from buying irradiated foods without knowing it. Pre-packaged foods that have been wholly irradiated display the international radiation symbol and a statement that the product has been irradiated. Food that is not pre-packaged must have a sign with this information displayed beside the food. Although, when single ingredients are irradiated, it is a whole different story. Only pre-packaged foods that contain an irradiated ingredient that composes more than 10% of the product has to indicate in the ingredients that the product is irradiated. On the other hand, if the irradiated material in the food counts for less than a tenth of the product, it does not need to be labeled.

Conclusion to Preservation

To conclude, food preservation is used to allow us to import larger quantities of food and store them for longer. Two of the most common forms of this, are in almost every single house in North America, Europe and Australia: fridges and freezers. There are also massive quantities of canning in the most developed countries and continents. There are many different types of methods of preservation, from freezing, to carbonating. But, the main effort in doing this has always remained the same. The reason for preserving foods is to prevent the growth of microbial organisms, and ensure the safety and life duration of an item.

This technique was used since ancient times. It has been continuously reoccurring in history and will always happen in the future. Food preservation was discovered by ancient civilizations and is now used all around the world, and will remain one of the longest lasting and most efficient technologies developed by human cultures. One of the techniques that will probably be used more and more as technologies grow is the process of ionizing radiation to irradiate foods. Nevertheless, this does cause controversy because of the simple words “nuclear radiation”. To conclude, the preservation of food is a great method to keep food healthy and maintain its most important values for longer amounts of time.

Canning

Canning is a method of preserving food in which the food contents are processed and sealed in an airtight container. Canning provides a shelf life typically ranging from one to five years, although under specific circumstances it can be much longer. A freeze-dried canned product, such as canned dried lentils, could last as long as 30 years in an edible state. In 1974, samples of canned food from the wreck of the *Bertrand*, a steamboat that sank in the Missouri River in 1865, were tested by the National Food Processors Association. Although appearance, smell and vitamin content had deteriorated, there was no trace of microbial growth and the 109-year-old food was determined to be still safe to eat.

Method of canning - The original fragile and heavy glass containers presented challenges for transportation, and glass jars were largely replaced in commercial canneries with cylindrical tin or wrought-iron canisters (later shortened to "cans"). Cans are cheaper and quicker to make, and much less fragile than glass jars. Glass jars have remained popular for some high-value products and in home canning. Can openers were not invented for another thirty years — at first, soldiers had to cut the cans open with bayonets or smash them open with rocks. Today, tin-coated steel is the material most commonly used. Laminate vacuum pouches are also used for canning.

To prevent the food from being spoiled before and during containment, a number of methods are used: pasteurisation, boiling (and other applications of high temperature over a period of time), refrigeration, freezing, drying, vacuum treatment, antimicrobial agents that are natural to the recipe of the foods being preserved, a sufficient dose of ionizing radiation, submersion in a strong saline solution, acid, base, osmotically extreme (for example very sugary) or other microbially-challenging environments.

Other than sterilization, no method is perfectly dependable as a preservative. For example, the microorganism *Clostridium botulinum* (which causes botulism) can only be eliminated at temperatures above the boiling point of water.

From a public safety point of view, foods with low acidity (a pH more than 4.6) need sterilization under high temperature (116-130 °C). To achieve temperatures above the boiling point requires the use of a pressure canner. Foods that must be pressure canned include most vegetables, meat, seafood, poultry, and dairy products. The only foods that may be safely canned in an ordinary boiling water bath are highly acidic ones with a pH below 4.6, such as fruits, pickled vegetables, or other foods to which acidic additives have been added.

Double seams

Invented in 1888 by Max Ams, modern double seams provide an airtight seal to the tin can. This airtight nature is crucial to keeping micro-organisms out of the can and keeping its contents sealed inside. Thus, double seamed cans are also known as Sanitary Cans. Developed in 1900 in Europe, this sort of can was made of the traditional cylindrical body made with tin plate. The two ends (lids) were attached using what is now called a double seam. A can thus sealed is impervious to contamination by creating two tight continuous folds between the can's cylindrical body and the lids. This eliminated the need for solder and allowed improvements in manufacturing speed, reducing cost.

Double seaming uses rollers to shape the can, lid and the final double seam. To make a sanitary can and lid suitable for double seaming, manufacture begins with a sheet of coated tin plate. To create the can body, rectangles are cut and curled around a die, and welded together creating a cylinder with a side seam.

Rollers are then used to flare out one or both ends of the cylinder to create a quarter circle flange around the circumference. Precision is required to ensure that the welded sides are perfectly aligned, as any misalignment will cause inconsistent flange shape, compromising its integrity.

A circle is then cut from the sheet using a die cutter. The circle is shaped in a stamping press to create a downward countersink to fit snugly into the can body. The result can be compared to an upside down and very flat top hat. The outer edge is then curled down and around about 140 degrees using rollers to create the end curl.

The result is a steel tube with a flanged edge, and a countersunk steel disc with a curled edge. A rubbercompound is put inside the curl.

Seaming

Opened can

The body and end are brought together in a seamer and held in place by the base plate and chuck, respectively. The base plate provides a sure footing for the can body during the seaming operation and the chuck fits snugly into the end (lid). The result is the countersink of the end sits inside the top of the can body just below the flange. The end curl protrudes slightly beyond the flange.

First operation

Once brought together in the seamer, the seaming head presses a first operation roller against the end curl. The end curl is pressed against the flange curling it in toward the body and under the flange. The flange is also bent downward, and the end and body are now loosely joined together. The first operation roller is then retracted. At this point five thicknesses of steel exist in the seam. From the outside in they are:

- End
- Flange
- End Curl
- Body
- Countersink

Second operation

The seaming head then engages the second operation roller against the partly formed seam. The second operation presses all five steel components together tightly to form the final seal. The five layers in the final seam are then called; a) End, b) Body Hook, c) Cover Hook, d) Body, e) Countersink. All sanitary cans require a filling medium within the seam because otherwise the metal-to-metal contact will not maintain a hermetic seal. In most cases, a rubberized compound is placed inside the end curl radius, forming the critical seal between the end and the body.

Probably the most important innovation since the introduction of double seams is the welded side seam. Prior to the welded side seam, the can body was folded and/or soldered together, leaving a relatively thick side seam. The thick side seam required that the side seam end juncture at the end curl to have more metal to curl around before closing in behind the Body Hook or flange, with a greater opportunity for error.

Seamer setup and quality assurance

Many different parts during the seaming process are critical in ensuring that a can is airtight and vacuum sealed. The dangers of a can that is not hermetically sealed are contamination by foreign objects (bacteria or fungicide sprays), or that the can could leak or spoil.

One important part is the seamer setup. This process is usually performed by an experienced technician. Amongst the parts that need setup are seamer rolls and chucks which have to be set in their exact position (using a feeler gauge or a clearance gauge). The lifter pressure and position, roll and chuck designs, tooling wear, and bearing wear all contribute to a good double seam.

Incorrect setups can be non-intuitive. For example, due to the springback effect, a seam can appear loose, when in reality it was closed too tight and has opened up like a spring. For this reason, experienced operators and good seamer setup are critical to ensure that double seams are properly closed.

Quality control usually involves taking full cans from the line - one per seamer head, at least once or twice per shift, and performing a teardown operation (wrinkle/tightness), mechanical tests (external thickness, seamer length/height and countersink) as well as cutting the seam open with a twin blade saw and measuring with a double seam inspection system. The combination of these measurements will determine the seam's quality.

Use of a Statistical Process Control (SPC) software in conjunction with a manual double-seam monitor, computerized double seam scanner, or even a fully automatic double seam inspection system makes the laborious process of double seam inspection faster and much more accurate. Statistically tracking the performance of each head or seaming station of the can seamer allows for better prediction of can seamer issues, and may be used to plan maintenance when convenient, rather than to simply react after bad or unsafe cans have been produced.

Nutritional value

Canning is a way of processing food to extend its shelf life. The idea is to make food available and edible long after the processing time. A 1997 study found that canned fruits and vegetables are as rich with dietary fiber and vitamins as the same corresponding fresh or frozen foods, and in some cases the canned products are richer than their fresh or frozen counterparts. The heating process during canning appears to make dietary fiber more soluble, and therefore more readily fermented in the colon into gases and physiologically active byproducts. Canned tomatoes have a higher available lycopenecontent. Consequently, canned meat and vegetables are often among the list of food items that are stocked during emergencies.[12] In 2013, the Can Manufacturers Institute launched the Cans Get You Cooking Campaign[13] with the support of Crown Holdings, Inc., Ball Corporation, and Silgan Containers. The goal of the campaign is to get consumers to use more canned goods in their daily meals.

Migration of can components

In canning toxicology, *migration* is the movement of substances from the can itself into the contents. Potential toxic substances that can migrate are lead, causing lead poisoning, or bisphenol A, a potential endocrine disruptor that is an ingredient in the epoxy commonly used to coat the inner surface of cans. Some cans are manufactured with a BPA-free enamel lining produced from plant oils and resins.

Salt content

Salt (sodium chloride), dissolved in water, is used in the canning process. As a result, canned food can be a major source of dietary salt. Too much salt increases the risk of health problems, including high blood pressure. Therefore, health authorities have recommended limitations of dietary sodium. Many canned products are available in low-salt and no-salt alternatives.

Rinsing thoroughly after opening may reduce the amount of salt in canned foods, since much of the salt content is thought to be in the liquid, rather than the food itself.

Botulism

Foodborne botulism results from contaminated foodstuffs in which *C. botulinum* spores have been allowed to germinate and produce botulism toxin, and this typically occurs in canned non-acidic food substances. *C. botulinum* prefers low oxygen environments, and can therefore grow in canned foods. Botulism is a rare but serious paralytic illness, leading to paralysis that typically starts with the muscles of the face and then spreads towards the limbs. In severe forms, it leads to paralysis of the breathing muscles and causes respiratory failure. In view of this life-threatening complication, all suspected cases of botulism are treated as medical emergencies, and public health officials are usually involved to prevent further cases from the same source.

Thermal process time calculations for canned foods - The purpose of thermal processing during manufacture of canned fishery products is the destruction of bacteria by application of moist heat. Only having satisfied the safety requirements of protecting consumer health, and the commercial requirements of preventing non-pathogenic spoilage, does the canner set about choosing a thermal process schedule that will optimise the sensory quality of the finished product.

Of the bacteria contaminating fishery products, some (the pathogenic bacteria) cause food poisoning while others only spoil the food. Of particular concern to fish canners is the possibility of there being contamination by *Clostridium botulinum* which, if present, can form heat resistant spores capable of withstanding a mild thermal process. As this micro organism can grow at the pH of fish flesh it is important that the processor ensure that all his cans have received a process that is sufficiently severe to kill spores and vegetative forms of the bacterium. Survival of *Clostridium botulinum*, after the thermal process, is an extreme health risk as low-acid canned foods (pH > 4.5) support growth of the organism, and under certain conditions will also favour formation of the neurotoxin responsible for outbreaks of botulism.

Sterilization is a heat treatment given foods capable of supporting the growth of heat resistant spore forming bacteria. Sterilization processes destroy all pathogenic contaminants and all other micro organisms capable of growing under normal storage conditions; survivors of the process will be extremely heat resistant spores which pose no health risk and only grow at elevated temperatures (= 40 ºC). Rather than make canned foods absolutely sterile, canners aim for "commercial sterility" which means that the contents are safe (as all pathogenic microorganisms have been destroyed) and shelf-stable at normal storage temperatures. Were the thermal process designed to make all cans absolutely sterile, there would be unnecessary loss of sensory and nutritional quality without there being any increase in the safety of the product.

The higher the temperature of sterilization the greater is the rate of thermal destruction, which is why canners process their canned fish in steam under pressure rather than in water at atmospheric pressure. The rate of thermal destruction is also affected by the nature of the product (liquids heat faster than solids) and the container size (large cans of fish packed in brine take longer to reach lethal temperatures, than do small cans containing the same product). The total sterilization effect of a thermal process can be expressed as the sum of all the sterilization effects achieved by all the time-temperature combinations throughout the entire thermal process. By convention, sterilizing effect is expressed in standard units of minutes at 121.1 ºC, so that. an entire processing cycle is expressed as being equivalent, to holding the product at 121.l ºC for a given time. The unit of sterilization is the Fo unit, where an Fovalue of one minute is equivalent to holding the product at 121.1 ºC for one minute and then cooling it instantly:

Selection of Thermal Processing Conditions

The purpose of sterilizing cans of fishery products is to rid the container and the contents of all pathogenic micro-organisms and to prevent. spoilage by non-pathogenic contaminants under normal storage conditions. Selection of processing conditions necessary to fulfill these criteria is based upon experimental studies in which the rate of heat penetration to the slowest heating point (SHP) of the container is measured during simulated retorting cycles. The data from these trials (or from suitable reference sources) are .used by fish canning technologists to determine the processing temperatures and times necessary to render the canned product commercially sterile. Manufacturers of canned fish (and all low-acid canned foods) can specify their thermal processes in terms of target Fo values, where the Fo value is a measure of thermal processing severity. Having selected an appropriate Fo value (which may be far in excess of that required to reduce to an acceptably low level, the probability of survival of *Clostridium botulinum* spores -as may be the case when the process is designed to bring about bone softening) the canner then adopts a time and a temperature for the thermal process which will ensure its delivery at the SHP of the container.

Heat Resistance of Bacterial Spores

The heat resistance of bacterial spores is specified by the time required to kill 90 per cent of the population at constant temperature; this enables a comparison of heat resistance of spores of many different bacteria. For most spores of importance in canned food spoilage their heat resistance is measured at 121.1 ºC (250 ºF), a common retorting temperature, and is expressed as the D value. A typical plot of the number of survivors against heating time is shown in Figure 1. It can be seen that the time to reduce the population from 1 000 000 to 100 000 is the same as that required to reduce it from 100 to 10. That is, the D value is constant for specific bacterial spores when they are subjected to heat at constant temperature. In Table 1 are summarised the D values of bacterial spores important in canned foods.

Destruction of all spores of *Clostridium botulinum* is the minimum safety requirement , when thermally processing low-acid canned foods. Canners aim to reduce the probability of one spore surviving the thermal process to such a low level that, for all practical purposes, the contents of the container pose no health risk due to survival of *Clostridium botulinum* (spores). Experience has shown that a process equivalent in sterilising effect to twelve decimal reductions of the population of *Clostridium botulinum* is sufficient to protect consumer safety. Such a process is referred to as a "12 D" process and it is equivalent to holding the contents of the container at 121.1 ºC for 2.8 min (12 D= 12 x 0.23 = 2.8 min). A process as severe as this will satisfy requirements (under conditions of good manufacturing practice); however, it will be insufficient to reduce to a commercially acceptable level, the probability of survival for the extremely heat resistant spores (with D values of 2.0 to 5.0 min) of non-pathogenic bacteria. This is why canned fish manufacturers select a thermal process which goes beyond the safety requirements of destruction of *Clostridium botulinum*.

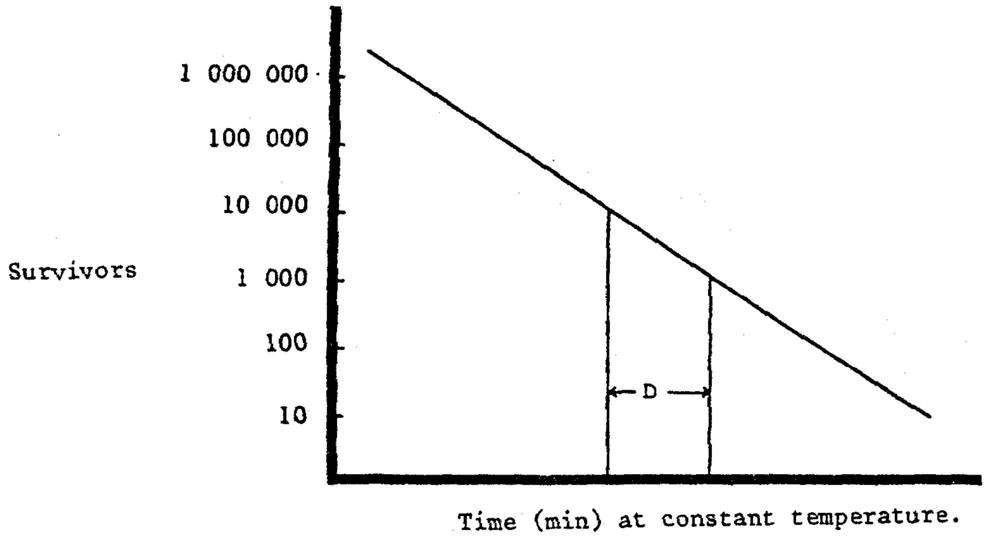


Figure 1 Survivor curve for bacterial destruction at constant temperature

Although the probability of survival for spores of non-pathogenic heat resistant bacteria may be several thousand times that for *Clostridium botulinum*spores, their presence is of no great concern to canners for two reasons:

1. should they lead to spoilage, there is no associated health risk, and
2. they only grow at temperatures above 40 ºC (i.e., they are thermophilic) and their optimum growth temperature is around 55 ºC, which is above that in most warehouses) and retail outlets .

Table 1 Decimal reduction times (D-values) of bacteria important in low acid canned foods.

Organism	**D value (min. at 121.1 ºC)**
B. stearothermophilus	4.0 - 5.0
C. thermosaccharlyticum	3.0 - 4.0
D. nigrificans *	2.0 - 3.0
C. botulinum (A & B)	0.1 - 0.23

C. sporogenes (P.A. 3679)	0.1 - 1.5
B. coagulans	0.01 - 0.07

* Formerly *C. nigrificans*

Lethality of Heat During Heating and Cooling

Although by convention the sterilising effect of a process is expressed in standard units of minutes at 121.1 ºC (the symbol used is Fo). the product inside a can does not instantaneously reach processing temperature and in some cases of conduction heating, the temperature at the thermal centre of the can never reaches that of the heating medium (which need not be at 121.1 ºC) .This paradox is resolved by making use of a relationship which shows that the rate of change in the thermal destruction of bacteria (i.e. the rate of change in their D values) is logarithmic around temperatures commonly used in heat sterilisation. This means that the lethal rate of destruction at any temperature can be related to that at a reference temperature. This relationship is graphically represented . in Figure 2 which shows a thermal death time curve passing through 1 min at 121.1 ºC. This "phantom" curve shows that relative to the lethal rate of unity at 121.1°C the lethal rates at 91.1, 101.1, 111.1, 131.1, 141.1 and 151.1 ºC are 0.001, 0.01, 0.1, 10, 100 and 1 000, respectively.

The sterilising effect of a thermal process (the process Fo value) can therefore be computed by integrating the combined lethal effect of exposure at all time/temperature combinations throughout the process. This means that a process that delivers an Fo value of 2.8 min (the so called 12D process for *Clostridium botulinum)* is equivalent in . sterilising effect to heating the contents of the can to 121.1 ºC instantly, holding it at that temperature for 2.8 min, and then cooling it instantly. Similarly, a process for solid style canned tuna packed in 84 x 46.5 mm cans may have a target Fo value of 10 min, which can be achieved by processing for 74 min at 116 ºC or 50 min at 121.1 ºC. With each process, however, the sterilising effect is the same as, and equivalent to, holding the can of tuna at 121.1 ºC for 10 min under conditions of instantaneous heating and cooling.

Calculating Fo Values

To be sure of commercial sterility the Fo value at the SHP, the thermal centre of the container, must be sufficient to kill all *Clostridium botulinum* and reduce survival probabilities for other more heat resistant bacteria to an acceptable level. It is assumed that bacterial spores will randomly contaminate the fish and that therefore they may be located at the SHP. Although a pessimistic approach, this caters for the ``worst case`` scenario on which product safety must be based.

The measure Fo value heat penetration studies are conducted for representative packs of the canned fish filled to the maximum fill weight likely to be encountered. These cans are then fitted with thermocouple probes which must be located so as to measure the temperature at the SHP. (As can-to-can variation in the rate of heat penetration can be significant, it is recommended that at least twelve replicates are tested before data from the slowest heating of all the test cans are used to compute the Fo value for the process).The thermocouples are connected to digital or graphical recorders, some of which indicate the product temperature during the thermal process, while others can be purchased which automatically compute Fo value. Where automatic computation is not possible, the temperature-time data can be used in a number of ways to calculate Fo value.

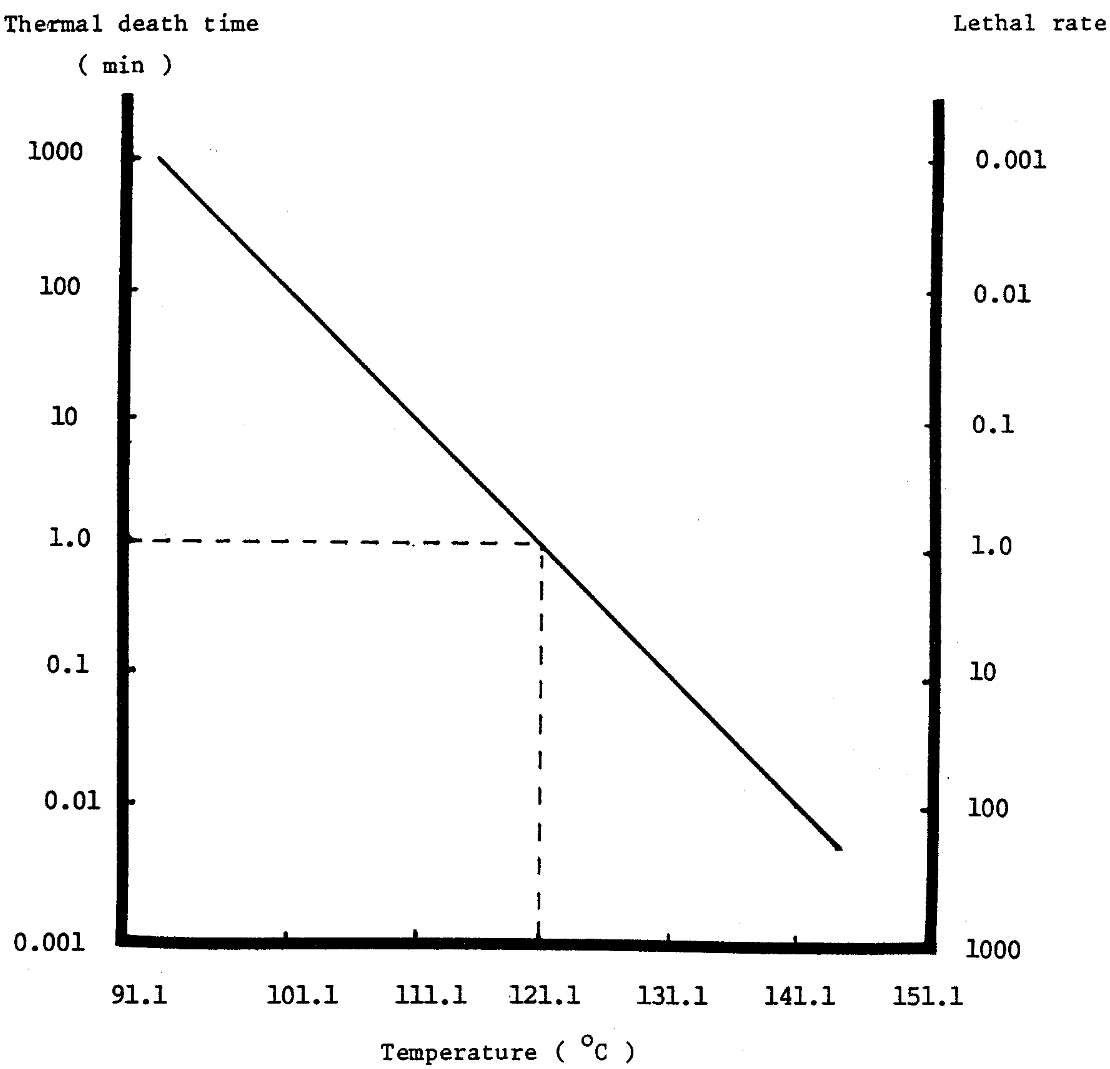


Figure 2 Thermal death time curve passing through 1 min at 121.1 ºC.

Spoilage in canned foods

Spoilage of canned food occurs by 2 ways:

- Survival of spores of some thermophilic bacteria during heating of canned food .
- Recontamination of microorganism from outside through leak in the container.

Types of biological spoilage of canned food

Type of spoilage of canned food by the microorganism. Usually, are divided into those caused into those caused by thermophilic bacteria and those caused by mesophilic bacteria .Other methods of classification are based on kind of charge in food like acid production , purification blacking .

Spoilage by thermophilic spore-forming bacteria

Due to heat resistant nature of these organisms, they produce three type of spoilage i.e flat sour , TA (Thermophilic spoilage) spoilage and sulfur or sulfide strikes.Spores of thermophilic bacteria are not easily by heat treatment applied during canning .

1. **Flat sour :** This type of spoilage occurs mainly in low acid foods and its caused by species of Bacillus such as Bacillus coagulants and Bacillus stearothermophilius spores of these thermophilic are not killed by heat treatment applied during canning . Later spores germinate in food and cause spoilage . They produce acid without gas in food and cause spoilage , Therefore , the can remains flat during spoilage and hence spoilage can not be detected by examination of the can from outside. The spoilage likely acidic food such as peas , commonly etc.and is caused by species of Bacillus .Their organism is responsible for production number of acid without gas in food.
2. **Thermophilic anaerobic (TA) spoilage :**Thermophilic anaerobic strains for thermophilic anaerobes . The causative agent of such spoilage is thermophilic spore-forming anaerobic such as Clostridium thermal saccharolytic , which from acid and gas (Mixing of carbon dioxide and hydrogen) swells The can if it help long enough at high temperatures and many eventually cause bursting . The spoiled food usually has sour , cheesy odour , the source of the organism . The spoiled food has usually sour odour or taste

3. **Sulphides or sulfur striker spoilage :**It is caused by Desulfotomoculumnigrificans spoilage usually occurs in low acid food . Spore of this organism is usually less heat resistant than those of flat sour and TA bacteria . Therefore , spoilage by this organism indicates inadequate heat treatment during canning . The organism produced hydrogen sulphide that reacts with a tin of canned to from black spots of fees in food and the inner wall of the can . Hydrogen sulphide produced give putrid odour which is evidenced when the can is opened.

Spoilage caused by mesophilic spore forming bacteria

These spoilage measures from spore-forming bacteria of the genera Clostridium and Bacillus .

1. **Spoilage by mesophilic (<u>Clostridium species</u>) :**Clostridium species such as clostridium butyric. Clostridium Pastorium causes the butyric acid type fermentation in acid food with swelling of the container (due to the production of hydrogen) other species such as Clostridium Sporogenes, Clostridium putrefacient, Clostridium, botulinum are proteolytic and putrefactive organism demo posting proteins with malodorous compounds such as hydrogen sulphide, indole, mercaptans, ammonia. Anaerobes grow best in low-acid canned food such as meat, fish, corn, peas etc.
2. **Spoilage by mesophilic (<u>Bacillus species</u>) :**Many species of Bacillus are aerobic and therefore can not grow in a well-evacuated can . They cause spoilage especially in Polymyxa and Bacillus mesenteric cause spoilage of many control food. Since spores of the organism are heat resistance. They usually spoiled food by contamination through leakage container.

Spoilage by non-spore forming bacteria

Nonspore forming bacteria cause spoilage of canned food if mild heat treatment of applied during canned or when they enter into the can through leakage. Most of the nonspace forming bacteria enter into the canned through leakage during cooling by contamination water. Many Thermo bacteria such as Enterococcus streptococcus thermophiles, Micrococcus, Lactobacillus and Leuconostoc species can survive pasteurization temperatures and spoiled the canned food. However, in most cases, spoilage by spore-forming bacteria indicate leakage of the container .Type of spoilage depend on the type of microorganism eg. coliforms and heterofermentative lactic acid bacteria swell the can by the production of gas . Nongas forming bacteria such as Pseudomonas, Alkaligenes, Micrococcus, Proteus etc .also spoiled canned food.

Spoilage of yeast

When yeast is grown in canned food they cause swelling of canned by the production of carbon dioxide spoilage by yeast indicates recontamination through leakage of heat processing during canning plus poor evacuation. Many yeasts are killed by resterilization temperatures and their presence indicates inadequate heating canned fruit , jam jalis .juices etc when spoiled by yeast swelling of canned due to the production of carbon dioxide .

Spoilage by mold

Some species of the mold such as Sclerotia and Bysschlamys fully are same what heat resistant and survive mild heat treatment. Other molds enter through leakage in the can. Mould cause spoilage of high acid and high sugar food such as jam species of Aspergillus, Penicillium etc. are found commonly in canned food.

Module 2

8L

Lecture 1

Water activity and its significance to food preservation: RH, definition and relation between RH and aw; IMF

2.1. Water activity:

The a_w of a food or solution is the ratio of the water vapour pressure of the food or solution (p) to that of pure water (p_o) at the same temperature: - $a_w = p/p_o$

The water activity scale extends from 0 (bone dry) to 1.0 (pure water) but most foods have a water activity level in the range of 0.2 for very dry foods to 0.99 for moist fresh foods. Water activity is in practice usually measured as equilibrium relative humidity (ERH).

2.2. Significance of water activity to food preservation:

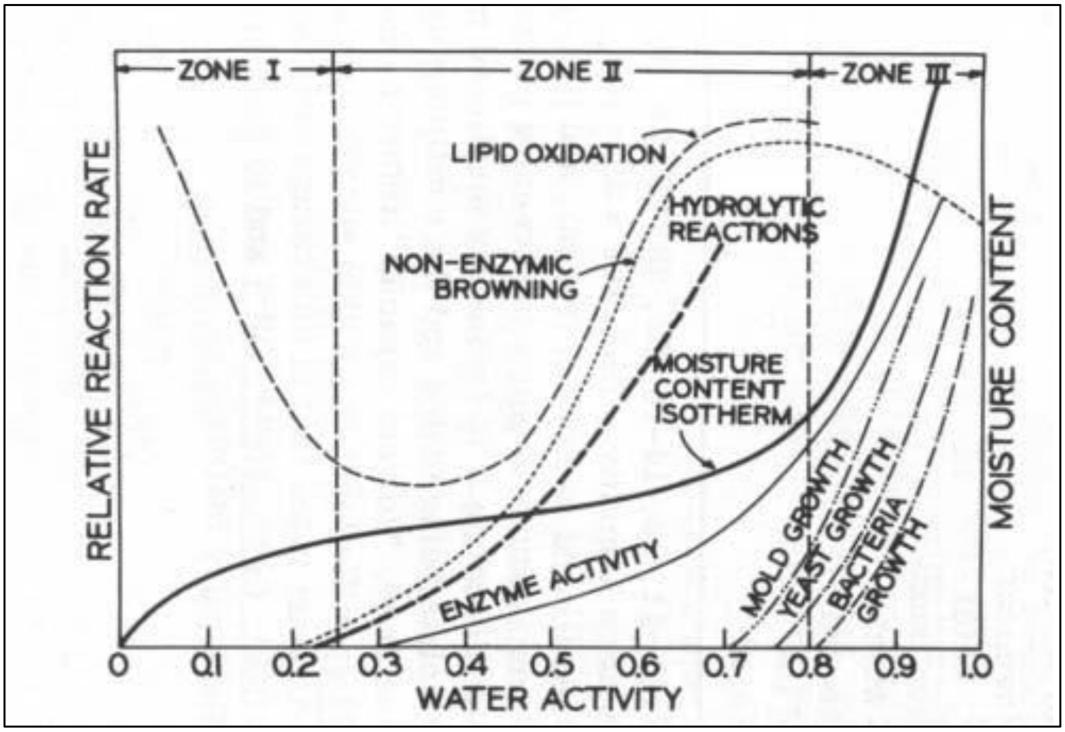
Water activity affects the shelf life, safety, texture, flavor, and smell of foods.

While temperature, pH and several other factors can influence if and how fast organisms will grow in a product, water activity may be the most important factor in controlling spoilage.

Most bacteria, for example, do not grow at water activities below 0.91, and most molds cease to grow at water activities below 0.80.

By measuring water activity, it is possible to predict which microorganisms will and will not be potential sources of spoilage.

Water activity--not water content--determines the lower limit of available water for microbial growth. In addition to influencing microbial spoilage, water activity can play a significant role in determining the activity of enzymes and vitamins in foods and can have a major impact their color, taste, and aroma.



2.3. Definition of relative humidity (RH):

Relative humidity (RH) is the ratio of the partial pressure of water vapor to the equilibrium vapor pressure of water at a given temperature. Relative humidity depends on temperature and the pressure of the system of interest. It requires less water vapor to attain high relative humidity at low temperatures; more water vapour is required to attain high relative humidity in warm or hot air.

2.4. Relation between RH and aw:aw=RH/100

2.5. IMFs:

INTERMEDIATE MOISTURE FOODS or IMFs are food product that has a water activity below that which is required for the growth of microorganisms; or a food containing unavailable water.IMF foods have water activity in B/w 0.6-0.9 or 10 to 50% moisture.

Purpose of intermediate moisture food:

- The purpose is to achieve a desirable water activity by the various ingredients so that food product maintain enough water for palatability and can be stored safely.
- Addition of preservatives provides the margin of safety against spoilage organisms
- *Staphylococcus aureus* is one of the organism of high concern which can tolerate aw as low as 0.83-0.86 under aerobic conditions.

Examples of IMFs: Jams, Jellies, Candies, Baked foods, Honey, Dried fruits and vegetables etc.

Lecture 2

Dehydration and drying of food Items: moisture content (dry basis, wet basis), aims of food dehydration, free and bound moisture, Drying curve and drying rate curve

2.6. Dehydration and drying of food Items:

2.6.1. Moisture Content:

Dry basis moisture content: Dry basis moisture content (designated Md in the text) is described by the percentage equivalent of the ratio of the weight of water (WW) to the weight of the dry matter (Wd).

Dry weight moisture content can range from 0 to very large percentages.

Dry basis moisture is most commonly used for describing moisture changes during drying. When a sample loses or gains moisture, the change in the dry basis moisture is linearly related to the weight loss or gain.

$$M_d = \left(\frac{W_w}{W_d}\right) \times 100$$

Wet basis moisture content: Wet basis moisture content (designated MW in the text) is described by the percentage equivalent of the ratio of the weight of water (WW) to the total weight of the material (Wt).

Wet basis moisture is used to describe the water content of agricultural materials and food products. When the term "moisture content" is used in the food industry it almost always refers to wet basis moisture content. One important example occurs in the grain industry where moisture content of whole grains is determined at each point in the marketing channel where the grain changes ownership. Wet basis moisture content can range from 0 to 100 percent.

$$M_w = \left(\frac{W_w}{W_t}\right) \times 100 = \frac{W_w}{W_w + W_d}$$

2.7. Aims of food dehydration:

i. Increasing shelf life by decreasing water activity.

ii. Decreasing the weight and size of the food.

2.8. Free and bound moisture:

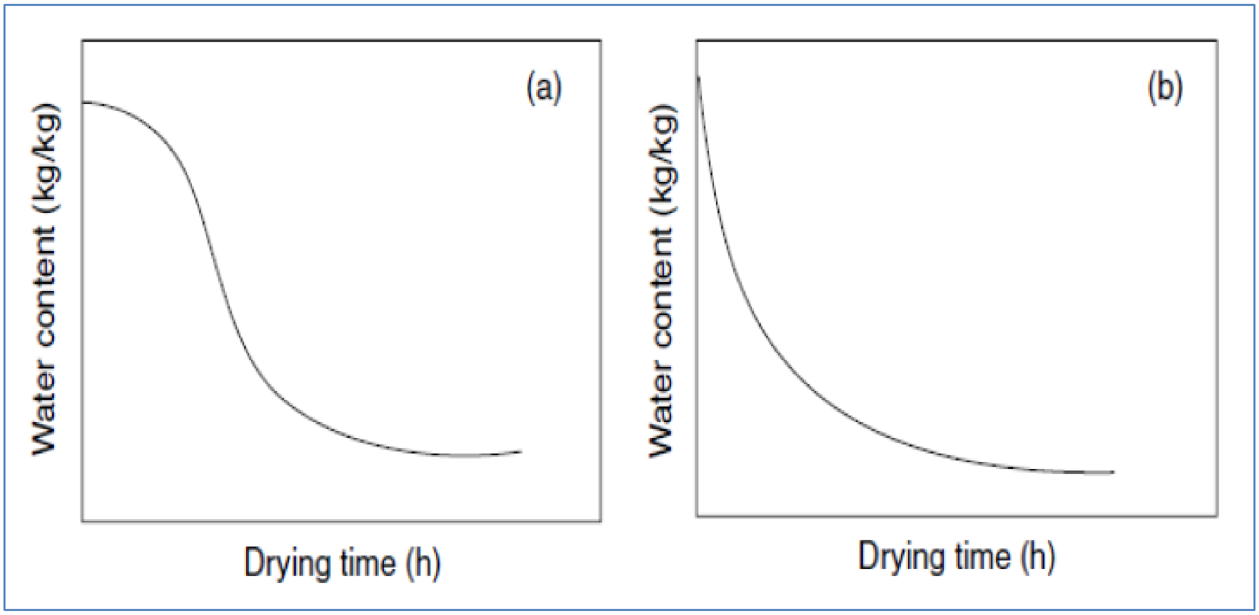
- Moisture content of a substance which exerts as equilibrium vapour pressure less than of the pure liquid at the same temperature is referred to as bound moisture. .
- Moisture content of the solid which exerts an equilibrium vapour pressure equal to that of pure liquid at the given temperature is the unbound moisture.
- The moisture content of solid in excess of the equilibrium moisture content is referred as free moisture. During drying, only free moisture can be evaporated. The free moisture content of a solid depends upon the vapour concentration in the gas.
- The moisture contents of solid when it is in equilibrium with given partial pressure of vapour in gas phase is called as equilibrium moisture content.
- The moisture content at which the constant rate drying period ends and the falling rate drying period starts is called critical moisture content. During the constant rate drying period , the moisture evaporated per unit time per unit area of drying surface remains constant and in falling rate drying period the amount of moisture evaporated per unit time per unit area of drying surface continuously decreases.

2.9. Drying curve and drying rate curve:

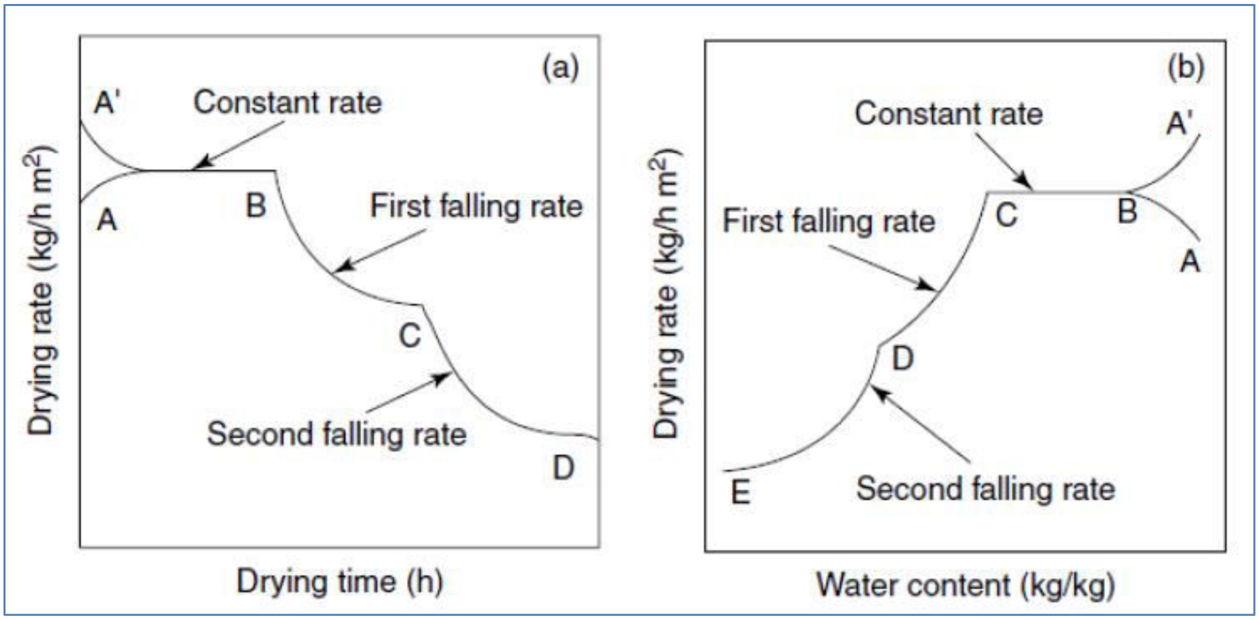
Drying curve usually plots the drying time versus moisture contents and the drying rate curve is plotted drying time vs. drying rate.

Three major stages of drying can be observed in the drying curve and drying rate curve are:

- Transient early stage, during which the product is heating up (transient period)
- Constant rate period, in which moisture is comparatively easy to remove
- Falling rate period, in which moisture is bound or held within the solid matrix



Typical drying curves (water content versus drying time): (a) with a lag period, (b) without a lag period



Typical drying rate curves: (a) drying rate versus drying time and (b)drying rate versus water content

Lecture 3

<u>Factors affecting the dehydration process and the undesirable changes due to drying</u>

2.10.Factors affecting the dehydration process:

- Surface area (surface to volume ratio) : smaller food piece, more rapid rate of moisture loss
- Temperature of the drying air: ↑in temperature will, ↑ DH rate
- Air velocity : Maximize velocity of heated air moving around the food particles
- Humidity of the drying air : the drier the air, the more moisture it can absorb , % RH of drying air determines the final moisture content of food
- Atmospheric pressure and vacuum : water boils at 100C. At lower pressure=boiling temp will decrease. ex. under vacuum, water will boil at 32C. It is important for heat-sensitive food products.

2.11. Undesirable changes due to drying:

- Shrinkage
- Case hardening
- Chemical changes

Shrinkage: Water migrates from the interior of the food to the surface where it evaporates & is carried away by the dehydrating medium. As water migrates to the surface of the food, it carries with the water soluble substances dissolved in it.

Case hardening: Rapid drying causes compounds such as sugars to form a hard, fairly impermeable case around the food piece. It can cause the rate of dehydration to decrease. It is common in high-sugar products. e.g., tropical and temperate fruit products.

Chemical changes:

- browning & flavour changes due to reactions : maillard browning ↑ as the conc. of solutes↑
- denaturation of proteins, aggregation of polysaccharides: loss of water binding capacity
- loss of water-soluble components or concentrates/ on the surface of the food (leads to case hardening): loss of volatiles (esp flavor compounds)

Lecture 4

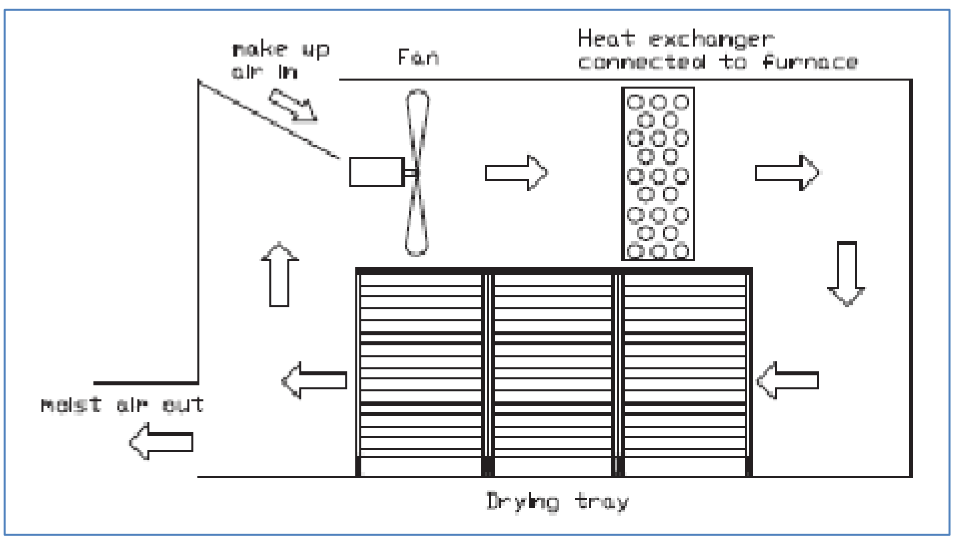
Descriptions, diagrams, advantages and disadvantages of different types of dryers: tray dryer, tunnel dryer, fluidized bed dryer

2.12. Methods of dehydration:

1) Sun Drying
2) Spray Drying
3) Tray and Tunnel Air Drying
4) Drum Drying
5) Freeze Drying
6) Vacuum Microwave Drying
7) Deep Fat Frying
8) Vacuum Extrusion Drying

2.13. Tray dryer:

Schematic Diagram of Tray Dryer



The simplest form of the dryer in this category is a cabinet with a heater at the bottom that is laboratory oven.These ovens are of very little value because there is no control of the heat transfer or humidity.If a fan is fitted to the oven the forced hot air is circulated which helps in increasing the heat transfer and also in reducing he local vlour concentrations. Despite this there is no adequate control. The best type of a tray dryer is that of the directed circulation form, in which the air is heated and is directed across the material in a controlled flow. The material to be dried is spread on the tiers of the trays. The trays used have solid,perforated or wire mesh bottoms. In a modern tray dryers a uniform temperature and air is maintained by the use of a well-insulated cabinet with strategically placed fans and heating coils.

There is an alternate arrangement of the shelves so that air can flow uniformly without any obstructions. Heater is fixed in such a way that the air is reheated before passing over each shelf.

Principle:

- In tray dryer hot air is continuously circulated. Forced convection heating takes place to remove moister from the solids placed in trays.
- Simultaneously the moist air is removed partially.

Arrangement:

- Tray dryer consists of a rectangular chamber whose walls are insulated.
- Trays are placed inside the heating chamber.
- The number of trays may vary with the size of the dryer.
- Dryers of the laboratory size may contain a minimum of the three trays, whereas dryers of industry size may contain more than 20 trays.
- Each tray is rectangular or square and about 1.2 to 2.4 meters square in area.
- Trays are usually loaded from 10 to 100 mm deep.
- The distance between the bottom of upper tray and surface of the substance loaded in the subsequent tray must be 40 mm.
- Alternately the trays can be placed in trucks on wheels, which can be rolled in to and out of the chamber.
- Two such trucks can be arranged in side the dryers. Dryers I fitted with a fan for circulating air oven the trays.
- Electrically heated elements are provided inside rather than outside to heat the air steam also can be used as it is cheaper.
- In the corner of the chamber direction vanes are placed to direct air in the expected path.
- When the air passes over each shelf a certain amount of heat is given up to provide latent heat of vaporization. In such type of dryers there can be a good control of heat and humidity provided it is designed correctly.

Advantages:

- In the tray dryers the handling of the materials, loading and unloading of the materials can be done without losses.
- Tray dryer is operated batch wise. Batch drying isused extensively in the manufacture of the pharmaceuticals for the following reasons
- Each batch of the materials can be handled as separate entity.
- The batch sizes in the pharmaceuticalindustry are relatively small 250 kg or less per batch compared with the chemical industry 1000 kg or more per hour.

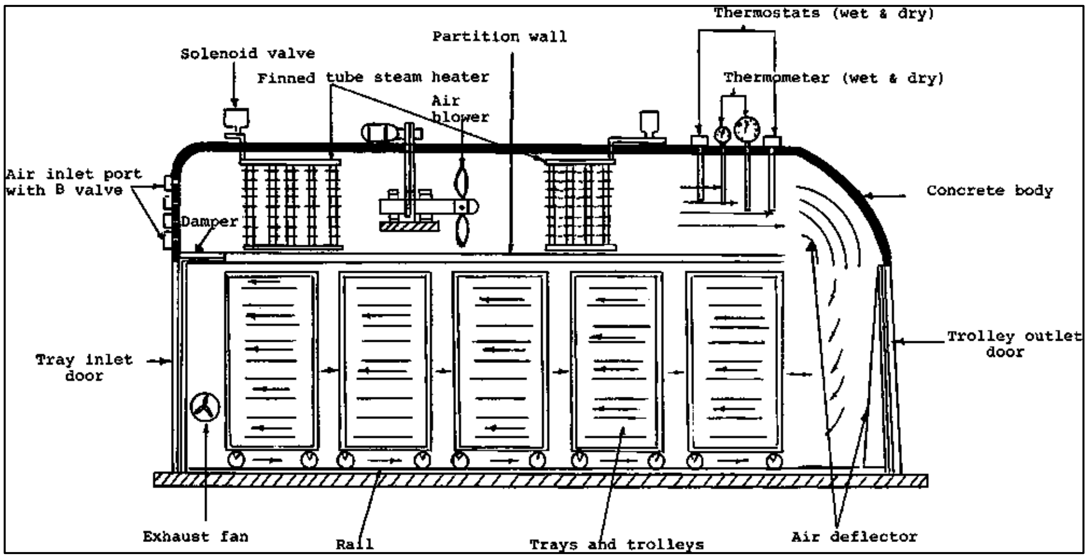
- The same equipment is readily adjusted for the use in drying a wide variety of the materials.
- Valuable products can be handled efficiently.

Disadvantages:

- Tray dryers require more labor to load and unload.
- Hence increases in the cost.
- The process is time consuming.

2.14. Tunnel dryer:

Schematic Diagram of Tunnel Dryer



The tunnel dryer is a modification of the tray dryer in which the oven is replaced by a tunnel which receives damp materials at one end and discharges the dried products at the other end.

It may be operated batch wise or continuously. The tunnel dryer can be of any size and the movement of the solid materials can be affected by placing it on the trays on rails and at suitable intervals atray may be pushed into the inlet which displaces the tray from the dried end. In the tunnel dryer to pass the materials the conveyer belts are used and involves in the drying of the materials.

Components:

The tunnel dryer consists of

1. Steam or electric heating air
2. Cycling dry with heated air
3. Proper temperature and drying tunnel

Principle:

Its work principle is that used steam or electric heating air, then made a cycling dry with heatedair. There is even dry and lower discrepancy of temperature difference in the each side of oven.

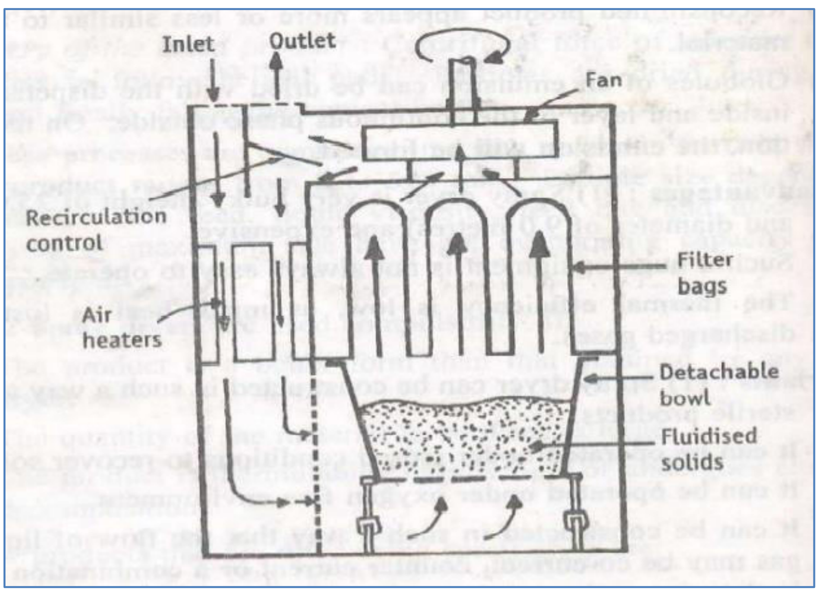
In the dry course of supplying continuously fresh air and discharging hot air so that the oven. Might be in good condition and kept proper temperature and humidity.

Working:

- Wet solid is introduced into the trays of the tunnel dryer.
- Tray dryer are placed in the chamber.
- Fresh air is passed in to the chamber through the inlet by the heater and the chamber gets heated up.
- The water is picked up by the dry air which is circulated in to the chamber of the funnel dryer.

2.15. Fluidized bed dryer:

Schematic Diagram of Fluidized Bed Dryer



Materials processed in a Fluidized Bed Dryer float on a cushion of air or gas. The process air is supplied to the bed through a perforated distributor plate and flows through the bed of solids at a sufficient velocity to support the weight of particles in a fluidized state. Bubbles form and collapse within the fluid bed of material promoting intense particle movement. In this state the solids behave like a fee-flowing boiling liquid. Very high heat and mass transfer rates are obtained as a result of the intimate contact between individual particles and the fluidizing gas.

The design of the distributor plate ensures that the fluidizing gas is evenly distributed across the area of the bed. The gas velocity is such that only the very fine material fraction is carried over to the dust collection equipment. A high turndown ratio of production capacity is possible and fluctuations of the feed rate are easily absorbed. In most cases, there are no moving parts in contact with the product.

Advantages:

- Ideal for removal of surface and bound moisture in powder, crystalline or granular materials
- Good thermal efficiency
- Can handle a wide range of materials, particle size distributions and material cohesiveness
- Enables quick replacements, minimizing shutdown times and maintenance requirements, especially useful for hygienic applications
- Enables energy savings and system integration
- Plug flow is especially suited to products that require longer residence time and a relatively tight moisture specification
- For use as an elutriator or avoid excessive carry-over
- Good when turndown is required
- Enables high inlet temperatures for non-heat sensitive products which reduces the capital and running costs
- Reduces airflow and plant size and improves cost, emissions and power consumption

Disadvantages:

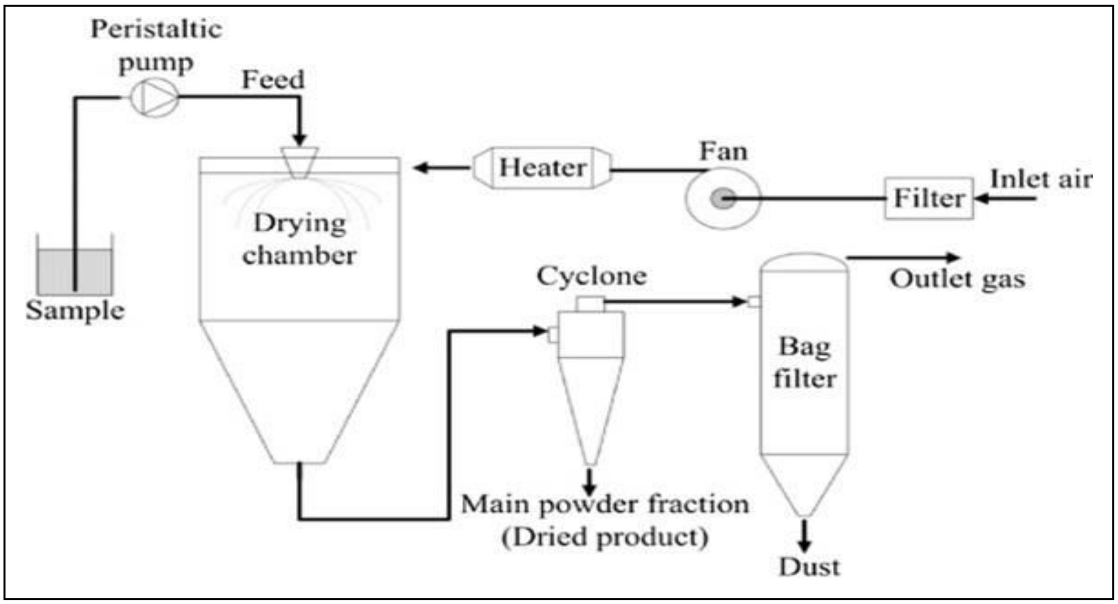
- Possibility of Product Loss: In fluidized state, particles are subjected to a turbulent state. In such circumstances, there is a high possibility of product loss.
- Chances of Electrostatic Build Up May be High
- Drying Sticky Material is Quite Difficult: The fluidization principle, which a fluid bed dryer depends on, requires a free movement of particles. Therefore, sticky or adhesive materials will not move freely, hence it will be nearly impossible to use this equipment.

Lecture 5

Descriptions, diagrams, advantages and disadvantages of spray dryer, drum dryers, freeze dryer

2.16. Spray Dryer:

Schematic Diagram of Spray Dryer



Spray drying is a one-step continuous unit operation that employs liquid atomization to produce droplets that are dried to individual particles when moved in a hot gaseous drying medium. A spray dryer consists of a feed pump, atomizer, air heater, air dispenser, drying chamber and systems for exhaust air cleaning and powder recovery/separator.

Phases of spray drying:

- **Feed preparation:** This can be a homogenous, pumpable and free from impurities solution, suspension or paste.
- **Atomization (transforming the feed into droplets):** Most critical step in the process. The degree of atomization controls the drying rate and therefore the dryer size. The most commonly used atomization techniques are:

  1. Pressure nozzle atomization: Spray created by forcing the fluid through an orifice. This is an energy efficient method which also offers the narrowest particle size distribution.

2. Two-fluid nozzle atomization: Spray created by mixing the feed with a compressed gas. Least energy efficient method.Useful for making extremely fine particles.

3. Centrifugal atomization: Spray created by passing the feed through or across a rotating disk. Most resistant to wear and can generally be run for longer periods of time.

- **Drying:** A constant rate phase ensures moisture evaporates rapidly from the surface of the particle. This is followed by a falling rate period where the drying is controlled by diffusion of water to the surface of the particle.
- **Separation of powder from moist gas:** To be carried out in an economical (e.g. recycling the drying medium) and pollutant-free manner. Fine particles are generally removed with cyclones, bag filters, precipitators or scrubbers.
- **Cooling and packaging**.

Applications of spray drying:

- Pharmaceuticals
- Bone and tooth amalgams
- Beverages
- Flavours, colourings and plant extracts
- Milk and egg products
- Plastics, polymers and resins
- Soaps and detergents
- Textiles and many more

Advantages of Spray Dryers:

- Product quality and properties can be effectively controlled and maintained through the entire drying operation.
- Thermolabile products/pharmaceutical can be dried at atmospheric pressure and low temperature.
- Spray dryer permits high- tonnage production in continuous operation adaptable to conventional PLC control (Programmable Logic Controller) and it is relatively simple to operate.
- Feed stock in solution, slurry, emulsion, paste and melt form can be dried if pumpable.
- Corrosion problem is minimal and the selection of materials of construction of spray dryer is simplified since the dried material comes in contact with the equipment surfaces in an anhydrous condition.
- Spray dryer produces dry powder particle of controllable particle size, shape, form, moisture content and other specific properties irrespective of dryer capacity and heat sensitivity.
- Spray dryer handles a wide range of production rate and provides extensive flexibility in its design that is product specification are readily met through the selection of appropriate spray dryer design and its operation from a wide range of available design.
- It is an energy intensive equipment because;

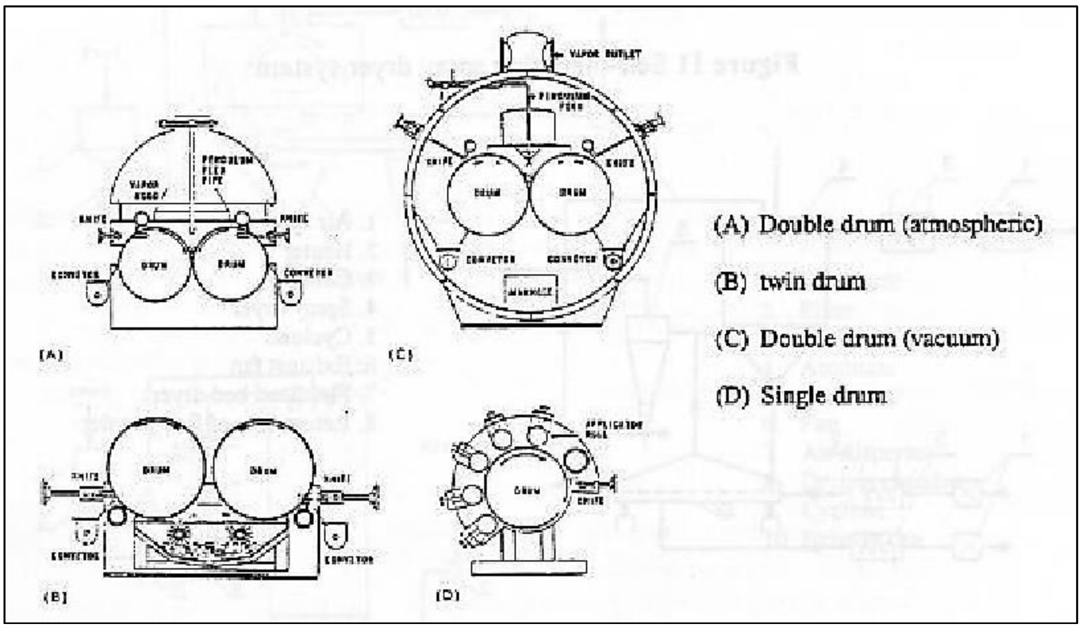
i. Specific heat of evaporation can be supplied in a short time.
ii. The temperature difference across the drying chamber is relatively small and
iii. An appreciable amount of heat is lost with exhaust air.

Disadvantages of spray dryers:

- Spray dryer is bulky and also expensive to install.
- It is difficult to clean after use.
- It has a low thermal efficiency that is a lot of heat is wasted during operation.
- Solid materials cannot be dried using spray dryers.
- Product degradation or fire hazard may result from product deposit on the drying chamber.

2.17. Drum dryers:

Schematic Diagram of Different Drum Dryer



Principle: This drum dryer is basically conduction dryer. Wet feed film (in liquid or paste form) is applied to the rotating metal cylinder inside which, a heating medium is supplied. Material film dries to the final moisture level and is scraped off.

Special Features of Drum Dryer:
- Suitable for handling liquid or pasty feeds.
- Product is powdery, flaky form
- Uniform drying due to uniform application of film.
- Medium range capacities.
- Very High thermal efficiency
- Continuous operation
- Compact installation
- Closed construction is possible

Advantages of drum drying:

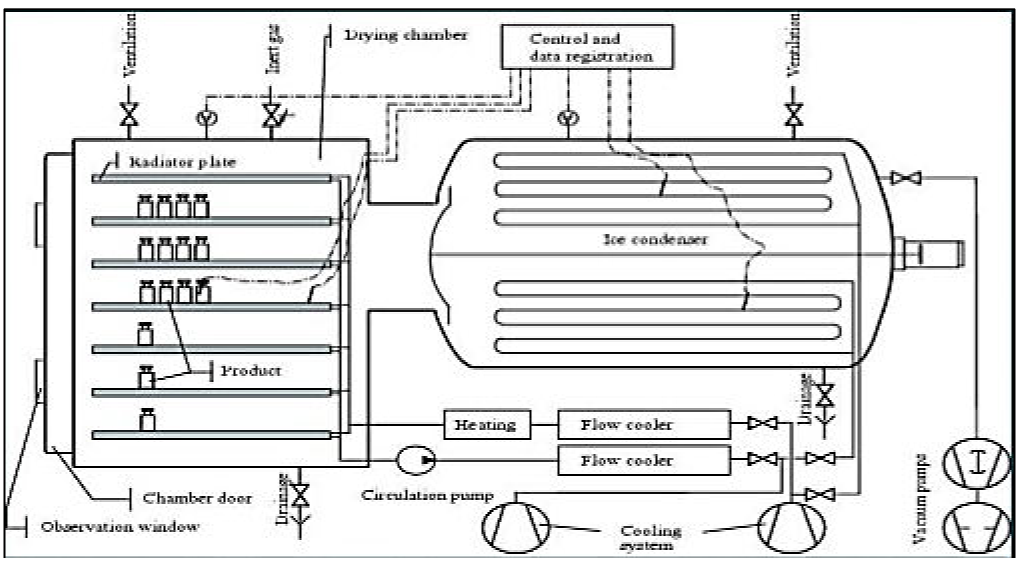
- large production capacity
- continuous operation
- simple structure
- easy to operate
- less failure
- low maintenance costs

Disadvantages of drum drying:

- The equipment is large, one-time investment are high;
- installation and removal are difficult;
- The heat loss is large,
- thermal efficiency is low
- material in the dryer stay for a long time

2.17. Freeze dryer or Lyophilizer:

Schematic Diagram of Freeze Dryer



Stages to Freeze Drying:

i. Freezing Phase:

There are various methods to freezing the product. Freezing can be done in a freezer, a chilled bath (shell freezer) or on a shelf in the freeze dryer. Cooling the material below its triple point ensures that sublimation rather than melting will occur. This preserves its physical form.

Large ice crystals are easiest to freeze dry. Slow freezing or annealing will produce larger ice crystals. For Biological materials, if the crystals are too large, they may break the cell walls which will offer less than favorable freeze drying results. To prevent this from happening, the freezing is done rapidly. For materials that tend to precipitate, Annealing can be used. Fast freezing, then raise the product temperature to allow the crystals to grow.
The freezing phase can be considered the most critical step in the freeze drying process. Proper freeze drying can reduce drying times by 30%.

ii. Primary Drying (Sublimation) Phase:

Primary drying (sublimation) is the phase in which the pressure is lowered and heat is added to the material in order for the water to sublimate. The vacuum speeds sublimation. The cold condenser provides a surface for the water vapor to adhere and solidify. The condenser also protects the vacuum pump from the water vapor. About 95% of the water in the material is removed in this phase. Primary drying can be a slow process. Too much heat can alter the structure of the material.

iii. Secondary Drying (Adsorption) Phase:

During Secondary drying (adsorption), the ionically-bound water molecules are removed. By raising the temperature higher than in the primary drying phase, the bonds are broken between the material and the water molecules. Freeze dried materials retain a porous structure. After the freeze-drying process is complete, the vacuum can be broken with an inert gas before the material is sealed. Most materials can be dried to 1-5% residual moisture.

Lecture 6

Low temperature preservation: cold storage preservation; cold chain

2.18. Low temperature preservation:

- Low temperature slow down and stop microbial growth and biochemical activities
- Retard chemical reactions and action of food enzymes
- Inhibition of microbial or chemical spoilage
- Inhibition temperature for some microorganisms
  - Psychrophil bacteria ....(-5 to -10) °C
  - Yeasts ....(-10 to -12) °C
  - Moulds ....(-15 to -18) °C
- Biochemical activity fully inhibits due to freezing of protoplasm

2.18.1. Effects of temperature reduction on microorganisms:

- Slower metabolism → stop

- Slower reproduction → stop

2.18.2. Optimum condition for low temperature preservation:

Surprisingly, some bacteria can grow at temperatures several degrees below freezing. Most foods remain unfrozen until -2°C or lower. Rapidly attained subfreezing temperatures tend to render microbes growth but do not necessarily kill them. Slow freezing is more harmful to bacteria; the ice crystals that form and grow disrupt the cellular and molecular structure of the bacteria. Once frozen, one third of the population of some vegetative bacteria might survive a year, whereas other species might have very few survivors after this time.

Disadvantage: Psychrotrophs grow slowly at refrigerator temperatures and will alter the appearance and taste of foods after a time. For example, a single microbe reproducing only three times a day would reach a population of more than 2 million within a week.

2.18.3. Cold Storage Temperature for Different Products:

Product	Temperature (°C)	RH (%)
Banana	11.7-15.6	85-90
Beans	7.2	85-90
Cabbage, lettuce, carrot	0	90-95
Nuts	0-2.2	65-70
Onion	0	70-75
Tomatoes	4.4-10	85-90

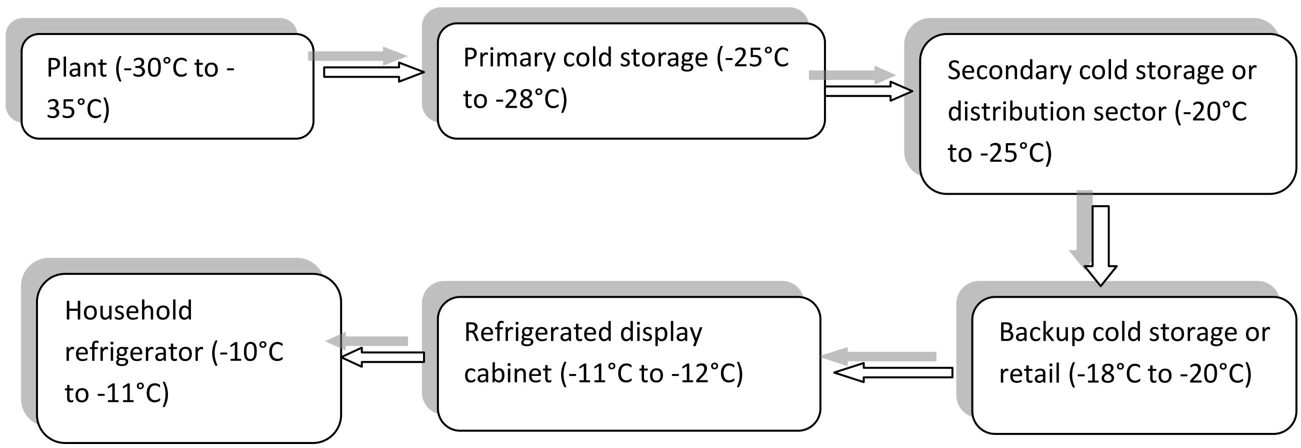
2.19. Cold Storage Preservation:

- Aim: to maintain quality and lengthen the shelf-life
- Temperature is not far above freezing and usually involves cooling by ice or chemical refrigeration
- Most perishable foods, like, eggs, dairy products, meats, seafoods, vegetables, fruits are stored in chilling condition for a limited time period
- Enzymes and microbial changes in foods are not prevented but slow down
- Generally temperature is maintained at (1-4)^{o}C

2.19.1: Factors to be considered for chilling storage:

- Temperature: Optimum storage temperature
- Relative Humidity:
  - Too low RH → loss of moisture → loss of weight → Softening of vegetables and shrinkage of food
  - Too high RH → favour the growth of microbes
- Ventilation
- Composition of storage atmosphere

2.10. Cold Chain Preservation:



Lecture 7

Freezing: slow freezing, quick freezing, dehydro-freezing; time-temperature relationship in freezing

2.21. Freezing:

Freezing is the use of storage temperatures below –18°C to accomplish the followings:

1. Preservation:
   - Pathogen growth is halted below –4°C
   - Spoilage microorganisms don't grow below –10°C
   - Chemical reaction rates are significantly reduced
2. Processing aid:
   - Freezing changes the texture and viscosity for further processing, e.g. slicing meatproducts
3. Product definition:
   - Freezing defines some food products, e.g. ice-cream and frozen deserts

2.21.1. Sharp Freezing/ Slow freezing:

- Freezing in air with only natural air circulation
- Temperature: (-15to -29) ° c for 3 to 72 hrs.

- Sometimes form large irregular shaped ice crystals in food cells. When food is thawed, flavour and some nutrients are lost as large ice crystals pierce the cells.

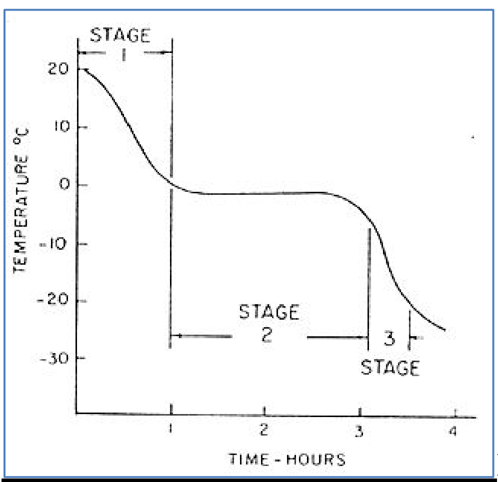
2.21.2. Quick Freezing:

- Time: 30 minutes or less
- Small packages or small units of food
- Direct immersion of the food or packages in the refrigerant
- Indirect Contact: Food in contact with the passage through which the refrigerant (at -17.8 to -45.6° C) flows
- Air blust freezing: Frigid air at -17.8 to – 34.4°C is blown
- Small ice crystal formed: less mechanical damage
- Prompt prevention of microbial growth
- Rapid slowing of enzyme action

2.21.3. Dehydrofreezing:

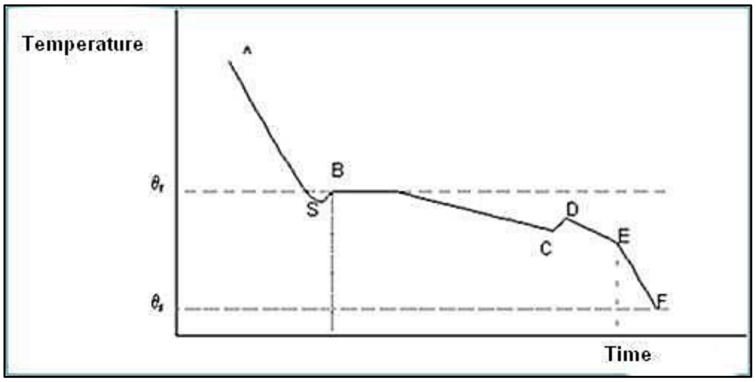
- Half of the moisture of fruits and vegetables are removed before freezing
- Freezing by liquid nitrogen or liquid CO2

2.22. Time-temperature relationship in freezing:



During the first stage of cooling, the temperature falls fairly rapidly to just below 0°C, the freezing point of water. As more heat requires to be extracted during the second stage, in order to turn the bulk of the water to ice, the temperature changes by a few degrees and this stage is known as the period of "thermal arrest". When about 55% of the water is turned to ice, the temperature again begins to fall rapidly and during this third stage most of the remaining water freezes. A comparatively small amount of heat has to be removed during this third stage.

2.22.1. Freezing curve of food materials:



This curve has the following sections:

- AS: The food is cooled below its freezing point of 0º C. At point S, which corresponds to a temperature below freezing, the water remains liquid. This subcooling can be up to 10 ° C below the freezing point.
- SB: The temperature rises rapidly to the freezing point, because ice crystals will form and at a higher speed release latent heat, which is extracted by freezing the food.
- BC: The heat is removed at the same rate as in previous phases, eliminating the latent heat with the formation of ice and the temperature remaining constant. Increasing concentration of solutes in the unfrozen water fraction causes the decrease of freezing point, so the temperature decreases. This is the phase in which most of the ice forms.
- CD: One of the solutes reaches saturation and crystallizes. The release of the corresponding latent heat increases the eutectic temperature of the solute.
- DE: The crystallization of water and solutes continues.
- EF: The temperature falls for the mixture of water and ice.

In fact, the freezing curve for food is somewhat different from simple solutions, with the rate at which freezing occurs for food being higher.

Lecture 8

Different freezing processes: air blast freezing, immersion freezing, contact-plate freezing, Cryogenic freezing

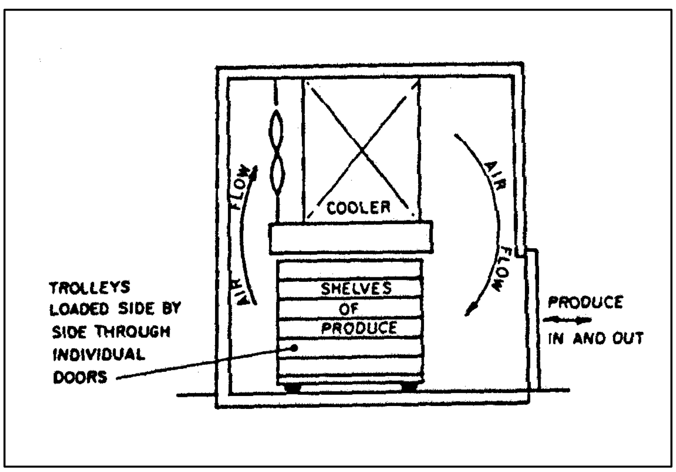
2.23. Air blast freezing:

Vigorous circulation of cold air enables freezing to proceed at a moderately rapid rate. Products are placed on trays, either loose or in packages and the trays are placed on freezing coils in a low temperature room with cold air blowing over the product. In some installations of this system, the cold air that is in the low temperature room is circulated by means of large fans, whereas in other installations the air is blown through refrigerated coils located either inside the room or in an adjoining blower room.

Tunnel freezing is possibly the most commonly used freezing system. Tunnel freezing is substantially a system in which a long, slow moving mesh belt passes through a tunnel or enclosure containing very cold air in motion. The speed of the belt is variable according to the time necessary to freeze the product. Usually the cold air is introduced into the tunnel at the opposite end from the one where the product to be frozen enters, that is, the air flow is usually counter to the direction of the flow of the product. The temperature of the air is usually between –18° and –34°. The air velocity varies, however if rapid freezing is to be had, it is necessary to recirculate a rather large volume of the air in order to obtain a relatively small rise in the temperature of the air as it touches and leaves the product. Air has a very low specific heat and for that reason a large volume must be carefully distributed through the system.

Air velocities ranging all the way from 100 ft. per min. Up to 3500 ft. per min have been reported, and it is difficult to establish any speed as having more or less common usage. Possibly 2500 ft per min may be considered a practical and economical air velocity at –29° C.

Schematic diagram of air blast freezer

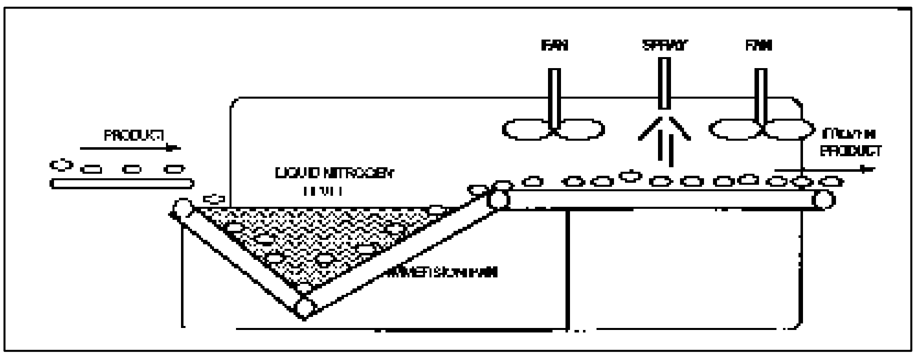


2.24. Immersion freezing:

Liquid immersion freezing (usually referred to as direct immersion freezing) is accomplished when a food product, packaged or unpackaged, is frozen by immersion in or by spraying with a freezant that remains liquid throughout the process. Aqueous solutions of the following substances have been used as freezants: propylene glycol, glycerol, sodium chloride, and mixtures of salt and sugar. This technique, although not common, is used commercially for canned citrus juice concentrate (cans of juice are passed continuously through a chamber containing liquid freezant); for poultry especially during the initial stages of freezing (to impart a uniform, white color to the surface); and an occasionally for fish and shrimp.

The major advantages of liquid immersion freezing are that it results in rapid freezing (especially for foods which are unpackaged or are packaged in skin-tight films) and it is easily adapted to continuous operations. It is difficult, however, to find freezants with suitable properties.

Schematic diagram of immersion freezer



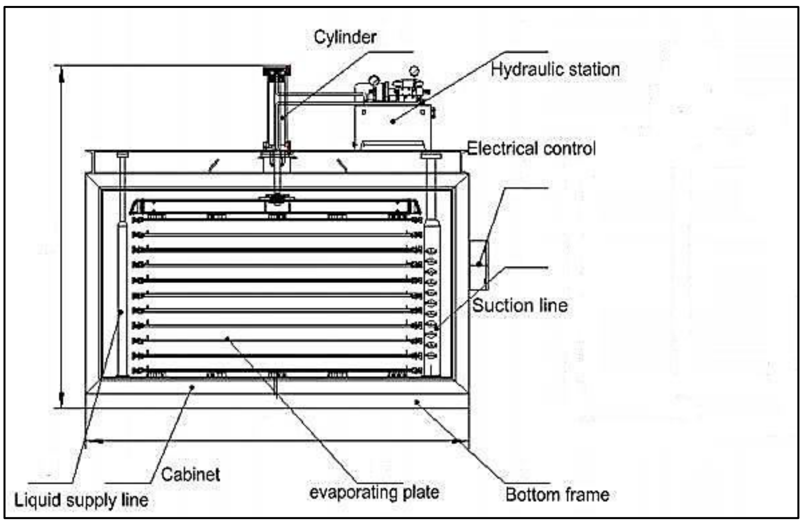
2.25. Contact-plate freezing:

Contact freezing is the one of the most efficient ways of freezing in terms of heat transfer mechanism. In the process of freezing, the product can be in direct or indirect contact with the freezing medium. For direct contact freezers, the product being frozen is fully surrounded by the freezing medium, the refrigerant, maximizing the heat transfer efficiency. For indirect contact freezers, the product is indirectly exposed to the freezing medium while in contact with the belt or plate, which is in contact with the freezing medium (Mallett, 1993). Plate freezers can be arranged with the plates horizontal to form a series of shelves and, as the arrangement suggests, they are called horizontal plate freezers (HPF). When the plates are arranged in a vertical plane they form a series of bins and in this form they are called vertical plate freezers (VPF).

The main uses for HPF are the freezing of prepacked cartons of fish and fish products for retail sale and the formation of homogeneous rectangular blocks of fish fillets, called laminated blocks, for the preparation of fish portions. The thickness of package or block frozen is 32 to 100 mm and the freezer can readily adapt from the thicker to the thinner package provided the range required is made known to the supplier at the time of purchase. There is no direct contact between the fish and the freezer plates when freezing by this method since the fish is always packaged before freezing. An HPF will only operate correctly if good contact is made on both the top and bottom surfaces of the pack or tray to be frozen Horizontal plate freezers intended to be operated with a hot gas defrost are fitted with additional pipework which allow the cold refrigerant to be discharged from the bottom of the freezer as the defrost proceeds.

The main advantage of VPF is that fish can be frozen in bulk without the requirement to package or arrange on trays. The plates form what is in effect a bin with an open top and fish are loaded directly into this space. This type of freezer is therefore particularly suitable for bulk freezing and it has also been extensively used for freezing whole fish at sea. The maximum size of block made by this method is usually 1 070 mm x 535 mm. Other dimensions however, can be produced in which the thickness can vary from 25 to 130 mm, but will depend on the fish to be frozen. The maximum weight and dimensions are also limited by the physical effort required from the operator to lift the block, and by the ease with which it can be handled so that damage to the fish is kept to a minimum. In most cases, fish can be loaded between the plates without wrappers and water need not be added either to strengthen the frozen block or improve the contact with the plates. Fish such as cod and haddock produce compact blocks with a block density of approximately 800 kg/m^3.

Schematic diagram of contact plate freezer



2.26. Cryogenic freezing:

Cryogenic freezing is a relatively new method of freezing in which the food is exposed to an atmosphere below -60 °C through direct contact with liquefied gases such as nitrogen or carbon dioxide (Hung and Kim, 1996). This type of system differs from other freezing systems since it is not connected to a refrigeration plant; the refrigerants used are liquefied in large industrial installations and shipped to the food-freezing factory in pressure vessels. Thus, the small size and mobility of cryogenic freezers allow for flexibility in design and efficiency of the freezing application. Low initial investment and rather high operating costs are typical for cryogenic freezers (Persson and Lohndal, 1993).

Liquid Nitrogen freezers: Liquid nitrogen, with a boiling temperature of -196 °C at atmospheric pressure, is a by-product of oxygen manufacture. The refrigerant is sprayed into the freezer and evaporates both on leaving the spray nozzles and on contact with the products. The system is designed in a way that the refrigerant passes in counter current to the movement of the products on the belt giving high transfer efficiency. The refrigerant consumption is in the range of 1.2-kg refrigerant per kg of the product. Typical food products used in this system are fish fillets, seafood, fruits, berries (Persson and Lohndal, 1993).

Liquid carbon dioxide freezers: Liquid carbon dioxide exists as either a solid or gas when stored at atmospheric pressure. When the gas is released to the atmosphere at -70 °C, half of the gas becomes dry-ice snow and the other half stays in the form of vapor. This unusual property of liquid carbon dioxide is used in a variety of freezing systems, one of which is a pre-freezing treatment before the product is exposed to nitrogen spray (George, 1993).

Module 3

8L

Lecture 1

Preservation by fermentation: definition, benefits and major steps of fermentation, Different types of food fermentation processes

3.1. Fermentation:

Fermentation is a metabolic process converting sugar to acids, gases and/or alcohol usingyeastor bacteria. Fermentation occurs when microorganisms consume susceptible organic substrates as part of their own metabolic process. Some fermentation may cause spoilage to some food, but some are also beneficial for the foods as well as for our health. These second types of fermentation techniques are the oldest methods of food preservations.

The derivation of the word fermentation signified a gentle bubbling condition. This bubbling condition is occurs due to converting the carbohydrates to carbon dioxide gas. But the microorganisms and the enzymes acting on sugars did not always evolve gas. And not only the carbohydrates, some microorganisms are also act on proteins and fats.

The term fermentation refers to break down of carbohydrate like materials either aerobic or anaerobic conditions. For example, conversion of lactose to lactic acid by *Streptococcus lactis*bacteria is favored by anaerobic conditions and it is true fermentation; conversion of ethyl alcohol to acetic acid by *Acetobacteraceti*bacteria is favored by aerobic condition.

3.2.Three major steps of fermentation:

- Acquisition and pretreatment of the raw material
- Fermentation or incubation
- Product recovery ant post treatments.

3.3.Beneficial roles of fermentation:

i. Fermented foods are inhibitory to common pathogenic microorganisms
ii. Fermentation reduces the pH of the foods. The foods become more acidic. It prevents the growth of bacteria.
iii. In case of fermentation some antimicrobial factors are produced, like bacteriocin, diacetyl, hydrogen peroxide etc.
iv. Fermentation reduced the toxic factors.
v. Reduces the free moisture content which inhibits the growth of microorganisms.
vi. Fermented foods are more nutritious than their unfermented conditions.
vii. During fermentation some vitamins, essential amino acids, organic acids etc. are produced.

viii. Microorganisms not only are catabolic, breaking down more complex compounds, but they also are anabolic and synthesize several complex vitamins and other growth factors. Thus, the industrial production of such materials as riboflavin, vitamin B12 and the precursor of vitamin C is largely by special fermented process.

ix. During fermentation carbohydrates, proteins and fats are breaking down to simpler form,which make the food more digestible. Fermentation especially by certain molds, breakdownindigestible coating and cell walls both chemically and physically. Molds are rich in cellulose splitting enzymes; in addition mold growth penetrates food structures by way of its mycelia. This alters texture and makes the structure more permeable to the cooking water as well as to human digestive juices. Similar phenomena result from the enzymatic actions of yeasts and bacteria.

x. It enhances the bioavailability of some micronutrients. In some foods the micronutrients are present in complex forms which we cannot digest. But, fermentation converts the complex forms to simpler forms, and makes the more digestible.

xi. The characteristic textures and flavors of the fermented foods make them more acceptable to the consumers.

3.4. Fermented Foods:

Fermented foods are may be defined as those foods which have been subjected to the action of microorganisms causing desirable biochemical changes and modification of food.

Fermented foods are very popular because they are more notorious, digestible, safer and have characteristic flavors.

3.4.1. Examples of fermented food product:

- Beverages: alcoholic (beer, wine), nonalcoholic (tea coffee)
- Cereal products:Idli, Dhosa, Dhokla etc.
- Fruits and vegetables: Pickles, Sauerkraut etc.
- Milk products:Dahi, Yoghurt, Cheese
- Bakery products: Bread, Cake etc.
- Vinegar, Antibiotics etc.

3.5. **Factors controlling the growth and activity of micro-organisms in food fermentation:**

- availability of carbon and nitrogen sources, and any specific nutrients required by individual microorganisms
- substrate pH
- moisture content
- incubation temperature
- redoxpotential
- stage of growth of microorganisms

- presence of other competing microorganisms

Lecture 2

Production procedure of fermented dairy products (e.g., dahi, cheese)

3.6. Dahi preparation:

Raw milk

↓

Boil for few seconds to 10 minutes

↓

Cool to bogy temperature (37^0C)

↓

Addition of starter culture (1-2% V/V in summer, 5-10% V/V in winter)

↓

Incubate at ambient temperature (40^0C to 45^0C) for 8-16 hrs.

↓

Dahi

↓

Store at 4^0C to arrest the fermentation

An active culture produces 0/9% to 1% acetic acid calculated as lactic acid after 6-12 hrs of fermentation. A good quality dahi has a pH of 4.6 to 5.

Starter culture:

- *Streptococcus lactis*
- *Streptococcus thermophilus*
- *Lactobacillus cremoris*
- Mix-culture: *Streptococcus thermophiles* and*Lactobacillus bulgaricus*

3.7. Cheese:

Cheese is a dairy product having characteristic texture and flavour. There are differenttypes of cheese as Roquefort cheese, Camembert cheese, Cottage cheese, Cheddarcheese, Swiss cheese,Baker's cheese etc.
Different types of cheese vary in their composition, i.e., fat, moistureandprotein content.Cheese can be produced fromwhole milk, skimmed milk, partly skimmed milk and whey. Externally

cream or milk solid-not-fat (SNF) may or may not be added to it. The casein of milk is precipitated using rennet and lactic acid or enzymes obtained from micro-organisms and lactic acid. The casein may or may not be ripened. Yeasts, molds and bacteria are used as ripening agent. The texture and flavour, i.e., quality of cheesedepends upon the method of manufacture, it is ripened or not, fat content of the milk and the ration of casein to SNF.

- **Cottage cheese:**It is soft, unripen chasse. Milk is coagulated by bacteria producing lactic acid. The precipitated casein is warmed and then washed and cooled by cold water. It contains 4% fat. Shelf life: 2-3 weeks.

- **Camembert cheese:**It is a soft ripened cheese. It has a characteristic leathery external texture and internal semisolid mass. The casein is ripened externally by the moldPenicillium*camemberty.* The enzymes produced by this organism during ripening, hydrolysis of casein and other protein occur and they break into short chain peptides and water soluble proteins are formed.

- **Roquefort cheese:**It is a semisoft ripened cheese. *Penicilliumroquefortyi*s used as ripening organism. It is used internally.

- **Cheddar cheese:** This is a hard ripened cheese. The casein requires long time for curing at low temperature. During ripening the hardness decreases to extent and favour improved.

3.7.1. Manufacturing of cheddar cheese:

The casein of milk is precipitated by using acid and rennet. Rennet is obtained from the fourth chamber of the stomach of calves.

i. **Production of rennet:**At first the fresh stomach is collected. Then it is cleaned, washed and enflatened and then air dried. Then it is cut into chips. 100 gms of chips are added to 1 lit. Water along with 50 gms salt. It is kept for 5-6 days. After that 50 gms salt is added and whole mass is filtered. The filtrate contains enzyme which is then spray dried and stored in powder form for long time. This filtrate has the capacity to precipitate casein from 10,000 times volume milk.

ii. **Pasteurization of milk:**Milk is pasteurized before addition of lactic acid producing starter culture.

iii. **Renneting:**After the desired acidity is obtained, rennet is added and mixed well to the milk. Coagulation starts in about 10 minutes. The milk is agitated for 10 minutes to stop cream rising. Then, the vat is covered and left for 45 mins.

iv. **Curd cutting:** The curd is cut with knife into small pieces as removal of whey is easy from small cubes. Then, heating is done nearly at 38^0C and the whey is squeezes out from the cubes. Due to application of mild heat acidity increases.

v. **Cheddaring:** The curd is pushed in vat and whey is drawn off. The curds are then piled.

vi. **Milling:** The cheddar curd is passed through a curd mill which cuts the curd into slabs.

vii. **Salting:** 1.5 to 2.5 pounds of salt per 100 pounds of milk is added to create the flavour of cheese. Salt also acts as preservative.

viii. **Pressing:** The curd is packed in a cloth-bag then it is pressed to make solid blocks of cheese. After 1 hr. The pressure is released. The pressure continues in case of hard cheese for 3-4 days. The cloth is changed when it is necessary.

ix. **Ripening:** The cheeses are taken to ripening room where the temperature and humidity are in controlled. The temperature is maintained nearly at 58^0F-65^0F. During ripening casein is splitted into peptones and peptides. It creates a rubbery mass and a soft flavour.

x. **Packaging and storage:** The cheese is wrapped in wax paper or metal coil and kept under refrigeration.

Cheddar cheese contains 33%water, 33% fat, and 4% ash and rest protein.

Lecture 3

Vinegar production, sauerkraut production procedures

3.8. Vinegar:

Vinegar may be defined as the condiment made from sugary, starchy material by alcoholic and subsequent acetous fermentation. The term literally signified sour wine. The composition depends on the nature of material which undergoes alcoholic and acidulous fermentation. The condition of manufacture, aging and storage will influence the composition of the product. Vinegar should contain at least 4 gms of acetic acid per 100 ml and a corresponding quantity of the mineral salt of the material from which it is made.

Types of vinegar according to their raw materials:

- Cider vinegar: made from apple juice by fermentation
- Wine or grape vinegar: made from grapes by acetic acid fermentation
- Spirit vinegar: made by acetic acid fermentation of dilute ethyl alcohol
- Malt vinegar: made from barley malt and other cereals
- Other vinegar: can be made from orange, pineapple, ripe banana, pear. Peach, apricot etc.

Organisms:

Large no. of bacteria can produce acetic acid in small amount from various substrates but few bacteria have desired characteristics for vinegar production.*Acetobacteraceti, Acetobacterpasteuriunus, Acetobacterxylinum*may be isolated from vinegar.

3.8.1. Steps of vinegar production:

i. **Yeast fermentation:** Before acetic acid fermentation can take place the sugar in the raw material must be converted to alcohol by yeast fermentation. Yeast may be naturally present in fruit juice and may bring about successful fermentation. But the manufacturer uses a starter culture in order to ensure suitable fermentation. Although compressed yeast used as starter culture but the use of selected wine yeast like *Saccharomyces cerevisiaevarellipsoides*improves the flavour of the final product. Fermentation may be carried out at 24^0C-27^0C. The course of fermentation is followed by a hydrometer which indicates the percentage of sugar present in the mash. When fermentation is completed yeast, pulp and other sediments are removed by settling. A storage period of (2-3) weeks is allowed for sedimentation. After which the clear medium is drawn off. Adjustment for the optimum alcohol concentration and acidified by the addition of some pure vinegar.

ii. **Adjustment of alcohol concentration:** Adjustment of alcohol concentration of medium is necessary for successful fermentation. Alcohol concentration of 10%-13% is easily fermented. More or less of this concentration can hamper the vinegar production. The alcohol fermentation greater than 14%, the alcohol is incompletely oxidised. If the alcohol concentration is about (1-2) % esters and acetic acid are oxidized to CO_2 and H_2O.

iii. **Acidification:** initial acidification is carried out with 2 objectives:
   - To inhibit the development of undesirable bacteria.
   - To supply desirable acetic acid producing bacteria.

   Usually 10%-22% by volume of strong vinegar is used. A medium should not be acidified before the composition of alcoholic fermentation because if the sugar in the medium is incompletely converted to alcohol which result low acetic acid and poor quality of vinegar.

iv. **Supply of Oxygen:** the conversion of ethanol to acetic acid is an oxidative process, so, supply of O_2 is necessary for proper fermentation.

v. **Supporting Medium:** A raft or light wooden support may be used as supporting material for bacterial field. The ideal supporting material should be effective in producing satisfactory acidification of alcoholic substrate. The supporting medium should not be toxic or produced any colour, flavour or odour.

vi. **Temperature:**The acetic acid bacteria have a particular temperature relation. The temperature of 26.7^0C-29.4^0C is favourable for acetic acid production.

vii. **Storage:**storage, the vinegar fermentation should be allowed to proceed until the vinegar reached its maximum stage. After the Stage, when the alcohol has been converted to acetic acid, the acetic acid bacteria and their enzymes will gradually destroy vinegar by oxidation unless they are inhibited by exclusion of oxygen.

So, barrel or tank in which vinegar is stored should be completely filled and then sealed toprevent access of air to the vinegar.

viii. **Ageing:**Ageinggives the vinegar a flavour and clarity. Aging generally take place during storage.

ix. **Clarification:**It is done by filtration by mixing filter aids like Betonite clay with the vinegar, allowed to stand and clear vinegar is separated.

x. **Bottling:** Bottles should be completely filled, tight to pack and crack should be avoided to prevent the contact of air. The pasteurization of bottle is carried out at 60^0C to 66^0C for 30 mins.

3.9. Sauerkraut:

It is a clean sound product of characteristic flavour, obtained by fully fermentation, chiefly lactic, of properly prepared and shredded cabbage in the presence of 2% to3% salt.

Organisms:

- *Leuconostocmesenteroids*
- *Lactobacillus plantarum*
- *Pediococcuscerevisae*

3.9.1. Steps of sauerkraut production:

Fresh cabbage

↓

Trim and clean

↓

Shred (2-5 mm thickness)

↓

Addition of salt

↓

Fill into vats

↓

Cover and seal with proper weight

↓

Fermentation (10-15 days)

↓

Pasteurization

↓

Canned or packed in plastic container with preservatives

Lecture 4

Production procedure of fermented beverage(e.g., beer), production procedure of olive pickle

3.10. Fermented alcoholic beverage (beer):

Raw materials:

- **Yeast:** *Saccharomyces cerevisiae*
- **Malt:** Malt is barley grain which is the main raw material in beer production. The barley grain has been germinated to the point where roots and stems are just begun to appear. The green malt is then gently dried to stop growth yet leave the enzyme activity intact. Germination results in activation of enzymes which convert starches in the malted barley and in other cereal grains into sugar, which can be easily fermented by yeast during the fermentation step. This is necessary because yeast cannot utilize the starch in the cereal grains for conversion of ethanol and carbon dioxide.
- **Hops:** Hops are plants, the flowers of which contain resins and essential oils that contribute a characteristic bitter flavour and pleasant aroma of beer. Hops also contain tannins, which add beer colour. Hops are added during brewing and after the enzymes of the malt have converted the starch to the sugar maltose. Hops also have mild preservative properties and add foam-holding capacity to the beer.
- **Cereal Adjunct:** Corn, rice and other cereals are used in beer-making to provide supplemental carbohydrates, principally starch, for conversion to sugar for subsequent fermentation. Without adjunct the carbohydrate may ferment protein. So, the

carbohydrate would remain after fermentation and produce a heavier beer. Burt generally lighter beers are desirable.

3.10.1. Manufacturing procedure of beer:

i. **Mashing:**The first step of beer making is to combine the malted barley and cereal adjuncts with water and mildly cook the mixture, known mash, to extract readily soluble materials and to gelatinize the starches, thus making them more susceptible to extraction and enzymatic breakdown into dextrin and maltose.This processoccurs in a specially designed vessel and the operation is known as mash vessel. Mashing may begin at 38^0 C and thenstep wisely heated for 30 minutes to 77^0C temperature. The liquid fraction in the vessel is now high in yeast-fermentable sugars can be separated from the spent grai. This liquid fraction is known as "wort".

ii. **Brewing:**The wort is next passed to the brew kettle. The hops are added to thewort and the mixture is brewed by bottling in the kettle for about 2.5 hrs. After brewing the hops residue is allowed to settle and the wort is drawn from the kettle through the bed of hops, which partially filters the wort. The wort is then cooled, the solids allowed to precipitate, and it is ready for fermentation.

The boiling or brewing of the wort with the hops serves several purposes. It concentrates thewort, nearly sterilizes it, inactivates enzymes, precipitates remaining proteins that wouldotherwise contribute to beer turbidity, caramelizes sugars slightly, and extracts the flavour, preservatives and tannin like substances from hops.

iii. **Fermentation:**The cooled wort is inoculated with *Saccharomyces* yeast and fermentation of the sugar formed from starch during mashing proceeds. Fermentation in tanks, under near sterile conditions with respect to contaminating microorganisms, is carried out at temperatures from about 3^0C to 14^0C, depending on the strain of yeast and the brewery. The fermentation is complete in about 9 days. It produces alcohol content in wort of about 4.6% by volume. Fermentation lowers the pH of the wort to about 4.0 and produces dissolved CO_2 in wort to the extent about 0.3% by weight.

iv. **Storage:**After fermentation beer is quickly chilled to 0^0C, passed through filters to remove most of the yeast and other suspended material. The storage period of green or young beer is called laagering period. During this period the settling of yeasts, pulps, proteins occur and esters and flavour compounds are developing to create the aroma of the beer.

Additional CO_2 is adder during storage. This may be done by periodically pumping the beer through a carbonator or bubblingCO_2 into the storage tank.

Chill haze is a condition caused by remaining traces of degraded protein and tannins that form a colloidal haze when beer is cooled to low temperatures. To prevent this from occurring in the finished product, various chill proofing treatments may be given or clays toadsorb the colloidal material or use of photolytic enzyme for further solubilize of the protein fraction.

v. **Finish and packaging:**After finishing and packing beer is pasteurized at 60^0C temperature for several minutes to complete removal of micro-organisms.

3.11. Production procedure of olive pickle:

Ripe fruit
↓
Peeling and discarding of skins
↓
Removal of seeds
↓
Soaking of pulp in water
↓
Grinding in a bamboo basket
↓
Collecting the extract in a earth were pot
↓
Addition of fermented wine inoculum
↓
Covering the pots with banana leaves
↓
Fermentation at 18^0C to 30^0C for 3-4 week
↓
Decantation
↓
Storing

- Final pH: 3.8-4.2
- Total acidity: 0.7% to 1% lactic acid

Organisms:

- *Enterobacteraerogenes*
- *Leuconostocmesenteroids*
- *Streptococcus sp.*
- *Lactobacillus plantarum*
- *Pediococcus sp.*

Lecture 5

Production procedure of soy-sauce and some oriented fermented foods

3.12. Production procedure of soy-sauce:

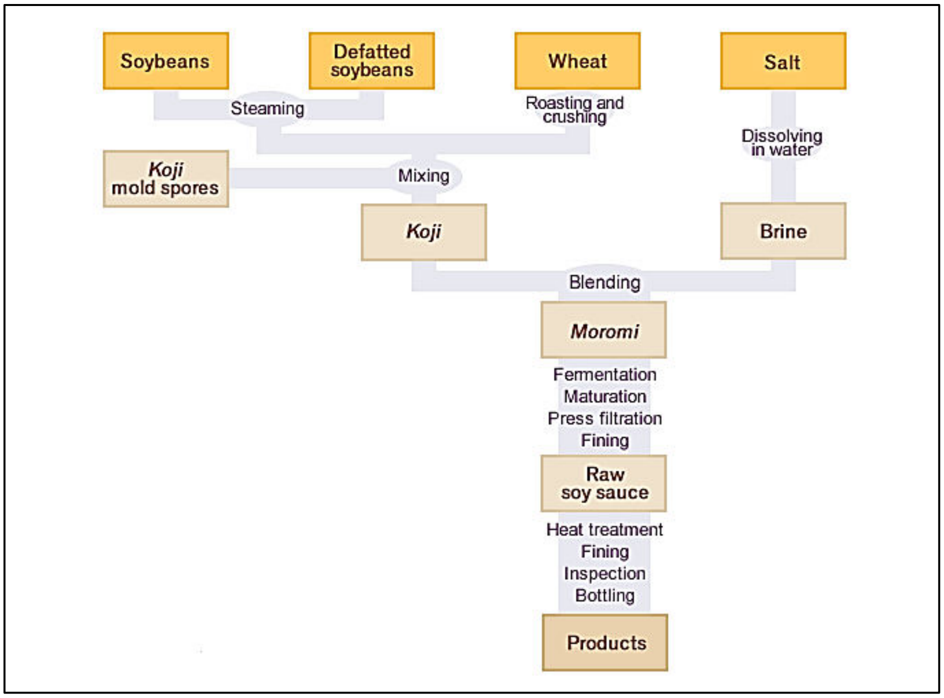
Raw materials:

- Soybeans and defatted soybeans: The proteins that are the main ingredient of soybeans are broken down by the protein-breaking enzyme protease from the kojimold, to produce the amino acids that are the umami constituents of soy sauce. Defatted soybeans retain the proteins that are essential for the soy sauce manufacturing process, but have had the unnecessary fats removed in advance.

- Wheat: The starch that is the main constituent of wheat is converted to glucose by the action of the enzyme amylase from the kojimold, generating sweetness and depth. The glucose is further changed into organic acids such as lactic and acetic acid by lactic acid bacteria. These soften the saltiness and bring together the taste of soy sauce. Part of the glucose is converted to alcohol by the action of yeast, heightening the fragrance.

- Salt: Salt is dissolved in water to be added at the shikomi ingredient blending stage, and is the base of the salty taste. It also has an important role in suppressing putrefactive bacteria and other destructive organisms, to leave the valuable microorganisms, kojimold, lactic acid bacteria, and yeast, free to work.

Production procedure of soy-sauce:



3.13. Production procedure of some oriented fermented foods:

3.13.1. Tofu production:

- **Soaking the beans:**

i. Dried beans, which come in 60-pound (27 kg) sacks, are soaked in water for 12 to 14 hours. The beans soften as they absorb the water and double in size.

ii. Processing the soybeans

- **After soaking**, the beans are mashed with special Japanese stone grinders or other pureeing machines and mixed with water into slurry. The slurry is boiled to neutralize an enzyme that hinders digestion.
- **The soy milk is extracted** with a roller press, separating it from the pulp, which consists of the hull and fiber. This process may take about two hours to complete. The remaining pulp can be used to feed live-stock.
- **Solidifying the soy milk:** Once the whey is extracted, the soybean juice is pumped into curding vats. A coagulating agent is mixed in, such as calcium sulfate, magnesium chloride, or nigari. The coagulant alters the pH and curds the milk much like the process for making cottage cheese. This step takes about 20 minutes.
- **Pressing the tofu**
- **Cutting the tofu**
- **Packaging the tofu:** Tofu may be packaged into shrink-wrapped blocks or continuous thermo-form packages. Water may be added to the packages, or tubs, and then they are sealed, weighed, and dated. Some companies process the soy milk directly in its package.
- **Pasteurizing the tofu:**The packaged tofu is pasteurized at about 180°F (82°C). Pasteurization extends the shelf life of tofu to about 30 days. The tofu is then chilled in

water until it is ready to be placed into boxes and shipped to distributors. Tofu must be refrigerated at below 45°F (7°C) to keep it fresh.

3.13.2. Natto production:

Natto is a traditional Japanese food made from soybeans fermented with *Bacillus subtilis* var. *natto*.

Natto is made from soybeans, typically natto soybeans. Smaller beans are preferred, as the fermentation process will be able to reach the centre of the bean more easily. The beans are washed and soaked in water for 12 to 20 hours to increase their size. Next, the soybeans are steamed for 6 hours, although a pressure cooker may be used to reduce the time. The beans are mixed with the bacterium *Bacillus subtilis*. From this point on, care must be taken to keep the ingredients away from impurities and other bacteria. The mixture is fermented at 40 °C (104 °F) for up to 24 hours. Afterward the natto is cooled, then aged in a refrigerator for up to one week to allow the development of stringiness.

In Natto-making facilities, these processing steps have to be done by avoiding incidents in which soybeans are touched by workers. Even though workers use *B. subtilisnatto* as the starting culture which can suppress some undesired bacterial growth, workers pay extra-close attention not to introduce skin flora onto soy beans.

Lecture 6

Curing: curing of meet; Hurdle technology

3.14. Curing of meat:

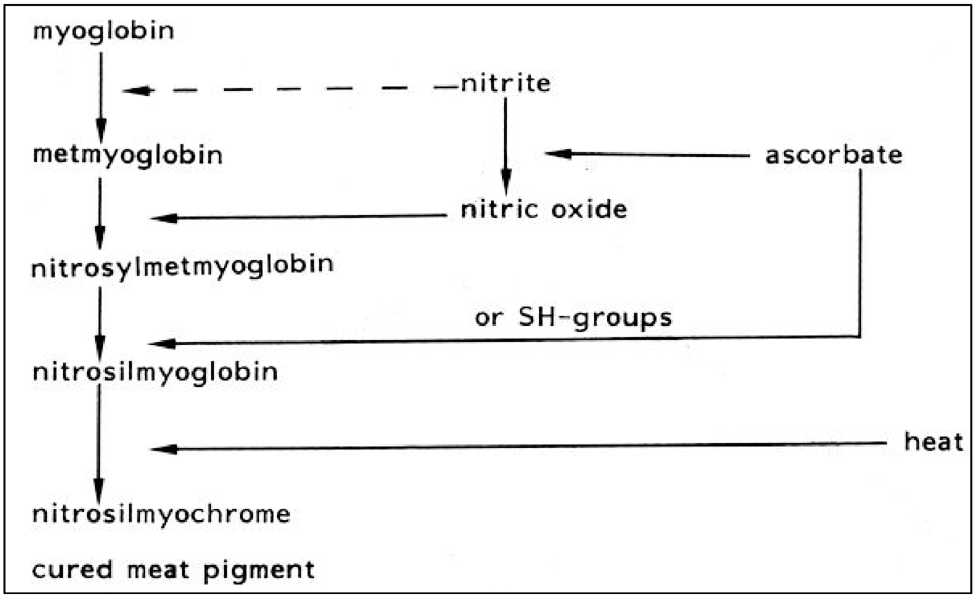
- Curing is actually a general term referring to any process that helps preserve meat. It can mean salting, brining, aging, drying or canning. The goal of all of these processes is to slow spoilage and prevent the growth of microorganisms.

- None of these curing processes is necessarily better or worse, and choosing one over the other often depends on the desired end result. Basic salting and brining is best for short-term preservation, while aging, drying, and canning all result in a product that can be stored for much longer. Products like beef jerky and salt cod can last almost indefinitely!

- Salt is a key ingredient to almost all curing processes. Whether it's applied in a dry-rub or as part of a brining solution, the salt works to draw moisture out of the meat. The less moisture in the meat, the longer it can be saved before being eaten.

- Additionally, nitrites can be added to the curing mixture as further insurance against bacterial growth. Smoking the meat also helps prevent spoilage and keep the fats in the meat from going rancid.

Chemical reactions behind nitrite curing process



3.15. Hurdle technology:

Most of the food products in the market are preserved (i.e. retained its stability) based on more than one hurdle or preservation method. The microbial and chemical safety aspects must be considered first before sensory properties. The microbial stability and safety of the most traditional and novel foods is based on a combination of several preservation factors (called hurdles), and the microorganisms present in food are unable to overcome. This is illustrated by the so-called hurdle effect, first highlighted by Leistner (1978). The critical limits are being used by the industry when each hurdle such as heat treatment, water content, pH and storage temperature is applied alone. Fundamental based theoretical concepts of F-value (hurdle: heat treatment), water activity (hurdle: water content) and glass transition (hurdle: glassy state; depending on water, storage temperature, and structure) are the most successful in determining food stability during food processing and storage.

Commonly used hurdles:

- High Temperature
- Low temperature
- Low water activity
- Acidity
- Low redox potential
- Competitive microorganism
- Preservatives

Physical hurdles:

- High Temperature: Sterilization, Pasteurization and Blanching
- Low temperature : Chilling and Freezing
- Ultraviolet radiation

- Ionizing radiation
- Electromagnetic energy (Microwave energy, Radio frequency energy, Oscillating magnetic field pulses and High electric field pulses)
- Photodynamic inactivation
- Ultra high pressure
- Ultra-sonication
- Packaging film (Plastic, multi layer, active coating and edible coating)
- Modified atmospheric packaging (Gas packaging, Vacuum packaging, Moderate vacuum and active packaging)
- Aseptic packaging
- food microstructure

Physico-chemical hurdles:

- Low water activity (aw)
- Low pH & redox potential (Eh)
- Salt
- Nitrite
- Nitrate
- Carbon dioxide
- Oxygen
- Ozone
- Organic acids
- Lactic acid
- Lactate
- Ethanol
- Propyle glycol
- Spices & Herbs
- Acetic acid
- Acetate
- Ascorbic acid
- Sulphate
- Smoking
- Phosphates
- Gluconolctones
- Phenols
- Chelators
- Surface treatment agents
- Lactoperoxidas& Lysozyme
- Maillard reaction products

Microbially derived hurdles:

- Competitive flora
- Protective cultures
- Bacteriocins
- Antibiotics

Advantages and disadvantages of Hurdle technology:

Hurdles	Advantages	Disadvantage
Low dose irradiation	• Inactive vegetative microorganisms • In-package treatment • Additional shelf life	• Microbial spores resistant • Consumer resistance • Capital costs
Modified atmospheric packaging	• Reduces oxidation and microbial spoilage	• No significant effect on pathogen
Freezing	• Longer shelf life	• Thawing required • Higher costs
High hydrostatic pressure	• In- package treatment	• Spores resistant • Possibility of textural changes
Chemicals (pH, salt, spices)	• Low cost	• Impact on sensory quality
Protective cultures	• Effective against spore formers	• Cost of handling cultures • Heat sensitivity
Bacteriocins	• Many are heat stable • Effective against spore formers	• Inconsistency of inhibitory effect • Decompose during storage

Lecture 7

Non-thermal processing: Gas Packaging: CAP, MAP; High pressure processing

3.16. Non-thermal processing:

3.16.1. Gas Packaging:

CA storage and MA storage:

Controlled Atmosphere Storage or Controlled Atmosphere Packing (CAP) and Modified Atmosphere Storage or Modified Atmosphere Packing (MAP) is the newer trends of food packaging. Fruits and vegetables can be stored successfully by CA and MA storage. Their self-life will become longer by using these methods.

The fruits and vegetables are used as fresh. Hence, their cells are remaining alive and the living cells respirate. If we reduce the respiration rates of those living cells then, the self-life can be increased.

In atmosphere the amount of Oxygen present in 21%. If we reduced the percentage of O_2 in atmosphere, then we can easily reduce the rate of respiration of the live cells of fruits and vegetables.

MA storage/ packing: In this method the fruits and vegetables are packed in closed containers, where the gas permeability is restricted. During respiration the Oxygen is consumed and CO_2 is produces. In this kind of packaging system, as, the gas permeability is restricted, the amount of O_2 inside the container decreased as well as the amount of CO_2 increased. This atmosphere decreases the rate of respiration and increase the self-life of the fruits and vegetables.

CA storage/packing: In this method some inert gases are inserted into the packing. By inserting these gases the percentage of O_2 reduced inside the package, and it reduces the respiration rates and increases the self-life of the fruits and vegetables.

Advantages of CAP and MAP:

i. The self-life of fruits and vegetables can be enhanced and the toxicity due to the presence of the preservatives is nil.
ii. No problem of chill injury
iii. Transportation is easy

Disadvantages of CAP and MAP:

i. In absence of O_2 or in very low concentration of O_2 a bad odor may arise.
ii. Extra costing is needed to control the gas ratio.

3.16.2. High pressure processing:

Pascalization, or high pressure processing (HPP), is a method of preserving and sterilizing food, in which a product is processed under very high pressure, leading to the inactivation of certain microorganisms and enzymes in the food. The technique was named after Blaise Pascal, a French scientist of the 17th century whose work included detailing the effects of pressure on fluids. During pascalization, more than 50,000 pounds per square inch (340 MPa, 3.4 kbar) may be applied for around fifteen minutes, leading to the inactivation of yeast, mold, and bacteria. Pascalization is also known as named for physicist Percy Williams Bridgman.

HPP stops chemical activity caused by microorganisms that play a role in the deterioration of foods. The treatment occurs at low temperatures and does not include the use of food additives. However, some treated foods still require cold storage because pascalization does not stop all enzyme activity caused by proteins, some of which affects shelf life.

HPP Procedure: The pumps may apply pressure constantly or intermittently. The application of high hydrostatic pressures (HHP) on a food product will kill many microorganisms, but the spores of some bacteria may need to be separately treated with acid to prevent their reproduction. Pascalization works especially well on acidic foods, such as yogurts and fruits, because pressure-tolerant spores are not able to live in environments with low pH levels. The treatment works equally well for both solid and liquid products.

The pumps may apply pressure constantly or intermittently. The application of high hydrostatic pressures (HHP) on a food product will kill many microorganisms, but the spores of some bacteria may need to be separately treated with acid to prevent their reproduction. Pascalization works especially well on acidic foods, such as yogurts and fruits, because pressure-tolerant spores are not able to live in environments with low pH levels. The treatment works equally well for both solid and liquid products.

Pressures above 400 MPa / 58,000 psi at cold (+ 4ºC to 10ºC) or ambient temperature inactivate the vegetative flora (bacteria, virus, yeasts, moulds and parasites) present in food, extending the products shelf life importantly and guaranteeing food safety.

High Pressure Processing respects the sensorial and nutritional properties of food, because of the absence of heat treatment, and maintains its original freshness throughout the shelf-life.

Lecture 8

Minimal processing

3.16.3. Minimal processing:

Minimal processing describes non thermal technologies to process food in a manner to guarantee the food safety and preservation as well as to maintain as much as possible the fresh-like characteristics of fruits and vegetables.

Flow-diagram of a general minimal processing:

Washing
↓
Mechanical or manual threshing
↓
Sorting
↓
Second washing
↓
Draining
↓
Dipping in antioxidant solution
↓
Centrifugation
↓
Packaging
↓
Refrigerated storage, maintain proper temperature and RH

Example of minimal processing:

Processing guidelines for peeled and sliced potato:

Processing Temperature	4-5◦C
Raw Material	Suitable variety of raw material lot should be selected using a rapid storage test of prepared produce at room temperature. Attention must be focused on browning susceptibility.
Pretreatment	Careful washing with good quality of water before peeling. Damaged and contaminated parts, as well as spoiled potatoes, must be removed.
Peeling	• One stage peeling: Knife machine • Two stage peeling: slight carbon-drum first, then knife peeling
Washing	• Washing immediately after peeling. The temperature and the amount of washing water should be 4-5◦C and 3lit/kg potato. Washing time under 1 min. • Observation: The microbiologic quality of washing water must be excellent. • In washing water- in particular, for slicedpotato-it is preferable to use citricacid with ascorbic acid (maximum concentration of both o.5%), possibly combinedwith calcium chloride, sodium benzoate, or 4-hexyl resorcinol to prevent browning.
Slicing	Slicing should be done immediately after washing with sharp knives
Straining off	Loose water should be strained off in a colander
Packaging	• Packaging immediately afterwashing in vacuum or in gas mixture of 20% CO_2 + 80% N_2. The headspace volume of a package 2lit/kg potato. • Suitable O_2permeability of packaging materials is 70 cm^3/m^2 24 hr. 101.3 kpa, 23◦C, RH 0% (80 nylon-polyethelyneum)
Storage	4-5◦C preferably in dark
Other Remarks	Good manufacturing practices must be followed (hygiene, lowtemperatures and disinfection)
Shelf life	The shelf life of pre-peeled whole potato is 7-8 days at 5◦C. Due to browning, sliced potato has very poor stability: the shelf life is only 3-4 days at 5◦C.

Module 4

8L

Food irradiation is the process of exposing foodstuffs to ionizing radiation. Ionizing radiation is energy that can be transmitted without direct contact to the source of the energy (radiation) capable of freeing electrons from their atomic bonds (ionization) in the targeted food. This treatment is used to preserve food, reduce the risk of food borne illness, prevent the spread of invasive pests, and delay or eliminate sprouting or ripening. Irradiated food does not become radioactive. The radiation can be emitted by a radioactive substance or generated electrically.

Irradiation is also used for non-food applications, such as medical devices.[3]

Although consumer perception of foods treated with irradiation is more negative than those processed by other means, a large amount of independent research has confirmed irradiation to be safe. One family of chemicals (2ACB's) are uniquely formed by irradiation (unique radiolytic products), and this product is nontoxic. When irradiating food, all other chemicals occur in a lower or comparable frequency to other food processing techniques.

Food irradiation is permitted by over 60 countries, with about 500,000 metric tons of food annually processed worldwide. The regulations that dictate how food is to be irradiated, as well as the food allowed to be irradiated, vary greatly from country to country. In Austria, Germany, and many other countries of the European Union only dried herbs, spices, and seasonings can be processed with irradiation and only at a specific dose, while in Brazil all foods are allowed at any dose.

Uses

Irradiation is used to reduce or eliminate the risk of food born illnesses, prevent or slow down spoilage, arrest maturation or sprouting and as a treatment against pests. Depending on the dose, some or all of the pathogenic organisms, microorganisms, bacteria, and viruses present are destroyed, slowed down, or rendered incapable of reproduction. Irradiation cannot revert spoiled or over ripened food to a fresh state. If this food was processed by irradiation, further spoilage would cease and ripening would slow down, yet the irradiation would not destroy the toxins or repair the texture, color, or taste of the food.When targeting bacteria most foods are irradiated to significantly reduces the number of active microbes, not to sterilize all microbes in the product. In this respect it is similar to pasteurization.

Irradiation is used to create safe foods for people at high risk of infection or for conditions where food must be stored for long periods of time and or proper storage conditions are not available. Foods that can tolerate irradiation at sufficient doses are treated to ensure that the product is completely sterilized. This is most commonly done with rations for astronauts, special diets for hospital patients.

Irradiation is used to create shelf stable products. Since irradiation reduces the populations of spoilage microorganisms and because pre-packed food can be irradiated, the packaging prevents recontamination into the final product.

Irradiation is used to reduce post harvest losses. It reduces populations of spoilage micro-organisms in the food and can slow down the speed at which enzymes change the food and therefore slows spoilage, ripening, and inhibits sprouting (e.g. of potato, onion and garlic).

Food is also irradiated to prevent the spread of invasive pest species through trade in fresh vegetables and fruits, either within countries or trade across international boundaries. Pests such as insects could be transported to new habitats through trade in fresh produce and which could significantly affect agricultural production and the environment were they to establish themselves. This "phytosanitary irradiation" aims to render any hitch-hiking pest incapable of breeding. The pests are sterilized when the food is treated by low doses of irradiation. In general the higher doses required to destroy pests such as insects, mealybugs, mites, moths and butterflies either affect the look or taste or cannot be tolerated by fresh produce. Low dosage treatments (less than 1000 gray) enables trade across quarantine boundaries and may also help reduce spoilage.

Public perception

Irradiation has been approved by many countries, for example in the US the FDA has approved food irradiation for over 50 years. However, in the past decade the major growth area is for fruits and vegetables that are irradiated to prevent the spread of pests. In the early 2000s in the US, irradiated meat was common at some grocery stores, but because of lack of consumer demand it is no longer common. Because consumer demand for irradiated food is low, reducing the spoilage between manufacture and consumer purchase and reducing the risk of food borne illness is currently not sufficient incentive for most manufactures to supplement their process with irradiation. Nevertheless, food irradiation does take place commercially and volumes are in general increasing at a slow rate, even in the European Union where all member countries allow the irradiation of dried herbs spices and vegetable seasonings but only a few allow other foods to be sold as irradiated.

Although there are some consumers who choose not to purchase irradiated food, a sufficient market has existed for retailers to have continuously stocked irradiated products for years. When labeled irradiated food is offered for retail sale, these consumers buy it and re-purchase it, indicating that it is possible to sucessfully market irradiated foods, therefore retailers not stocking irratiated foods might be a major bottelneck to wider adption of irrated foods. It is however, widely believed that consumer perception of foods treated with irradiation is more negative than those processed by other means and some industry studies indicate the number of consumers concerned about the safety of irradiated food decreased between 1985 and 1995 to levels comparable to those of people concerned about food additives and preservatives. Even though is it is untrue "People think the product is radioactive," said Harlan Clemmons, president of Sadex, a food irradiation company based in Sioux City, Iowa. Because of these concerns and the increased cost of irradiated foods, there is not a widespread public demand for the irradiation of foods for human consumption.

Impact

Irradiation reduces the risk of infection and spoilage, does not make food radioactive, and the food is shown to be safe, but it does cause chemical reactions that alter the food and therefore alters the chemical makeup, nutritional content, and the sensory qualities of the food. Some of the potential secondary impacts of irradiation are hypothetical, while others are demonstrated. These effects include cumulative impacts to pathogens, people, and the environment due to the reduction of food quality, the transpiration and storage of radioactive goods, and destruction of pathogens, changes in the way we relate to food and how irradiation changes the food production and shipping industries.

Immediate effects

The radiation source supplies energetic particles or waves. As these waves/particles pass through a target material they collide with other particles. Around the sites of these collisions chemical bonds are broken, creating short lived radicals (e.g. the hydroxyl radical, the hydrogen atom and solvated electrons). These radicals cause further chemical changes by bonding with and or stripping particles from nearby molecules. When collisions damage DNA or RNA, effective reproduction becomes unlikely, also when collisions occur in cells, cell division is often suppressed.

Irradiation (within the accepted energy limits, as 10 MeV for electrons, 5 MeV for X-rays [US 7.5 MeV] and gamma rays from Cobalt-60) can not make food radioactive, but it does produce radiolytic products, and free radicals in the food. A few of these products are unique, but not considered dangerous.

Irradiation can also alter the nutritional content and flavor of foods, much like cooking. The scale of these chemical changes is not unique. Cooking, smoking, salting, and other less novel techniques, cause the food to be altered so drastically that its original nature is almost unrecognizable, and must be called by a different name. Storage of food also causes dramatic chemical changes, ones that eventually lead to deterioration and spoilage.

Misconceptions

A major concern is that irradiation might cause chemical changes that are harmful to the consumer. Several national expert groups and two international expert groups evaluated the available data and concluded that any food at any dose is wholesome and safe to consume as long as it remains palatable and maintains its technical properties (e.g. feel, texture, or color).

Irradiated food does not become radioactive, just as an object exposed to light does not start producing light. Radioactivity is the ability of a substance to emit high energy particles. When particles hit the target materials they may free other highly energetic particles. This ends shortly after the end of the exposure, much like objects stop reflecting light when the source is turned off and warm objects emit heat until they cool down but do not continue to produce their own heat. To modify a material so that it keeps emitting radiation (induce radiation) the atomic cores (nucleus) of the atoms in the target material must be modified.

It is impossible for food irradiators to induce radiation into a product. Irradiators emit electrons or photons and the radiation is intrinsically radiated at precisely known strengths (wavelengths for photons, and speeds for electrons). These radiated particles at these strengths can never be strong enough to modify the nucleus of the targeted atom in the food, regardless of how many particles hit the target material, and radioactivity can not be induced without modifying the nucleus.

Chemical changes

Compounds known as free radicals form when food is irradiated. Most of these are oxidizers (i.e., accept electrons) and some react very strongly. According to the free-radical theory of aging excessive amounts of these free radicals can lead to cell injury and cell death, which may contribute to many diseases.[29] However, this generally relates to the free radicals generated in the body, not the free radicals consumed by the individual, as much of these are destroyed in the digestive process.

When fatty acids are irradiated, a family of compounds called 2-alkylcyclobutanones (2-ACBs) are produced. These are thought to be unique radiolytic products. Most of the substances found in irradiated food are also found in food that has been subjected to other food processing treatments, and are therefore not unique. Furthermore, the quantities in which they occur in irradiated food are lower or similar to the quantities formed in heat treatments.

The radiation doses to cause toxic changes are much higher than the doses used to during irradiation, and taking into account the presence of 2-ACBs along with what is known of free radicals, these results lead to the conclusion that there is no significant risk from radiolytic products.

Process

Typically, when the food is being irradiated, pallets of food are exposed to a source of radiation for a specific time. Dosimeters are placed on the pallet (at various locations) of food to serve as a check and ensure that the correct dose was achieved Most irradiated food is processed by gamma irradiation., however the usage of electron beam and X-ray is becoming more popular as well. With gamma irradiation, special precautions are taken because gamma rays are continuously emitted by the radioactive material. In most designs, to nullify the effects of radiation, the radioisotope is lowered into a water-filled storage pool, which absorbs the radiation but does not become radioactive. This allows pallets of the products to be added and removed from the irradiation chamber and other maintenance to be done. Sometimes movable shields are used to reduce radiation levels in areas of the irradiation chamber instead of submerging the source. For x-ray and electron irradiation these precautions are not necessary as the radiation is generated by electricity, the source of the radiation can be switched off.

For x-ray, gamma ray and electron irradiation, shielding is required when the foods are being irradiated. This is done to protect workers and the environment outside of the chamber from radiation exposure. Typically permanent or movable shields are used In some gamma irradiators the radioactive source is under water at all times, and the hermetically sealed product is lowered into the water. The water acts as the shield in this application. Because of the lower penetration depth of electron irradiation, treatment to entire industrial pallets or totes is not possible.

Dosimetry

The radiation absorbed dose is the amount energy absorbed per unit weight of the target material. Dose is used because, when the same substance is given the same dose, similar changes are observed in the target material. The SI unit for dose is grays (Gy or J/kg). Dosimeters are used to measure dose, and are small components that, when exposed to ionizing radiation, change measurable physical attributes to a degree that can be correlated to the dose received. Measuring dose (dosimetry) involves exposing one or more dosimeters along with the target material.

For purposes of legislation doses are divided into low (up to 1 kGy), medium (1 kGy to 10 kGy), and high-dose applications (above 10 kGy).High-dose applications are above those currently permitted in the US for commercial food items by the FDA and other regulators around the world.[60] Though these doses are approved for non commercial applications, such as sterilizing frozen meat for NASA astronauts (doses of 44 kGy) and food for hospital patients.

Applications By Overall Average Dose		
	Application	**Dose (kGy)**
Low dose (up to 1 kGy)	Inhibit sprouting of bulbs and tubers	0.03–0.15 kGy
	Delay fruit ripening	0.03–0.15 kGy

Applications By Overall Average Dose		
	Application	Dose (kGy)
	Stop insect/parasite infestations to help clear quarantine	0.07–1.00 kGy
Medium dose (1 kGy to 10 kGy)	Delay spoilage of meat	1.50–3.00 kGy
	Reduce risk of pathogens in meat	3.00–7.00 kGy
	Increase sanitation of spices	10.00 kGy
High dose (above 10 kGy)	Sterilization of packaged meat	25.00–70.00 kGy
	Increase juice yield	
	Improve re-hydration	

Efficiency illustration of the different radiation technologies (electron beam, X-ray, gamma rays)

Electron irradiation uses a stream of electrons accelerated by an electric voltage or radio frequency wave to a velocity close to the speed of light. Electrons have mass and negative electric charge, and therefore electron beams at the energies allowed for food irradiation do not penetrate into the product beyond several centimeters, depending on product density.

Gamma irradiation involves packets of light (photons) that originate from radioactive decay of atomic nuclei. Each element gives rise to Gamma rays with specific energies characteristic of the source element, these rays have zero mass and no electrical charge. The ones used for food irradiation are able to penetrate through food products. The radioactive isotope radioisotope cobalt-60 is used as the source in all commercial scale gamma irradiation facilities Gamma irradiation is most widely used technology because the deeper penetration of the gamma rays enables administering treatment to entire industrial pallets or totes (reducing the need for material handling) and it is significantly less expensive than using an X-ray source. Generally cobalt-60is used as a radioactive source for gamma irradiation. Cobalt-60 is bred from cobalt-59 using neutron irradiation in specifically designed nuclear reactors. In limited applications caesium-137, a less costly alternative recovered during the processing of spent nuclear fuel, is used as a radioactive source. Insufficient quantities are available for large scale commercial use. An incident where water-soluble caesium-137 leaked into the source storage pool requiring NRC interventio has led to near elimination of this radioisotope.

Irradiation by X-ray is similar to irradiation by gamma rays but the rays produced have a distribution of energetic packets of light (X-rays). X-rays are generated by colliding accelerated electrons with a dense material (this process is known as bremsstrahlung-conversion), and the x-rays so produced have a spectrum characteristic of the dense target material. Like electron beams, x-rays do not necessitate the use of radioactive materials and can be switched off when not needed. X-rays ability to penetrate the target is similar to gamma irradiation. X-ray machines produce better dose uniformity than Gamma irradiation but require much more electricity as only as much as 12% of the input energy is converted into X-rays.

PRESERVATIVES • are substances which, under certain conditions, either delay the growth of microorganisms without necessarily destroying them or prevent deterioration of quality during manufacture and distribution. • Can be naturally occurring or synthetic substance that is added to products such as foods, pharmaceuticals, paints, biological samples, wood, etc. to prevent decomposition by microbial growth or by undesirable chemical changes.
Preservatives………… • these substances are added in very low quantities (up to 0.2%) which do not alter the organoleptic and physicochemical properties of the foods at or only very little. • This method is usually based on the combined or synergistic activity of several additives, intrinsic product parameters and extrinsic factors
• Food preservatives, spices, and flavouring agents have been added to foods for thousands of years. These compounds which are added to foods are termed as food additives • Chemical food preservatives are applied to foods as direct additives during processing, or develop by themselves during processes such as fermentation.
If it deceive the customer or if the desired effect can be obtained by other manufacturing practices that are economically and technologically satisfactory.ϖ if it disguise faulty quality or processing and handling that is not allowed, ϖif it reduces the nutritive value of a food, ϖ to improve appearance of food 2. An additive is not justified ϖto maintain the nutritional quality of food, ϖGuidelines for use of food additives 1.

Additives should be used only 3. The smallest amount of additive should be used that will produce the desired effect under good manufacturing practices. 4. The additive used must conform to a standard purity. 5. Additives should be subjected to adequate toxicological evaluation and should be kept under observation for possible deleterious effects 6. The approval of an additive should be limited to specific foods for specific purposes under specific conditions. Sorbet acid for example is an approved food additive, but its use in meat was denied because its presence could mask spoilage produced by microorganisms.
Chemical Preservatives • The purpose of using a chemical agent as a preservative is to retard food spoilage caused by microorganisms the WHO has estimated that 20% of the world's food is lost by this type of spoilage. • Partial prevention of this spoilage can be achieved through the use of refrigeration, drying, freezing and fermentation. • The use of chemical additives or preservatives will prolong the shelf life of the food even further as moisture retainers. • Chemicals that function to preserve the food are generally added after the food has been processed and before it is packaged.ϖfirming agents ϖas stabilizers, ϖ as antioxidants, ϖtheir enzyme activity or then genetic mechanisms. • Preservatives may also serve ϖInterfere with the cell membranes of microorganisms, ϖChemical Preservatives • Chemical preservatives

Preservatives are classifieds into two categories. Class 1 and Class 2 presrvatives. Class I preservatives are generally preservatives that are found in the common kitchen. The Class-I Preservative includes salt, vinegar, salt, vegetable oil, honey, sugar and wood smoke.

Sorbates, sulfites and benzoates are some of the Class II preservatives used. When Class-I Preservative is found in the nature, Class-II Preservative is man made. Class-II Preservatives are unnatural preservatives. As Class 1 preservatives are natural, there is no need to be cautious while using it. On the other hand, some risk is involved when using Class II preservatives as they are chemicals. This means that there are certain limits in using Class II preservatives and more restrictions are implemented in its usage.

In some products, only Class 1 preservatives are used and in some Class II preservatives are used. But one can also come across a mix of these two classes of preservatives in foods, which ensures more longevity.

When looking at the two preservatives, it is always better to choose products that come with Class 1 preservatives as they are not dangerous to the health.

Summary

1. Class I preservatives are generally preservatives that are found in the common kitchen. Class-II Preservative is man made. Class-II Preservatives are unnatural preservatives.
2. The Class-I Preservative includes salt, vinegar, salt, vegetable oil, honey, sugar and wood smoke. Sorbates, sulfites and benzoates are some of the Class II preservatives used.
3. There are certain limits in using Class II preservatives and more restrictions are implemented in its usage.
4. When looking at the two preservatives, it is always better to choose products that come with Class 1 preservatives as they are not dangerous to the health.
5. As Class 1 preservatives are natural, there is no need to be cautious while using it. On the other hand, some risk is involved when using Class II preservatives as they are chemicals.

Antimicrobial preservatives prevent degradation by bacteria. This method is the most traditional and ancient type of preserving—ancient methods such as pickling and adding honey prevent microorganism growth by modifying the pH level. The most commonly used antimicrobial preservative is lactic acid. Common antimicrobial preservatives are presented in the table Nitrates and nitrites are also antimicrobial. The detailed mechanism of these chemical compounds range from inhibiting growth of the bacteria to the inhibition of specific enzymes.

E number	chemical compound	comment
E200 – E203	sorbic acid, sodium sorbate and sorbates	common for cheese, wine, baked goods
E210 – E213	benzoic acid, sodium benzoate and benzoates	used in acidic foods such as jams, salad dressing, juices, pickles, carbonated drinks, soy sauce
E214 – E219	hydroxybenzoate and derivatives	stable at a broad pH range

E220 – E227	sulfur dioxide and sulfites	common for fruits
E249 – E250	nitrite	used in meats to prevent botulism toxin
E251 – E252	nitrate	used in meats
E270	lactic acid	-
E280 – E283	propionic acid and sodium propionate	baked goods

Sugar and Salt

Bacteria evolved in environments where the concentration of sugars and salts is the same as or lower than those inside the cell. High sugar concentrations cause the bacterium to lose water by osmosis and it doesn't have any cellular machinery to pump it back in against the osmotic gradient. Without enough water, the bacteria can't grow or divide. Mould is more tolerant though and can grow on some jams.

The **salt** is a water absorbent and hence removes water from any food. In absence of water bacteria don't multiply and hence act as **preservative**. Basically, **salt** works by drying food. **Salt** absorbs water from foods, making the environment too dry to support harmful mold or bacteria.

Vinegar

Vinegar is a liquid consisting of about 5–20% acetic acid (CH_3COOH), water, and other trace chemicals, which may include flavorings. The acetic acid is produced by the fermentation of ethanol by acetic acid bacteria.[1] Vinegar is now mainly used as a cooking ingredient, or in pickling. As the most easily manufactured mild acid, it has historically had a great variety of industrial, medical, and domestic uses, some of which (such as its use as a general household cleaner) are still commonly practiced today.

Commercial vinegar is produced either by a fast or a slow fermentation processes. In general, slow methods are used in traditional vinegars where fermentation proceeds slowly over the course of a few months or up to a year. The longer fermentation period allows for the accumulation of a non-toxic slime composed of acetic acid bacteria. Fast methods add mother of vinegar(bacterial culture) to the source liquid before adding air to oxygenate and promote the fastest fermentation. In fast production processes, vinegar may be produced between 20 hours to three days.

Sodium Benzoate

Sodium benzoate is a preservative. As a food additive, sodium benzoate has the E number E211. It is bacteriostatic and fungistatic under acidic conditions. It is most widely used in acidic foods such as salad dressings (vinegar), carbonated drinks (carbonic acid), jams and fruit juices (citric acid), pickles (vinegar), and condiments. It is also used as a preservative in medicines and cosmetics.Concentration as a food preservative is limited by the FDA in the U.S. to 0.1% by weight.

Mechanism of Action - The mechanism starts with the absorption of benzoic acid into the cell. If the intracellular pH falls to 5 or lower, the anaerobic fermentation of glucose through phosphofructokinase decreases sharply, which inhibits the growth and survival of microorganisms that cause food spoilage.

In the United States, sodium benzoate is designated as generally recognized as safe (GRAS) by the Food and Drug Administration The International Programme on Chemical Safety found no adverse effects in humans at doses of 647–825 mg/kg of body weight per day.

Potassium Metabisulphite –

Potassium metabisulfite, $K_2S_2O_5$, also known as **potassium pyrosulfite**, is a white crystalline powder with a pungent sulfur odour. The main use for the chemical is as an antioxidant or chemical sterilant. It is a disulfite and is chemically very similar to sodium metabisulfite, with which it is sometimes used interchangeably. Potassium metabisulfite is generally preferred out of the two as it does not contribute sodium to the diet.

Potassium metabisulfite has a monoclinic crystal structure which decomposes at 190 °C, yielding potassium sulfite and sulfur dioxide:

$$K_2S_2O_5(s) \rightarrow K_2SO_3(s) + SO_2(g)$$

It is used as a food additive, also known as E224. It is restricted in use and may cause allergic reactions in some sensitive persons.

Potassium is an inhibitor of the polyphenol oxidase enzyme.

Potassium metabisulfite is a common wine or must additive, in which it forms sulfur dioxide gas (SO_2). This both prevents most wild microorganisms from growing, and it acts as a potent antioxidant, protecting both the color and delicate flavors of wine.

Potassium metabisulfite causes skin irritation, serious eye irritation, and may cause respiratory irritation. Hence, it should be manipulated under individual protective elements, such as gloves, coat, mask and glasses. Also, it should be manipulated under alkaline conditions as potassium metabisulfite reacts with acids, liberating toxic gases.

Nitrates & nitrites

Nitrates and nitrites are chemicals found naturally in some foods, or added to others as a preservative. But there is concern that foods containing nitrite, particularly cured meats, may be linked to cancers. Learn more about these chemicals, where they're found, and how they may affect our health.

Biopreservatives

Biopreservation, defined as the extension of shelf life and enhanced safety of foods by the use of natural or controlled microbiota and/or antimicrobial compounds, is an innocuous and ecological approach to the problem of food preservation and has gained increasing attention in recent years. Consequently, certain lactic acid bacteria (LAB), with demonstrated antimicrobial properties commonly associated with foods, are being assayed to increase the safety and/or prolong the shelf life of foods. The antagonistic properties of LAB derive from competition for nutrients and the production of one or more antimicrobial active metabolites such as organic acids (lactic and acetic), hydrogen peroxide, and antimicrobial peptides (bacteriocins). Nowadays the use of LAB bacteriocins is considered an integral part of hurdle technology. Their combined use allows most pathogenic and spoilage bacteria to be controlled and also extend their inhibitory activity spectrum to such intrinsically resistant organisms as the Gram-negative bacteria.

Food Antibiotics

In India, nisin is the only food permitted antiiotics.

Nisin is a polycyclic antibacterial peptide produced by the bacterium*Lactococcus lactis* that is used as a food preservative. It has 34 amino acidresidues, including the uncommon amino acids lanthionine (Lan), methyllanthionine (MeLan), didehydroalanine (Dha), and didehydroaminobutyric acid (Dhb). These unusual amino acids are introduced by posttranslational modification of the precursor peptide. In these reactions a ribosomallysynthesized 57-mer is converted to the final peptide. The unsaturated amino acids originate from serine and threonine, and the enzyme-catalysed addition of cysteine residues to the didehydro amino acids result in the multiple (5) thioetherbridges.

Subtilin and epidermin are related to nisin. All are members of a class of molecules known as lantibiotics.

In the food industry, nisin is obtained from the culturing of *L. lactis* on natural substrates, such as milk or dextrose, and it is not chemically synthesized.

While in general most bacteriocins inhibit only closely related species, nisin is a rare example of a "broad-spectrum" bacteriocin effective against many Gram-positive organisms, including lactic acid bacteria (commonly associated with spoilage), *Listeria monocytogenes* (a known pathogen), *Staphylococcus aureus*, *Bacillus cereus*, *Clostridium botulinum*, etc. It is also particularly effective against spores. Gram-negative bacteria are protected by their outer membrane but may become susceptible to nisin action after a heat shock or when this is coupled with the chelator EDTA. Nisin is soluble in water and can be effective at levels nearing the parts-per-billion range. Nisin is used in processed cheese, meats, beverages, etc. during production to extend shelf life by suppressing Gram-positive spoilage and pathogenic bacteria. In foods, it is common to use nisin at levels ranging from ~1-25 ppm, depending on the food type and regulatory approval. As a food additive, nisin has an E number of E234.

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Lactic Acid Bactria-

Lactic acid bacteria are among the most important groups of microorganisms used in food fermentation. They contribute to the taste and texture of fermented products and inhibit food spoilage bacteria by producing growth-inhibiting substances and large amounts of lactic acid. As agents of fermentation LAB are involved in making yogurt, cheese, cultured butter, sour cream, sausage, cucumber pickles, olives and sauerkraut, but some species may spoil beer, wine and processed meats.

In general, the LAB may be characterized as Gram-positive, aerobic to facultatively anaerobic, asporogenous rods and cocci which are oxidase, catalase, and benzidine negative, lack cytochromes, do not reduce nitrates to nitrite, are gelatinase negative, and are unable to utilize lactate.

The Lactic Acid bacteria are grouped as either **Homofermenters** or **Heterofermenters** based on the end product of their fermentation. The **Homofermenters** produce lactic acid as the major product of fermentation of glucose. The **Heterofermenters** produce a number of products besides lactic acid, including carbon dioxide, acetic acid, and ethanol from the fermentation of glucose.

The term **Lactic Acid Bacteria** is conventionally reserved for genera in the order *Lactobacillales*, which includes *Lactobacillus, Leuconostoc, Pediococcus, Lactococcus* and *Streptococcus,* in addition to *Carnobacterium, Enterococcus, Oenococcus, Tetragenococcus, Vagococcus,* and *Weisella***.**

Because they obtain energy only from the metabolism of sugars, lactic acid bacteria are restricted to environments in which sugars are present. They have limited biosynthetic ability, having evolved in environments that are rich in amino acids, vitamins, purines and pyrimidines, so they must be cultivated in complex media that fulfill all their nutritional requirements. Most are free-living or live in beneficial or harmless associations with animals, although some are opportunistic pathogens. They are found in milk and milk products and in decaying plant materials. They are normal flora of humans in the oral cavity, the intestinal tract and the vagina, where they play a beneficial role.

A few LAB are pathogenic for animals, most notably some members of the genus *Streptococcus*. In humans, *Streptococcus pyogenes* is a major cause of disease (strep throat, pneumonia, and other pyogenic infections, scarlet fever and other toxemias), *Streptococcus pneumoniae* causes lobar pneumonia, otitis media and meningitis; some viridans and nonhemolytic oral streptococci play a role in dental caries and may be an insidious cause of endocarditis. The pathogenic streptococci are dealt with elsewhere in the text. This chapter deals primarily with LAB in association with food and dairy microbiology, to a lesser extent with LAB as beneficial components of the human normal flora and probiotics.

Lactic acid bacteria are among the most important groups of microorganisms used in food fermentations. They contribute to the taste and texture of fermented products and inhibit food spoilage bacteria by producing growth-inhibiting substances and large amounts of lactic acid. As agents of fermentation LAB are involved in making yogurt, cheese, cultured butter, sour cream, sausage, cucumber pickles, olives and sauerkraut, but some species may spoil beer, wine and processed meats.

In addition to L. acidophilus, other lactic-producing bacteria involved in food fermentation include:

- L. bulgaricus,
- L. plantarum,
- L. caret,
- L. pentoaceticus,
- L brevis and
- L. thermophilus

Lactic acid bacteria are primarily located on the surface, or skin of fruits and vegetables.