UNIT 12 METHODS OF FOOD PROCESSING – 2

Structure

12.1 INTRODUCTION

In the previous unit, we began our discussion on the methods of food processing by covering the two major methods – thermal processing and dehydration. Here, in this unit, we shall focus on the other food processing methods which include freezing, microwave processing, irradiation, fermentation, deep fat frying and use of salt, sugar and chemicals as preservatives. What is freezing and the different types of freezing systems available for foods? How do microwaves help to process and preserve food? How can simple home-based methods such as deep fat frying and use of salt, sugar and chemicals act as a preservative technique/measure? These are a few issues discussed in this unit.

Objectives

After studying this unit, you will be able to:

- list the different food processing techniques,
- discuss the freezing systems in details,
- describe microwave processing, its applications and advantages,
- enumerate the different fermented products and their method of preparation involving use of various microorganisms, and
- explain the use of salt, sugar and chemicals as preservatives.

12.2 FREEZING

Freezing, as a method, is the easiest, most convenient and least time-consuming way of preserving foods. Freezing, however, does not sterilize foods or destroy the organisms that cause spoilage. How then does it preserve foods? Well, the extreme cold simply slows the growth of microorganisms and the chemical changes that affect quality or cause spoilage. You already know that all microbial and biochemical activities are temperature dependant and slow down as the temperature is reduced. As a rule of thumb, for every 10°C temperature change, the rate of reaction changes by a factor of 2 to 3.

Further, freezing helps to preserve food by its action on enzymes. Enzymes, as we already know, are complex proteins present in all living tissues that help organisms ripen and mature. During freezing, enzyme action is slowed but not stopped. If not inactivated, these enzymes can cause colour and flavour changes and loss of nutrients during freezer storage.

We are all familiar with chilling and refrigerated storage. At home or at the industry level, refrigerated storage of food is generally practiced. In the unit operation of chilling, the temperature of a food is reduced generally to between –1°C and 7°C and thus subsequent storage at refrigerated temperature extends the shelf life of both the fresh and processed foods. It is also used as an adjunct process to extend the storage life of mildly processed (e.g. pasteurized, fermented and irradiated) and low-acid foods. In the United States, refrigerated storage of food is mandated by regulations at temperatures at or below 7.2°C. Such foods are also marketed under refrigeration and labeled as 'needing refrigeration'. Commercially sterilized and processed foods that may become contaminated after opening should also be labeled for refrigerated storage.

Chilling and refrigerated storage prevents the growth of bacteria, particularly the *thermophiles* (organisms that grow at high temperature) and *mesophiles* (organisms that grow at medium temperature). *Psychrophiles* (organisms that grow at low temperatures), however, can and do cause food spoilage during low temperatures storage, but there are some psychrophillic pathogens, as listed in Table 12.1, that need attention.

Table 12.1: Psychrophilic foodborne pathogenic bacterial species

Identified species	Foods Associated
Aeromonas hydrophila	Sea foods
Escherichia coli *Pseudomonas species*	Milk and milk products Meat and meat products Water habitats
Bacillus cereus	Cereal and cereal products Milk and milk products Meat and meat products
Listeria monocytogenes *Yersinia enterocolitica* *Campylobacter jejuni*	Milk and milk products Meat and meat products

Freezing, you would realize, is the most convenient way of preserving foods. Different types of freezing systems are available for foods. Let's get to learn about these systems.

12.2.1 Freezing Systems

Different types of freezing systems are available for foods. No single freezing system can satisfy all freezing needs, because of the wide variety of food products and process characteristics. Can you mention a few of these characteristics which may influence the choice for a particular system? The selection criteria of a freezing system will depend on the type of the product, reliable and economic operation, easy cleanability and hygienic design and desired product quality.

Although all commercial freezing processes are operated at atmospheric conditions, there are potential applications of high-pressure assistant freezing and thawing of foods. The pressure-induced freezing point and melting point depression enables the sample to be supercooled to low temperature (e.g. – 22°C at 207.5 M pa) resulting in rapid and uniform nucleation and growth of ice crystals on release of pressure.

The different freezing systems are summarized herewith:

A) *Freezing by Contact with a Cooled Solid: Plate Freezing*

In this method, the product is sandwiched between metal plates and pressure is usually applied for good contact. Plate freezers are only suitable for regular-shaped materials or blocks. When the product has been frozen, hot liquid is circulated to break the ice seal and defrost. Spacers are used between the plates during freezing to prevent crushing or bulging of the package.

B) *Freezing by Contact with a Cooled Liquid: Immersion Freezing*

In this method, the food is immersed in low-temperature brine to achieve fast temperature reduction through direct heat exchange. The fluids usually used are salt solutions (sodium chloride), sugar solutions, glycol and glycerol solutions, and alcohol solutions. In order to ensure that the food does not come into contact with liquid refrigerants, flexible membranes are used to enclose the food completely, while allowing rapid heat transfer.

C) *Freezing by Contact with a Cooled Gas*

Different methods are available for freezing by contact with cooled gas. These include:

i) *Cabinet Freezing:* This method involves circulation of cold air in a cabinet where the product is placed in a tray. The moisture pick-up from the product may deposit on the cooling coils as frost, which acts as an insulation.

ii) *Air-Blast Freezing:* The method employs the use of high velocity cold air to reduce the temperature of the food. Air velocities between 2.5 and 5 m/s give the most economical freezing. Lower air velocities result in slow product freezing and higher velocities increase unit freezing costs considerably. This method can be further divided into fluidized bed freezing, belt freezing and tunnel freezing, depending on how the air interacts with the product. Let us discuss each of these methods:

- *Fluidized Bed Freezing:* A fluidized bed freezer consists of a bed with a perforated bottom through which refrigerated air is blown vertically upwards. The air velocity must be greater than the fluidization velocity. This freezing method is suitable for small particulate food bodies of fairly uniform size e.g., peas, diced carrots, corns and berry fruits. The high degree of fluidization improves the heat transfer rate and results in good use of floor space.

- *Belt Freezing:* The first mechanized air-blast freezers consisted of a wire mesh belt conveyor in a blast room for continuous product flow. Uniform product distribution over the entire belt is required to achieve uniform product contact and effective freezing. Controlled vertical airflow forces cold air up through the product layer, thereby, creating good contact with the product particles and increasing the efficiency. The principal current design is the two-stage belt freezer. Temperatures used are usually – 10 to 4°C in the pre-cool section and – 32 to – 40°C in the freezer section.

- *Tunnel Freezing:* In this process, the products are placed in trays or racks in a long tunnel and cool air is circulated over the product.

iii) *Cryogenic Freezing:* Cryogenic freezing, as you would realize, is one of the fast, flexible and cheap method of freezing. In this, the liquefied gases are placed in direct contact with the foods. Food is exposed to an atmosphere below – 60°C through direct contact with liquid nitrogen or liquid carbon dioxide or their vapour. This is a very fast method of freezing, thus adequate control is necessary for achieving quality products. It also provides flexibility by being compatible with various types of food products and having a low capital cost. The rapid formation of small ice crystals greatly reduces the damage caused by cell rupture, preserving colour, texture, flavour and nutritional value. The rapid freezing also reduces the evaporative weight loss from the products, provides high product throughout and has low floor space requirements.

The cryo-mechanical technique utilizes a cryogenic gas to create a frozen crust on a fluid product, after which the product may be conveyed to a conventional mechanical freezer. The advantages of liquid nitrogen are that it is colourless, odourless and is chemically inert and boils at 195.8°C. It is usually used for high-value products due to the high capital cost for gas compression. The product can be exposed to a cryogenic medium in three ways:

a) the cryogenic liquid is directly sprayed on the product in a tunnel freezer,

b) the cryogenic liquid is vapourized and blown over the food in a spiral freezer or batch freezer, and

c) the product is immersed in the cryogenic liquid in an immersion freezer.

With this, we come to an end on our discussion on freezing as a method of preservation. Let us now attempt the exercises given in check your progress exercise 1 and see how much we have grasped the knowledge on this subject.

Check Your Progress Exercise 1

1) Fill in the blanks:

   i) The freezing process involves slowing down the growth of .... and .... changes.

   ii) For every 10°C temperature change, the rate of reaction changes by a factor of.. .

   iii) The temperature range which extends the shelf-life of fresh and processed foods is ....

   iv) ....organisms cause food spoilage during low temperatures storage.

   v) The selection criteria of a freezing method are type of product, reliable and economic operation, easy .... and product ....

2) Explain how the process of freezing helps in preservation of foods.

....

....

3) What are the different methods of freezing?

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4) Is a single freezing system enough to satisfy all freezing needs. Why?

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....

5) Explain, very briefly, what is meant by 'Cryogenic freezing'? Also, give its advantages over other freezing methods.

....

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....

12.3 MICROWAVE PROCESSING

You would have realized that usage of microwave as one of the techniques of food processing, has tremendously increased in recent times. Can you suggest why? Here, in this section, we would look into various aspects of microwave processing which make it a choice of food technologists, as well as, households.

Food industry, in the recent years, has witnessed the emergence of microwave oven as a substitute for thermal oven for a number of food processes and products. Microwave processing results in an excellent retention of nutritional and sensory value, besides having other advantages namely savings in energy, cost, time etc. Though it had a limited applicability in the past, microwave processing is a boon to the food industry and it has a tremendous potential, if explored properly. The modern life, as well as, the increasing number of working industries requires simplified routines and standardization of foods with lesser preparation time and convenience in usage. The increasing consumer demands for foods, which offer more convenience in the use and savings in preparation, make the food processor to go for microwave oven as an alternative to the conventional thermal ovens. The speed with which the heating takes place in the microwave oven, contributes to the most to its rapid growth and practically, it has become a household item today.

Let us then understand what are microwave radiation, how they heat and their advantages, in the following sections.

12.3.1 A Look at Microwave Processing

The first thing which comes to our mind while on the topic of microwave processing is what microwaves are? Microwaves are basically *electromagnetic waves that have a frequency between 300 MHz and 300 GHz*. These two frequencies correspond to wavelengths of 1 m and 1 mm, respectively. All domestic microwave ovens and laboratory microwave processors operate at 2.45 GHz. Microwave energy is not suited for every application. But, in those applications where it fits, it can provide many process benefits. Let us look at the microwave process.

The most common way to heat a product is from the outside in – heat penetrates, molecule by molecule into the interior of the product. As a rule, when a product's moisture content is high (50 to 95%), conventional heating methods are the most economical technology. But heating products with a low moisture content (below 20%) is difficult. Microwave energy has the unique ability to heat certain molecules while not heating others. Because of this unique characteristic, microwave energy often is employed to draw out the last few percent of moisture in a range of products. This ability can be especially helpful in applications such as drying, where the residual moisture can have damaging results.

Microwaves pass through a product like light passes through glass. Materials without a dipolar electrical charge (some plastics, for example) do not react with the waves. However, asymmetrically charged materials, especially water, which is by far the most common material with a dipolar charge, react to the microwaves by trying to align themselves to the electromagnetic charge. Because of the microwaves electromagnetic field reverses as much as a couple of billions times per second, the dipolar molecules continually change alignment, producing energy that is converted into heat. The amount of energy converted is dependent on the electric field strength, the microwave frequency and the dielectric properties of the food. In effect, the water molecules heat themselves until the product becomes so hot that the water present in the product evaporates. Combination curing with microwave is better than any other heating methods. Microwaves can remove the last few percent of moisture from a product's interior and this process can be completed rapidly without overheating the already dried material. In fact, drying materials to levels as low as 3% moisture content, within a relatively short time is possible with microwaves.

In many applications where microwave technology is considered, a combination of microwave and conventional heating methods often is the best. Conductive or convective processing steps can be used before, during and after the microwave stage. The choice depends on product and the process. If microwaves are used first, the result is more effective for initial heating. If conventional and microwave heating are applied at the same time, there is a synergistic effect. Microwave heat pumps the product's moisture to the surface, where it is evaporated by convective airflow producing more effective drying than convection-only systems.

The heating of materials by microwave is affected by a number of properties of the equipment and the material being heated. The important factors influencing the heating patterns are:

- microwave frequency
- microwave power and speed of heating
- mass of the material
- moisture content of the product
- product density, and
- product temperature

A discussion on these factors follows:

- *Frequency:* There are two available frequencies for microwave heating-915 and 2,450 MHz, the frequency affects the depth of penetration into a material. Generally very large materials such as 30 kg blocks of frozen fish to be tempered might be better processed at 915 MHz, while the cooking of individual sausage patties favor 2,450 MHz.
- *Microwave power and speed of heating:* Most industrial systems operate at microwave power outputs ranging from 5 to 100 kW with some extending beyond these limits. The higher the power output, the faster the heating for a given mass. Varying the power output usually controls the speed of microwave heating. Speed is usually the most attractive feature of microwave heating. This is a double-edged sword, however, since it is possible to heat rapidly cooking, baking and other food processes are complex physiochemical systems requiring the input of heat to initiate and accelerate reactions. However, these reactions must occur in a proper order and be given proper time to occur. One of the best examples of critical nature of the rate of heat input is 'baking'. Another problem that can arise from excess speed of heating is non-uniform temperature distribution. This occurs because the heating may be so fast as to prevent the effectiveness of thermal conductivity in transferring the heat to the cooler portions.
- *Mass:* There are two considerations – the total mass being heated at one time and the mass of an individual piece, the latter will be treated below under physical geometry and density. As far as the total mass is concerned, there is a direct relationship between the mass and the amount of microwave power, which must be applied to achieve the desired heating. Microwave systems can be built to accommodate 25, 250 or 2500 kg or any amount of material per hour. When total mass is small, this might best be done in a batch oven, where the mass is large, it

would often be better done in a conveyorised system. Such systems have an added advantage of providing greater heating uniformity by moving the product though the microwave field.

- *Moisture content:* Water content is the major influencing factor that indicates how well materials, particularly foods, absorb microwave energy. Usually, the more water present, the higher the dielectric loss factor and hence the better heating. However, the lower moisture product may also heat well, since its specific heat decreases. As the product becomes dryer, very often wetter areas absorb the microwave energy preferentially and moisture-leveling effect is seen. This effect is very useful in drying operations.
- *Density:* The density of a product has an effect upon its dielectric constant. The dielectric constant of air is 1.0 and air is for all practical purposes, completely transparent at the industrial heating frequencies, thus air inclusion will reduce materials' dielectric constant. Hence as material's density increases so does its dielectric constant, almost linearly. Very porous material, such as bread dough, because of air inclusion are good insulators and become better insulators as they are baked and their density decreases. Thus, heat transfer into these materials is very difficult and slow, except in microwave heating, where microwaves penetrate deeply and are able to bake the bread in one third of conventional time or less.
- *Temperature:* The temperature of a material plays a role in microwave heating in several ways:

  1) The dielectric loss may increase or decrease with temperature, depending upon the material since temperatures and moisture levels change during heating, they may have a profound effect upon the dielectric properties.
  2) Freezing has a major effect upon a material's heating ability, because of the vast difference in dielectric properties of ice and water. Water is highly absorptive and heats faster, ice is highly transparent and doesn't heat. This is why *tempering*, the rising of the temperature of frozen materials to just below the thawing point, is done rather than *thawing*.
  3) The starting temperature of the food products being heated by microwaves should either be controlled or known, so the microwave power can be adjusted to obtain uniform final temperatures. In other words, if a microwave system is set to rise the temperature of the material from 200 to 800°C, but the starting temperature is only 150°C, it will rise the temperature to only 750°C unless the microwave power incidence into the system is increased.
  4) Higher core heating is achieved at 915 MHz and surface heating at 2450 MHz.
  5) Edge and corner overheating: Irregular shaped products heat non-uniformly. Chicken heats more near bone than in the meat.
  6) Spot heating in heterogeneous products: Frozen foods heat non-uniformly. Microwave penetration is greater in ice than in water but absorption in water is higher.

With the basic understanding on microwave heating, can you now enumerate the basic advantages of microwave processing? Try listing them down and tally your responses with the advantages enumerated herewith.

12.3.2 Advantages of Microwave Heating

Compounds with a high dielectric constant (e.g. water and ethanol) tend to heat readily under microwave heating, while less polar materials with no net dipole moment (e.g. CO_2) and highly ordered materials (such as ice) are poor microwave absorbers. This circumstance arises because energy transfer is not primarily by conduction or convection, as with conventional heating, but by dielectric loss. The difference in mechanism of heating offers the following advantages for microwave assisted processing:

1) Rapid response: The sample absorbs the energy directly, so the time required for the heating up reaction mixtures are short, allowing selectivity in some reactions and enabling operators to efficiently manage their work.
2) Because the reaction mixture heats directly, the chamber does not heat up substantially. When the power is turned off, heat input ceases immediately, an important safety consideration.
3) There are minimal temperature gradients across the reaction vessel, so the temperature of the material on the wall is not significantly different from that in the body of the reaction mixture.
4) Both continuous and batch microwave reactors can allow unstable products to be quickly cooled at the completion of the reaction.

Now that we know about the advantages of microwave assisted processing, can you next, suggest the applications of microwave i.e., the uses of microwave at home and/ or industrial level. We have highlighted few of the applications here for your knowledge.

12.3.3 Microwave Food Processing Applications

Table 12.2 lists microwave applications in food processing. In some instances, these processes can be extended to other similar products, e.g. the pasta drying process could be used in some variation in the process to dry many other food and agriculture products. Microwave vacuum drying has been applied to grains, seeds and fruit juices and could also be applied to various vegetables and other heat-sensitive materials. Microwave sterilization of foods in hermetically sealed containers is just now coming of age and has a great future.

Table 12.2: Food applications of microwave

Process	Products
Tempering	meat, fish, poultry
Cooking	bacon, meat patties, sausage, potatoes, sardines, chicken.
Drying	pasta, onions, rice cakes, egg yolk, snack foods, seaweed
Vacuum drying	orange juice, grains, seeds.
Freeze drying	meat, vegetables, fruits
Pasteurization	bread, yogurt.
Sterilization	pouch packed foods
Baking	bread, doughnuts
Roasting	nuts, grains
Blanching	vegetables, potatoes, corn, fruits
Rendering	lard, tallow

Microwaves are commonly used for reheating of pre-prepared chilled and frozen foods. The defrosting of frozen foods is best accomplished in stages with resting periods allowed for heat conduction within the food, so eliminating the formation of hot spots due to uneven microwave absorption. Most commercial microwave ovens have facilities that allow programming of a suitable sequence for the defrosting of frozen foods.

Whether used in combination with conventional heating or alone, microwaves have a place in industrial processing. Five potential applications are:

1) *Baking:* Microwave's ability to speed up the internal heating can accelerate the baking process. Microwave heating can be combined with convection heating to create a crispy crust and pleasing appearance in less time.

2) *Curing:* Because it leads to rapid heating throughout the product, microwaves may be used for bulk polymerization reactions that are heat initiated.

3) *Blanching:* When combined with a humid or steam atmosphere, rapid uniform heating with microwaves can be effective for blanching fruits and vegetables. Microwave processing does not incur the leaching losses associated with hot water or steam blanching.

4) *Removing Solvent:* Many solvents are efficiently vapourized with microwaves, permitting solvent removal at relatively low temperatures. Microwaves also can be used to cure glue and other adhesives.

5) *Moisture Leveling:* Because their heating effect is roughly proportional to the moisture content, microwaves can be used to equalize the moisture content within a product that has a non-uniform moisture level.

Finally, having read about the advantages and applications of microwave processing, can you now critically analyze and suggest the advantages of microwave over conventional heating. To help you in this task, we have highlighted the points in the next section, where we have compared microwave and conventional heating.

12.3.4 Microwave v/s. Conventional Heating

The primary difference between the supply of heat by microwaves or by the conventional thermal ways is in the initial distribution of heat. In conventional heating, the heat energy is applied to the outside surface of the food and it is conducted from there to the center of the food. With microwaves, food is heated principally by the generation and deposition of heat throughout a 3 dimensional space in the food itself. This is, therefore referred to as *volume heating*, because its effect is throughout the product. The food container and air in the oven will be heated only after they receive heat from the food. Thus, very rapid heating times can be obtained with direct coupling of the energy in to the product rather than placing the reliance on the transfer of heat energy through the container surface and subsequent conduction to the center of the mass.

The main advantage of microwave oven over conventional electric and gas ovens is its high thermal efficiency in converting the electrical energy to heat in the food. In ordinary ovens, a major portion of the energy is lost in heating the air that surrounds the food, fairly a good amount escapes through the vent, besides being lost through the conduction to the outside air. In contrast, almost all the heat generated by microwaves, which reaches the interior of the oven, is produced inside the food material itself. According to the reports, microwave ovens are 40% efficient as compared to 14% for standard electric ovens and 7% for gas ovens.

We shall end our discussion on microwave processing here and take up the discussion on another major method of food processing, involving the use of radiation i.e., food irradiation.

12.4 FOOD IRRADIATION

Food irradiation is one of the food processing technologies available to the food industry to control organisms that cause food-borne diseases and to reduce food losses due to spoilage and deterioration. Irradiation is *the use of radiation from gamma rays, x-rays, electron beams or radioactive materials on food.* The radiation sterilizes food and kills bacteria and controls certain factors that cause food spoilage but does not make the food itself radioactive.

Food irradiation technology too offers some advantages over conventional processes. Each application should be evaluated on its own merit as to whether irradiation provides a technical and economical solution that is better than traditional processing methods.

For products where irradiation is permitted, commercial applications depend on a number of factors including the demand for the benefits provided, competitiveness with alternative processes and the willingness of consumers to buy irradiated food products. There are a number of applications of food irradiation. For each application, it is important to determine the optimum dosage range required to achieve the desired effect. Too high a dosage can produce undesirable changes in texture, colour and taste of foods. Irradiation can extend the shelf-life of foods in a number of ways. By reducing the number of spoilage organisms (bacteria, mould and fungi), irradiation can lengthen the shelf-life of fruits and vegetables. Since ionising radiation interferes with cell division, it can be used as an alternative to chemicals to inhibit sprouting and thereby extend the shelf-life of potatoes, onions and garlic. Exposure of fruits and vegetables to ionizing radiation slows their rate of ripening. Strawberries, for example, have been found to be suitable for irradiation, their shelf-life can be extended three-fold, from 5 to 15 days.

Ionizing radiations can also be used as an alternative to chemical fumigants for disinfestation of grains, spices, fruits and vegetables. Many countries prohibit the import of products suspected of being contaminated with live insects to protect the importing country's agricultural base. With the banning of certain chemical fumigants, irradiation has the potential to facilitate the international shipment of food products.

Recently, there has been a lot of interest and controversy linked with irradiated foods. In this context, it is important to know about the global development and international trade perspective on this issue. The next sub-section throws some light on this interesting issue.

Global Developments and International Trade

Are irradiated foods wholesome and safe? What is the consensus on wholesomeness? Let's find out. In 1980, an FAD/IAEA/WHO Expert Committee reviewed in detail all the accumulated data on food irradiation from the past 40 years. The Expert Committee concluded that irradiation to an overall dose of 10 kGy (kilograys) presents no toxicological hazard and introduces no special nutritional or microbiological problems, thus establishing the wholesomeness of irradiated foods up to an overall average absorbed dose of 10 kGy.

Data were insufficient to formulate conclusions on applications of food irradiation above 10 kGy. Data on radiation chemistry, nutritional and microbiological aspects of food treated above 10 kGy is currently being compiled.

In 1983, *the Codex Alimentarius Commission*, an international group that develops global food standards for the FAO and the WHO, incorporated the 1980 Expert Committee's conclusions regarding the wholesomeness of irradiated foods into the Codex General Standard for Irradiated Foods. This proposed international standard was submitted to member countries to accept or to modify according to individual country needs. Currently, most countries that allow food irradiation approve its use on a case-by-case basis.

The *Codex Alimentarius Commission* has also adopted a *Recommended International Code of Practice* for the *Operation of Radiation Facilities for the Treatment of Foods*. It is intended to serve as a guide for irradiation operators and government regulators.

What about the International Trade?

More than 30 countries have given clearances for the use of food irradiation to process some 40 food items and approximately 30 facilities world-wide treat food by irradiation processing. Approvals for additional items are being considered in many countries and many food irradiation facilities are being planned. It was anticipated in 1988 that by 1990 there could be approximately 50 commercial/demonstration irradiators in 25 countries.

Check Your Progress Exercise 2

1) Fill in the blanks:

   i) Microwaves are...waves with a frequency between .... and ....

   ii) Microwaves heat a product by generating and depositing heat in the food itself. This is called .... heating.

   iii) Heating products with .... moisture content is difficult as compared to ....moisture content.

   iv) One of the purpose of food irradiation is to control organisms that cause ....diseases and reduce .... loss.

   v) A high radiation dose can lead to undesirable changes in ...., ... and .... of foods.

   vi) Ionizing radiations can extend the shelf-life and inhibit sprouting because they interfere with... .

2) Describe the mechanism of microwave processing.

   ....

   ....

   ....

3) What are the factors that influence microwave heating pattern?

   ....

   ....

4) List a few advantages of microwave heating over conventional heating.

   ....

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   ....

5) Mention a few potential applications of microwave heating.

   ....

   ....

6) Define irradiation.

   ....

   ....

Next let us study about one of the ancient methods of food processing and preservation i.e., fermentation.

12.5 FERMENTATION

Fermented foods, whether from plant or animal origin, are an intricate part of the diet of people in all parts of the world. It is the diversity of raw materials used as substrates, methods of preparation and sensory qualities of finished products that are so astounding, as one begins to learn more about the eating habits of various cultures. The preparation of many indigenous or "traditional" fermented foods and beverages remains as a household art. The preparation of others, e.g. soy sauce, has evolved to a biotechnological state and is carried out on a large commercial scale.

Fermented foods which are reviewed in the following section, including bread, fermented dairy products, vegetables and sauces, coffee and cocoa, have been scientifically studied during many decades and knowledge about these foods keeps pace with developments in modern science. This resulted in production methods that follow advances in modern technology. Fermented foods, which are popular in Japan include *shoyu* (fermented soybean products), *miso* (fermented soybean products), *natto* (soybean products, made by fermentation with bacteria) and *sake*, have followed the same modern trend. In contrast, some other fermented foods of Asian and African countries including *emple, gari, kimchi* and some other have come to the attention of modern scientists only in the last two decades and many others have not yet been studied at all. Consequently, most of these foods are still manufactured according to traditional, less technologically advanced methods, using simple equipments and produced on a small village industrial scale or just at home for family consumption. You may recall, we have studied about fermented foods in the Food Microbiology and Safety Course in Unit 1 also.

Before we continue further with our study on fermented foods, let us first understand what we mean by fermented foods. Basically, fermented foods are *agricultural products which have been converted by enzymic activities of microorganisms into desirable food products whose properties are considered more attractive than those of the original raw materials.* In addition to its external attractive properties, its nutritional values and keeping qualities are in many cases better than the raw materials. Moreover, if the manufacturing procedures are followed, the foods are usually safe for consumption. All of these beneficial properties of the final product increase the economic value of the original agricultural commodity. Generally, traditional methods of manufacturing fermented foods are not complicated and expensive equipment is not required. Therefore, fermentation of indigenous foods is considered as an inexpensive and effective means of food production that could be utilized in alleviating World food problems. Some common fermented foods used in Indian cuisine are highlighted herewith in Box 12.1, for your reference and better understanding of the fermentation process.

Box 12.1: Fermented Foods of India

You may be familiar with the fermented foods used in India. A brief description of these foods follows:

Idli: Idli is a fermented and steamed snack made from various proportions of rice and black gram. It is typically eaten for breakfast and is especially popular in South India, although consumed throughout the country. Proportions of rice to black gram cotyledons, used to prepare *idli* range from 1:4 to 4:1, depending upon the taste preference and availability of ingredients. *Idli* containing higher amounts of rice is characterized by a more predominant starchy flavour. Other ingredients such as cashew nuts, ghee, chilli peppers, ginger, fried cumin seeds or curry leaves may be added to the dough in small quantities to impart an additional flavour.

Dehulled black gram and rice are washed and soaked in water separately for 5 to 10 hours at an ambient temperature. The amount of soaking water can vary from 1.5 to 2.2 times the dry weight of the black gram or rice. About 1.5 times water over dry ingredients is optimum for fermentation and for *idli* preparation. After soaking, the black gram is ground with water to give a coarse paste, whereas, the rice is ground to give a smooth gelatinous paste. Salt (about 0.8%) is added to the combined mixture of pastes and fermentation is allowed to proceed for 15 to 24 hours. Upon steaming, the softy, spongy final product resembling a sour bread or pancake is consumed, while still hot. The spongy open texture of *idli* is attributed to the protein (globulin) and polysaccharide (arabino-galactan) in black gram.

Acidification and leavening are the most important processes which occur during fermentation. *Idli* batter volume increases 1.6 to 3.1 times and the pH falls from an initial 6.0 to 4.3 during fermentation. Thus, the sour taste of *idli* is a necessary and desirable characteristic. While several reports have been made on the microbiology of *idli* fermentation, no comprehensive studies on the microorganisms involved and the changes brought about by them have been made. Bacteria identified as a part of the microflora responsible for the production of good *idli* include *Leuconostoc mesenteroides, Lactobacillus delbrueckii, L.fermenti, L.lactis, Streptococcus faecalis* and *Pediococcus cerevisiae.* Yeasts involved in *idli* fermentation include *Oidium lactis (Geotrichum candidum), Torulopsis holmii, T.candida* and *Trichosporon pullulans.* Soured buttermilk or yeast is sometimes added to the dough to reduce the fermentation time and, consequently, influence the microbial profile of the total fermentation process.

The lactic acid bacteria are obviously responsible for pH reduction in *idli*. They may also contribute significantly to the improvement of the nutritional value of unfermented black gram and rice. The effects of *Leuconostoc mesenteroides, Lactobacillus fermenti, L.delbrueckii* and *Bacillus* species on changes in amino nitrogen, free sugar, thiamin, riboflavin and inorganic phosphate content, as well as, sensory qualities of traditional *idli*, rice-soyabean *idli* (black gram replaced by soyabeans), *dhokla* and *khaman* have been investigated. The increase in thiamine and riboflavin contents as a result of fermentation is particularly notable in the light of inadequacies of these vitamins in the diets of some Indian children. Bacteria may also play a role in the breakdown of phytate present in black gram. A strain of *L.mesenteroides* isolated from soyabean *idli* secretes *–N-acetylglucosaminidase* and *–D-mannosidase,* which are involved in the hydrolysis of hemagglutinin, has been reported.

There is some debate as to the effect of fermentation of *idli* on the Protein Efficiency Ratio (PER). The PER of *idli* was improved as a result of fermentation. In some cases, an increase in methionine content resulting from fermentation has been observed. A loss of 77% of the inorganic sulfur during black gram and rice blend fermentation was also reported. Using in-vitro digestion techniques, an improvement in the availability of essential amino acids during the fermentation has been reported. Studies on the substitution of other *Phaseolus* species for black gram have shown that the products with acceptability comparable to that of a traditional *idli* can be prepared. Evaluation of soyabean *idli* prepared using several types of bacterial inoculants has also been attempted. It was concluded that chemical, physical and organoleptic characteristics of the soybean products are not unlike that of traditional *idli. Idli* containing great northern beans (*Phaseolus vulgaris L.*) in place of black gram, has also been evaluated. *Idli* containing great northern beans had somewhat different flavour and a sticky top surface. The incorporation of great northern beans into *idli* would offer the advantage of increased roughage.

Waries: Waries (*Punjabi waries*) are the spicy condiments shaped in the form of a ball about 3 to 8 cm in diameter, which are used in cooking with vegetables, grain legumes or rice in India. Dehulled grain legumes are soaked in water, ground into a coarse paste and mixed with spices and a small amount of paste from a previous fermented batch. Some spices used include asafetida, caraway, cardamom, cloves, fenugreek, ginger, red pepper and salt. After fermenting as a mass for 4 to 10 days at ambient temperature, the paste is formed into balls and air-dried in the sun. The surface of the balls becomes sealed with a mucilaginous coating during the drying process, thus entrapping gases produced by the yeasts present inside. Yeasts identified as contributing to fermentation of *waries* are *Candida* spp. and *Saccharomyces cerevisiae.* Waries can also be prepared from bengal gram and mung bean flours.

Papadam: Papadam is similar to *waries*, but does not contain fenugreek or ginger. These circular tortilla-like wafers are prepared from a mixture of black gram paste and spices, which have been fermented for 4 to 6 hours. Yeasts responsible for fermentation are the same as those found in *waries. Papadams* are served either roasted or deep fat fried and consumed as a relish.

Dhokla: Dhokla is a steamed fermented food prepared from a mixture of wheat semolina and bengal gram flours (2:1 ratio). The flours plus about 3% salt are made into a thick batter by adding water and then allowing them to ferment by adding water and then further allowing them to ferment for about 14 hours. Chopped fenugreek leaves are added to the dough before steaming for 20 minutes in a pan with oil. The product is then cut into pieces and may be seasoned with cracked mustard seeds before eating as a condiment with other breakfast foods in India.

Khaman: Khaman is a steamed and fermented condiment prepared from bengal gram flour in India. Dehulled seeds are washed, soaked for 4 hours, ground with water (2:3, bengal gram:water) and seasoned with salt before fermenting for 12 hour. Like *dhokla*, the dough is then steamed and seasoned with mustard seeds before eating. Thiamin and riboflavin are reported to increase significantly.

Kenima: Kenima is a fermented soyabean product prepared in Nepal, Sikkim and Darjeeling districts of India. Soyabeans are soaked over night, dehulled and cooked in water for 2 to 3 hours. The cooled soybeans are inoculated by the addition of a portion from a fermented batch, wrapped in leaves and fermented at 22°C to 23°C for 24 to 48 hrs. The microorganisms responsible for the mucilaginous end product known as *kenima* have not been identified. When deep fat fried and salted, *kenima* has a nut-like flavour, much like that of tempeh.

Jalebies: Jalebies are a spiral shaped, deep fat fried confectionary product made from fermented wheat flour. Chickpea flour may be added to the fermented wheat flour before the paste is fried. The fresh fried *jalebies* are dipped in the sugar syrup.

Kurdi: Kurdi is a deep – fat fried, salty, crispy product prepared from fermented wheat. Wheat grains are soaked for about 5 days at 30°C, before the slurry is fried to make the snack, which is consumed in Central India. Little is known about the fermentation process, although yeasts and lactic acid bacteria are undoubtedly involved.

Kanji: Kanji is a fermented beer – like beverage, common in the households and market places in India. North Indian *kanji* is prepared from purple or occasionally orange cultivars of carrots, beets, spices, a portion from a previous batch of *kanji* and water. South Indian *kanji* is prepared in two steps, the first involving the preparation of *torani* (a fermented rice liquor) and the second involving the fermentation of *torani* and a mixture of vegetables, spices and water. *Hansenula anomala var. anomalahas* been isolated from *kanji* collected in North India (Delhi) whereas *H. anomala, Candida guilliermondii, C. tropicalis and Geotrichun candidum* have been isolated from the South Indian *kanji.*

In the recent years, a growing number of food scientists and microbiologists have recognized the value of indigenous fermented foods as a potential source of food supply for many parts of the world. Special attention is paid to the microorganisms and their role in the fermentation process. Consequently, in this unit you will find that we have classified indigenous fermented foods according to the microorganisms involved in the process. Let us learn about these different fermented foods used worldwide.

12.5.1 Types of Fermentation and Fermented Foods

Some foods are mainly fermented by moulds, others mainly by bacteria, another category by a mixture of moulds and yeasts and a number are firstly fermented by moulds followed by fermentation with a mixture of bacteria and yeasts. We will learn about these different fermented foods, starting with the foods prepared by mould fermentation.

Foods Fermented by Moulds

The most well known foods which are manufactured mainly by the activity of moulds are *Tempeh* (fermented soyabean product from Indonesia), *Oncom* and *Angkak*. *Tempeh* is made by fermentation of soybeans with *Rhizopus oligosporous*, *Oncom* is made form peanut press cake and is fermented by *Neurospora* species, *Angkak* is made by the fermentation of rice with *Monascus purpureus* to produce red coloured kernels. The product itself is not a food, but it is used to give an attractive red colour to certain products made of fish and soybeans to certain alcoholic beverages. What is the role of moulds in fermentation of foods? Read and find out.

Role of the moulds: The different functions of moulds in food fermentation include:

- *Synthesis of Enzymes:* One of the most important functions of the mould in food fermentations is synthesis of enzymes. These enzymes generally decompose complex compounds including proteins, carbohydrates and fats into smaller molecules. At the same time, other compounds may be synthesized from the food substrate. These complex chemical changes are accompanied by changes in the original properties of the raw materials. Taste, flavour, texture, colour, palatability and other properties of the raw materials are usually modified in such a way that the final product becomes more attractive to the consumer.

- *Mould Growth:* Mould growth on certain products contributes to the appearance of the food, which is desired by the consumer. For example, *Neurospora* spp. provides *oncom* – cakes with a coating of its pink-orange coloured and powdery conidia. *Rhizopus oligosporus* covers *tempeh* with a clean white mycelium surface layer and additionally has the function of binding together the soybeans into a solid, compact cake.

- *Synthesis of Colouring Compounds:* The function of *Monascus purpureus* during fermentation of *angkak* is to produce the red-coloured compound monascorubrin ($C_{22}H_{24}O_5$) and the yellow pigment monascoflavin ($C_{17}H_{22}O_4$) in soaked rice.

- *Protection of the Product*: In spite of the deep seated prejudice against mouldy products in the Occidental culture, which seems to be justified by the discovery of aflatoxin and other mycotoxins in the last two decades, studies on certain mould species, which are traditionally used for fermentation of Oriental foods, showed that they do not produce toxins, but, on the other hand, they resist accumulation of certain toxins which otherwise will be produced by other microorganisms in the food. This could be considered as a protection of the product against other harmful microorganisms. A good example of such a protective role is demonstrated by *Rhizopus oligosporus*, the mould species that is used for fermentation of *tempeh*. This mould species does not produce aflatoxin. On the contrary, if aflatoxin is already present in the growth substrate, its content could be lowered by *R.oligosporus* to about 40% of its original content. In addition, it was found that *R. oligosporus* inhibits growth, sporulation and aflatoxin production by *Aspergillus flavus*. Extended studies showed that other species of *Rhizopus*, including *R. arrhizus*, *R. oryzae* and *R. chinensis*, do not produce aflatoxin and on addition, inhibit aflatoxin production by *A. flavus* and *A. parasiticus* if they grow in the same substrate. Another study showed that when, during fermentation of coconut press cake into tempeh bongkrek, contamination takes place with *Pseudomonas cocovenenans*, toxin production by these bacteria under certain conditions is inhibited by *R. oligosporous*.

Foods Fermented by Bacteria

In vegetable, fish, as well as, some soybean fermentations, one or more species of lactic acid bacteria play an important role. Their production of organic acids not only contributes to the desired taste and flavour of the final product, but it also makes the substrates unfavourable for proliferation of spoilage and other undesirable microorganisms. At the same time, the acids make the substrate more suitable for growth of desirable microorganisms, which improve the properties of the food. The role of carbon dioxide produced by *Leuconostoc mesenteroides* is in different products not the same. In vegetable fermentations, it provides an anaerobic condition, which inhibits proliferation of aerobic microorganisms. In fermentation of *idli* and *puto*, carbon dioxide is essential for leavening the dough. As you read through this section you will realize that foods fermented by bacteria are made of different raw materials. In each of these raw materials, the bacteria involved have a different role. Let us then find out.

A) *Fermented Vegetable Products:* Production of fermented vegetables on a large scale took place for the first time during construction of the Chinese Great Wall in the third century B.C. The foods which were made of cabbage, radish, turnip, cucumber and other vegetables, were supplied as a portion of the workers' rations. In general, bacterial activity during fermentation of vegetables follows the same pattern. The majority of microorganisms on vegetables consists of strains of soil and water species of genera such as *Pseudomonas, flavobacterium, Achromobacter, Aerobacter, Escherichia and Bacillus.* Lactic acid bacteria, which are required for the desired fermentation, are originally present in comparatively low numbers. At the start of the fermentation, salt is added in such a concentration (2.5-6.0%) that undesirable putrefactive bacteria are kept under control, long enough to favour lactic acid producing bacteria to proliferate. Under these conditions, *Leuconostoc mesenteroides* is considered to establish proper environmental conditions for proliferation of other species of lactic acid bacteria rather than producing favourful compounds. *Lactobacillus brevis* is important in imparting character to the final product and is often characterized by its ability to ferment pentose sugars. *Lactobacillus plantarum* is the high acid-producing species, and together with *P. cerevisiae* plays a major role, particularly in fermentation of vegetables in brine. In brine, acidity beyond 1% is rarely attained, while in a dry-salted vegetable, an acidity of 2.0-2.5% can be reached if sufficient sugar is present.

B) *Fermented Fish Products:* Large quantities of small fish are fermented to produce fish or shrimp sauces and pastes in South East Asia. The basic procedure is to mix the freshly netted small and trash fish with sea salt to such an amount that the extracted fish juices contain about 20% salt in final product. The fish sauces are salty condiments to be added in small quantities to other foods. Similar process in which less hydrolysis occurs, lead to fish or shrimp pastes. The pastes may be mixed with cereals. Despite their high protein content, these products are of limited nutritional value because of the low level of consumption. The role of microorganisms in the fermentation process is clearly different from that in fermented vegetable products. The high salt content of these products leaves only salt-tolerant microorganisms survive. These originated from the natural microbial population of the fish or shrimp itself, and from the salt and microorganisms introduced during the manufacturing process from fermentation tanks, equipments and workers.

C) *Fermented Seeds:* Here we shall discuss about a few fermented seeds which are generally area-specific. Let us start our discussion on fermented soyabean products.

   Natto: One of the few soybean products, which are made by fermentation with bacteria, is the Japanese *natto*. It is made of soaked and cooked soybeans which traditionally are wrapped in rice straw and left for one or two days in a warm place. The rice straw is considered to have various functions. It supplies the essential microorganisms for the fermentation, provides the aroma of straw to the product, which is considered pleasing and absorbs partly the unpleasant odour of ammonia, which is released during the fermentation. The essential microorganisms for this fermentation were found to be *Bacillus natto,* which is classified as a related strain of *B. subtilis*. During the fermentation, the beans become covered with a viscous, sticky polymer. The product is considered of good quality if long stringy threads are formed when two beans are pulled apart. *Natto* has a slimy appearance and has a gray colour, its flavour is strong and persistent. It is consumed with rice or used as a side dish. Although *natto* is well known in Japan because of its exceptional properties, it is not as popular as other fermented soybean products, including *miso* and *shoyu*. Similar to other traditional Japanese fermented foods, *natto* has been scientifically studied, and production on a modern technological base using a pure culture starter has been developed. One of the new developments is production of powdered *natto*, which could be added to biscuits or soup.

Thua-nao: Thua-nao is a food product of Thailand, which closely resembles *natto.* Unlike *natto*, however, *thua-nao* is lightly mashed into a paste to which salt and other flavouring agents are added.

Dage: Dage is an Indonesian food product made of different oil-rich seeds *(Mucuna pruriens, Aleurites moluccana, Arachis hypogae* and others) or their residues. Like traditional *natto*, it is subjected to natural fermentation by bacteria. On a very limited scale, *dage* is made at home and used as a side dish or as an ingredient in preparing certain dishes. Not much is known about the microbiology and biochemistry of this type of products, which is of very limited importance.

D) *Fermented Starch-rich Raw materials:* Fermentation of starch-rich substrates by bacteria into fermented foods is practised mainly in Africa. The most important raw materials are maize *(Zea mays)* and cassava (*Manihot* sp.)

E) *Fermented Maize Products:* Not less than 20 different fermented maize products are known in African countries. Manufacture of these foods follows basically the same outline. Corn is soaked for one to three days, ground and mixed with some water to make thick dough. During preparation of *banku, kenkey, akpler* and other foods, the mash is left one to three days for fermentation. However, if *ogi* or *agidi* are to be made, the mash of ground maize is diluted with water, sieved to remove the bran and the filtrate left for fermentation. Presumably, the fermentation process in the thick maize dough, as well as, in the diluted maize suspension follows the same pattern. The microorganisms involved may be the same as in *ogi*. It was found that *Corynebacterium* spp. hydrolyzed starch and initiated acidification, later on, it was replaced by *Aerobacter cloace*. The highest acidity, mainly attributable to lactic acid was produced by *Lactobacillus plantarum*. At the beginning of the souring period, *Saccharomyces cerevisiae* proliferates rapidly while, at the end, *Candida mycoderma* was predominant. These two microorganisms were considered to contribute to the flavour of the product and to its enrichment with vitamins. *Aerobacter cloacae*, on the other hand, decreased the thiamin and panthothenic acid contents, but increased the riboflavin and niacin contents. In most cases, the fermented mash is concentrated by cooking until it becomes a thick porridge or cake.

F) *Fermented Rice Products:* We are all familiar with *idli, dosa* etc., the fermented rice products from south of India. *Idli* is soft and spongy steamed bread, which is now popular all over India. It is made from a mixture of milled rice and dehulled black gram (*Phaseolus mungo*), which is left for natural fermentation overnight. Instead of yeasts, which are usually required for manufacturing bread, the predominant microorganism producing acid and gas in the natural fermentation of *idli* is *Leuconostoc mesenteroides.* This bacterium is generally present on Indian black gram. In the later stages of the fermentation, *Streptococcus faecalis* and *P. cerevisiae* may also play a role. It was reported that the fermentation does not improve the nutritional value, but it does improves the palatability of the product in terms of flavour, taste and texture. When the dough has been raised sufficiently, it is steamed and is served while it is hot. It is a common snack or breakfast food used almost daily in the homes and restaurants in India. Similar foods in India are *dosa* and *appam* which are made by fermentation of a mixture of rice, other legumes and certain ingredients. These are essentially pancakes, which are prepared on a hot pan after the fermentation is finished. *Puto* from the Philippines is essentially steamed bread or cake made by natural fermentation of fine-ground flour of glutinous rice. The carbon dioxide for leavening the dough is presumably produced by the same species of lactic acid bacteria as for manufacture of *idli*.

G) *Fermented Cassava:* In several countries of West Africa (Nigeria, Ghana), *gari* is an important staple food. For its manufacture, fresh cassava *(Manihot utilissima)* is peeled, grated and the greater part of the juice squeezed out. The remaining pulp is left for three or four days for natural fermentation to occur. In the first stage, *Corynebacterium* spp. attacks the starch with production of organic acids. The lower pH value causes hydrolysis of a cyanogenic glucoside with liberation of gaseous hydrocyanic acid. Organic acids also make conditions favourable for growth of *Geotrichum candidum*. This microorganism produces a variety of aldehydes and esters, which are responsible for the characteristic taste and aroma of *gari*. Other reports also mentioned the probable role of *Leuconostoc* spp. and *Streptococcus faecium*. The fermented pulp is finally fried in iron or earthenware pans. Sometimes the pan is greased with palm-oil, in which case the *gari* comes out yellow. The resulting product is dry and granular and has the property of swelling up in cold water. It can be consumed simply with water, without any cooking. Sugar may be added, or it may be mixed with spices (pepper) or other foods like fish or egg.

H) *Fermented Plant Juice:* Throughout the tropics, the sugar of palm trees of many species is spontaneously fermented into alcoholic beverages. The microflora isolated during this fermentation are rather complex, but it is considered certain that *Zymomonas* spp. are largely responsible for the alcoholic content (4-5%) and carbon dioxide formation. The fruity odour and the taste of palm wine may be also due to production of some acetaldehydes by *Zymomonas* spp. Lactic acid bacteria contribute to the acidity by producing small amounts of lactic and acetic acids. Similar bacterial alcoholic fermentation occurs during fermentation of the juice of certain species of *Agave* in Mexico to produce the alcoholic beverage pulque. Only small numbers of yeast cells are usually found in these alcoholic beverages. Because formation of alcohol and carbon dioxide from sugar fermentation is a characteristic of yeasts, alcoholic fermentation by bacteria is not a common process.

The discussion so far focussed on foods fermented by bacteria. You would realize that moulds and yeasts too play an important role in fermentation. The next section highlights the foods fermented by moulds and yeast.

Foods Fermented by a mixture of Moulds and Yeasts

After focusing on bacteria, here, we shall look at the fermented foods produced by the action of moulds and yeasts. We start with *ragi*.

Ragi: Ragi itself is not a food, it is an inoculum used to induce fermentation of certain food products. It is known in many Asian countries under different names. Most probably, its origin is China, where *'chu'* was already described in the Old Chinese classics as the most important ingredient in the manufacture of alcoholic beverages. Later records gave thorough descriptions of its preparation and applications. It is made of rice flour, which is moulded into flattened round cakes of 2-3 cm diameter. Numerous fungi and yeasts have been isolated from *ragi*. Of the many mould species which have been isolated from *ragi*, *Mucor* and *Rhizopus* species are the most important. *Chlamydomucor oryzae*, recently re-identified as *Amylomycesrouxii,* plays a major role. Yeast srains isolated from *ragi* included species of *Candida, Endomycopsis* and also *Saccharomyces.* They produce alcohol from the sugar, which is produced from starch by the mould. It was found that for a good fermentation of glutinous rice into good quality tape, a combination of *Chlamydomucor oryzae* and *Endomycopsis chotadi* was essential. This combination of microorganisms was the starting point for later studies on tape fermentation.

Having learnt about *ragi* and the microorganisms involved in its preparation, next let us learn about the starch-rich preparations which can be prepared using *ragi*.

Fermented starch-rich raw materials: When *ragi* is innoculated into a starch-containing substrate like steamed rice, cassava, maize or sorghum, a soft juicy product with a sweet, mild sour taste and mild alcoholic flavour is obtained after two or three days incubation at 25-30^{o}C. Let us get to how about the other fermented products.

Fermented Rice: Such a product made of rice is known in different countries under different names. It is consumed as such, without any preparation and is considered as a delicacy. In China, *lao-chao* has a unique place in the diets of new mothers. It is believed that *lao-chao* helps them regain their strength.

Bern: In Indonesia, a confectionary is made by separating the juice which is produced during the fermentation of *tape ketan*. Traditionally, the liquid is dried in the sun until a solid cake is obtained. It is considered a delicacy, particularly for children and is known under the name of *brem.*

Rice Wine: When fermentation of rice is extended to several weeks, more alcohol and more liquid are produced. To produce *rice wine,* the liquid is expressed and kept for clarification and ripening during several months. The beverage is well-known under different names in different countries. Depending on the fermentation time, the alcohol content differs and a concentration of 15% can be reached. By distillation, a beverage can be obtained with approximately 50% alcohol.

Tape-ketcella: In Indonesia, peeled, washed and steamed cassava tubers are fermented by inoculation with ragi to produce *tape-ketcella* or *peuyeum.* The final product is food with a soft texture, a lightly sour-sweet taste and a mild alcoholic flavour. It is considered as a delicacy and is usually consumed without additional preparation. Sometimes it is shortly deep-fried in coconut oil before consumption. It may also be mixed with other ingredients to make a kind of pie.

There are certain fermented food preparations which are formed by the action of moulds, bacteria and yeast put together. Let us learn about such food preparations next.

Foods firstly fermented by moulds followed by fermentation with a mixture of bacteria and yeasts

The most studied foods in this category are those developed in Japan from traditional foods produced on a scale ranging from a house industry to high-industrialized products. These include *shoyu,* the Japanese type of soy sauce, and *miso*, a pasty product made of a mixture of rice and soybeans. For its fermentation, the traditional inoculum

Tane koji is applied. Let's get to know about these products.

a) *Tane koji:* Presumably, this starter originated from ancient China and was introduced into Japan in about 200 A.D. Once in Japan, it followed a typical Japanese way of development. From a traditional inoculum, it has developed into an inoculum made of pure cultures of mould strains whose properties are studied and controlled with the newest methods of modern microbiology. It is a green-yellow powder consisting of mould spores of one or more selected strains of *Aspergillus oryzae* and *A. soyae* which produce protease, amylases and a great variety of other enzymes. Modern day *tane koji* for a particular fermentation is composed of spores of several strains of *A.oryzae* mixed together in a definite proportion in order that various enzymes can be produced in the proper amounts during the different stages of fermentation.

b) *Soy Sauce:* Soy sauce is a brown coloured, liquid condiment which has different names in different countries. It is made by a two-stage batch fermentation, which involves the biochemical activities of moulds, bacteria and yeasts. The first stage consists of growing one or more mould species on cooked soybeans or on a mixture of soybeans and wheat, oats, rye or tapioca. Japanese *shoyu* is made from equal amounts of soybeans and wheat. For the fermentation of Japanese *shoyu*, the raw materials are inoculated with *Tane koji*, which contains spores of selected strains of *Aspergillus oryzae* and *A. soyae*. In less sophisticated traditional soysauce factories throughout South East Asia, mould species grow spontaneously on the soybeans by natural contamination from the air and from the bamboo trays on which soybeans of former batches were incubated. The moulds involved are species of *Aspergillus, Rhizopus* or *Mucor.* Some Indonesian *kecap* manufacturers inoculate the cooked soybeans with *tempeh* inoculum, which contains spores of *Rhizopus oligosporus*. In this first stage of mould fermentation, enzymic breakdown of insoluble protein in the raw materials into soluble polypeptides, peptides and amino acids takes place by extracellular proteases of the mould. Starches are hydrolyzed to disaccharides and monosaccharides by amylase secreted by the mould, while extracellular invertase hydrolyses sucrose in the soybeans.

When after two or three days, mould growth has reached a certain level, the moulded raw materials are placed into brine containing 15-20% sodium chloride, in which the second stage of fermentation takes place. The contribution of bacteria and yeasts in this second part of the fermentation to the development of flavour and taste of soy sauce is well documented. After a fermentation of at least six months duration and traditionally two or three years, the liquid is removed by decanting or siphoning. In modern factories, the liquid is expressed with a hydraulic press from the residue. After final treatments including pasteurization, clarification, filtration and eventually addition of chemical preservatives, the brown liquid is bottled for distribution to the consumers. Basically, there are two major kinds of soy sauce. The Chinese type is made of soybeans alone or from a mixture of soybeans and wheat with a higher percentage of the soybeans. In some cases, wheat could be substituted by wheat bran, oats, *kaoliang* and rye. An Indonesian *kecap* manufacturer uses tapioca-flour for this purpose. The Chinese type soy sauce is of high specific gravity and viscosity and high nitrogen content, it is dark in colour and is sometimes sweetened with cane sugar. The Japanese type soy sauce is made of equal amounts of soybeans and wheat. It is lower in viscosity and lighter in colour than the Chinese type.

c) *Other Fermented Soybean Products:* Several other soybean products as indicated in Table 12.3 are basically similar to soy sauce with respect to microorganisms and fermentation principles, although the composition of raw materials, methods of manufacture, consistency and appearance of the final foods are all different.

In the first stage of fermentation, moulds are grown on cooked soybeans or on a mixture of soybeans and cassava flour for the manufacture of *taoco.* In many Japanese families, breakfast consists of cooked rice and *miso* soup. *Miso* is also used as seasoning agent to prepare fish and vegetable dishes. For production of *miso*, the moulds are grown on steamed rice. The moulds are introduced as spores of *Aspergillus oryzae* and *A. soyae* in *tane koji*. A mixture of soybeans and wheat flour is used for the manufacture of *hamanatto*. The other less sophisticated products could be purposely inoculated or naturally contaminated with strains of *Aspergillus oryzae, Rhizopus oryzae, R. oligosporus* or a mixture of two or more species.

Table 12.3: Soybean foods produced by a two stage fermentation

Country	Product
Japan	Hamanatto
Japan	Miso
Orient	Soy sauce
Indonesia	Taoco
Philippines	Tao-si
China Japan	Tou-shih

We conclude our discussion on fermented foods, by presenting a brief review of specific aspects related to the fermented foods discussed so far.

Specific Aspects of Fermented Foods

A. Mould Species: The mould species that are traditionally used for the fermentation of foods in different parts of the World belong to different genera. Species of *Rhizopus, Mucor* and *Aspergillus* are used for fermentation of foods throughout the Orient, with the exception of Japan. In Japan, it is restricted to species of *Aspergillus* including *A.oryzae* and *A.soyae*. The difference between Japan and other Asian countries in the application of mould species is thought to be due to the development of *tane koji* and its general use as a starter for food fermentation in Japan. *Tane koji* is made by growing moulds on steamed rice. In other Asian countries, on the other hand, *ragi*-type starters are in common use. These starters are made by cultivating moulds on cakes made of rice or wheat flour, which has not been steamed or cooked. The difference in preparing growth substrates for manufacture of the two types of inocula is thought to be the cause of a natural selection of the mould species which were developing in each of the type starters over many centuries, when they were produced with non-aseptic, traditional methods. The relative humidity of the areas may be an important selective factor, so that fungi in the order *Mucorales* are found in the tropics while *Aspergillus* species grow in semi tropical countries such as China and Japan. Exceptions in Asian countries are *Monascus purpureus* for manufacture of *angkak* from rice and *Neurospora* species for production of *oncom* from peanut press cake. In Occidental countries, only *Penicillium* species are used for fermentation of foods including Roquefort and Camembert types of cheeses and certain fermented meat products.

B. Lactic acid Bacteria: In vegetable, fish, as well as, some soybean fermentations, one or more species of lactic acid bacteria play an important role. Their production of organic acids not only contributes to the desired taste and flavour of the final product, but it also makes the substrates unfavourable for proliferation of spoilage and other undesirable microorganisms. At the same time, the acids make the substrate more suitable for growth of desirable microorganisms, which improve the properties of the food. The role of carbon dioxide produced by *Leuconostoc mesenteroids* is in different products not the same. In vegetable fermentations, it provides an anaerobic condition, which inhibits proliferation of aerobic microorganisms. In fermentation of *idli* and *puto,* carbon dioxide is essential for leavening the dough.

C. Yeasts: When yeasts are involved in the fermentation process, production of alcohols improves the aroma of the product. In addition, alcohol at a certain concentration makes the substrate unsuitable for microorganisms, which may create undesirable properties in the product. Combined with the organic acids that are produced by lactic acid bacteria, the inhibitory effect of alcohol on undesirable microorganisms is increased.

D Salt: Application of salt in fermentation of vegetables, fish and soybeans inhibits proliferation of putrefactive microorganisms. Salt also affects the development of pathogenic and toxin-producing species. Growth of *Salmonella* spp. is prevented by concentrations of about 6% sodium chloride. *Clostridium botulinum* is the species to which is attached most interest because of the fatal toxin produced when it multiplies in food, but all types of *Cl.botulinum* are inhibited by 10-12% salt. *Staphylococcus aureus* is able to resist up to 15% salt or occasionally even 20% but 5% is the highest salt concentration at which toxin fermentation is recorded. *Pseudomonas cocovenenas* died in 1% soya peptone medium containing 3.5% sodium chloride. Although 2% salt in a coconut medium did not suppress its growth, toxin production is completely suppressed. On the other hand, some useful and unharmful species, including lactic acid producing bacteria and some yeast species, are less affected by salt. *Lactobacillus delbrueckii* can adjust to growing readily on media containing 18% sodium chloride. The salt concentrations in many fermented foods are too high for microorganisms to cause undesirable effects. Fermented fish pastes contain 15-25% salt. For the manufacture of fish sauces approximately 30% salt is applied. In the fermentation of vegetables, moderate salt concentrations of between 4 and 6% are used in the brine. Not withstanding the marginal salt concentrations, if the required conditions are supplied, lactic acid producing bacteria will soon proliferate and produce enough acids. The combination of salt and acids will protect the product against undesirable effects of harmful microorganisms.

Considering also the protective role of certain mould species in fermented foods, it may be concluded that fermentation of indigenous foods is surrounded by many safety factors, provided the procedure of preparation is properly followed.

Check Your Progress Exercise 3

1) What do you mean by the term 'fermented foods'?

....

....

2) List a few fermented foods that are consumed in India.

....

....

3) What are the moulds and the functions of moulds in the fermentation of foods?

....

....

4) Fill in the blanks:

a) .... is an inoculum used to induce fermentation of food products. It is prepared from a mixture of .... and ....

b) The red-coloured compound is synthesized by ....during fermentation of angkak, while yellow pigment in soaked rice.

c) In fermentation, salt is added in a concentration of ....% .

d) .... alongwith *P.cerevisiae* plays a major role in the fermentation of vegetables in the brine.

e) The two microorganisms which contribute to the flavour in fermented maize products are .... and ....

12.6 DEEP FAT FRYING

All of us enjoy fried products, whether home-made or bought from market. Let us see what is the technology involved in frying process and the factors affecting it.

Deep fat frying is considered one of the oldest processes of food preparation. Deep fat frying can be defined as *a process of cooking and drying through contact with hot oil and it involves simultaneous heat and mass transfer.* For decades, consumers have desired deep-fat fried products because of their unique flavour-texture combination. During deep fat frying, a food product's surface is sealed when the product is immersed in hot oil so that all the flavours and the juices are retained in a crispy crust. Many foods have been successfully deep fat fried, examples include potato chips, french fries, doughnuts, extruded snacks, fish sticks and the traditional fried chicken products.

The frying technology is important to many sectors of the food industry, including suppliers of oils and ingredients, food service operators, food industries and manufacturers of frying equipment. The amount of food fried and oils used at both the industrial and commercial levels are vast.

We will start our understanding on this subject by first learning about the deep fat frying process and the factors that influence the process.

Deep Fat Frying Process

Deep fat frying involves simultaneous heat and mass transfer mechanisms. In addition, the physical properties of the material vary with changing temperature and moisture content. Therefore, theoretical treatment of the process is very complicated and a complete analytical solution to deep-fat frying processes is not available. Several simplified models have been developed, each of which is specified with regard to the material and boundary conditions. Many physical, chemical and nutritional changes occur in foods during deep-fat frying. Many of these changes are functions of oil temperature and quality, product moisture and oil contents and product residence time in the fryer. Undesirable effects could be minimized and the process could be better controlled if temperature, moisture and oil distribution in food with respect to time could be accurately predicted. In general, the frying process of a single product (french fries, for example) can be divided into four stages that are characterized by the following:

- *Initial Heating:* Short period, submersion of the food in the hot oil, product's surface heated to the boiling temperature of water, natural convection between oil and product's surface, no evaporation.
- *Surface Boiling:* Initial of evaporation, turbulence around the oil surrounding the product, forced convention between product's surface and hot oil, initiation crust formation at the product's surface.
- *Falling Rate:* More internal removal of moisture from the food, rise in internal core temperature to the boiling point, increase of crust layer in thickness, decrease in vapour transfer to the surface.
- *Bubble End Point:* Reduction of the rate of moisture removal, decrease of bubbles leaving from product's surface, continued increase in the crust layer thickness.

The quality of the products from deep fat frying depends on the process conditions and on the type of oils and foods used during the process. The factors that influence the frying process include:

- the temperature of the heated oil, time and the fryer type (batch or continuous)
- the chemical composition of the frying oils, the physical and physico-chemical constants
- the presence of additives and contaminants. These can have a marked effect on the palatability, digestibility and metabolic utilization of a fried food, and
- finally, the food weight / frying oil volume and surface area / volume ratios determine how much fat penetrates the food.

With a brief look at the factors influencing the deep fat frying process, we end our study on this topic.

Finally, let us learn about the use of salt, sugar and chemicals as preservatives.

12.7 USE OF SALT, SUGAR AND CHEMICALS AS PRESERVATIVES

Salt, sugar and chemicals have been used for ages as preservatives. What is the principle behind their use?

Sugar and salt in concentrated solutions have a high osmotic pressure. When these are sufficient to draw water from microbial cells or prevent normal diffusion of water into these cells, a preservative condition exists. The critical concentration of sugar in water to prevent microbial growth will vary depending upon the type of microorganisms and the presence of other food constituents, but usually 70% sucrose in solution will stop growth of all microorganisms in foods. Less than this concentration may be effective but for short periods of time unless the foods contain acid or they are refrigerated. Salt becomes a preservative when its concentration is increased. Levels of about 18% to 25% in solution generally will prevent all growth of microorganisms in foods. Except in the case of certain briny condiments, however, this level is rarely tolerated in foods. We have already looked at the role of salt in fermentation of foods earlier in sub-section 12.5.1.

Chemical food preservatives, on the other hand, are those substances which are added in very low quantities (up to 0.2%) and which do not alter the organoleptic and physico-chemical properties of the foods or only very little. Many chemicals will kill microorganisms or stop their growth, but most of these are not permitted in foods. Preservation of food products containing chemical food preservatives is usually based on the combined or synergistic activities of several additives, intrinsic product parameters (e.g. composition, acidity, water activity) and extrinsic factors (e.g. processing temperature, storage atmosphere and temperature). This approach minimizes undesirable changes in product properties and reduces concentration of additives and extent of processing treatments.

The concept of combinations of preservatives and treatments to preserve foods is frequently called the *'hurdle or barrier concept'*. Combinations of additives and preservatives systems provide unlimited preservation alternatives for applications in the food products to meet consumer demands for healthy and safe foods.

Chemical food preservatives are applied to foods as direct additives during processing or develop by themselves during processes such as fermentation. Certain preservatives have been used either accidentally or intentionally for centuries. These include sodium chloride (common salt), sugar, acids, alcohols and components of smoke. In addition to preservation, these compounds contribute to the quality and identity of the products and are applied through processing procedures such as salting, curing, fermentation and smoking.

Usual accepted chemical food preservatives are detailed in Table 12.4.

Table 12.4: Chemical food preservatives

Agent	Acceptable daily intake (mg/Kg body weight)	Commonly used levels (%)
Lactic acid	No limit	No limit
Citric acid	No limit	No limit
Acetic acid	No limit	No limit
Sodium Diacetate	15	0.3-0.5
Sodium benzoate	5	0.03-0.2
Sodium propionate	10	0.1-0.3
Potassium sorbate	25	0.05-0.2
Methyl paraben	10	0.05-0.1
Sodium nitrite	0.2	0.01-0.02
Sulphur dioxide	0.7	0.005-0.2

Some common chemical preservatives used in food products are summarized in Table 12.5.

Table 12.5: Common preservatives in food products

Preservative	Food products
Citric acid	fruit juices; jams; other sugar preserves
Acetic acid	vegetable pickles; other vegetable products
Sodium benzoate	vegetable pickles; preserves; jams; jellies; semi-processed products
Sodium propionate	fruits; vegetables
Potassium sorbate	fruits; vegetables; pickled products; jams, jellies
Methyl paraben	fruit products; pickles; preserves
Sulphur dioxide	fruit juices; dried / dehydrated fruits and vegetables; semi-processed products

Traditional chemical food preservatives and their use in fruit and vegetable processing technologies could be summarized as follows:

1) *Common salt:* brined vegetables

2) *Sugars* (sucrose, glucose, fructose and syrups)

   – foods preserved by high sugar concentrations: jellies, preserves, syrups, juice concentrates

   – interaction of sugar with other ingredients or processes such as drying and heating, and

   – indirect food preservation by sugar in products where fermentation is important (naturally acidified pickles and sauerkraut).

3) *Acidulants* and other preservatives formed or added to fruit and vegetable products include:

   Lactic acid: This acid is the main product of many food fermentations. It is formed by the microbial degradation of sugars in products such as sauerkraut and pickles. The acid produced in such fermentations decreases the pH to levels unfavourable for growth of spoilage organisms, such as putrefactive anaerobes and butyric acid-producing bacteria. Yeasts and moulds that can grow at such pH levels can be controlled by the inclusion of other preservatives, such as sorbate and benzoate.

Acetic acid: Acetic acid is a general preservative inhibiting many species of bacteria, yeasts and to a lesser extent, moulds. It is also a product of the lactic acid fermentation, and its preservative action even at identical pH levels is greater than that of lactic acid. The main applications of vinegar (acetic acid) include products such as pickles, sauces and ketchup as can be seen in Table 12.5.

Other acidulants include:

- Malic and tartaric (tartaric) acids are used in some countries mainly to acidify and preserve fruit sugar preserves, jams, jellies etc.
- Citric acid is the main acid found naturally in citrus fruits it is widely used (in carbonated beverages) and as an acidifying agent of foods, because of its unique flavour properties. It has an unlimited acceptable daily intake and is highly soluble in water. It is a less effective antimicrobial agent than other acids.
- Ascorbic acid or vitamin C, its isomer isoascorbic or erythorbic acid and their salts are highly soluble in water and safe to use in foods.

Commonly used lipophilic (fat loving) acid food preservatives

- *Benzoic acid* in the form of its sodium salt, constitutes one of the most common chemical food preservative. Sodium benzoate is a common preservative in acid or acidified foods such as fruit juices, syrups, jams and jellies, sauerkraut, pickles, preserves, fruit cocktails etc. as highlighted in Table 12.5. Yeasts are inhibited by benzoate to a greater extent than are moulds and bacteria.
- *Sorbic acid is* generally considered non-toxic and is metabolized among other common food preservatives. The WHO has set the highest acceptable daily intake (25 mg/kg body weight) for sorbic acid. Sorbic acid and its salts are practically tasteless and odourless in foods when used at reasonable levels (< 0.3 %) and their antimicrobial activity is generally adequate.
- *Sorbates* are used for mould and yeast inhibition in a variety of foods including fruits and vegetables, fruit juices, pickles, sauerkraut, syrups, jellies, jams, preserves, high moisture dehydrated fruits etc. Potassium sorbate, a white fluffy powder, is very soluble in water (over 50%) and when added to acid foods, it is hydrolyzed to the acid form. Sodium and calcium sorbates also have preservative activities, but their application is limited compared to that for the potassium salt, which is employed because of its stability, general ease of preparation and water solubility.

4) *Gaseous chemical food preservatives*:

a) *Sulphur dioxide and sulphites:* Sulphur dioxide (SO_2) has been used for many centuries as a fumigant and especially as a wine preservative. It is a colourless, suffocating, pungent-smelling, non-flammable gas and is very soluble in cold water (85 g in 100 ml at 25°C). Sulphur dioxide and its various sulphites dissolve in water and at low pH levels yield sulphurous acid, bisulphite and sulphite ions. The various sulphite salts contain 50-68% active sulphur dioxide. A pH dependent equilibrium is formed in water and the proportion of SO_2 ions increases with decreasing pH values. At pH values less than 4.0, the antimicrobial activity reaches its maximum. Sulphur dioxide is used as a gas or in the form of its sulphite, bisulphite and metabisulphite salts, which are powders. The gaseous form is produced either by burning sulphur or by its release from the compressed liquefied form. Metabisulphite is more stable to oxidation than bisulphites, which in turn show greater stability than sulphites.

The antimicrobial action of sulphur dioxide against yeasts, moulds and bacteria is selective, with some species being more resistant than others. *Sulphur dioxide* and *sulphites* are used in the preservation of a variety of food products. In addition to wines, these include dehydrated/dried fruits and vegetables, fruit juices, acid pickles, syrups, semi-processed fruit products etc. In addition to its antimicrobial effects, sulphur dioxide is added to foods for its antioxidant and reducing properties, and to prevent enzymatic and non-enzymatic browning reactions.

b) *Carbon dioxide:* Carbon dioxide (CO_2) is a colourless, odourless, non-combustible gas, acidic in odour and flavour. In commercial practice, it is sold as a liquid under pressure (58 kg per cm^3) or solidified as dry ice. Carbon dioxide is used as a solid (dry ice) in many countries as a means of low-temperature storage and transportation of food products. Besides keeping the temperature low, as it sublimes, the gaseous CO_2 inhibits growth of psychrotrophic microorganisms and prevents spoilage of the food (fruits and vegetables, etc.). Carbon dioxide is used as a direct additive in the storage of fruits and vegetables. In the controlled/modified environment storage of fruit and vegetables, the correct combination of O_2 and CO_2 delays respiration and ripening, as well as, retarding mould and yeast growth. The final result is an extended storage of the products for transportation and for consumption during the off-season. The amount of CO_2 (5-10%) is determined by factors such as nature of product, variety, climate and extent of storage.

c) *Chlorine:* The various forms of chlorine constitute the most widely used chemical sanitizer in the food industry. These chlorine forms include chlorine (Cl_2), sodium hypochlorite (NaOCl), calcium hypochlorite ($Ca(OCl)_2$) and chlorine dioxide gas (ClO_2). These compounds are used as water adjuncts in processes such as product washing, transport and cooling of heat-sterilized cans, in sanitizing solutions for equipment surfaces etc. Important applications of chlorine and its compounds include disinfection of drinking water and sanitation of food processing equipment.

While on the topic of chemical preservatives, we must understand that the use of these substances are subjected to certain rules. These general rules for chemical preservatives highlighted below require strict attention.

General rules for chemical preservation

Chemical food preservatives have to be used only at a dosage level, which is needed for a normal preservation and not more. “Reconditioning” of chemical preserved food, e.g. a new addition of preservative in order to stop a microbiological deterioration already occurred is not recommended. The use of chemical preservatives MUST be strictly limited to those substances which are recognized as being without harmful effects on human beings’ health and are accepted by National and International Standards and Legislations.

Next, you will find some general rules/points which you can keep in mind, while using chemical preservatives.

As a general rule, it is possible to take the following facts as a basis:

- sulphur dioxide and its derivatives can be considered as an “universal” preservative, they have an antiseptic action on bacteria, as well as, on yeasts and moulds
- benzoic acid and its derivatives have a preservative action which is stronger against bacteria than on yeasts and moulds
- sorbic acid acts on moulds and certain yeast species, in higher dosage levels it acts also on bacteria, except lactic and acetic ones, and

- formic acid is more active against yeasts and moulds and less on bacteria.

Remember, while using chemical preservatives, the initial number of microorganisms in the treated product determines the efficiency of the chemical preservative. The efficiency is less, if the product has been contaminated, because of preliminary careless hygienic treatment or an incipient alteration. Therefore, with a low initial number of microorganisms in the product, the preservative dosage level could be reduced.

Check Your Progress Exercise 4

1) Define deep fat frying as a process of food preparation.

....

....

2) How can the undesirable changes occurring in foods during deep fat frying be minimized?

....

....

....

3) List the stages of frying process and the factors affecting the frying process.

....

....

....

4) Explain barrier concept in the context of preservation.

....

....

5) Fill in the blanks:

   i) The substances which are added in very low quantities and do not alter the organoleptic and physico-chemical properties of the foods are .... preservatives.

   ii) ...., ..., ..., alcohol and components of smoke are a few of the chemical food preservatives.

   iii) An acidulant which has an unlimited acceptable daily intake is ....

   iv) SO_2 has been used for many centuries as a preservatives because of its antimicrobial activity, ,..............................., and .... property.

   v) Benzoic acid is a commonly used .... acid food preservative.

12.8 LET US SUM UP

In this unit, we have studied about a few more methods of food processing. Here, we had a detailed discussion on various commonly used, as well as, commercially employed methods of processing. These included simple and ancient methods such as freezing, fermentation, deep fat frying and use of chemical preservatives to the technologically advanced, recent methods such as microwave heating and irradiation.

Preparation of certain foods involving these processing techniques, particularly, fermentation have been described in this unit.

After going through this unit, and the previous one, your knowledge on the various food processing techniques must be complete.

12.9 GLOSSARY

Acidulant : food additives that are used to impart a sharp flavour, for instance citric acid.

Cryogenic Freezing : a fast, flexible and cheap method of freezing in which liquefied gases at an atmosphere below – 60°C, are placed in direct contact with the foods.

Deep fat Frying : a process of cooking and drying through contact with hot oil.

Hurdle or Barrier concept : combination of preservatives and treatments to preservatives and treatments to preserve foods.

Irradiation : use of radiation on food to sterilize food and kill bacteria and control certain factors that cause food spoilage, without making the food itself radioactive.

Sauerkraut : sour cabbage.

12.10 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1) i) microorganisms, chemical
   ii) 2-3
   iii) –1°C to 7°C
   iv) Psychrophillic
   v) cleanability, quality

2) Freezing, as a method of food preservation, is the easiest, most convenient and least time-consuming. It does not sterilize foods or destroy the organisms that cause spoilage. Instead the extreme cold simply slows down the microbial growth and the chemical changes that affect quality or cause spoilage.

3) Plate freezing, immersion freezing, contact with cooled gas are the different methods of freezing.

4) No, a single freezing system is not enough to satisfy all freezing needs because of a variety of food products and process characteristics.

5) Cryogenic freezing refers to the exposure of food, to an atmosphere below-60°C through direct contact with liquefied or vapourized gases such as N_2 and CO_2. It is a fast method, flexible, has a low capital cost, reduces evaporative weight loss, high product throughput, low floor space requirements, decreases damage due to cell rupture, preservs colour, texture, flavour and nutritional value.

Check Your Progress Exercise 2

1) i) electromagnetic, 300 MHz, 300 GHz
   ii) volume
   iii) low , high
   iv) foodborne , food

v) texture, colour, taste

vi) cell division

2) The electromagnetic field of microwaves reacts with water-charged material, symmetrically charged material. This reaction leads to the continual change in the alignment of dipolar charge of water, and consequently, production of energy that is converted into heat. This conversion depends on electric field strength, microwave frequency and dielectric properties of the food.

3) The factors that influence microwave heating pattern are microwave frequency, microwave power and speed of heating, mass of the materials, moisture content, density and temperature.

4) A few advantages of microwave heating over conventional heating are rapid response to heat up the reaction mixtures, the immediate cessation of heat input as soon as the power in turned off, minimal temperature gradients and quick cooling of the unstable products.

5) A few potential applications of microwave heating are baking, curing, blanching, removing solvents, moisture leveling.

6) Irradiation is the use of radiation from gamma rays, X-rays, electron beams or radioactive materials on food.

Check Your Progress Exercise 3

1) Fermented foods are the agricultural products which have been converted by enzymic activities of microorganisms into desirable food products whose properties are considered more attractive than those of the original raw material.

2) *Idli, Waries, Papadam, Dhokla, Khaman, Kenima, Jalebies, Kurdi, Kanji* are a few fermented foods that are consumed in India.

3) Species of *Rhizopus*, *Mucor* and *Aspergillus* are some of the moulds used for fermentation. The functions of moulds in the fermentation of foods are: synthesis of enzymes, mould growth, synthesis of colouring compounds and protection of the product.

4) a) *Ragi*, yeast, mould

b) *Monascus purpureus*

c) 2.5-6.0

d) *Lactobacillus plantarum*

e) *S. cerevisiae*, *Candida mycoderma*

Check Your Progress Exercise 4

1) Deep fat frying is a process of cooking and drying through contact with hot oil. It involves simultaneous heat and mass transfer.

2) The undesirable changes occurring in foods during deep fat frying can be minimized by predicting the temperature, moisture and oil distribution in foods with respect to time.

3) The stages of frying process are initial heating, surface boiling, falling rate and bubble end-point. The factors affecting the frying process include temperature of the heated oil, time and the type of fryer, chemical composition of the frying oils, the physical and physico-chemical constants, presence of additives and contaminants and food weight/ frying oil volume and surface area/volume ratios.

4) Barrier concept is the concept of combinations of preservatives and treatments to preserve foods.

5) i) chemical

   ii) Sodium chloride, sugar, acids

   iii) citric acid

   iv) antioxidant, reducing

   v) lipophilic

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