- **Content Creator:** Dr Mohammed Wasim Siddiqui, Bihar Agricultural University,Bhagalpur
- **Course Reviewer:** Dr.Jagmohan Singh, Sher-E-Kashmir University Of Agricultural Sciences And Technology Of Jammu, Jammu

Course Name	Fundamentals Of Food Technology
Lesson 1	Food, Food Groups, And Functions
Content Creator Name	Dr Mohammed Wasim Siddiqui
University/College Name	Bihar Agricultural University,Bhagalpur
Course Reviewer Name	Dr.Jagmohan Singh
University/college Name	Sher-E-Kashmir University Of Agricultural Sciences And Technology Of Jammu ,Jammu

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Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

Objective

1. To give a basic concept of food, food groups, its functions and nutrition
2. To aware students about healthy and balanced food

Glossary

Food: substance consisting essentially of protein, carbohydrate, fat, and other nutrients used in the body of an organism to sustain growth and vital processes and to furnish energy.

Food group: any of the categories into which different foods may be placed according to the type of nourishment they supply, such as carbohydrates or proteins

Nutrition: The process of taking in food and using it for growth, metabolism, and repair. Nutritional stages are ingestion, digestion, absorption, transport, assimilation, and excretion.

1.1 Food

Food is essential for the survival of living organisms. It provides us with energy to carry out daily activities and develop, grow and repair our body parts in case of any damage. Therefore understanding the importance of consuming the right kind of food becomes a necessity.

1.1 Social relation of Food

- Food is vital element for existence of life, we have acquired extensive knowledge about the use of food as part of its significance in community, social, and religious value. For the social value, food tells more than nutritional value in a community.
- It has been used as expression of love, share, friendship, and social acceptance.

- It has been symbol of happiness in certain occasions, celebration events, and many more.

1.2 Scientific knowledge about Food

- Food is anything (basically from plant and animal source) to be consumed (eaten or drunk) and absorbed by the body in order to gain energy, building, functioning, regulating & protecting material. Thus, food is fuel for life.
- Foods are complex substances composed of chemical constituents called nutrients. Thus, food is vital, basic component which nourishes the life. Food is the material which make our body, intake of proper & right food is necessary for maintaining a healthy life
- The consumption pattern of food varies based on different circumstances; geography, social & religious aspects, health & safety, Quality aspect, sensorial & textural properties, processing methods and applied engineering technology, and others.
- Foods is produced by farmers or gardeners and changed by industrial processing at food industries by the application of technologies.
- Processed food may include certain natural ingredients such as additives (preservatives, emulsifier, antioxidants, color, flavour, and many others), processing technologies alters the properties & structure, improve functionality of food, alters nutrients components, alters appearance and sensory properties, and many others depending on the applied technologies.

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1.2Classification of foods

- Based on the functions, foods are grouped as energy yielding, body building and protective, and other functions.
- Nutrient components (Carbohydrate, proteins, fat & oils, minerals and vitamins) involved in these activities can be termed as energy yielding nutrients, body-building nutrient, and protective nutrients.
- Carbohydrate, fat & oils, and proteins produces energy and can be considered as energy yielding.
- Proteins are essential components for body building, thus food rich in proteins are called body building foods.
- Protein, Minerals, and Vitamins are essential components to maintain better health. These components perform regulatory function of body such as heartbeat, water balance, transport, salt channel, immunity, and many others.

1.2.1 There are six major nutrients: Carbohydrates (CHO), Lipids (fats), Proteins, Vitamins, Minerals, Water.

The food groups which are the primary sources of each of the following:-

Proteins: meat, dairy, legumes, nuts, seafood and eggs

Carbohydrates: pasta, rice, cereals, breads, potatoes, milk, fruit, sugar

Lipids (most commonly called fats): oils, butter, margarine, nuts, seeds, avocados and olives, meat and seafood

Vitamins: common vitamins include the water soluble B group vitamins and vitamin C and the fat soluble vitamins A, D, E and K

Fruits and vegetables are generally good sources of Vitamin C and A and folic acid (a B group vitamin)

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Grains and cereals are generally good sources of the B group vitamins and fibre

Full-fat dairy and egg yolks are generally sources of the fat soluble vitamins A, D and E

Milk and vegetable or soya bean oil are generally good sources of vitamin K, which can also be synthesized by gut bacteria

Minerals: (sodium, calcium, iron, iodine, magnesium, etc.): all foods contain some form of minerals.

Milk and dairy products are a good source of calcium and magnesium

Red meat is a good source of iron and zinc

Seafood and vegetables (depending on the soil in which they are produced) are generally good sources of iodine

Water: As a beverage and a component of many foods, especially vegetables and fruits.

1.3 The 11-food group plan was suggested by the U.S. Department of Agriculture in 1964 is discussed below.

Note-You may refer for other food group plan depending on organizing body for your study from other source.

Food may be classified into 11 categories broadly

(1) Cereals and Grains
(2) Pulses (Legumes)
(3) Nuts and oilseeds
(4) Fruits & Vegetables
(5) Milk and milk products
(6) Eggs
(7) Meat, fish and other animal foods
(8) Fats and oils
(9) Sugar and other carbohydrate foods
(10) Spices and condiments

Note. The nutritional importance of the different food groups in planning balanced diets is will be discussed later.

1.3.1 Cereals

- Cereals are generally of the gramineous family and, in the FAO concept, refer to crops harvested for dry grain only.
- Cereals are the most important group of foodstuffs as they form the staple food of a large majority of the population throughout the world.
- They impart for 70 to 80 per cent of the diets of the low income groups in

  India and other developing countries.

- They contain about 6 to 12 per cent proteins and are good sources of some vitamins e.g., thiamine, niacin, pantothenic acid and vitamin B6 and minerals e.g., Phosphorus and iron.
- Hence, they provide 70 to 80 % of the calories, 6-10% of proteins and other nutrients mentioned above in the diets of the low income groups.
- All cereals except ragi are poor to moderate sources of Calcium. Ragi is one of the richest sources of Calcium containing about 344 mg/100g.
- Cereals are deficient in Vitamins A, D, B12 and C.
- Puffed cereals are consumed widely as a snack by the low income groups in India.
- Some common cereals products are; Wheat, Rice, Maize, Barley, Millets, Rye, Sorghum, Buckwheat, etc.

1.3.2 Pulses

- Legumes are a nutritious staple of diets around the world. They are an inexpensive source of protein, vitamins, complex carbohydrates, and fiber.
- Although used interchangeably, the terms “legumes,” “pulses,” and “beans” have distinct meanings. A legume refers to any plant from the Fabaceae family that would include its leaves, stems, and pods. A pulse is the edible seed from a legume plant. Pulses include beans, lentils, and peas. For example, a pea pod is a legume, but the pea inside the pod is the pulse. The entire legume plant is often used in agricultural applications (as cover crops or in livestock feed or fertilizers), while the seeds or pulses are what typically end up on our dinner plates. Beans in their various forms (kidney, black, pinto, navy, chickpeas, etc.) are just one type of pulse.
- Rich source of protein containing 18-25 % (may varies) approximately in different source.
- Good source of many vitamins B and minerals, but are deficience in vitamin A, D, B12, and C.
- Germination of pulses enhances its nutritional value.
- Some common pulses are; chickpeas, common beans, common peas (garden peas), lentils, lupins, mung beans, peanuts, pigeon peas, runner beans, soybeans

1.3.3 Nuts & Oilseeds

- Rich source of proteins, protein content may vary from 18-40%, soyabean is the richest source of protein contains around 40% along with B-vitamins, vitamin E, phosphorus and Iron.
- They are deficient in Vitamin A, D, B12 and C.
- Oilseed grains are grown primarily for the extraction of their edible oil. Vegetable oils provide dietary energy and some essential fatty acids. They are also used as fuel and lubricants.
- Because of high-value proteins oilseeds can be used as alternative milk formulation, which can be fed to children, adolescent, and older. This can also be considered as an alternative for lactose intolerance people.
- Some Common oilseeds are:

Mustard family
Rapeseed
Black mustard
India mustard
Rapeseed (including canola)
Aster family
Sunflower seeds
Safflower
Sunflower seed
Other families
Flax seed (Flax family)
Hemp seed (Hemp family)
Poppy seed (Poppy family)

1.3.4 Fruit & Vegetables

- ✓ Fruits and vegetables contain important vitamins, minerals and plant chemicals. They also contain fibre.
- ✓ There are many varieties of fruit and vegetables available and many ways to prepare, cook and serve them.
- ✓ A diet high in fruit and vegetables can help protect you against cancer, diabetes and heart disease

 Vegetables

Vegetables may be broadly divided into three groups from the nutritional point of view

(i) Green leafy vegetables

(ii) Roots and tubers

(iii) Other vegetables

Green Leafy Vegetables

- Green leafy vegetables are rich in β carotene (provitamin A)
- They are good sources of **c**alcium, riboflavin, folic acid and vitamin C
- Daily consumption of 100g of leafy vegetables by adults and 50g by children
- will provide the daily requirements of β carotene, folic acid and vitamin C
- and a part of the calcium and riboflavin requirements
- They are the **cheapest among the protective foods**.

Roots and Tubers

- The important foods in this group are potato, sweet potato, tapioca, carrot
  elephant yam and colocasia.
- They are, in general, good sources of carbohydrate.
- They are, however, poor sources of proteins, except potato which is a fair
  source.

- Carrot and yellow flesh variety of sweet potato are good sources of carotene
  but potato, tapioca and white flesh variety of sweet potato do not have much of carotene.
- Since they are poor sources of proteins, they can be used only in small amounts as a partial substitute for cereals.
- Consumption of excessive amounts of tapioca by young children is the main cause for the protein malnutrition.

Other Vegetables

- This group includes a large number of vegetables.
- Some of them are good sources of Vitamin C.
- Yellow pumpkin is a fair source of β carotene.

Fruits

- Mango and papaya are in general good sources of β carotene, Amla and guava are very rich in vitamin C.
- They are the cheapest among the fruits.
- Tomato, citrus, papaya, cashew apple and pineapple are also the richest source of Vitamin C.
- Apple, banana and grapes are poor sources of vitamin C.

1.3.5 Milk & Milk Products

- **Dairy products or milk products** are a type of food produced from or containing the milk of mammals. They are primarily produced from mammals such as cattle, water buffaloes, goats, sheep, camels and humans. Dairy products include food items such as yogurt, cheese and butter. A facility that produces dairy products is known as a dairy, or dairy factory. Dairy products are consumed worldwide, with the exception of most of East and Southeast Asia and parts of central Africa.

- Milk is almost a complete food except for iron and vitamin C.
- Milk proteins are of high biological value - 100 ml of cow‟ s milk provides about 3.2g protein, 4.1g fat, 120 mg calcium, 0.19 mg riboflavin, 53µg of vitamin A and substantial amounts of B-vitamins and minerals.
- Fat content of buffalo milk is twice the amount present in cow‟ s milk.
- **Full Fat Milk Powder**
- It is eight times as rich as cow‟ s milk containing about 26 per cent proteins and 26 per cent fat.
- It can be reconstituted with 7 times its weight of warm water and is used in place of fresh milk.
- **Skimmed Milk Powder**
- Skim milk powder is prepared from fat–free milk.
- It is completely devoid of fat and vitamin A.
- It‟ s about 10 times as rich as fresh skim milk and contains about 35 % proteins.
- It can be used as a supplement to the diets of children.
- It is **not suitable for feeding infants**.

1.3.6 Eggs

- Eggs provide an inexpensive source of high-quality protein, vitamins, and minerals, including vitamins A and B12, folic acid, and phosphorus.
- It is a fair source of vitamin D but doesn‟ t contain Vitamin C.
- They are an excellent source of riboflavin. The egg is also said to be a complete protein, because it contains a complete count of essential amino acids.

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- The white supplies more than half the protein in an egg. The yolk supplies the fat, along with the remaining protein, and most of the calories.
- Eggs are also graded and are classified by both size and quality. The best are grade AA or A, both of which are related to the level of freshness and the quality of the shell at marking. Most recipes are based on large eggs. Nutritionally, there's no difference between brown eggs and white eggs. Different colored eggs come from different varieties of hens.

1.3.7 Meat, Fish, and other animal foods.

Meat

- Meat is rich in proteins (18-22 per cent) of high biological value.
- It is fair source of B-vitamins.
- It does not contain Vitamin A, C or D and fibre.

Fish

- Rich source of proteins (18-22 %) are of high biological value. It is a fair source of B-vitamins.
- Fatty fish contain some vitamin A and D.
- Large fish are rich in P, but are deficient in calcium.
- Small fish eaten with bones are good sources of Ca.

1.3.8 Fats & Oils

- They serve as source of energy and provide the essential fatty acids.

- Butter, ghee and vanaspathi are good source of vitamin A (2500 IU per 100g).
- The common vegetable oils and fats do not contain carotene and vitamin A.
- Many of them are good source of Vitamin E

1.3.9 Sugar and other carbohydrates

- The carbohydrate foods commonly used are cane sugar, jaggery, glucose, honey, syrup, custard powder, arrowroot flour and sago.
- They serve mainly as a source of energy.
- Honey and jaggery contain limited quantities of minerals and

1.3.10 Spices & Condiments

vitamins.

- Spices and Condiments are not important sources of nutrient in average diets, but are used mainly for enhancing the palatability of the diet.
- The flavour principles present in them help to improve the flavour an acceptability of food preparations.
- Spices are the treasure of antioxidants and health promoting components.

1.4 The five food group plan

The nutrition expert group of Indian Council of Medical Research, India suggested a five food group plan and the nutrients supplied by each food group are given in Table.

S.No	FOOD GROUP	NUTRIENTS

1.	**Milk group** Milk, cheese, ice cream (cheese and ice cream can replace part milk)	Calcium, Phosphorus, Proteins and Vitamins.
2.	**Meat group** Beef, veal, pork, lamb, poultry, fish, eggs	Proteins, Phosphorus, Ironand B- Vitamins
3.	**Vegetable-fruit group**	Vitamins, Minerals and Fibre
4.	**Broad-Cereals group** (Whole grain, enriched, restored)	Thiamine (B_1), Niacin (B_5) Riboflavin, Iron, Carbohydrates and Fibre.
Five Food Group Plan		

1.5 Components of Food

Food Component	**Functions**
Carbohydrates	These are digested and broken down into glucose and provide energy to the body
Fats	Store energy, protects and insulates the important organs
Proteins	Help in metabolism, act as enzymes, and hormones
Vitamins	These help in maintaining healthy bones, boost the immune system, heal wounds, repair and damage of cells and converting food into energy
Iodine	Formation of thyroid hormone

Calcium	Helps in the proper functioning of the nervous system and maintain healthy bones
Phosphorus	Helps to maintain acid-base balance in the body
Sodium	Controls the blood pressure
Iron	Facilitates the formation of haemoglobin
Fibres	They help in food absorption and prevents constipation
Water	They help in absorbing nutrients from the food and release waste from the body in the form of urine and sweat.

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Course Name	Fundamentals Of Food Technology
Lesson 2	Nutrition Energy & Health
Content Creator Name	Dr Mohammed Wasim Siddiqui
University/College Name	Bihar Agricultural University, Bhagalpur
Course Reviewer Name	Dr.Jagmohan Singh
University/college Name	Sher-E-Kashmir University Of Agricultural Sciences And Technology Of Jammu ,Jammu

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Objective

1. To get an idea about nutrition energy and their relation with health
2. To get a clear concept about role of nutrients in human health and diseases

Glossary

Nutrition: The process of taking in food and using it for growth, metabolism, and repair. Nutritional stages are ingestion, digestion, absorption, transport, assimilation, and excretion.

Health: The word health refers to a state of complete emotional and physical well-being.

Disease: any harmful deviation from the normal structural or functional state of an organism, generally associated with certain signs and symptoms and differing in nature from physical injury. A diseased organism commonly exhibits signs or symptoms indicative of its abnormal state.

Macronutrient: nutrients that people need in relatively large quantities.

Micronutrient: nutrients that people need in relatively less quantities.

2.1 Introduction

Nutrition is the science of food and its relationship to health – how the human body uses food and processes the nutrients it contains to enable the body to perform functions (i.e. the heart to beat, the lungs to breathe, the kidneys to filter blood, the brain to think etc.).

2.2 Importance of nutrition

Nutrition is essential for growth and development, health and wellbeing. Eating a healthy diet contributes to preventing future illness and improving quality and length of life. Your **nutritional status** is the state of your health as determined by what you eat. There are several ways of assessing nutritional status, including anthropometric (i.e. physical body measurement), food intake and biochemical measurement.

2.3 Nutrients are divided into two groups: macro and micronutrients.

2.3.1 Macronutrients

Macronutrients are nutrients that people need in relatively large quantities.

Carbohydrates

Sugar, starch, and fiber are types of carbohydrates.

Sugars are simple carbohydrates. The body quickly breaks down and absorbs sugars and processed starch. They can provide rapid energy, but they do not leave a person feeling full. They can also cause a spike in blood sugar levels. Frequent sugar spikes increase the risk of type 2 diabetes and its complications.

Fiber is also a carbohydrate. The body breaks down some types of fiber and uses them for energ; others are metabolized by gut bacteria, while other types pass through the body.

Fiber and unprocessed starch are complex carbohydrates. It takes the body some time to break down and absorb complex carbs. After eating fiber, a person will feel full for longer. Fiber may also reduce the risk of diabetes, cardiovascular disease, and colorectal cancer. Complex carbs are a more healthful choice than sugars and refined carbs.

Proteins

Proteins consist of amino acids, which are organic compounds that occur naturally. There are 20 amino acids. Some of these are essential, which means people need to obtain them from food. The body can make the others. Some foods provide complete protein, which means they contain all the essential amino acids the body needs. Other foods contain various combinations of amino acids. Most plant-based foods do not contain complete protein, so a person who follows a vegan diet needs to eat a range of foods throughout the day that provides the essential amino acids.

Fats

Fats are essential for:

- lubricating joints
- helping organs produce hormones
- enabling the body to absorb certain vitamins
- reducing inflammation
- preserving brain health

Too much fat can lead to obesity, high cholesterol, liver disease, and other health problems.
However, the type of fat a person eats makes a difference. Unsaturated fats, such as olive oil, are more healthful than saturated fats, which tend to come from animals.

Water

The adult human body is up to 60% water, and it needs water for many processes. Water contains no calories, and it does not provide energy. Many people recommend consuming 2 liters, or 8 glasses, of water a day, but it can also come from dietary sources, such as fruit and vegetables. Adequate hydration will result in pale yellow urine. Requirements will also depend on an individual's body size and age, environmental factors, activity levels, health status, and so on.

2.3.2 Micronutrients

Micronutrients are essential in small amounts. They include vitamins and minerals. Manufacturers sometimes add these to foods. Examples include fortified cereals and rice.

Minerals

The body needs carbon, hydrogen, oxygen, and nitrogen. It also needs dietary minerals, such as iron, potassium, and so on. In most cases, a varied and balanced diet will provide the minerals a person needs. If a deficiency occurs, a doctor may recommend supplements.

Potassium

Potassium is an electrolyte. It enables the kidneys, the heart, the muscles, and the nerves to work properly. The *2015–2020 Dietary Guidelines for Americans* recommend that adults consume 4,700 milligrams (mg) of potassium each day.

Too little can lead to high blood pressure, stroke, and kidney stones.

Too much may be harmful to people with kidney disease.

Avocados, coconut water, bananas, dried fruit, squash, beans, and lentils are good sources.

Sodium

Sodium is an electrolyte that helps:

- maintain nerve and muscle function
- regulate fluid levels in the body

Too little can lead to hyponatremia. Symptoms include lethargy, confusion, and fatigue. Learn more here. Too much can lead to high blood pressure, which increases the risk of cardiovascular disease and stroke.

Table salt, which is made up of sodium and chloride, is a popular condiment. However, most people consume too much sodium, as it already occurs naturally in most foods. Current guidelines recommend consuming no more than 2,300 mg of sodium a day, or around one teaspoon. This recommendation includes both naturally-occurring sources, as well as salt a person adds to their food. People with high blood pressure or kidney disease should eat less.

Calcium

The body needs calcium to form bones and teeth. It also supports the nervous system, cardiovascular health, and other functions. Too little can cause bones and teeth to weaken. Symptoms of a severe deficiency include tingling in the fingers and changes in heart rhythm, which can be life-threatening. Too much can lead to constipation, kidney stones, and reduced absorption of other minerals. Current guidelines for adults recommend consuming 1,000 mg a day, and 1,200 mg for women aged 51 and over.
Good sources include dairy products, tofu, legumes, and green, leafy vegetables.

Phosphorus

Phosphorus is present in all body cells and contributes to the health of the bones and teeth. Too little phosphorus can lead to bone diseases, affect appetite, muscle strength, and coordination. It can also result in anemia, a higher risk of infection, burning or prickling sensations in the skin, and confusion.Too much in the diet is unlikely to cause health problems though toxicity is possible from supplements, medications, and phosphorus metabolism problems. Adults should aim to consume around 700 mg of phosphorus each day. Good sources include dairy products, salmon, lentils, and cashews.

Magnesium

Magnesium contributes to muscle and nerve function. It helps regulate blood pressure and blood sugar levels, and it enables the body to produce proteins, bone, and DNA. Too little magnesium can eventually lead to weakness, nausea, tiredness, restless legs, sleep conditions, and other symptoms. Too much can result in digestive and, eventually, heart problems.

Nuts, spinach, and beans are good sources of magnesium. Adult females need 320 mg of magnesium each day, and adult males need 420 mg.

Zinc

Zinc plays a role in the health of body cells, the immune system, wound healing, and the creation of proteins. Too little can lead to hair loss, skin sores, changes in taste or smell,and diarrhea, but this is rare. Too much can lead to digestive problems and headaches. Adult females need 8 mg of zinc a day, and adult males need 11 mg. Dietary sources include oysters, beef, fortified breakfast cereals, and baked beans. For more on dietary sources of zinc, click here.

Iron

Iron is crucial for the formation of red blood cells, which carry oxygen to all parts of the body. It also plays a role in forming connective tissue and creating hormones.

Too little can result in anemia, including digestive issues, weakness, and difficulty thinking. Learn more here about iron deficiency. Too much can lead to digestive problems, and very high levels can be fatal.
Good sources include fortified cereals, beef liver, lentils, spinach, and tofu. Adults need 8 mg of iron a day, but females need 18 mg during their reproductive years.

Manganese

The body uses manganese to produce energy, it plays a role in blood clotting, and it supports the immune system. Too little can result in weak bones in children, skin rashes in men, and mood changes in women. Too much can lead to tremors, muscle spasms, and other symptoms, but only with very high amounts.
Mussels, hazelnuts, brown rice, chickpeas, and spinach all provide manganese. Male adults need 2.3 mg of manganese each day, and females need 1.8 mg.

Copper

Copper helps the body make energy and produce connective tissues and blood vessels. Too little copper can lead to tiredness, patches of light skin, high cholesterol, and connective tissue disorders. This is rare. Too much copper can result in liver damage, abdominal pain, nausea, and diarrhea. Too much copper also reduces the absorption of zinc.

Good sources include beef liver, oysters, potatoes, mushrooms, sesame seeds, and sunflower seeds. Adults need 900 micrograms (mcg) of copper each day.

Selenium

Selenium is made up of over 24 selenoproteins, and it plays a crucial role in reproductive and thyroid health. As an antioxidant, it can also prevent cell damage. Too much selenium can cause garlic breath, diarrhea, irritability, skin rashes, brittle hair or nails, and other symptoms. Too little can result in heart disease, infertility in men, and arthritis. Adults need 55 mcg of selenium a day. Brazil nuts are an excellent source of selenium. Other plant sources include spinach, oatmeal, and baked beans. Tuna, ham, and enriched macaroni are all excellent sources.

Vitamins

People need small amounts of various vitamins. Some of these, such as vitamin C, are also antioxidants. This means they help protect cells from damage by removing toxic molecules, known as free radicals, from the body.

Vitamins can be:

Water-soluble: The eight B vitamins and vitamin C

Fat-soluble: Vitamins A, D, E, and K

Water soluble vitamins

People need to consume water-soluble vitamins regularly because the body removes them more quickly, and it cannot store them easily.

Vitamin	Effect of too little	Effect of too much	Sources
B-1 (thiamin)	Beriberi Wernicke-Korsakoff syndrome	Unclear, as the body excretes it in the urine.	Fortified cereals and rice, pork, trout, black beans
B-2 (riboflavin)	Hormonal problems, skin disorders, swelling in the mouth and throat	Unclear, as the body excretes it in the urine.	Beef liver, breakfast cereal, oats, yogurt, mushrooms, almonds
B-3 (niacin)	Pellagra, including skin changes, red tongue, digestive and neurological symptoms	Facial flushing, burning, itching, headaches, rashes, and dizziness	Beef liver, chicken breast, brown rice, fortified cereals, peanuts.

B-5 (pantothenic acid)	Numbness and burning in hands and feet, fatigue, stomach pain	Digestive problems at high doses.	Breakfast cereal, beef liver, shiitake mushroom, sunflower seeds
B-6 (pyridoxamine, pyridoxal)	Anemia, itchy rash, skin changes, swollen tongue	Nerve damage, loss of muscle control	Chickpeas, beef liver, tuna, chicken breast, fortified cereals, potatoes
B-7 (biotin)	Hair loss, rashes around the eyes and other body openings, conjunctivitis	Unclear	Beef liver, egg, salmon, sunflower seeds, sweet potato
B-9 (folic acid, folate)	Weakness, fatigue, difficulty focusing, heart palpitations, shortness of breath	May increase cancer risk	Beef liver, spinach, black-eyed peas, fortified

			cereal, asparagus
B-12 (cobalamins)	Anemia, fatigue, constipation, weight loss, neurological changes	No adverse effects reported	Clams, beef liver, fortified yeasts, plant milks, and breakfast cereals, some oily fish.
Vitamin C (ascorbic acid)	Scurvy, including fatigue, skin rash, gum inflammation, poor wound healing	Nausea, diarrhea, stomach cramps	Citrus fruits, berries, red and green peppers, kiwi fruit, broccoli, baked potatoes, fortified juices.

Fat-soluble vitamins

The body absorbs fat-soluble vitamins through the intestines with the help of fats (lipids). The body can store them and does not remove them quickly.

People who follow a low-fat diet may not be able to absorb enough of these vitamins. If too many build up, problems can arise.

Vitamin	Effect of too little	Effect of too much	Sources
Vitamin A (retinoids)	Night blindness	Pressure on the brain, nausea, dizziness, skin irritation, joint and bone pain, orange pigmented skin color	Sweet potato, beef liver, spinach, and other dark leafy greens, carrots, winter squash
Vitamin D	Poor bone formation and weak bones	Anorexia, weight loss, changes in heart rhythm, damage to cardiovascular system and kidneys	Sunlight exposure plus dietary sources: cod liver oil, oily fish, dairy products, fortified juices
Vitamin E	Peripheral neuropathy, retinopathy, reduced immune response	May reduce the ability of blood to clot	Wheatgerm, nuts, seeds, sunflower and safflower oil, spinach

Vitamin K	Bleeding and hemorrhaging in severe cases	No adverse effects but it may interact with blood thinners and other drugs	Leafy, green vegetables, soybeans, edamame, okra, natto

Multivitamins are available for purchase in stores or online, but people should speak to their doctor before taking any supplements, to check that they are suitable for them to use.

Antioxidants

Some nutrients also act as antioxidants. These may be vitamins, minerals, proteins, or other types of molecules. They help the body remove toxic substances known as free radicals, or reactive oxygen species. If too many of these substances remain in the body, cell damage and disease can result.

Encompassed on above definition of nutrition, **how much energy (kilojoules) a body needs to maintain a healthy weigh**t.

2.4 Energy

Energy is delivered to the body through foods. Any energy consumed (in the form of carbohydrates, protein or fat) and not used for metabolism, growth or physical activity will be stored as body fat. There are many factors that dictate how much energy a person needs, but in simple terms the more the body moves, the greater the amount of energy will be needed. The kilojoule is the measure of energy used in Australia. It is the International unit for energy, but some countries (e.g. USA) still use the calorie.

The conversion is:

4.2kJ = 1 calorie.

We use it to determine how much energy a food will provide when we eat it. The nutrients that provide energy are commonly referred to as macronutrients (carbohydrates, lipids, and proteins). Carbohydrates and proteins provide a similar amount of energy per gram of food. Lipids are a concentrated source of energy and provide almost twice the amount of energy than that supplied by proteins and carbohydrates.

For your information only:

CHOs = 16 kJ per gram of CHO

Protein = 17 kJ per gram of protein

Lipids = 37 kJ per gram of lipid

Children aged between 4-18 years require ~6500 to 14000 kJ per day. The approximate number of kilojoules a child consumes per day will depend on their age and physical activity level. The values given are for average physical activity only.

2.5 Nutritional Deficiencies

Nutrients in excess:

Saturated fats are often referred to as 'bad fats' as they are known to contribute to plaque formation in the arteries and the prevalence of cardiovascular diseases.

Sodium (salt) helps to regulate blood pressure. An over consumption of sodium may contribute to the incidence of high blood pressure in sensitive individuals.

Energy: Excess energy in any form will lead to overweight. However foods high in added sugar and fats are the easiest to over-consume.

Under consumption of nutrients:

Fibre from wholegrain sources has shown to decrease the risk of cardiovascular disease, type 2 diabetes and colon cancer.

Carbohydrates: Carbohydrates consist of 'simple' sugars (monosaccharides and disaccharides) and starches (polysaccharides or 'complex' carbohydrates). Once eaten, carbohydrates are broken down to glucose and used for energy by the body. This group of foods (bread, rice, pasta, grains, some vegetables, legumes, milk and fruit) are good sources of nutrients as well as energy.

2.6 A note on GI:

- Many people ask about it. Simply put, it is the Glycemic Index (a value/number) given to indicate how quickly the glucose formed when we eat CHOs, is absorbed into the bloodstream.
- A high GI means CHOs are quickly digested and absorbed; a low GI means CHOs are digested and absorbed at a slower rate. This has an effect on the release of insulin which is important in the management of diabetes (especially type 2 diabetes).
- The GI is useful for comparing foods within a food group, e.g. white bread vs. wholegrain bread. However, relying solely on GI to determine the type of foods to eat can be misleading, e.g. chocolate, which is high in fat and sugar has a low GI.

Sugar:

- It is important to monitor the amount of added sugar in foods such as refined cereals. Naturally occurring sugars in foods are not a problem (e.g. lactose in milk or fructose in fruit).
- However, when sugars are extracted from their natural source they are devoid of nutrients and in excess replace other valuable nutrients in the diet and provide excess kilojoules.

Fibre:

- Is a part of plants, such as fruits, vegetables, unrefined grains and cereals, legumes, nuts, and seeds that cannot be digested using the normal digestive enzymes in the stomach and small intestine.
- Fibre (especially soluble fibre) is broken down by bacteria in the large intestine. The by-products of this process are important for healthy gut function.
- Fibre has many other beneficial properties such as promoting a feeling of fullness after eating, slowing down the absorption of glucose, and hindering the absorption of cholesterol from food.
- The refining of wheat, rice, pasta, etc. removes fibre. When fruits and vegetables are peeled or the skin is removed, a lot of the fibre (and other nutrients) are also removed.

Lipids

- It is the term used to describe fats and oils. By definition, fats are solid at room temperature and oils are liquid at room temperature. However, lipids are generally referred to as fats.

Most lipids we eat can be classified as saturated or unsaturated. All fats and oils contain a mixture of saturated and unsaturated fats. They are classified according to the dominant type of fat.

The **saturated fats** generally come from animal sources and are often referred to **as 'bad fats'** because of the negative effect they have on cardiovascular (heart) health. Unsaturated fats generally come from plant sources and are referred to as **'good fats'** because of their positive effects on cardiovascular health.

- However, all types of fat are a rich source of energy (calories or kilojoules) and too much of either type of fat can lead to us becoming overweight.

The **unsaturated fats** can further be classified as monounsaturated or polyunsaturated fats. Polyunsaturated fats are classified as omega-3 or omega-6 fats.

A note on trans-fats:

- They are formed when liquid vegetable oils are 'hydrogenated' to form solid substances such as margarine, fat for deep-frying or shortening for baking.
- Trans fats act like saturated fats and are worse for heart health. They are found in pies, cakes, doughnuts, biscuits etc. They are also naturally present in milk and meat.
- Trans fats from milk and meat products may not have the same negative effects as other trans fats. Food Standards, such as **FSSAI** the government body responsible for food safety, monitors the levels of trans fats in food and is working with health organizations such as the Heart Foundation and The Dietitians Association to reduce the level of trans fat in the food supply. If a claim for fat is made on the label, the level of trans fat must be included in the NIP.

Assignment Activity: What foods contain mostly saturated or unsaturated fats?

Do the exercise on saturated and unsaturated fats. If asked, explain it is the chemical structure that is different, but most of the unsaturated fats are considered healthy.

There may be some surprises in this table. For instance, some plant sources are classified as saturated and game meats are classified as unsaturated. Re-emphasize that fats are classified as being saturated or unsaturated according to which fat is present in the largest amount.

Saturated: Full-fat dairy (butter, cheese, cream, and milk), fatty meats, lard, palm oil (often referred to as **vegetable oil** and found in commercial foods), and coconut cream/milk.

Unsaturated: Oils (all but coconut and palm e.g. olive, canola, grape seed, sunflower, safflower, peanut, macadamia, etc.), margarines made from oils, lean meats, nuts and seeds, avocados.
Note: be aware of oils made from nuts or seeds – as it is source of food allergy to allergic people. High grade oils are unlikely to cause a reaction, but it is impossible to tell from the label if the oil is high grade.

Omega 3: An important fat found in fatty fish and nuts. Essential for brain function and needed by most cells, hence the need to eat fish 2-3 times per week.

Reference: Participant‘s Workbook p.7 / Trainer’s Manual p.12

Sodium:

- **Salt** is a combination of the minerals **sodium and chloride**. The terms sodium and salt are often used interchangeably.
- It is important to monitor the sodium content of food in children and adolescents so they don’t get used to eating very salty foods, as eating patterns are developed during childhood.
- High levels of sodium in food and drinks have been linked to an increased excretion of calcium (via the kidneys).
- Calcium is important to bone strength and children cannot afford to lose calcium, as it helps protect them against osteoporosis later in life. High intakes of sodium may also increase the risk of high blood pressure in adulthood in sensitive individuals (2013 Australian Dietary Guidelines).

Calcium

- It is important for healthy bones and teeth. You may have heard the term 'peak bone mass'.
- This refers to the greatest amount of bone that you have in your lifetime. Peak bone mass is achieved somewhere between the ages of 16 and 30.

- Because most bone is formed in childhood and adolescence, calcium is an important nutrient for children.
- Low calcium intakes have been associated with low bone mass, which often results in bone fractures later in life (osteoporosis).

2.7 The recommended dietary intake (RDI)

- For school children aged 9 -18 years is 1000mg - 1300mg of calcium a day. The most recent National Children's Nutrition and Physical Activity Survey identified calcium as a nutrient at risk, especially in older children.
- Older children (9-16 years) were least likely to meet the estimated average requirements (EAR)[2] of 800mg – 1050 mg of calcium daily (Dept of Health and Ageing 2008).
- In the 12-13 year old age group almost 70% of all children did not meet the EAR; this figure rises to almost 90% if we look at girls aged 12-13 years in isolation.

Dairy products are the best source of calcium in the diet.

- Other sources of calcium may include fortified soy products (milk, yoghurts) and fish with bones (salmon, sardines).
- Almonds are often cited as an alternative source of calcium. However, eating the amounts required to gain an equivalent 'serve size' of calcium compared to a fortified soy drink would require the consumption of in excess of 3000kJs. (1 cup low-fat calcium fortified soy ~ 500kJs

  1 **RDI** - The average daily dietary intake level that is sufficient to meet the nutrient requirements of nearly all (97–98 per cent) healthy individuals in a particular life stage and gender group
  2 **EAR** - A daily nutrient level estimated to meet the requirements of half the healthy individuals in a particular life stage and gender group (NHMRC 2006)

2.8 BALANCED DIET, RECOMMENDED DIETARY ALLOWANCES FOR VARIOUS AGE GROUPS

Balanced diet

- A balanced diet is one which contains different types of food in such quantities and proportions so that the need for calories, proteins, minerals, vitamins and other nutrients is adequately met and a small provision is made for extra nutrients to withstand short duration lean periods. (Srilakshmi, 2000)
- A balance diet may be defined as one which contains various groups of food stuffs such as energy yielding foods, body building foods and protective foods in the correct proportion so that individual is assured of obtaining the minimum requirements of all the nutrients.
- The components of balanced diet will differ according to age, sex, physical activity, economic status and the physiological state viz. pregnancy, lactation etc.

Recommended Dietary Allowance

- The nutrition Advisory Committee of the Indian Council of Medical Research (ICMR) has recommended the dietary allowances. The RDA implies addition of safety amount to the estimated requirement to cover both the variations among the individual and lack of precision inherent in the estimate requirement. To calculate the balanced diet RDA are prescribed for various individuals.

2.9 PLANNING OF BALANCED DIETS

Balanced Diets at High Cost

It will include liberal amounts of costly foods such as milk, eggs, meat, fish and fruits and moderate quantities of cereals, pulses, nuts and fats.

Balanced Diets at Moderate Cost

These diets will include moderate amount of milk, eggs, meat, fish, fruits and fats and liberal amounts of cereals, pulses, nuts and green leafy vegetables.

Balanced Diet at Low Cost

These diets will includes small amounts of milk, eggs, meat, fish and fats and liberal amounts of cereals, pulses, nuts and green leafy vegetables.

The ICMR Nutrition Expert Group (1968) recommended balanced diets at low costs.

Diets for Pregnant and Nursing Mothers

Balanced diets at low cost are suggested by the ICMR Nutrition Expert Group for pregnant and lactating women. The diets include fair amounts of legumes and green leafy vegetables.

Assignment- Prepare the Recommended dietary chart on the basis of supplied supplementary chart for different age groups

Body mass index (BMI)

Body mass index (**BMI**) is a good indicator of your nutritional status. It is a value derived from the mass (weight) and height of a person. The BMI is defined as the body mass divided by the square of the body height, and is universally expressed in units of kg/m2, resulting from mass in kilograms and height in meters.

The BMI may be determined using a table or chart which displays BMI as a function of mass and height using contour lines or colors for different BMI categories, and which may use other units of measurement (converted to metric units for the calculation).

The BMI is a convenient rule of thumb used to broadly categorize a person as underweight, normal weight, overweight, or obese based on tissue mass (muscle, fat, and bone) and height. Commonly accepted BMI ranges are underweight (under 18.5 kg/m2), normal weight (18.5 to 25), overweight (25 to 30), and obese (over 30).

References

1. Advanced textbook on food and nutrition by M. Swaminathan
2. Textbook of Food and Nutrition by Annie Fredrick

Course Name	Fundamentals Of Food Technology
Lesson 3	Function And Properties Of Food
Content Creator Name	Dr Mohammed Wasim Siddiqui
University/College Name	Bihar Agricultural University, Bhagalpur
Course Reviewer Name	Dr.Jagmohan Singh
University/college Name	Sher-E-Kashmir University Of Agricultural Sciences And Technology Of Jammu ,Jammu

There are two basic functions of food discussed below

3.1 Physiological function of food

As we discussed in previous chapter, Food is the fundamental source to provide energy to our body. The body need energy to perform involuntary function for living, extra activities of daily life, to break down ingested food into usable form of nutrients, for the growth, for keeping warm. The energy is obtained by the oxidation process of food components.

- Building the body, the food we eat is the part of our body which means our body is developed by utilizing or consuming right foods. The food eaten each day helps to maintain the structure of the adult body and to replace worn out cells of the body.
- The other vital function of food is to regulate the activity of the body, it include regulation of varied activities,
    - ✓ Heart beat
    - ✓ Maintenance of the body temperature.
    - ✓ Control of water balance
    - ✓ Clotting of blood
    - ✓ Removal of waste products from the body
- The other function of the food is to maintain or improve the immunity, which serve in the form of resistance to diseases.
- Food is also responsible for psychological & emotional wellbeing. The acceptance and importance of food consumption should be planned accordingly based on nutritional requirements.

Social function of food

- Food has been the central part of our culture, it has been part of our community, social, and religious beliefs.
- Food has been used as expression of love in different occasions of our life. It is used as a symbol of happiness in the ceremonies.

Properties of Food

We have discussed the chemical constituents of foods earlier, here we will learn about the different properties of food somehow exhibited due to its chemical constituents.

3.2 Classification of Food Properties Proposed by Paulus (1989)

Physical Properties	Nutritive properties	Sensory properties
Define by the food it self	Define by the food itself	Define by food and people
Determined objectively	Determined objectively	Determined subjectively
Important to describe process condition from engineering point of view	Primarily not related for process condition	Primarily not relevant for process condition
Primarily not relevant to food quality	Important for food quality	Important for food quality

The classification of food properties now proposed contains four major classes:

(i) **physical and physicochemical properties**,
(ii) kinetic properties,
(iii) sensory properties,
(iv) health properties

3.3 Important Physical & Physicochemical properties of food

3.3.1 Solution

A solution is homogenous mixture of two or more than two substance dissolved in a medium. The dissolved molecules are uniformly distributed throughout the solution.

A Solution include **Solvent + Solute.**

3.3.2 Solubility

The amount of solute that can be dissolved in a given amount of solution at a given temperature is called its solubility.

3.3.3 Hydration

The process of causing something to absorb water or in other words the process of combining a substance chemically with water molecules.

The attachment of molecules of the solvent to solute molecules of ions, by electrical attraction or chemical bonding. The water molecule is highly polar and so water is an excellent solvent for ionic substances. The salvation that takes place in this case is known as hydration.

3.3.4 Vapor Pressure

The intermolecular forces in a liquid prevent escape of most molecules from the surface.

3.3.5 Boiling Point

Boiling point (Bp) is the temperature at which a liquid turns to vapor. A liquid boil when its vapor pressure is equal to the external atmospheric pressure.

3.3.6 Freezing Point

Freezing point (Fp) is the temperature at which a liquid turns to solid when it is cooled.

3.3.7 Melting Point

The temperature at which solid changes its state to liquid at atmospheric pressure is called the melting point (Mp) of that liquid. This is the point at which both liquid and solid phase exists at equilibrium. The melting point of the substance also varies with pressure and is specified at standard pressure.

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3.3.8 Osmotic Pressure

The process by which is water is drawn from a solution through a semi permeable membrane is called osmosis. During this movement there is a minimum pressure must be exerted for preventing the flow of water is the osmotic pressure.

Osmotic pressure is the minimum pressure which needs to be applied to a solution to prevent the inward flow of its pure solvent across a semipermeable membrane. It is also defined as the measure of the tendency of a solution to take in pure solvent by osmosis.

3.3.9 Viscosity

Viscosity measure the resistant of a fluid to flow or also can be understand as the thickness of a fluid. The internal friction which resist the liquid to their flowing and tends to bring it into the position of rest.

A fluid having very low viscosity flow easily.

3.3.10 Surface and interfacial tensions

Surface tension is the property of the liquid in contact with gas phase (usually air). Interfacial tension, on the other hand, is the property between any two substances. It could be liquid-liquid, liquid-solid or solid-air.

Surface and interfacial tension are usually presented by the symbol σ and it is measured by force per unit length. Its SI unit is millinewton per meter (mN/m) which is equivalent to often used cgs unit, dynes per centimeter (dynes/cm).

The boundary between a liquid and a gas or vapour is termed surface, whereas that of a liquid-liquid or solid-liquid junction interface.

This parameter include **cohesion** and **adhesion** force.

3.3.11 Specific gravity

The density of one substance in relation to the density of another material is known as specific gravity.

3.3.12 Colloids

Colloid is the mixture that has particles ranging between 1 to 1000 nanometers in diameter, yet are able to remain evenly distributed in a solution. If the dimensions are smaller than this the substance is considered a solute ion and if they are larger than the substance is a suspension.

Colloid is classified into two groups' viz., crystalloids and colloids, depending upon their ability to diffuse through parchment membrane. According to Graham, colloidal solutions contain substances whose molecular aggregates possess a diameter greater than 1 µm and less than 100 µm. If the particle size is greater than 100 µm, a suspension is obtained.

Assignment: Differentiate between true solution, colloids, and suspension with suitable examples.

Classifying Colloids

There are two kind of classification of colloids:

1. On the basis of water affinity: Lyophilic colloids (no affinity for water such as inorganic colloids), and lyophobic colloids (greater affinity to water, organic colloids such as starch, proteins, etc.)
2. The classification of colloids is based on the phase of the dispersed substance and what phase it is dispersed in. The types of colloids includes sol, emulsion, foam, and aerosol.
   A. Food Sols and Gels
   B. Emulsion
   C. Foam
   D. Aerosol

When a dispersion medium of a colloid is water it is termed as **Hydrocolloids.**

Food sols & Gels:

Food sols are the dispersion of solid colloidal particle in continuous liquid phase. Typical example are dispersion of egg albumin in water and dilute gelatin in water.

Food Gels are the dispersion of liquid phase into solid phase (the major constituent is solid and minor is liquid). Common examples are jelly, starch gels, and others. While jelly is formed, gelatin is scattered into a liquid and heated to make a sol. As the solution cooks, protein molecules unwind developing a network which traps water and creates a gel. Similarly Corn flour is heated in water, starch absorb water and form viscous substance.

The rheology of sols are greater than water and it increases with increase in solid colloids. The rheology is gel is very high provide rigidity, elasticity, etc depending on the jelling agent.

Note- The spontaneous exudation of liquid from a gel is called syneresis (weeping), the phenomena occurs due to in-stabilized formulation.

Food Emulsion

Emulsion is the dispersion of two immiscible liquids which is stabilized by an emulsifying agent called emulsifier. Emulsification process require an emulsifier and mechanical agitation.

Emulsion is of two types

A. Oil in Water
   When oil particle as dispersed phase are stabilized in a continuous phase of water such as milk, mayonnaise, salad oil, cream soup, ice-cream.
B. Water in oil
   When water particle as dispersed phase are stabilized in a continuous phase of oil such as butter, margarine, egg yolk.

Foam

The small bubbles of gas (usually air) dispersed in liquid or semi-solid phase is called foam. The particles of the dispersed substance are suspended in the mixture and do not completely dissolved within. The bubbles are separated from each other by liquid or semisolid wall also called film or lamellae that are elastic stable foams.

Dispersion Medium	Dispersed Phase	Type of Colloid	Example
Solid	Solid	Solid sol	Ruby glass
Solid	Liquid	Solid emulsion/gel	Pearl, cheese
Solid	Gas	Solid foam	Lava, pumice
Liquid	Solid	Sol	Paints, cell fluids
Liquid	Liquid	Emulsion	Milk, oil in water
Liquid	Gas	Foam	Soap suds, whipped cream
Gas	Solid	Aerosol	Smoke
Gas	Liquid	Aerosol	Fog, mist

3.3.13 Color

Consistent and accurate measurements of the colour and visual appearance of food products is extremely important. Various methods are available for colour measurement, allowing a wide variety of sample types to be measured. Colour measurement results are typically provided on the CIELAB scale. Others are available on request.

3.3.14 Structure

The structure of food influences texture. Examples include porous products such as aerated foods and bakery products where the bubble structure affects softness, and starch-based snacks where it affects crispiness.

3.4 Food structure analysis using X-ray micro-CT

X-ray micro-CT offers non-destructive imaging and structure measurement in 3D. Images and movies showing the internal structure of products can be generated. Measurements of porosity, bubble size distribution and structure thickness (wall size) can be performed.

3.4.1 Texture

Food texture is an important sensory attribute as it affects the way food tastes and how it feels in the mouth. The texture depends on the rheological properties of the food and evaluation involves measuring the response of a food when it is subjected to forces such as cutting, shearing, chewing, compressing or stretching.

3.4.2 Rheology and interfacial properties

The rheological properties of food materials are important in determining the texture as well as how they behave physically when subjected to physical forces and forced to flow. The rheological properties of raw materials, intermediate products such as batters and doughs as well as final products can be studied.

3.4.3Thermal analysis

Thermal analysis techniques measure the physical and chemical properties of foods as a function of temperature or time.

The study of **food engineering** focuses on the analysis of equipment and systems used to process food on a commercial production scale. Engineering of systems for food materials can be more thorough if there is an understanding of the changes that occur in food as it is processed by the system. Raw food materials are biological in nature and as such have certain unique characteristics which distinguish them from other manufactured products.

3.4.4 Some Other properties:

Physical Characteristics

Shape, Surface area, Appearance, Size, Density, Drag coefficient, Weight, Porosity, Center of gravity, Volume, Color

Mechanical Properties

Hardness, Sliding coefficient of friction, Compressive strength, Static coefficient of friction, Tensile strength, Coefficient of expansion (moisture & thermal), Impact resistance, Shear resistance, Compressibility, moisture, thermal Elasticity, Plasticity, Bending strength, Aerodynamic properties , Hydrodynamic properties

Thermal Properties

Specific heat, Thermal conductivity, Emissivity, Thermal capacity, Surface conductance, Transmissivity, Thermal diffusivity, Absorptivity

Electrical Properties

Conductance, Dielectric properties, Resistance, Reaction to electromagnetic radiation, Capacitance, Conductivity—ability of seeds to hold a surface charge

Optical Properties

Light transmittance, Light absorbance, Contrast, Light reflectance, Color, Intensity

Sensory Properties

Color, taste, odor, texture, rheology, mouthfeel, and others.

Course Name	Fundamentals Of Food Technology
Lesson 4	Introduction To Food Technology
Content Creator Name	Dr Mohammed Wasim Siddiqui
University/College Name	Bihar Agricultural University,Bhagalpur
Course Reviewer Name	Dr.Jagmohan Singh
University/college Name	Sher-E-Kashmir University Of Agricultural Sciences And Technology Of Jammu ,Jammu

Objective

1. To get a basic concept about food and technologies involved in it.
2. Help to understand about the techniques and processes that are used to transform raw materials into food.

Glossary

Canning: method of preserving food from spoilage by storing it in containers that are hermetically sealed and then sterilized by heat.

Pasteurization: the process of heating milk and milk products to destroy food spoilage and disease-producing organisms.

Food chemistry: study the chemical processes and interactions of all biological and non-biological components of foods.

Food microbiology: study of the microorganisms that inhabit, create, or contaminate food, including the study of microorganisms causing food spoilage.

4.1 Introduction

Food Technology is an engineering science branch that deals with the techniques involved in production, processing, preservation, packaging, labeling, quality management, and distribution of food products.

The field also involves techniques and processes that are used to transform raw materials into food. Extensive research goes behind making food items edible as well as nutritious.

- As deep as we go into the dimensions of food technology, we require professionals in this field. And, this has led to the emergence of food technology courses.
- Early scientific research into food technology concentrated on food preservation.
- Nicolas Appert’s development in 1810 of the **canning** process was a decisive event. The process wasn’t called canning then and Appert

did not really know the principle on which his process worked, but canning has had a major impact on food preservation techniques.

- Louis Pasteur's research on the spoilage of wine and his description of how to avoid spoilage in 1864 was an early attempt to apply scientific knowledge to food handling. Besides research into wine spoilage, Pasteur researched the production of alcohol, vinegar, wines and beer, and the souring of milk. He developed **pasteurization**—the process of heating milk and milk products to destroy food spoilage and disease-producing organisms. In his research into food technology, Pasteur became the pioneer into bacteriology and of modern preventive medicine.
- The **modern food processing techniques** is the key to flourishing supermarkets we have today.

4.2 Scope of Food Technology

Food Technology developed as a discipline to systematically organize and link the various kinds of knowledge which are necessary to inform human activity in **food** handling, processing, distribution and marketing.

4.2.1 Food Technology applies:

1. The principles and concepts of engineering to problems of **food** handling and processing,
2. Studies the interrelationships between the properties of materials and the changing methods of handling and manufacturing them.

4.2.2 Components of Food Technology

- Food analysis and chemistry
- Food Quality Factors and their Measurement
- Nutritive aspects of food constituents and effect of processing and handling
- Food microbiology, mycology, and toxicology
- Food processing and engineering

4.2.3 Emerging trends in Food Technology

- Increased concern about the nutritional content of technologically derived, refined foods is expressed by both consumers and nutritionists.
- Dietary guidelines and nutrition education focus on partially replacing refined foods with whole grains, legumes, and other foods which retain their biochemical unity.
- Concern about **food** safety issues is very strong. **Food** scientists are responding to these nutritional and safety concerns in a variety of ways,
- Increased attention to **food** interactions and bioavailability of nutrients,
- Improved analytical and detection methods, and research and education in **food** safety.
- New product development, particularly in the area of reduced-fat and reduced-calorie products is predicted. New processing technologies such as high energy electric pulse processing, freeze concentration, and hydrostatic pressure processing (which are often not yet available in the U.S.) show promise.
- Biotechnology is a growing area.

4.2.4 Impact of developments in other Technologies on Food Technology

For the sake of completeness it should also be mentioned that development of **food technology** draws heavily on developments in other technologies, such as those in steel,tinplate, glass, aluminum, plastics, engineering, instrumentation, electronics, chemicals, andagriculture.

4.3 BRANCHES OF FOOD TECHNOLOGY

Food technology is comprised with multiple skill sets requirement, thus it require the skill set of food chemistry, food science and nutrition, food microbiology, food processing techniques, food engineering, food quality, food safety, food packaging, material science, food physics, food plant design, mechanics, fluid flow, thermodynamics, etc.

Food technology also include few specialization based on food groups:

- Dairy technology
- Sugar technology
- Alcohol and brewing technology
- Bakery and confectionery technology
- Oil and oil seed processing technology
- Post-harvest technology including Fruits and vegetables
- Meat- Fish processing technology
- Cereal science and technology
- Beverages technology

Insight of Food Technology:

4.3.1 Food Science

- **Food science** is the whole concept to study of the nutritional, chemical and physical properties of foods and of changes that may occur during processing, storage, etc.
- It is the basic science & applied science whose scope starts at overlap with agricultural science and nutrition and leads through the scientific aspects of food safety and food processing, informing the development of food technology.
- The **Institute of Food Technologists** defines food science as "the discipline in which the engineering, biological, and physical sciences are used to study the nature of foods, the causes of deterioration, the principles underlying food processing, and the improvement of foods for the consuming public
- The textbook Food Science defines food science in simpler terms as "**the application of basic sciences and engineering** to study the

physical, chemical, and biochemical nature of foods and the principles of food processing.

4.3.2 Food chemistry

- Food chemistry is the study of chemical processes and interactions of all biological and non-biological components of foods.

- The biological substances include such items as meat, poultry, lettuce, beer, and milk as examples. It is similar to biochemistry in its main components such as carbohydrates, lipids, and protein, but it also includes areas such as water, vitamins, minerals, enzymes, food additives, flavors, and colors.

- This discipline also encompasses how products change under certain food processing techniques and ways either to enhance or to prevent them from happening.

4.3.3 Food physical chemistry

- Food physical chemistry is the study of both physical and chemical interactions in foods in terms of physical and chemical principles applied to food systems, as well as the application of **physicochemical techniques** and instrumentation for the study and analysis of foods.

4.3.4 Food microbiology

- Food microbiology is the study of the microorganisms that inhabit, create, or contaminate food, including the study of microorganisms causing food spoilage. "Good" bacteria, however, such as probiotics, are becoming increasingly important in food science. In addition, microorganisms are essential for the production of foods such as cheese, yogurt, bread, beer, wine, and other fermented foods.

4.3.5 Quality control

- Quality control involves the causes, prevention and communication dealing with food-borne illness.
- Quality control also ensures that product meets specs to ensure the customer receives what they expect from the packaging to the physical properties, chemical properties, sensory properties, and nutritional properties of the product itself.

4.3.6 Food Engineering

- Food engineering is the discipline which applies principles of engineering, science, and mathematics to food manufacturing and operations, including the processing, production, mechanical, handling, storage, conservation, control, packaging and distribution of food products

4.4 Refrigeration and freezing

- The main objective of food refrigeration and/or freezing is to preserve the quality and safety of food materials.
- Refrigeration and freezing contribute to the preservation of perishable foods, and to the conservation some food quality factors such as visual appearance, texture, taste, flavor and nutritional contents.
- In addition, freezing food slows down the growth of bacteria that could potentially harm consumers

4.5 Evaporation

- Evaporation is used to pre-concentrate, increase the solid content, change the color, and reduce the water content of food and liquid products.
- This process is mostly seen when processing milk, starch derivatives, coffee, fruit juices, vegetable pastes and concentrates, seasonings,

sauces, sugar, and edible oil. In addition, evaporation is used in food dehydration processes.

- The purpose of dehydration is to prevent the growth of molds in food, which only build when moisture is present. This process can be applied to vegetables, fruits, meats, and fish, for example.

4.6 Packaging

- Food packaging technologies are used to extend the shelf-life of products, to stabilize food (preserve taste, appearance, and quality), and to maintain the food clean, protected, andappealing to the consumer.
- This can be achieved, for example, by packaging food in cans and jars. Because food production creates large amounts of waste, many companies are transitioning to eco-friendly packaging to preserve the environment and attract the attention of environmentally conscious consumers. Some types of environmentally friendly packaging include plastics made from corn or potato, bio-compostable plastic and paper products which disintegrate, and recycled content.
- Even though transitioning to eco-friendly packaging has positive effects on the environment, many companies are finding other benefits such as reducing excess packaging material, helping to attract and retain customers, and showing that companies care about the environment.

4.7 Energy for food processing

- To increase sustainability of food processing there is a need for energy efficiency and waste heat recovery.
- The replacement of conventional energy-intensive food processes with new technologies like thermodynamic cycles and non-thermal heating processes provide another potential to reduce energy consumption, reduce production costs, and improve the sustainability in food production.

4.8 Heat transfer in food processing

- Heat transfer is important in the processing of almost every commercialized food product and is important to preserve the hygienic, nutritional and sensory qualities of food.

- Heat transfer methods include induction, convection, and radiation. These methods are used to create variations in the physical properties of food when freezing, baking, or deep frying products, and also when applying ohmic heating or infrared radiation to food.

4.9 Food Safety

Food safety is used as a scientific discipline describing handling, preparation, and storage of food in ways that prevent food-borne illness. The occurrence of two or more cases of a similar illnesses resulting from the ingestion of a common food is known as a food-borne disease outbreak.

This includes a number of routines that should be followed to avoid potential health hazards. In this way food safety often overlaps with food defense to prevent harm to consumers**.**

4.9.1 Food Safety Management Systems (FSMS)

- A Food Safety Management System (FSMS) is "a systematic approach to controlling food safety hazards within a business in order to ensure that the food product is safe to consume.
- In some countries FSMS is a legal requirement, which obliges all food production businesses to use and maintain a FSMS based on the principles of Hazard Analysis Critical Control Point (HACCP).
- HACCP is a management system that addresses food safety through the analysis and control of biological, chemical, and physical hazards in all stages of the food supply chain.
- **FSSAI (Food safety and standard authority of India)** has been established under the Food Safety and Standards Act, 2006, which is a consolidating statute related to food safety and regulation in India.

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In order to avoid any form of food contamination and to insure food safety for consumers, food industries must have to follow **standard operation procedure (SOP**) in form of FSMS & HACCP measuring.

4.10 Food contamination

Food contamination happens when food are corrupted with another substance. It can happen In the process of production, transportation, packaging, storage, sales and cooking process. The contamination can be physical, chemical and biological.

4.10.1 Physical contamination

- Physical contaminants (or 'foreign bodies') are objects such as hair, plant stalks or pieces of plastic and metal. When the foreign object comes into the food, it is a physical contaminant. If the foreign objects are bacteria, both a physical and biological contamination will occur.

- Common sources to create physical contaminations are: hair, glass or metal, pests, jewelry, dirt and fingernails.

4.10.2 Chemical contamination

- Chemical contamination happens when food is contaminated with a natural or artificial chemical substance.
- Common sources of chemical contamination can include: pesticides, herbicides, veterinary drugs, contamination from environmental sources (water, air or soil pollution), and cross-contamination during food processing, migration from food packaging materials, presence of natural toxins or use of unapproved food additives and adulterants.

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4.10.3 Biological contamination

- Biological contamination refers to food that has been contaminated by substances produced by living creatures, such as humans, rodents, pests or microorganisms.
- This includes bacterial contamination, viral contamination, or parasite contamination that is transferred through environment, saliva, pest droppings, blood or faecal matter.
- Bacterial contamination is the most common cause of food poisoning worldwide. If an environment is high in starch or protein, water, oxygen, has a neutral pH level, and maintains a temperature between 5 °C and 60 °C (danger zone) for even a brief period of time (~0–20 minutes), bacteria are likely to survive.

4.11 Role of Food Technologist in safe food handling procedures (from market to consumer)

- Proper storage, sanitary tools and work spaces, heating and cooling properly and to adequate temperatures, and avoiding contact with other uncooked foods can greatly reduce the chances of contamination.
- Tightly sealed water and air proof containers are good measures to limit the chances of both physical and biological contamination during storage.
- Using clean, sanitary surfaces and tools, free of debris, chemicals, standing liquids, and other food types (different than the kind currently being prepared, i.e. mixing vegetables/meats or beef/poultry) can help reduce the chance of all forms of contamination.
- However, even if all precautions have been taken and the food has been safely prepared and stored, bacteria can still form over time during storage.

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- Food should be consumed within one to seven (1-7) days while it has been stored in a cold environment, or one to twelve (1-12) months if it was in a frozen environment (if it was frozen immediately after preparation). The length of time before a food becomes unsafe to eat depends on the type of food it is, the surrounding environment, and the method with which it is kept out of the danger zone.
- Always refrigerate perishable food within 2 hours—1 hour when the temperature is above 90 °F (32.2 °C).
- Check the temperature of your refrigerator and freezer with an appliance thermometer. The refrigerator should be at 40 °F (4.4 °C) or below and the freezer at 0 °F (-17.7 °C) or below.
- For example, liquid foods like soup kept in a hot slow cooker (65 °C) may last only a few hours before contamination, but fresh meats like beef and lamb that are promptly frozen (-2 °C) can last up to a year.
- The geographical location can also be a factor if it is in close proximity to wildlife. Animals like rodents and insects can infiltrate a container or prep area if left unattended.
- Any food that has been stored while in an exposed environment should be carefully inspected before consuming, especially if it was at risk of being in contact with animals.
- Consider all forms of contamination when deciding if a food is safe or unsafe, as some forms or contamination will not leave any apparent signs. Bacteria may not be visible to the naked eye, debris (physical contamination) may be underneath the surface of a food, and chemicals may be clear or tasteless; the contaminated food may not change in smell, texture, appearance, or taste, and could still be contaminated.
- Any foods deemed contaminated should be disposed of immediately, and any surrounding food should be checked for additional contamination.
- **ISO 22000** is a standard developed by the International Organization for Standardization dealing with food safety. This is a general

derivative of **ISO 9000**. ISO 22000 standard: The ISO 22000 international standard specifies the requirements for a food safety management system that involves interactive communication, system management, prerequisite programs, HACCP principles.

- ISO 22000 was first published in 2005. It is the culmination of all previous attempts from many sources and areas of food safety concern to provide an end product that is safe as possible from pathogens and other contaminants. Every 5 years standards are reviewed to determine whether a revision is necessary, to ensure that the standards remain as relevant and useful to businesses as possible.

Course Name	Fundamentals Of Food Technology
Lesson 5	Food Preservation And Different Food Preservation Techniques
Content Creator Name	Dr Mohammed Wasim Siddiqui
University/College Name	Bihar Agricultural University,Bhagalpur
Course Reviewer Name	Dr. Jagmohan Singh
University/college Name	Sher-E-Kashmir University Of Agricultural Sciences And Technology Of Jammu ,Jammu

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Objective

1. To aware the importance of preservation methods and techniques
2. How theses preservation methods and techniques help in improving quality and shelf life of food.

5.1 Introduction

Food preservation, any of a number of methods by which food is kept from spoilage after harvest or slaughter. Such practices date to prehistoric times. Among the oldest methods of preservation are drying, refrigeration, and fermentation. Modern methods include canning, pasteurization, freezing, irradiation, and the addition of chemicals. Advances in packaging materials have played an important role in modern food preservation.

5.2 Spoilage Mechanisms

Food spoilage may be defined as any change that renders food unfit for humanconsumption. These changes may be caused by various factors, including contamination by microorganisms, infestation by insects, ordegradationby endogenous enzymes (those present naturally in the food).

In addition, physical and chemical changes, such as the tearing of plant or animal tissues or the oxidation of certainconstituentsof food, may promote food spoilage. Foods obtained from plant or animal sources begin to spoil soon after harvest or slaughter. The enzymes contained in the cells of plant and animal tissues may be released as a result of any mechanical damage inflicted during postharvest handling. These enzymes begin to break down the cellular material. The chemical reactions catalyzed by the enzymes result in the degradation of food quality, such as the development of off-flavors, the deterioration of texture, and the loss of nutrients. The typical microorganisms that cause food spoilage are bacteria (e.g.,Lactobacillus), yeasts (e.g.,Saccharomyces), and molds (e.g.,Rhizopus).

5.2.1 Microbial contamination

Bacteria and fungi (yeasts and molds) are the principal types ofmicroorganismsthat cause food spoilage and food-borne illnesses. Foods may be contaminated by microorganisms at any time during harvest, storage, processing, distribution, handling, or preparation. The primary sources of microbial contamination are soil, air, animal feed, animal hides and intestines, plant surfaces, sewage, and food processing machinery or utensils.

Control of microbial contamination

The most common methods used either to kill or to reduce the growth of microorganisms are the

- application of heat,
- the removal of water,
- the lowering of temperature during storage,
- the reduction of pH,
- the control of oxygenand carbon dioxide concentrations,
- and the removal of the nutrients needed for growth.
- The use ofchemicalsas preservatives is strictly regulated by governmental agencies such as theFood and Drug Administration(FDA) in the United States and different government organizing body based in country. Although a chemical may havepreservativefunctions, its safety must be proved before it may be used in food products. To suppress yeast andmoldgrowth in foods, a number of chemical preservatives are permitted. List of such chemicals, known as GRAS (Generally Recognized as Safe), includescompoundssuch asbenzoic acid, sodium benzoate, propionic acid, sorbic acid, and sodium diacetate.

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5.2.2 Chemical deterioration

5.2.2.1 Enzymatic reactions

Enzymes

They are largeproteinmolecules that act as biologicalcatalysts, accelerating chemical reactions without being consumed to any appreciable extent themselves. The activity of enzymes is specific for a certain set of chemical substrates, and it is dependent on both pH and temperature.

The living tissues of plants and animals maintain a balance of enzymatic activity. This balance is disrupted upon harvest or slaughter. In some cases, enzymes that play a useful role in living tissues may catalyze spoilage reactions following harvest or slaughter. For example, the enzymepepsinis found in the stomach of all animals and is involved in the breakdown of proteins during the normal digestion process. However, soon after the slaughter of an animal, pepsin begins to break down the proteins of the organs, weakening the tissues and making them more susceptible to microbial contamination. After the harvesting of fruits, certain enzymes remain active within the cells of the plant tissues. These enzymes continue to catalyze the biochemical processes of ripening and may eventually lead to rotting, as can be observed in bananas. In addition, oxidative enzymes in fruits continue to carry out cellular respiration (the process of using oxygen to metabolize glucose for energy). This continued respiration decreases the shelf life of fresh fruits and may lead to spoilage. Respiration may be controlled by refrigerated storage or modified-atmosphere packaging. Table 1 lists a number of enzymes involved in thedegradationof food quality.

Enzymes that cause food spoilage		
enzyme	**food**	**spoilage action**
ascorbic acid oxidase	vegetables	destruction of vitamin C
lipase	cereals	Discoloration
	milk	hydrolytic rancidity
	oils	hydrolytic rancidity
lipoxygenase	vegetables	destruction of vitamin A, off-flavour
pectic enzyme	citrus juices	destruction of pectic substances
	fruits	excessive softening
peroxidase	fruits	Browning
polyphenoloxidase	fruits, vegetables	browning, off-flavour, vitamin loss
protease	eggs	reduction of shelf life of fresh and dried whole eggs
	crab, lobster	Overtenderization
	flour	reduction of gluten formation
thiaminase	meats, fish	destruction of thiamine

Table 1. Illustrating major enzymes responsible for food deterioration

5.2.2.2 Autoxidation

The unsaturated fatty acids present in the lipids of many foods are susceptible to chemical breakdown when exposed to oxygen. The oxidation of unsaturated fatty acids isautocatalytic; that is, it proceeds by a free-radicalchain reaction. Free radicals contain an unpaired electron (represented by a dot in the molecular formula) and, therefore, are highly reactive chemical molecules.

The basic mechanisms in a free-radical chain reaction involve initiation, propagation, and termination steps (Figure 1). Under certain conditions, in initiation a free-radical molecule (X ·) present in the food removes a hydrogen (H) atom from a lipid molecule, producing a lipid radical (L ·). This lipid radical reacts with molecular oxygen (O_2) to form aperoxy radical (LOO ·). The peroxy radical removes a hydrogen atom from another lipid molecule and the reaction starts over again (propagation). During the propagation steps, hydroperoxide molecules (LOOH) are formed that may break down into alkoxy (LO ·) and peroxy radicals plus water (H_2O). The lipid, alkoxy, and peroxy radicals may combine with one another (or other radicals) to form stable, nonpropagating products (termination). These products result in the development of rancid off-flavours. In addition to promotingrancidity, the free radicals and peroxides produced in these reactions may have other negative effects, such as the bleaching of food colour and the destruction of vitamins A, C, and E. This type of deterioration is prevalent in fried snacks, nuts,cookingoils, and margarine.

Initiation: $X\cdot + LH \rightarrow L\cdot + XH$

$L\cdot + O_2 \rightarrow LOO\cdot$

Propagation: $LOO\cdot + LH \rightarrow LOOH + L\cdot$

$2LOOH \rightarrow LO\cdot + LOO\cdot + H_2O$

Termination: $L\cdot, LO\cdot, LOO\cdot \rightarrow$ a number of stable nonpropagating species

Fig 1. Showing the mechanism of auto-oxidation in food.

5.2.2.3 Maillard reaction

Another **chemical reaction** that causes major food spoilage is non enzymatic browning, also known as the Maillard reaction. This reaction takes place between reducing sugars (simple monosaccharides capable of carrying out reduction reactions) and the amino group of proteins or amino acids present in foods. The products of the Maillard reaction lead to a darkening of colour, reduced solubility of proteins, development of bitter flavours, and reduced nutritional availability of certain amino acids such as lysine. The rate of this reaction is influenced by the water activity, temperature, and pH of the food product. Non enzymatic browning causes spoilage during the storage of dry milk, dry whole eggs, and breakfast cereals.

5.2.2.4 Light-inducedreactions

Light influences a number of chemical reactions that lead to spoilage of foods. These light-induced reactions include the destruction of chlorophyll (the photosynthetic pigment that gives plants their green colour), resulting in the bleaching of certain vegetables; the discoloration of fresh meats; the destruction of riboflavin in milk; and the oxidation of **vitamin C** and carotenoid pigments (a process called photosensitized oxidation). The use of packaging material that prevents exposure to light is one of the most effective means of preventing light-induced chemical spoilage.

Several **physical sources** are also responsible for deterioration of food and impact the quality of food

5.3 Techniques in food preservation

5.3.1 Curing

The earliest form of curing was **dehydration** or **drying**, used as early as 12,000 BC. Smoking and salting techniques improve on the drying process and add antimicrobial agents that aid in preservation. Smoke deposits a number of pyrolysis products onto the food, including the **phenols syringol, guaiacol** and catechol. Salt accelerates the drying process using osmosis and also inhibits the growth of several common strains of bacteria. More recently nitrite have been used to cure meat, contributing a characteristic pink color.

5.3.2 Cooling

Cooling preserves food by slowing down the growth and reproduction of microorganisms and the action of enzymes that causes the food to rot. The introduction of commercial and domestic refrigerators drastically improved the diets of many in the Western world by allowing food such as fresh fruit, salads and dairy products to be stored safely for longer periods, particularly during warm weather.

Before the era of mechanical refrigeration, cooling for food storage occurred in the forms of root cellars and iceboxes. Rural people often did their own ice cutting, whereas town and city dwellers often relied on the ice trade. Today, root cellaring remains popular among people who value various goals, including local food, heirloom crops, traditional home cooking techniques, family farming, frugality, self-sufficiency, organic farming, and others.

5.3.3 Freezing

Freezing is also one of the most commonly used processes, both commercially and domestically, for preserving a very wide range of foods, including prepared foods that would not have required freezing in their unprepared state. For example, potato waffles are stored in the freezer, but potatoes themselves require only a cool dark place to ensure many months' storage. Cold stores provide large-volume, long-term storage for strategic food stocks held in case of national emergency in many countries.

5.3.4 Boiling

Boiling liquid food items can kill any existing microbes. Milk and water are often boiled to kill any harmful microbes that may be present in them.

5.3.5 Heating

Heating to temperatures which are sufficient to kill microorganisms inside the food is a method used with perpetual stews. Milk is also boiled before storing to kill many microorganisms.

5.3.6 Sugaring

The earliest cultures have used sugar as a preservative, and it was commonplace to store fruit in honey. Similar to pickled foods, sugar cane was brought to Europe through the trade routes. In northern climates without sufficient sun to dry foods, preserves are made by heating the fruit with sugar. "Sugar tends to draw water from the microbes (plasmolysis). This process leaves the microbial cells dehydrated, thus killing them. In this way, the food will remain safe from microbial spoilage." Sugar is used to preserve fruits, either in an antimicrobial syrup with fruit such as apples, pears, peaches, apricots, and plums, or in crystallized form where the preserved material is cooked in sugar to the point of crystallization and the resultant product is then stored dry. This method is used for the skins of citrus fruit (candied peel), angelica, and ginger. Also, sugaring can be used in the production of jam and jelly.

5.3.7 Pickling

Pickling is a method of preserving food in an edible, antimicrobial liquid. Pickling can be broadly classified into two categories: chemical pickling and fermentation pickling.

In chemical pickling, the food is placed in an edible liquid that inhibits or kills bacteria and other microorganisms. Typical pickling agents include brine (high in salt), vinegar, alcohol, and vegetable oil. Many chemical pickling processes also involve heating or boiling so that the food being preserved becomes saturated with the pickling agent. Common chemically pickled foods include cucumbers, peppers, corned beef, herring, and eggs, as well as mixed vegetables such as piccalilli.

In fermentation pickling, bacteria in the liquid produce organic acids as preservation agents, typically by a process that produces lactic acid through the presence of lactobacillales. Fermented pickles include sauerkraut, nukazuke, kimchi, and surströmming.

5.3.8 Lye

Sodium hydroxide (lye) makes food too alkaline for bacterial growth. Lye will saponify fats in the food, which will change its flavor and texture. Lutefisk uses lye in its preparation, as do some olive recipes. Modern recipes for century eggs also call for lye.

5.3.9 Canning

Canning involves cooking food, sealing it in sterilized cans or jars, and boiling the containers to kill or weaken any remaining bacteria as a form of sterilization. It was invented by the French confectioner Nicolas Appert. By 1806, this process was used by the French Navy to preserve meat, fruit, vegetables, and even milk. Although Appert had discovered a new way of preservation, it wasn't understood until 1864 when Louis Pasteur found the relationship between microorganisms, food spoilage, and illness.

Foods have varying degrees of natural protection against spoilage and may require that the final step occur in a pressure cooker. High-acid fruits like strawberries require no preservatives to can and only a short boiling cycle, whereas marginal vegetables such as carrots require longer boiling and addition of other acidic elements. Low-acid foods, such as vegetables and meats, require pressure canning. Food preserved by canning or bottling is at immediate risk of spoilage once the can or bottle has been opened.

Lack of quality control in the canning process may allow ingress of water or micro-organisms. Most such failures are rapidly detected as decomposition within the can causes gas production and the can will swell or burst. However, there have been examples of poor manufacture (under processing) and poor hygiene allowing contamination of canned food by the obligate anaerobe Clostridium botulinum, which produces an acute toxin within the food, leading to severe illness or death. This organism produces no gas or obvious taste and remains undetected by taste or smell. Its toxin is denatured by cooking, however. Cooked mushrooms, handled poorly and then canned, can support the growth of Staphylococcus aureus, which produces a toxin that is not destroyed by canning or subsequent reheating.

5.3.10 Jellying

Food may be preserved by cooking in a material that solidifies to form a gel. Such materials include gelatin, agar, maize flour, and arrowroot flour. Some foods naturally form a protein gel when cooked, such as eels and elvers, and sipun culid worms, which are a delicacy in Xiamen, in the Fujian province of the People's Republic of China. Jellied eels are a delicacy in the East End of London, where they are eaten with mashed potatoes. Potted meats in aspic (a gel made from gelatin and clarified meat broth) were a common way of serving meat off-cuts in the UK until the 1950s. Many jugged meats are also jellied. A traditional British way of preserving meat (particularly shrimp) is by setting it in a pot and sealing it with a layer of fat. Also common is potted chicken liver; jellying is one of the steps in producing traditional pâtés.

Besides jellying of meat and seafood, a widely known type of Jellying is fruit preserves which are preparations of fruits, vegetables and sugar, often stored in glass jam jars and Mason jars. Many varieties of fruit preserves are made globally, including sweet fruit preserves, such as those made from strawberry or apricot, and savory preserves, such as those made from tomatoes or squash. The ingredients used and how they are prepared determine the type of preserves; jams, jellies, and marmalades are all examples of different styles of fruit preserves that vary based upon the fruit used. In English, the word, in plural form, "preserves" is used to describe all types of jams and jellies.

5.3.11 Jugging

Meat can be preserved by jugging. Jugging is the process of stewing the meat (commonly game or fish) in a covered earthenware jug or casserole. The animal to be jugged is usually cut into pieces, placed into a tightly-sealed jug with brine or gravy, and stewed. Red wine and/or the animal's own blood is sometimes added to the cooking liquid. Jugging was a popular method of preserving meat up until the middle of the 20th century.

5.3.12 Burial

Burial of food can preserve it due to a variety of factors: lack of light, lack of oxygen, cool temperatures, pH level, or desiccants in the soil. Burial may be combined with other methods such as salting or fermentation. Most foods can be preserved in soil that is very dry and salty (thus a desiccant) such as sand, or soil that is frozen.

Many root vegetables are very resistant to spoilage and require no other preservation than storage in cool dark conditions, for example by burial in the ground, such as in a storage clamp. Century eggs are traditionally created by placing eggs in alkaline mud (or other alkaline substance), resulting in their "inorganic" fermentation through raised pH instead of spoiling. The fermentation preserves them and breaks down some of the complex, less flavorful proteins and fats into simpler, more flavorful ones. Cabbage was traditionally buried during Autumn in northern US farms for preservation. Some methods keep it crispy while other methods produce sauerkraut. A similar process is used in the traditional production of kimchi. Sometimes meat is buried under conditions that cause preservation. If buried on hot coals or ashes, the heat can kill pathogens, the dry ash can desiccate, and the earth can block oxygen and further contamination. If buried where the earth is very cold, the earth acts like a refrigerator.

In Orissa, India, it is practical to store rice by burying it underground. This method helps to store for three to six months during the dry season.

Butter and similar substances have been preserved as bog butter in Irish peat bogs for centuries.

5.3.13 Confit

Meat can be preserved by salting it, cooking it at or near 100 °C in some kind of fat (such as lard or tallow), and then storing it immersed in the fat. These preparations were popular in Europe before refrigerators became ubiquitous. They are still popular in France, where they are called confit. The preparation will keep longer if stored in a cold cellar or buried in cold ground.

5.3.14 Fermentation

Some foods, such as many cheeses, wines, and beers, use specific micro-organisms that combat spoilage from other less-benign organisms. These micro-organisms keep pathogens in check by creating an environment toxic for themselves and other micro-organisms by producing acid or alcohol. Methods of fermentation include, but are not limited to, starter micro-organisms, salt, hops, controlled (usually cool) temperatures and controlled (usually low) levels of oxygen. These methods are used to create the specific controlled conditions that will support the desirable organisms that produce food fit for human consumption.

Fermentation is the microbial conversion of starch and sugars into alcohol. Not only can fermentation produce alcohol, but it can also be a valuable preservation technique. Fermentation can also make foods more nutritious and palatable. For example, drinking water in the Middle Ages was dangerous because it often contained pathogens that could spread disease. When the water is made into beer, the boiling during the brewing process kills any bacteria in the water that could make people sick. Additionally, the water now has the nutrients from the barley and other ingredients, and the microorganisms can also produce vitamins as they ferment.

5.4 Modern industrial techniques

Techniques of food preservation were developed in research laboratories for commercial applications.

5.4.1 Drying and Dehydration

The principle behind drying is that sufficient moisture is removed, which is essential for growth of microorganisms and for enzyme activity. Removal of moisture increases the storage life of the product due to reduced water activity. If the moisture content is reduced to 1 to 5 per cent then the product can be stored for more than a year. The processing should be done in such a way that the food value, natural flavour and characteristic cooking quality of the fresh material are retained after drying. A good dried product on reconstitution with water should resemble the original product.

5.4.2 Pasteurization

Pasteurization is a process for preservation of liquid food. It was originally applied to combat the souring of young local wines. Today, the process is mainly applied to dairy products. In this method, milk is heated at about 70 °C (158 °F) for 15–30 seconds to kill the bacteria present in it and cooling it quickly to 10 °C (50 °F) to prevent the remaining bacteria from growing. The milk is then stored in sterilized bottles or pouches in cold places. This method was invented by Louis Pasteur, a French chemist, in 1862.

5.4.3 Vacuum packing

Vacuum-packing stores food in a vacuum environment, usually in an air-tight bag or bottle. The vacuum environment strips bacteria of oxygen needed for survival. Vacuum-packing is commonly used for storing nuts to reduce loss of flavor from oxidization. A major drawback to vacuum

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packaging, at the consumer level, is that vacuum sealing can deform contents and rob certain foods, such as cheese, of its flavor.

5.4.4 Artificial food additives

Preservative food additives can be antimicrobial – which inhibit the growth of bacteria or fungi, including mold – or antioxidant, such as oxygen absorbers, which inhibit the oxidation of food constituents. Common antimicrobial preservatives include calcium propionate, sodium nitrate, sodium nitrite, sulfites (sulfur dioxide, sodium bisulfite, potassium hydrogen sulfite, etc.), and EDTA. Antioxidants include butylated hydroxyanisole (BHA) and butylated hydroxytoluene (BHT). Other preservatives include formaldehyde (usually in solution), glutaraldehyde (insecticide), ethanol, and methylchloroisothiazolinone. There is also another approach of impregnating packaging materials (plastic films or other) with antioxidants and antimicrobials, such as butylated hydroxyanisole, butylated hydroxytoluene, tocopherols, hinokitiol, lysozyme, nisin, natamycin, chitosan, and ε-polylysine.

5.4.5 Irradiation

Irradiation of food is the exposure of food to ionizing radiation. Multiple types of ionizing radiation can be used, including beta particles (high-energy electrons) and gamma rays (emitted from radioactive sources such as cobalt-60 or cesium-137). Irradiation can kill bacteria, molds, and insect pests, reduce the ripening and spoiling of fruits, and at higher doses induce sterility. The technology may be compared to pasteurization; it is sometimes called "cold pasteurization", as the product is not heated. Irradiation may allow lower-quality or contaminated foods to be rendered marketable.

National and international expert bodies have declared food irradiation as "wholesome"; organizations of the United Nations, such as the World Health Organization and Food and Agriculture Organization, endorse food irradiation. Consumers may have a negative view of irradiated food based on the misconception that such food is radioactive; in fact, irradiated food does not and cannot become radioactive. Activists have also opposed food irradiation for other reasons, for example, arguing that irradiation can be used to sterilize contaminated food without resolving the underlying cause of the contamination. International legislation on whether food may be irradiated or not varies worldwide from no regulation to a full ban.

Approximately 500,000 tons of food items are irradiated per year worldwide in over 40 countries. These are mainly spices and condiments, with an increasing segment of fresh fruit irradiated for fruit fly quarantine.

5.4.6 Pulsed electric field electroporation

Pulsed electric field (PEF) electroporation is a method for processing cells by means of brief pulses of a strong electric field. PEF holds potential as a type of low-temperature alternative pasteurization process for sterilizing food products. In PEF processing, a substance is placed between two electrodes, then the pulsed electric field is applied. The electric field enlarges the pores of the cell membranes, which kills the cells and releases their contents. PEF for food processing is a developing technology still being researched. There have been limited industrial applications of PEF processing for the pasteurization of fruit juices. To date, several PEF treated juices are available on the market in Europe. Furthermore, for several years a juice pasteurization application in the US has used PEF. For cell disintegration purposes especially potato processors show great interest in PEF technology as an efficient alternative for their preheaters. Potato applications are already operational in the US and Canada. There are also commercial PEF potato applications in various countries in Europe, as well as in Australia, India, and China.

5.4.7 Modified atmosphere

Modifying atmosphere is a way to preserve food by operating on the atmosphere around it. Salad crops that are notoriously difficult to preserve are now being packaged in sealed bags with an atmosphere modified to reduce the oxygen (O2) concentration and increase the carbon dioxide (CO2) concentration. There is concern that, although salad vegetables retain their appearance and texture in such conditions, this method of preservation may not retain nutrients, especially vitamins. There are two methods for preserving grains with carbon dioxide. One method is placing a block of dry ice in the bottom and filling the can with the grain. Another method is purging the container from the bottom by gaseous carbon dioxide from a cylinder or bulk supply vessel.

Carbon dioxide prevents insects and, depending on concentration, mold and oxidation from damaging the grain. Grain stored in this way can remain edible for approximately five years.

Nitrogen gas (N_2) at concentrations of 98% or higher is also used effectively to kill insects in the grain through hypoxia. However, carbon dioxide has an advantage in this respect, as it kills organisms through hypercarbia and hypoxia (depending on concentration), but it requires concentrations of above 35%,or so. This makes carbon dioxide preferable for fumigation in situations where a hermetic seal cannot be maintained.

5.4.8 Controlled Atmospheric Storage (CA): "CA storage is a non-chemical process. Oxygen levels in the sealed rooms are reduced, usually by the infusion of nitrogen gas, from the approximate 21 percent in the air we breathe to 1 percent or 2 percent. Temperatures are kept at a constant 0–2 °C (32–36 °F). Humidity is maintained at 95 percent and carbon dioxide levels are also controlled. Exact conditions in the rooms are set according to the apple variety. Researchers develop specific regimens for each variety to achieve the best quality. Computers help keep conditions constant." "Eastern Washington, where most of Washington’s apples are grown, has enough warehouse storage for 181 million boxes of fruit, according to a report done in 1997 by managers for the Washington State Department of Agriculture Plant Services Division. The storage capacity study shows that 67 percent of that space—enough for 121,008,000 boxes of apples—is CA storage.

Air-tight storage of grains (sometimes called hermetic storage) relies on the respiration of grain, insects, and fungi that can modify the enclosed atmosphere sufficiently to control insect pests. This is a method of great antiquity, as well as having modern equivalents. The success of the method relies on having the correct mix of sealing, grain moisture, and temperature.

A patented process uses fuel cells to exhaust and automatically maintain the exhaustion of oxygen in a shipping container, containing, for example, fresh fish.

5.4.9 Non thermal plasma

This process subjects the surface of food to a "flame" of ionized gas molecules, such as helium or nitrogen. This causes micro-organisms to die off on the surface.

5.4.10 High-pressure food preservation

High-pressure food preservation or pascalization refers to the use of a food preservation technique that makes use of high pressure. "Pressed inside a vessel exerting 70,000 pounds per square inch (480 MPa) or more, food can be processed so that it retains its fresh appearance, flavor, texture and nutrients while disabling harmful microorganisms and slowing spoilage." By 2005, the process was being used for products ranging from orange juice to guacamole to deli meats and widely sold.

5.4.11 Biopreservation

3D stick model of nisin. Some lactic acid bacteria manufacture nisin. It is a particularly effective preservative.

Biopreservation is the use of natural or controlled microbiota or antimicrobials as a way of preserving food and extending its shelf life. Beneficial bacteria or the fermentation products produced by these bacteria are used in biopreservation to control spoilage and render pathogens inactive in food. It is a benign ecological approach which is gaining increasing attention.

Of special interest are lactic acid bacteria (LAB). Lactic acid bacteria have antagonistic properties that make them particularly useful as biopreservatives. When LABs compete for nutrients, their metabolites often include active antimicrobials such as lactic acid, acetic acid, hydrogen peroxide, and peptide bacteriocins. Some LABs produce the antimicrobial nisin, which is a particularly effective preservative.

These days, LAB bacteriocins are used as an integral part of hurdle technology. Using them in combination with other preservative techniques can effectively control spoilage bacteria and other pathogens, and can inhibit the activities of a wide spectrum of organisms, including inherently resistant Gram-negative bacteria.

5.4.12 Hurdle technology

Hurdle technology is a method of ensuring that pathogens in food products can be eliminated or controlled by combining more than one approach. These approaches can be thought of as "hurdles" the pathogen has to overcome if it is to remain active in the food. The right combination of hurdles can ensure all pathogens are eliminated or rendered harmless in the final product.

Hurdle technology has been defined by Leistner (2000) as an intelligent combination of hurdles that secures the microbial safety and stability as well as the organoleptic and nutritional quality and the economic viability of food products.The organoleptic quality of the food refers to its sensory properties, that is its look, taste, smell, and texture.

Examples of hurdles in a food system are high temperature during processing, low temperature during storage, increasing the acidity, lowering the water activity or redox potential, and the presence of preservatives or biopreservatives. According to the type of pathogens and how risky they are, the intensity of the hurdles can be adjusted individually to meet consumer preferences in an economical way, without sacrificing the safety of the product.

Course Name	Fundamentals Of Food Technology
Lesson 6	Thermal Processing Of Food
Content Creator Name	Dr Mohammed Wasim Siddiqui
University/College Name	Bihar Agricultural University, Bhagalpur
Course Reviewer Name	Dr. Jagmohan Singh
University/college Name	Sher-E-Kashmir University Of Agricultural Sciences And Technology Of Jammu ,Jammu

Objective

1. To give basic concept of thermal processing and its use in food preservation
2. How it is helpful in preserving food and killing of spoilage organism.

6.1 Introduction

The safety and storage life of many perishable foods can be enhanced by the use of high temperatures to inactivate undesirable disease and spoilage-causing microorganisms and to inactivate enzymes in food that can cause spoilage.

6.2 Objectives of thermal processing/cooking

1. Improves the taste and food quality for e.g. roasting of groundnut and coffee seeds, frying of onions and papads, cooking meat with spices, frying cashew nuts in ghee, etc.

2. Destruction of microorganisms

Harmful microorganisms' causes infections or produce toxins. Eg. Clostridium botulism and Salmonella. Some moulds produce toxin. Aspergillus flavus produces aflatoxin in groundnuts, cereals and spices. Cooking helps to destroy the harmful microorganisms eg in cooked meat.

3. Improves digestibility

Cooking softens the connective tissue of the meat and the coarse fibres of cereals, pulses and vegetables so that the digestive period is shortened and Gastro Intestinal tract is less subjected to irritation. Cooking improves the texture and hence it becomes more chewable. Cooking also bursts the starch digestion is easier, rapid and complete. When dry heat is applied to starches they are converted to easily digestible dextrins. Cooking increases the access to enzymes and improves digestibility.

4. Increases variety

By cooking, same food can be made into different dishes, for eg. rice can be made into plain, bular, lemon rice, biriyani or combination with pulses into idli, wheat can be made into chapatis, bun, paratha or halwa.

Cooking

6.3 Limitations of thermal processing/cooking

- Thiamine and vitamin C which is heat sensitive, may be lost during cooking.
- Water soluble vitamins are leached into the water during cooking. Vitamin A content may be reduced due to oxidation and heat.
- Quality of protein may be reduced due to destruction of certain amino acids during cooking eg. bread crust has less quality of protein compared to the crumb.

6.4 Heat Transfer methods:

- Heat may be transferred to the food during cooking **by conduction, convection, radiation or by the energy or microwaves** – electronic heat transfer.
- Water or steam and air or fat or combination of these is used as cooking media.
- **Moist heat** involves water and steam.
- Air or fat are used in **dry heat**.

Note- Heat sufficient to destroy microorganisms and food enzymes also generally affect other properties of foods adversely. The mildest heat treatments that guarantee free-down from pathogens and toxins and produce the desired storage life will be the heat treatments of choice.

• Three categories of thermal preservation of foods are

– **Blanching**

– **Pasteurization**

– **Commercial Sterilization**

6.4.1 Blanching:

Blanching is a form of thermal processing applied mainly to vegetables and some fruit by exposing them to heated or boiling water or even culinary steam for a short period of time.

• Blanching is a food processing operation designed to

- Inactivate enzymes in plant tissues and enzymes
- Reduces Microbial load
- Wilt vegetable products to enable packing
- Drive off inter- and intracellular oxygen and other gases from plant tissues.

Blanching (scalding vegetables in boiling water or steam for a short time) is a must for almost all vegetables to be frozen. It stops enzyme actions which can cause loss of flavor, color and texture.

Advantage: Blanching cleanses the surface of dirt and organisms, brightens the color and helps retard loss of vitamins. It also wilts or softens vegetables and makes them easier to pack.

Blanching time is crucial and varies with the vegetable and size. Underblanching stimulates the activity of enzymes and is worse than no blanching. Overblanching causes loss of flavor, color, vitamins and minerals. Follow recommended blanching times.

Water Blanching

- For home freezing, the most satisfactory way to heat all vegetables is in boiling water. Use a blancher which has a blanching basket and cover, or fit a wire basket into a large pot with a lid.

- Use one gallon water per pound of prepared vegetables. Put the vegetable in a blanching basket and lower into vigorously boiling water. Place a lid on the blancher. The water should return to boiling within 1 minute, or you are using too much vegetable for the amount of boiling water. Start counting blanching time as soon as the water returns to a boil. Keep heat high for the time given in the directions for the vegetable you are freezing.

Steam Blanching

- Heating in steam is recommended for a few vegetables. For broccoli, pumpkin, sweet potatoes and winter squash, both steaming and boiling are satisfactory methods. Steam blanching takes about 1½ times longer than water blanching.
- To steam, use a pot with a tight lid and a basket that holds the food at least three inches above the bottom of the pot. Put an inch or two of water in the pot and bring the water to a boil.

- Put the vegetables in the basket in a single layer so that steam reaches all parts quickly. Cover the pot and keep heat high. Start counting steaming time as soon as the lid is on. See steam blanching times recommended for the vegetables listed below.

Microwave Blanching

Microwave blanching may not be effective, since research shows that some enzymes may not be inactivated. This could result in off-flavors and loss of texture and color. Those choosing to run the risk of low quality vegetables by microwave blanching should be sure to work in small quantities, using the directions for their specific microwave oven. Microwave blanching will not save time or energy.

Cooling/Shocking

- As soon as blanching is complete, vegetables should be cooled quickly and thoroughly to stop the cooking process. To cool, plunge the basket of vegetables immediately into a large quantity of cold water, 60ºF or below. Change water frequently or use cold running water or ice water. If ice is used, about one pound of ice for each pound of vegetable is needed. Cooling vegetables should take the same amount of time as blanching.
- Drain vegetables thoroughly after cooling. Extra moisture can cause a loss of quality when vegetables are frozen.

TABLE-1 Blanching Times*

Vegetable	Blanching Time (minutes)
Artichoke-Globe (Hearts)	7
Artichoke-Jerusalem	3-5
Asparagus Small Stalk Medium Stalk Large Stalk	 2 3 4
Beans-Snap, Green, or Wax	3
Beans-Lima, Butter, or Pinto Small Medium Large	 2 3 4
Beets	cook
Broccoli (flowerets 11/2 inches across) Steamed	 3 5
Brussel Sprouts Small Heads Medium Heads Large Heads	 3 4 5
Cabbage or Chinese Cabbage (shredded)	 1 1/2
Carrots Small Diced, Sliced or Lengthwise Strips	 5 2
Cauliflower (flowerets, 1 inch across)	 3

Vegetable	Blanching Time (minutes)
Celery	3
Corn Corn-on-the-cob Small Ears Medium Ears Large Ears Whole Kernel or Cream Style (ears blanched before cutting corn from cob)	 7 9 11 4
Eggplant	4
Greens Collards All Other	 3 2
Kohlrabi Whole Cubes	 3 1
Mushrooms Whole (steamed) Buttons or Quarters (steamed) Slices steamed)	 5 3 1/2 3
Okra Small Pods Large Pods	 3 4
Onions (blanch until center is heated) Rings	 3-7 10-15 seconds
Peas-Edible Pod	1 1/2-3
Peas-Field(blackeye)	2

Vegetable	Blanching Time (minutes)
Peas-Green	1 1/2
Peppers-Sweet Halves Strips or Rings	 3 2
Potatoes-Irish (New)	3-5
Pumpkin	cook
Rutabagas	3
Soybeans-Green	5
Squash-Chayote	2
Squash-Summer	3
Squash-Winter	cook
Sweet Potatoes	cook
Turnips or Parsnips Cubes	 2

*blanching times are for water blanching unless otherwise indicated.

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6.4.2 Pasteurization:

- Pasteurization is a thermal process that involves using temperatures of at least 72°C for 15 seconds (high temperature short time or HTST process), prior to packaging.

- In other words Pasteurization is a mild heat treatment of liquid foods (both packaged and unpackaged) where products are typically heated to below 100 °C.
- The process is intended to destroy or deactivate organisms and enzymes that contribute to spoilage or risk of disease, including vegetative bacteria, but not bacterial spores.
- Since pasteurization is not sterilization, and does not kill spores, a second "double" pasteurization will extend the quality by killing spores that have germinated.
- Acid food products (pH < 4.6) are mainly pasteurized to inactivate spoilage-causing microorganisms.
- Pathogenic microorganisms cannot grow and do not survive very well in acid foods such as citrus juices or apple juice (with the exception of Escherichia coli 0157:H7).
- The process was named after the French microbiologist, Louis Pasteur, whose research in the 1860s demonstrated that thermal processing would deactivate unwanted microorganisms in wine.

Ultra-high-temperature (UHT) pasteurization

- It involves heating milk or cream to 138°to 150° C (280° to 302° F) for one or two seconds. Packaged in sterile, hermetically sealed containers, UHT milk may be stored without refrigeration for months.
- Ultrapasteurized milk and cream are heated to at least 138° C for at least two seconds, but because of less stringent packaging they must be refrigerated. Shelf life is extended to 60–90 days.
- After opening, spoilage times for both UHT and ultrapasteurized products are similar to those of conventionally pasteurized products.

6.4.3 Sterilisation:

- Sterilization signifies the destruction of all viable organisms and their spores which could be cultivated using appropriate techniques by means of the application of temperatures in excess of 100°C.
- For example, a low acid food (pH>4.6) requires heating above 100°C, generally between 116°C and 130°C for a time which is sufficient to reduce the number of Clostridium botulinium spores by the value of 1012. However, high acid foods (fruit juices) do not need such intensive treatment as bacteriological development does not take place at these pH values.
- Nevertheless, normal practice inclines towards the application of the higher temperatures with a consequent reduction in processing times, which enables the product to retain the nutritional and organic properties to a maximum.
- HTST pasteurisation has a high degree of acceptance in the food industry given the operational efficiency which it brings. Properly operated these units allow high production volumes with minimum space. The principle of this system lies in establishing an appropriate relationship between the process variables of time-temperature-pressure.

Commercial Sterilization (CS):

- The basis for preservation by Commercial Sterilization (CS) is to destroy both spoilage and disease causing microorganisms in low-acid and acid foods, thus rendering the food "commercially sterile".
- Commercially sterile means the condition obtained in a food that has been processed by the application of heat, alone or in combination with other treatments, to render the food free from viable forms of microorganisms, including spores, capable of growing in the food at

temperatures at which the food is designed normally to be held during distribution and storage.

Table-2: Pasteurization conditions used for milk products

Pasteurization Type	Typical Product	Typical Storage	Temperature	Holding Time
Batch, vat	Milk	Refrigerated	145°F (62.8°C)	30 min
"	Viscous products, or products with more than 10% fat or added sweetener	"	150°F (65.6°C)	30 min
"	Egg nog, frozen dessert mixes	"	155°F (68.3°C)	30 min
Continuous, high temperature short time (HTST)	Milk	"	161°F (71.7°C)	15 sec
"	Viscous products, or products with more than 10% fat or added sweetener	"	166°F (74.4°C)	15 sec

"	Egg nog, frozen dessert mixes	"	175°F (79.4°C)	25 sec
"	"	"	180°F (82.2°C)	15 sec
Continuous, higher heat shorter time (HHST)	Milk	"	191°F (88.3°C)	1 sec
"	"	"	194°F (90°C)	0.5 sec
"	"	"	201°F (93.8°C)	0.1 sec
"	"	"	204°F (96.2°C)	0.05 sec
"	"	"	212°F (100°C)	0.01 sec
Continuous, Ultrapasteurization	Milk and cream	Refrigerated, extended storage	280°F (137.8°C)	2 sec
Aseptic, ultra high temperature (UHT)	Milk	Room temperature	275-302°F (135-150°C)	4-15 sec
Sterilization	Canned products	"	240°F (115.6°C)	20 min

6.5 Selection of Heat Treatment

The intensity of the heat treatment employed for a particular food preservation application depends upon a number of factors. The main considerations in selecting the required temperature-time conditions for thermal processing are:

- What is the objective or purpose? (Blanching or pasteurization or commercial sterilization)
- Are there additional preservation steps? (Is it combined with other preservation method?)
- What are the physical, chemical properties of the food? (Type of food)
- What is the heat resistance of microorganisms in the food?
- Foods that will be consumed within a short period of time afterprocessing can have storage life extended by a combination ofpasteurization and refrigerated storage (used for pasteurized milkand for pasteurized, vacuum packaged, cured meats).
- Longer storage times at ambient temperatures in evacuated sealedcontainers requires the use of commercial sterilization.
- The time-temperature combination required for pasteurization andcommercial sterilization is determined by the most heat-resistantdisease-causing and spoilage-causing microorganisms in theparticular food commodity.

6.6 Thermal Destruction of Microorganisms and Resistance to heat

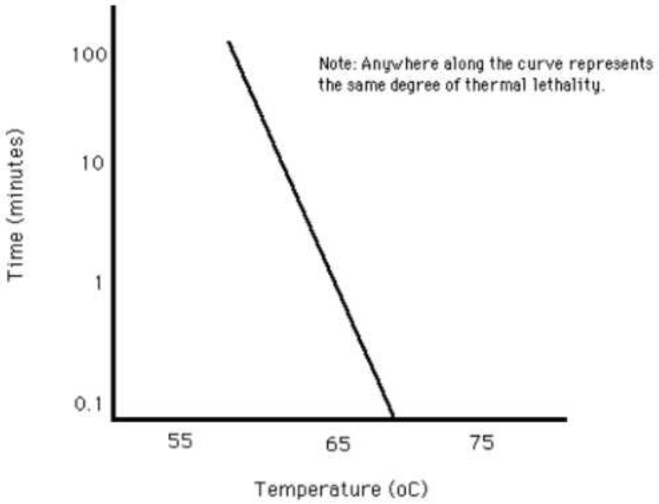
The most heat-resistant pathogen found in foods, especially those that are canned and held under anaerobic conditions, is **Clostridium, botulinum**.

- However, there are nonpathogenic spore-forming spoilage bacteria, such as Putrefactive Anaerobe 3679 (PA 3679) and Bacillus stearothermophilus (FS 1518), which are even more heat resistant than C. botulinum. If a heat treatment inactivates these spoilage organisms, C. botulinum and all other pathogens in the food also will be destroyed.
- Heat is lethal to microorganisms, but each species has its own particular heat tolerance. During a thermal destruction process, such as pasteurization, the rate of destruction is logarithmic, as is their rate of growth. Thus bacteria subjected to heat are killed at a rate that is proportional to the number of organisms present.

- The process is dependent both on the temperature of exposure and the time required at this temperature to accomplish to desired rate of destruction. Thermal calculations thus involve the need for knowledge of the concentration of microorganisms to be destroyed, the acceptable concentration of microorganisms that can remain behind (spoilage organisms, for example, but not pathogens), the thermal resistance of the target microorganisms (the most heat tolerant ones), and the temperature time relationship required for destruction of the target organisms.
- The extent of the pasteurization treatment required is determined by the heat resistance of the most heat-resistant enzyme or microorganism in the food. For example, milk pasteurization historically was based on Mycobacterium tuberculosis and Coxiella burnetti, but with the recognition of each new pathogen (C. Botulinum), the required time temperature relationships are continuously being examined.
- Thus, heat and time combination can be understand using **thermal death curve.**

Thermal Death Curve

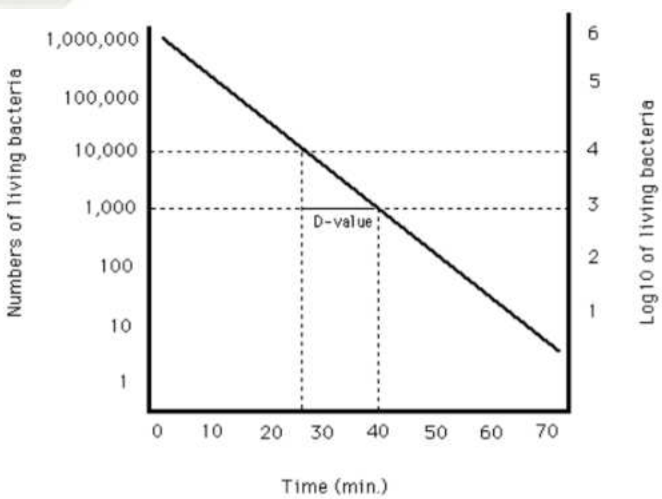
A thermal death curve for this process is shown below. It is a logarithmic process, meaning that in a given time interval and at a given temperature, the same percentage of the bacterial population will be destroyed regardless of the population present. For example, if the time required to destroy one log cycle or 90% is known, and the desired thermal reduction has been decided (for example, 12 log cycles), then the time required can be calculated. If the number of microorganisms in the food increases, the heating time required to process the product will also be increased to bring the population down to an acceptable level. The heat process for pasteurization is usually based on a 12 D concept, or a 12 log cycle reduction in the numbers of this organism.



Thermal Death Time Curve for *Coxiella burnetti*, z = 4oC

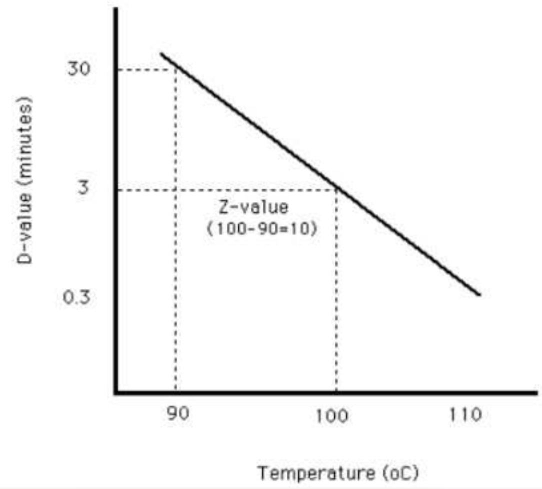
Several parameters help us to do thermal calculations

The D value is a measure of the heat resistance of a microorganism. It is the time in minutes at a given temperature required to destroy 1 log cycle (90%) of the target microorganism. (Of course, in an actual process, all others that are less heat tolerant are destroyed to a greater extent). For example, a D value at 72°C of 1 minute means that for each minute of processing at 72°C the bacteria population of the target microorganism will be reduced by 90%. In the illustration below, the D value is 14 minutes (40-26) and would be representative of a process at 72°C.



The Z value reflects the temperature dependence

The Z value reflects the temperature dependence of the reaction. It is defined as the temperature change required to change the D value by a factor of 10. In the illustration below the Z value is 10°C.



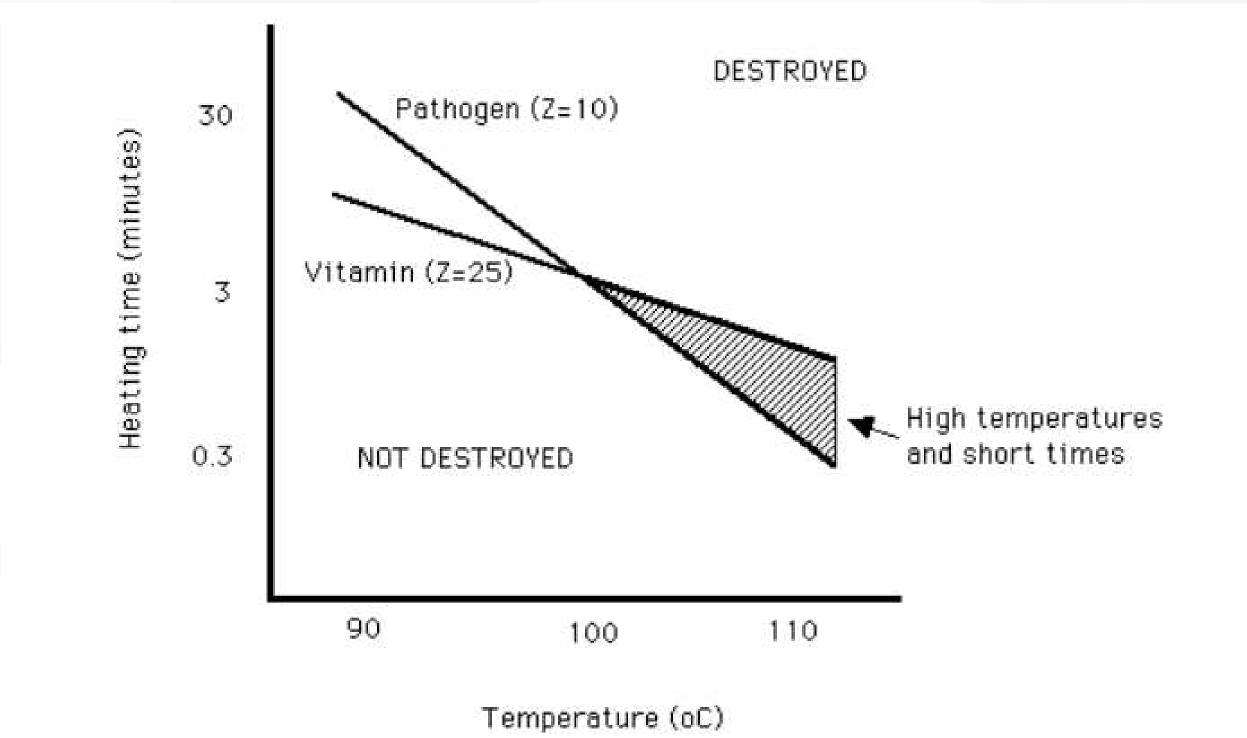
Reactions that have small Z values are highly temperature

Reactions that have small Z values are highly temperature dependent, whereas those with large Z values require larger changes in temperature to reduce the time. A Z value of 10°C is typical for a spore forming bacterium. Heat induced chemical changes have much larger Z values that microorganisms, as shown below.

- Bacteria Z (°C) 5-10 D121 (min) 1-5
- Enzymes Z (°C) 30-40 D121 (min) 1-5
- Vitamins Z (°C) 20-25 D121 (min) 150-200
- Pigments Z (°C) 40-70 D121 (min) 15-50

The figure below (which is schematic and not to scale) illustrates the relative changes in time temperature profiles for the destruction of microorganisms.

Above and to the right of each line the microorganisms or quality factors would be destroyed, whereas below and to the left of each line, the microorganisms or quality factors would not be destroyed. Due to the differences in Z values, it is apparent that at higher temperatures for shorter times, a region exists (shaded area) where pathogens can be destroyed while vitamins can be maintained. The same holds true for other quality factors such as colour and flavour components. Thus in UHT milk processing, very high temperatures for very short times (e.g., 140oC for 1-2 s) are favoured compared to a lower temperature longer time processes since it results in bacterial spore elimination with a lower loss of vitamins and better sensory quality.



6.7 Canning and bottling of foods

Canning is process of preservation by sealing and sterilization of food in air tight container. The main aim of canning is to create aseptic conditionsand

prevent recontamination. Heat is most common agent used to destroy the micro-organism.
The canning process is comprised of several scientific steps, and enhances the shelf life and quality of food products.

Canning process was first invented after prolonged research by Nicolas Appert and further in 1810 Peter Durand of England patented the use of tin-coated iron cans instead of bottles.

A typical commercial canning operation may employ the following general processes: washing, sorting/grading, peeling, coring, cutting, container filling, exhausting, container sealing, heat sterilization, cooling, labeling, and storage for shipment.

Typical canned products include beans (cut and whole), beets, carrots, corn, peas, spinach, tomatoes, apples, peaches, pineapple, pears and apricots. Juices are also preserved by canning like orange, pineapple, grapefruit, tomato, and cranberry.

Canned vegetables generally require more severe processing than fruits because the vegetables have much lower acidity and contain more heat-resistant soil organisms. Methods used for cooking vary widely like in some fruits preliminary treatments steps occur prior to heating but in vegetable preliminary steps done after blanching. Peeling is done either by steam or lye peeling.

The principle of canning is same as the process was invented but production and processing of canned foods have changed considerably over the past decades.

Technically bottling refers to storing in glass bottles and canning refers to storing in tin cans, although mode of preservation is same in both.

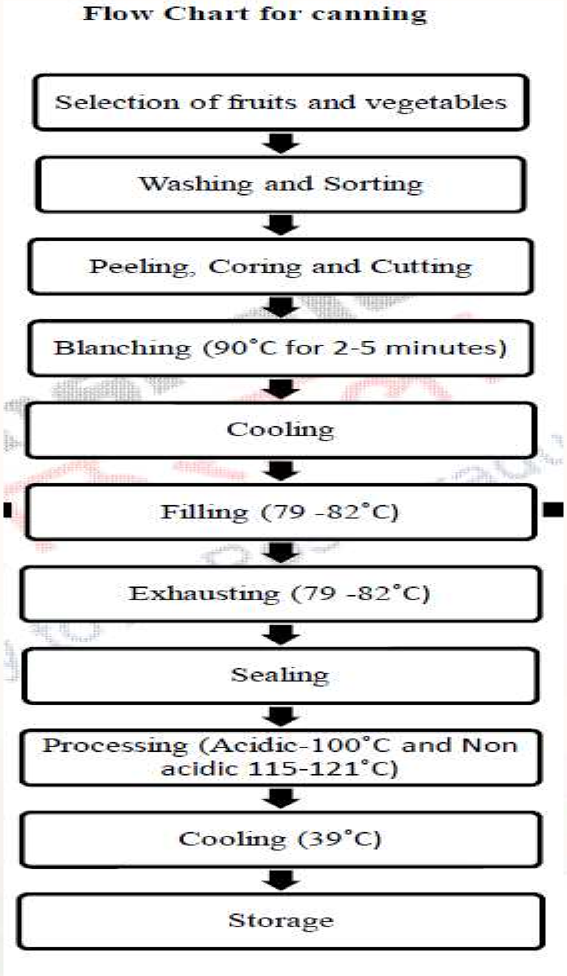
6.7.1 Preparation for canning

1. **Selection of fruits and vegetables:**Fruits and vegetables selected for canning should befresh. Fruits usedfor canning should be ripe, firm and evenly matured, and vegetables should betender. Fruits and vegetables should be stored at cool place and free from dirt, mechanical injuryand insect damage. The main processes for canning are described in this chapter.
2. **Sorting and grading:**Sorting for same kind of items is done by passing through series ofmoving screens. After sorting fruits and vegetables are graded for uniform quality of sizeand color. Different types of grading machines are used such as screen grader, roller grader,rope and cable grader. Hand picking methods is generally used for soft fruits and berries.
3. **Washing:** Fruits and vegetables are washed through high pressure sprays, steam, by soaking or agitating in water. Vegetables soaked in a dilute solution of potassium permanganate and root crops soaked in chlorine water (25-50 ppm).
4. **Peeling, Coring and Cutting:** Hand peeling, heat peeling, steam peeling, mechanical peeling and lye peeling methods are used. Hand peeling is done in case of irregular shape fruits and vegetables. In heat peeling fruits and vegetables are exposed to a hightemperature of 40˚C for 10-60 seconds. In steam peeling, steam is used to loosen the skinwhich is then removed by mechanical means. Fruit are immersed in 1- 2% lye solution for30 seconds to 2 minutes in lye peeling. Mechanical peeling is done in case of fruits likepeaches, apricots, sweet orange and vegetables like carrot, sweet potatoes. Coring is theprocess of removing centre of various fruits and vegetables such as apple, pears, pineapple,

lettuce and cabbage, done by a hydraulic powered device with turbine wheels. A specialblade mounted on the turbine wheel spins and removes the core. Cutting is done accordingto the requirement of process.

5. **Blanching:** Blanching is done by dipping fruits and vegetables in hot water at temperature82-90˚ C for 2-5 minutes and then immediately cooled by immersion in cold water. Mainobjective of blanching is to inactivate the enzyme,to soften the texture, to loosen skin, toreduce the number of micro-organism, to enhance the green color of vegetables, to removeacid and astringent taste. Hard water cause toughening of tissue and destroys the naturaltexture, so it should be avoided.
6. **Cooling:** To keep fruits and vegetable into good condition, cooling is done after blanching.

Flow Chart for canning process



6.7.2 Filling: Before filling cans are subjected to steam jet or hot water to remove dust and foreign material. Automatic can filing machine is used by canning industry. Generally for fruits filling is done by hand to prevent the bruising. After filling syrup or brine is added.

a.) Syruping: Syrup is a solution of sugar in water, done only for fruits. Syrup is added to improve the flavor and serve as a heat transfer medium for facilitating processing.

Strained, hot syrup of concentration 20 to 55˚ brix is used and filled at about 79 to

82˚C, leaving head space of 0.3 to 0.5cm.

b.) Brining: Brine is a solution of salt of concentration 1-3%, used for vegetables. The brine should be filtered through a thick cloth before filling.

After Syruping or brining the cans are loosely covered with lids and exhausted. Lidding has certain disadvantages such as spilling of the contents and toppling of the lids. Hence lidding has now been replaced by clinching in which lids is partially seamed.

6.7.3 Exhausting: Exhausting is the process of removal of air from the cans. It is very essential as it avoids the corrosion of tinplate and pinholing during the storage. Exhausting is done to minimize discoloration, to reduce chemical reaction between the container and thecontents. It alsohelps in better retention of vitamin and prevents development of excessive pressure during sterilization. For exhausting heating method is generally used but can also be done bymechanical means. The can are passed through a tank of hot water at 82 to 87˚C for 5-10 minutes. At the end of exhausting temperature at the center of can should be about79 ˚C.

6.7.4 Sealing: After exhausting can are sealed immediately with the help of can sealer and temperature should not fall below 74˚C during sealing.

6.7.5 Processing: It is heating or cooling of canned foods to inactivate the bacteria. Processing time and temperature should be adequate to eliminate all bacteria and to minimize quality damage. Fruits and vegetables processed at temperature of 100˚C as presence of acid retards the bacteria and their spores. Non-acid vegetables are processed at high temperature115-121˚C. Temperature and processing time vary with size of can and nature of food.Temperature at the centre of can, should be maintained for long period of time to ensure the destruction of most heat resistant bacteria. Fruits and vegetables are classified into groups depend on pH value given in Table 1.

6.8 Processing methods:

Generally three types of processing methods are used for canning like open cookers, continuous non-agitating and continuous agitating cookers. Open cookers are made up on wooden tubs or galvanized iron tanks of desired capacity. In continuous non-agitating cookers, cans travel on a continuous moving belt in boiling water crates. Processing time reduced by using continuous agitating cookers.

- **Cooling:** Cans are cooled rapidly to 39˚C to stop the process and to prevent the stack burning. Cooling is done either by dipping or immersing can in cold water tank or by spraying jet of cold water. In case of canned vegetables, cooling is done by turning in cold water into pressure cooker.
- . **Storage:** After labelling cans are packed in strong wooden cases and stored in cool and dryplace. Storage at high temperature should be avoided as it shortens the shelf-life of the product.

6.9 Type of containers

Tin container: Tin cans are made up of thin steel plate of low carbon content, lightly coated on both sides with tin metal. Coating may not be uniform that result in discoloration of products or corrosion of tin plate. This situation can be avoided by lacquering of cans. There are two types of lacquering.

a) Acid-resistant: It is golden coloured enamel and can coated with it called R or A.R. cans.

It is used for high acidic fruits and vegetables e.g., peach, pineapple, grapefruit, strawberry and raspberry.

b) Sulphur resistant: This enamel is also of golden colour and cans arecoated with it called

C or S.R. cans. It is used for non- acidic products e.g., pea, corn, lima bean, red kidney bean.

Glass container: Contents are visible in glass container and reusable. They do not contaminate the contents but highly fragile in nature.

6.10 Bottling of fruits and vegetables

Bottles have high initial cost but reusable, and also proved to be very good containers for home preservation. Glass containers provides very attractive look and resistant to the development of metallic flavor. Although glass containers have high cost so they are not suitable for manufacturer's point of view. General steps followed in processing are same as that of canning. Bottles are thoroughly washed and sterilized before filling and 1-1.5 cm head space should be left. There is no need of exhausting separately as it is done simultaneously with sterilization by putting a false bottom under bottles. Water temperature should be raised slowly as too much fluctuation in temperature leads to breakage. At the time of sterilization lids are left open and boiling water for sterilization should be filled up to the neck of bottles. After completion of sterilization bottles are closed immediately.

6.11 Spoilage in canned foods

Generally there are two reasons for the spoilage of canned food

1.) Microorganism

2.) Spoilage due to physical and chemical changes

6.11.1 Microbial Spoilage

Thermophilic and mesophilic organism are responsible for canned food spoilage.

Thermophilic bacteria can survive at a high temperature of 100˚C. Facultative thermophiles can grow at 43˚C and obligate thermophiles grow at 43-77˚C. Spoilage by mesophilic organism is the indication of under processing. Generally Clostridium, Bacillus, yeast and fungi cause spoilage of can due to formation of carbon dioxide and hydrogen. Thermophiles can cans three types of spoilage:

a) **Flat sour**: Flat sour spoilage occurs mostly in non-acidic foods by Bacillus such as B.

coagulans and B. sterothermophiluswhich produce acid without gas formation. Flat sour spoiled product is unfit for consumption as it has sour odour and highly acidic.

b) **Themophilic acid spoilage**: Clostridium thermosaccharolyticum, an obligate thermophile, is responsible for TA spoilage in which cans swell due to production of carbon dioxide and hydrogen.

c) **Sulphide spoilage:** Also known as sulphur stinker is caused by Clostridium nigrificans in low acid foods and occurs in case of under processing of canned foods.

6.11.2 Spoilage due to physical and chemical changes:

Swell: It is bulging of can due to pressure of gases formed by microbial and chemical action.

- **Hydrogen Swell:** Hydrogen gas produced by the action of food acids on metal of can that can cause bulging of can. Canned food remains fit for consumption as it is free of microorganism.
- **Flipper:** Swelling of can when both ends become convex and flips out, but when can push back to normal condition by little pressure. Flipper caused by overfilling, underexhaustingand gas pressure due to spoilage.
- **Springer:** It occurs when the can swells at both end due to insufficient exhausting or overfilling.
- **Soft swell:** It is more or less similar to that of flipper in which both ends of can swell.
- When can is pressed, the end returned back to the normal position and springs back when pressure is removed.

- **Hard swell**: It is a final stage of swell in which bulged end cannot be pressed back to normal position and can ultimately burst.

Leakage: Leakage is due to defective seaming, nail holes caused by faulty nailing of cases, excessive internal pressure, corrosion and mechanical damage during handling.

Breathing: It is a very tiny leak in can through which air can pass in and destroy the vacuum.

Stack browning: When cans are not allowed to cool properly before storing stack browning takes place which results in discoloration, cooked flavor and soft product.

So, it is necessary to cool product to 39˚C before storage.

Course Name	Fundamentals Of Food Technology
Lesson 7	Low Temperature Processing Of Food
Content Creator Name	Dr Mohammed Wasim Siddiqui
University/College Name	Bihar Agricultural University, Bhagalpur
Course Reviewer Name	Dr. Jagmohan Singh
University/college Name	Sher-E-Kashmir University Of Agricultural Sciences And Technology Of Jammu ,Jammu

Objective

1. To know about low temperature processing of food.
2. How it is helpful in food industry, its mechanism and role in preventing microbial growth.

7.1 Food preservation by low temperature

Low temperature reduces the activity of microorganisms by reducing the chemical reaction and action of enzymes. Low temperature will prevent growth of microorganisms and slow down the metabolic activity resulted in delayed / prevent spoilage.

Chilling at low temperature of 4°C can prevent the growth of food poisoning microorganisms except the Clostridium botulinum type E and restrict the growth of a number of different spoilage microorganisms. Thus, it is used everywhere for temporary preservation of food.

Few Psychrotrophs can grow at low temperature range e.g. Flavobacterium spp. and Pseudomonas alcaligenes but they often showed a low growth rate.

Food preservation of low temperature is a physical method of food preservation. Lowering the storage temperature of food reduces or prevent spoilage by microorganism and/or chemical reactions.

Freezing temperature helps to reduce the number of viable microorganism but does not sterilize the food. The percentage of microorganisms killed during freezing and storage depends on

a) Type of food

b) Type of freezing

Low Temperature can be produced by

1. Chilling/Refrigeration
2. Freezing

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7.1.1 Chilling

Chilling is a processing technique in which the temperature of a food is reduced and kept at a temperature between –1°C and 8°C. The objective of cooling and chilling is to reduce the rate of biochemical and microbiological changes in foods, in order to extend the shelf life of fresh and processed foods, or to maintain a certain temperature in a food process, e.g. in the fermentation and treatment of beer. Cooling is also used to promote a change of state of aggregation, e.g. crystallization. In the wine industry, cooling (chilling) is applied to clarify the must before fermentation. The objective of cold stabilization is to obtain the precipitation of tartrates (in wines) or fatty acids (in spirits) before bottling.

Preservation of food above freezing point and below 15^{0} C is called chilling or refrigeration.

Chilling has minimal effect on the sensory and other quality attributes of food.

Chilling effects on food:

- Checked growth of microorganisms.
- Restricts postharvest and post slaughter metabolic activities of plant and animal tissues respectively.
- Deteriorative effect on chemical reactions including enzyme-catalyzed oxidative browning or oxidation of lipids and chemical changes associated with color degradation, autolysis of fish and loss of nutritive value of foods.
- Reduce moisture loss.

Field of application

- -1° C to + 1°C (fresh fish, meats, sausages and ground meats, smoked meats and fish).
- 0°C to + 5°C (pasteurized canned meat, milk and milk products, prepared salads, baked goods, pizzas, unbaked dough and pastry).

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- 0°C to + 8°C (fully cooked meats and fish pies, cooked or uncooked cured meats, butter, margarine, cheese and soft fruits).
- 8°C to 12°C in the wine industry. The must is kept at this temperature between 6 and 24 hours.

Advantages of Chilling

- There is very little change in flavour, colour, texture or shape.
- Fresh foods can be kept at maximum quality for a longer time.
- The consumer can be offered a much larger range of fresh and convenience foods.
- Nutrients are not destroyed.

Chilling Equipments

Mechanical refrigerators

Cryogenic systems

Mechanical refrigerators --- Mechanical refrigerators (fig-1) have four basic elements: an evaporator, a compressor, a condenser and an expansion valve. A refrigerant circulates between the four elements of the refrigerator, changing state from liquid to gas and back to liquid.

A mechanical refrigerator have 4 basic components; 1. Evaporator, 2. Condenser, 3. Compressor, 4. Expansion valve through which the refrigerant circulate and changing state from liquid to gas and then gas to liquid.

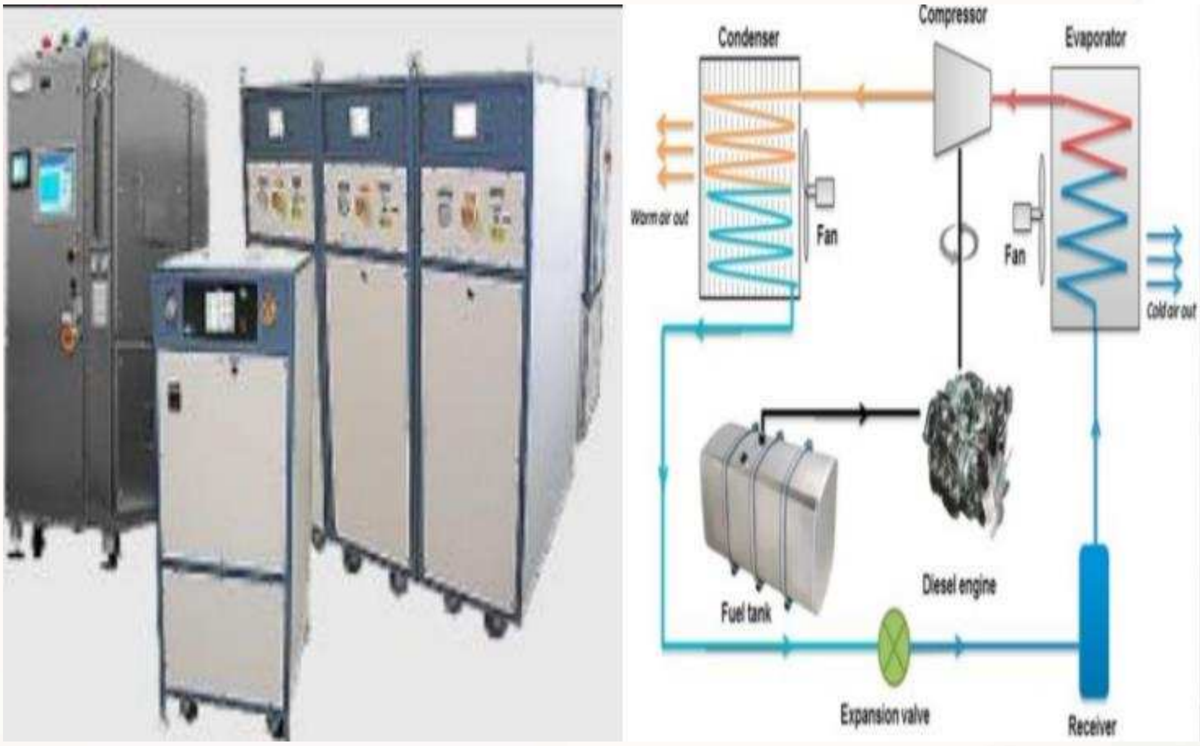


Fig-1

Cryogenic systems --- Cryogenic chillers (fig-2) use solid carbon dioxide, liquid carbon dioxide and liquid nitrogen. Solid carbon dioxide removes latent heat of sublimation and liquid cryogens remove latent heat of vaporization.

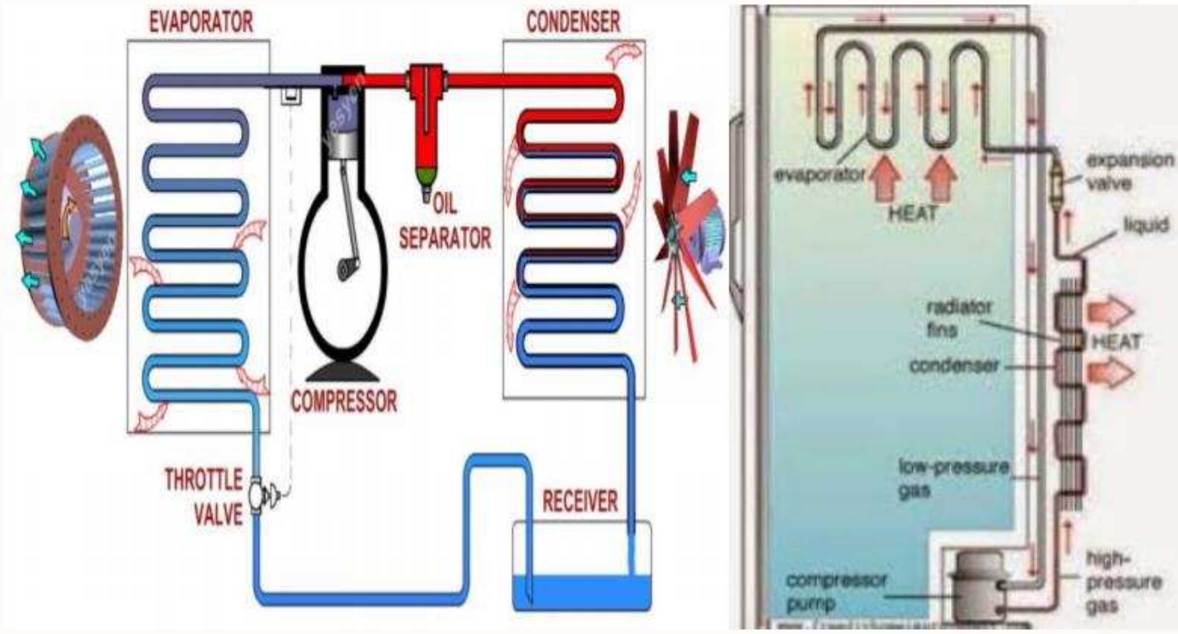


Fig-2

Cryogenic refrigerator

- The most significant effect of chilling of foods on the sensory characteristics of processed food is hardening due to solidification of fats and oils.
- Other effects include enzymatic browning, lipolysis, color and flavor deterioration, and retrogradation of starch to cause staling of bread, protein denaturation, and vitamin degradation.
- Growth of mesophilic and thermophilic microbes are greatly retarded at chilling temperature. Psychotrophic microorganism ofcourse grow well at chilling temperature (0^0-15^0 C) but the growth rate is retarded.
- Rate of respiration and ripening usually decline as the temperature goes below to 4^0 C in case of climacteric fruit.

Chilling Injury

Chilling injury is damage to plant parts caused by temperatures above the freezing point (32°F, 0°C). Plants of tropical or subtropical origin are most susceptible to injury. Chilling-injured leaves may become purple or reddish and in some cases wilt. Both flowers and fruit of sensitive species can be injured.

Super Chilling

Super chilling is that where temperature of food is maintained below 0°C but ice crystals are not generated. Super chilling is defined as a technology where food is stored just below the initial freezing temperature.

The temperature of the food products is lowered in the range of -1^0 to -4^{0}C by means of slurry ice and super chilled chambers without ice.

Refrigeration

Temperatures typically between 45 – 32°F (7.2 – 0°C). Preferably below 38°F.

Refrigeration or cold storage of food is a gentle method of food preservation. It has minimum adverse effects on the taste, texture, and the nutritional value of foods. It must be kept in mind, however, that refrigeration has a limited contribution towards preserving food. For most foods, we can expect refrigeration to extend the shelf-life by a few days. In many cases, refrigeration is not the sole means of preserving the food. Refrigeration temperature is a key factor in predicting the length of the storage period. For example, meat will last 6-10 days at 0° C, one day at 22° C and less than one day at 38° C. Household refrigerators are usually run at 4.7 -7°C. Commercial refrigerators are operated at a slightly lower temperature. On an average day, the room temperature is 25° C, thus leaving the food at this condition the sooner it will spoil. Most spoilage microorganisms prefer warmer temperatures, but there are a group of microorganisms called psychrophilic which will grow at refrigerated temperatures.

Refrigeration and freezing are used on almost all foods: meats, fruits, vegetables, beverages, etc. In general, refrigeration has no effect on a food's taste or texture. Freezing has no effect on the taste or texture of most meats, has minimal effects on vegetables, but often completely changes fruits (which become mushy). Refrigeration's minimal effects account for its wide popularity.

WHY DO WE SEE MORE NEW REFRIGERATED FOODS ENTERING THE MARKETPLACE THAN OTHER FOODS?

- Consumer demand for high quality foods:
- Typically less change in the quality of food product.
- Convenient – shorter cook times
- Changes in food distribution
- Buying habits
- Improved food distribution
- Improved processing techniques
- Aseptic processes
- Gas storage [CA (controlled atmosphere and MAP (modified atmosphere packaging)]

7.1.2 Freezing

In food processing, method of preserving food by lowering the temperature to inhibit microorganism growth. The method has been used for centuries in cold regions, and a patent was issued in Britain as early as 1842 for freezing food by immersion in an ice and salt brine.

Freezing is the unit operation in which the temperature of a food is reduced below its freezing point and a proportion of the water undergoes a change in state to form ice crystals. The immobilization of water to ice and the resulting concentration of dissolved solutes in unfrozen water lower the water activity (aw) of the food.

Except for beef and venison, which benefit from an aging process, meat is frozen as promptly as possible after slaughter, with best results at temperatures of 0 °F (−18 °C) or lower. Fruits are frozen in a syrup or dry sugar pack to exclude air and prevent both oxidation and desiccation.

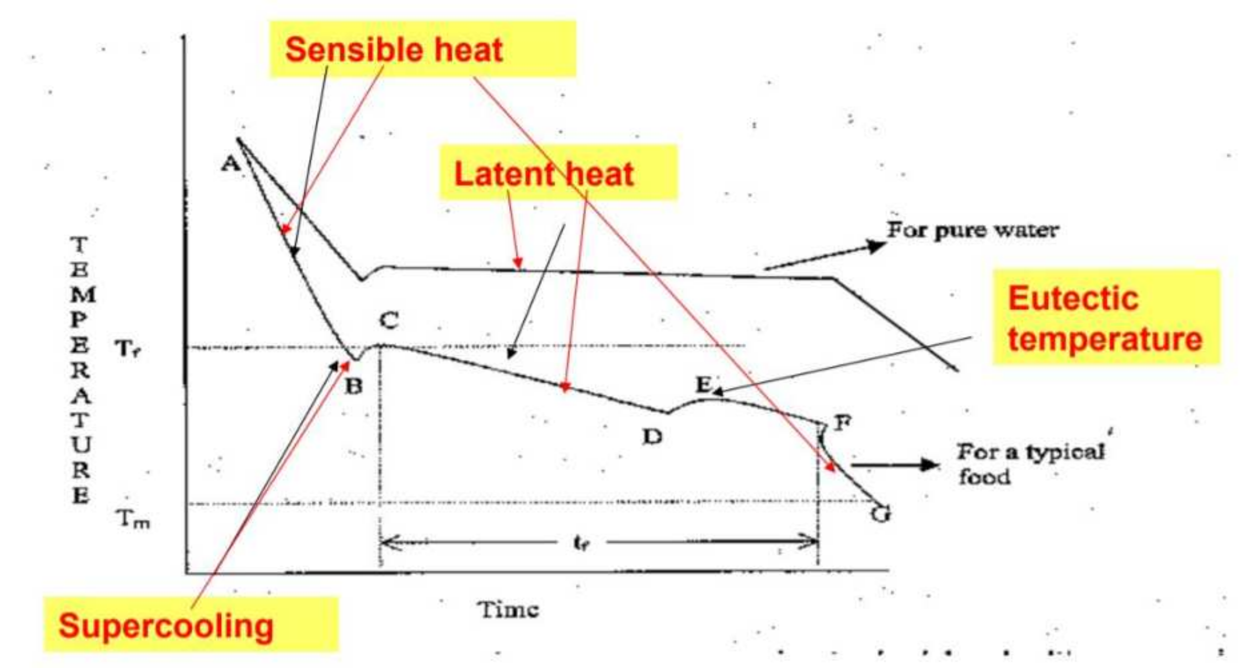
Principles of Freezing

- Does not sterilize food.
- Extreme cold (0^oF or -18^oC colder):
- Stops growth of microorganisms and
- Slows chemical changes, such as enzymatic reactions.

Preservation is achieved by a combination of low temperatures, reduced water activity and, in some foods, pre-treatment by blanching.

Principle of Freezing

- Sensible heat is removed firstly to lower the temperature of the food to the freezing point.
- Heat produced by respiration in fresh food (fruit & vegetables) is also removed.
- Then latent heat of crystallization is removed from ice crystals.
- The latent of heat of crystallization from other component (e.g. fat) of food is also removed.



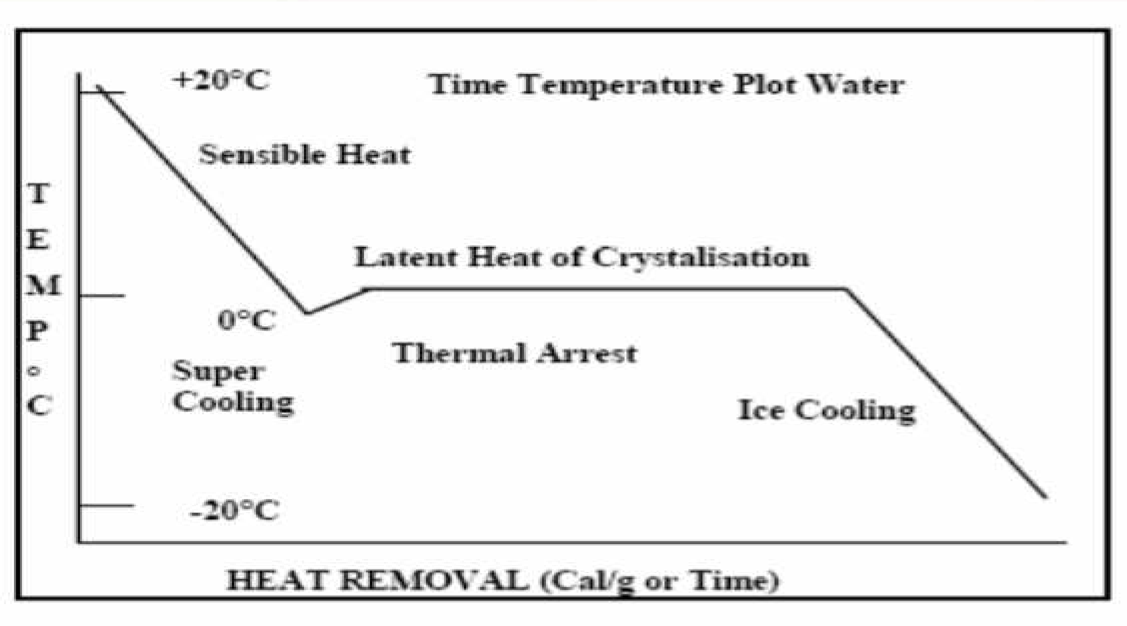


Fig-3

Type of Freezing

Plate Freezing: Product is pressed between hollow metal plates, either horizontally or vertically with a refrigerant circulating inside plates.

Immersion Freezing: Food can be frozen rapidly by direct immersion in liquid such as brine, syrup, glycerol, etc. at low temperature (-18 ºC).

Cabinet Freezing: Cold air is circulated in a cabinet where product is placed on a tray.

Advantages of Freezing

- Many foods can be frozen.
- Natural color, flavor, and nutritive value retained.
- Texture usually better than other methods of food preservation.
- Foods can be frozen in less time than they can be dried or canned.
- Simple procedures.Adds convenience to food preparation.
- Proportions can be adapted to needs unlike other home preservation methods. Kitchen remains cool and comfortable
- Frozen food can be kept for a very long period of time. Usually about 3 months.
- Deep freezing is the reduction of temperature in a food to a point where microbial activity cease

Disadvantages of Freezing

- Texture of some foods is undesirable because of freezing process.
- Initial investment and cost of maintaining freezer is high.
- Storage space limited by capacity of freezer

How Freezing Affects Food

- Chemical changes
- Cold burn
- Enzymes in vegetables
- Enzymes in fruit
- Rancidity
- Texture Changes
- Expansion of food
- Ice crystals

7.2 EFFECT OF FREEZING ON MICROORGANISMS

Considering the effect of freezing on a number of microorganisms that are unable to grow at freezing temperatures, it is well established that freezing is one method of preserving microbial cultures and freeze drying being perhaps the best method known. However, freezing temperatures have been shown to effect the killing of certain microorganisms of importance in foods.

The salient facts of what happens to certain microorganisms upon freezing:

1. Showed sudden mortality immediately on freezing and it varies with species.

2. The proportion of cells surviving immediately after freezing die gradually when stored in the frozen state.

3. This decline in numbers is relatively rapid at temperatures just below the freezing point, especially about −2◦C but less at lower temperatures and it is usually slow below −20◦C.

Bacteria differ in their capacity to survive during freezing with cocci being generally more resistant than Gram-negative rods. Of the food-poisoning bacteria, salmonellae are less resistant than Staphylococcus aureus or vegetative cells of clostridia, whereas endospores and food-poisoning toxins are apparently unaffected by low temperatures.

From the strict stand point of food preservation freezing should not be regarded as a means of destroying food borne microorganisms. Low freezing temperatures of about −20◦C are less harmful to microorganisms than the median range of temperatures, such as −10◦C. For example, more microorganisms are destroyed at −4◦C than at −15◦C or below. Temperatures below −24◦C seem to have no additional effect. Food constituents such as egg white, sucrose, corn syrup, fish, glycerol, and un-denatured meat extracts have all been found to increase freezing viability, especially of food-poisoning bacteria, whereas acid conditions have been found to decrease cell viability.

7.3 CHEMICAL EFFECTS OF FREEZING •

- Concentration of chemicals in liquid phase
- Increased acidity
- Low pH →protein denaturation
- Effect more pronounced during storage and slow freezing

Types of chemical changes

- Flavor and odor deterioration
- Pigment degradation
- Enzymatic browning
- Autoxidation of ascorbic acid
- Protein insolubilization
- Lipid oxidation

Prevention of chemical changes

- Inactivation of enzymes
- Low temperature storage
- Alternation of pH
- Exclusion of oxygen

Concerns with Frozen food

- Chemical reactions can occur in unfrozen water.
- Some foods blanched or sulfited before freezing.
- Vacuum packaging to keep out oxygen.
- Undesirable physical changes
- Fruits and vegetables lose crispness
- Drip loss in meats and colloidal type foods (starch, emulsions)
- The effect of refrigeration on foods is two folds
- Freezer burn

A decrease in temperature results in a slowing down of chemical, microbiological and biochemical processes.

At temperature below 0^0C water freezes out of solution as ice, which is equivalent in terms of water availability to dehydration or a reduction in**water activity**(aw).

Freezer burn

Freezer burn is the result of moisture loss from storage in the freezer. It leads to changes in the quality of your food and may result in ice crystals, shriveled produce, and tough, leathery, and discolored meats.

Despite the quality changes, freezer burnt food is safe to eat

7.4 Methods of freezing

Freezing techniques include:

The use of cold air blasts or other low temperature gases coming in contact with the food, e.g. blasts, tunnel, fluidized bed, spiral, belt freezers.

Indirect contact freezing, e.g. plate freezers, where packaged foods or liquids are brought into contact with metal surfaces (plate, cylinders) cooled by circulating refrigerant (multi-plate freezers).

Direct immersion of the food into a liquid refrigerant, or spraying liquid refrigerant over the food (e.g. liquid nitrogen, and freon, sugar or salt solutions).

7.5 Types of Freezing:

Air Freezing – Products frozen by either “still” or “blast” forced air.

- Cheapest (investment)
- Still slowest, more changes in product

- Blast faster, more commonly used

Indirect contact freezing – Food placed in direct contact with cooled metal surface.

- Relatively faster
- More expensive

Direct contact freezing – Food placed in direct contact with refrigerant (liquid nitrogen, "green" Freon, carbon dioxide snow)

- Faster
- Expensive
- Freeze individual food particles

7.6 Thawing

Thawing is the process of taking a frozen product from frozen to a temperature (usually above 0°C) where there is no residual ice, i.e. "defrosting". Thawing is often considered as simply the reversal of the freezing process. However, inherent in thawing is a major problem that does not occur in the freezing operation. The majority of the bacteria that cause spoilage or food poisoning are found on the surfaces of many foods. During the freezing operation, surface temperatures are reduced rapidly and bacterial multiplication is severely limited, with bacteria becoming completely dormant below -10°C. In the thawing operation these same surface areas are the first to rise in temperature and bacterial multiplication can recommence.

Effect of Thawing

Repeated freezing and thawing will destroy bacteria by disrupting cell membranes. Faster the thawing process the greater the number of bacterial survivors and the reason of this is not clear. It was pointed out that slow thawing showed potentially more detrimental effect than freezing.

7.7 Freezing equipments:

1. Mechanical Freezers
2. Cryogenic Systems
3. Cooled-air freezers
4. Blast freezers
5. Fluidized-bed freezers
6. Rapid Freezer
7. Cooled-surface freezers
8. Plate freezing
9. Cooled-liquid freezers
10. Immersion freezing
11. Cryogenic freezers

Course Name	Fundamentals Of Food Technology
Lesson 8	Drying And Dehydration Of Foods
Content Creator Name	Dr Mohammed Wasim Siddiqui
University/College Name	Bihar Agricultural University, Bhagalpur
Course Reviewer Name	Dr. Jagmohan Singh
University/college Name	Sher-E-Kashmir University Of Agricultural Sciences And Technology Of Jammu ,Jammu

Designed and developed under the aegis of NAHEP Component-2 Project "Investments In ICAR Leadership In Agricultural Higher Education"
Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

Objective

1. To know the basic concept of drying, its mechanism and usefulness in food industry.
2. How it is better than other preservation methods.

8.1 Why moisture removal?

Water is one of the most important factors controlling the rate of deterioration of food, by either microbial or non-microbial effects. Water activity (a_w) is used for the preservation of food, stabilization of the food supply, and developing different types of shelf-stable foods. Heating, freeze drying, freeze concentration, and osmotic concentration methods are used to reduce water activity of foods. Dried or low-moisture foods do not contain more than 25% moisture. Reduction of water activity in foods prevents the growth of vegetative microbial cells, germination of spores, and toxin production by molds and bacteria.

- Water is called universal solvent, it is required for growth, metabolism, and support of many chemical reaction occurring in food products.
- Microorganism requires water to support their growth, thus moisture is the crucial factor which determine the rate of food spoilage.

Free water

Water available for microbial growth, support chemical reactions, and act as a transporting medium for components.

Bound water

In the bound state water is not available for microbial growth, chemical reactions, and metabolic activities.

Water activity of a food

The water activity (a w) of a food is the ratio between the vapor pressure of the food itself, when in a completely undisturbed balance with the surrounding air media, and the vapor pressure of distilled water under identical conditions. A water activity of 0.80 means the vapor pressure is 80 percent of that of pure water.

The water activity increases with temperature. The moisture condition of a product can be measured as the **equilibrium relative humidity (ERH)** expressed in percentage or as the water activity expressed as a decimal.

8.2 Principle of Preservation by Drying/ Dehydration/ Concentration

Drying or dehydration removes that sufficient moisture which is essential for growth of microorganisms and for enzyme activity. Removal of moisture increases the storage life of the product due to reduced water activity. If the moisture content is reduced to 1 to 5 per cent then the product can be stored for more than a year. The processing should be done in such a way that the food value, natural flavour and characteristic cooking quality of the fresh material are retained after drying. A good dried product on reconstitution with water should resemble the original product.

8.2.1 Drying

Removal of water from the food by non-conventional energy source such as sunlight and wind.

8.2.2 Dehydration

The process of removal of moisture from the food under controlled condition such as temperature, relative humidity, and air flow.

Drying & Dehydration

- One of the oldest method of food preservation.
- Both drying and dehydration means removal of water.

- Removes moisture, inhibits the growth of bacteria, yeast & molds to prevent food spoilage.
- Slows down enzyme activity but not completely destroyed.
- Drying cause deteriorations of food quality and nutritional value.
- Dehydrated foods have lower water activity (a_w =0.2-0.6)
- This a_w is not enough free water for
    - Microorganism growth needs water activity a_w = 0.93 specially bacteria.

      Stephylo Aureous (a_w >0.85)

      Mold (a_w >0.6)
    - Chemical reaction needs a_w >0.3
- Microorganism is not killed, keep it in in active stage and will resume growth after food is rehydrated.

Theory

Dehydration involves the simultaneous application of heat and removal of moisture from foods. Factors that control the rates of heat and mass transfer are described. Except for osmotic dehydration, in which foods are soaked in concentrated solutions of sugar or salt to remove water using the difference in osmotic pressure as the driving force for moisture transfer. This method is used to produce 'crystallised' or sugared fruits and with salt it is used in some countries as a pre-treatment for fish and vegetables before drying.

Dehydration by heated air or heated surfaces is described in this chapter.

There are a large number of factors that control the rate at which foods dry, which can be grouped into the following categories:

- Related to the processing conditions
- Related to the nature of the food
- Related to the drier design.

The effects of processing conditions and type of food are described below and differences in drier design are summarized.

8.3 Drying using heated air

Psychrometrics There are three inter-related factors that control the capacity of air to remove moisture from a food:

1. The amount of water vapor already carried by the air

2. The air temperature

3. The amount of air that passes over the food.

The amount of water vapor in air is expressed as either absolute humidity (termed moisture content in Fig.1.) or relative humidity (RH) (in per cent).

Psychrometric is the study of inter-related properties of air–water vapor systems. These properties are conveniently represented on a psychrometric chart (Fig. 1).

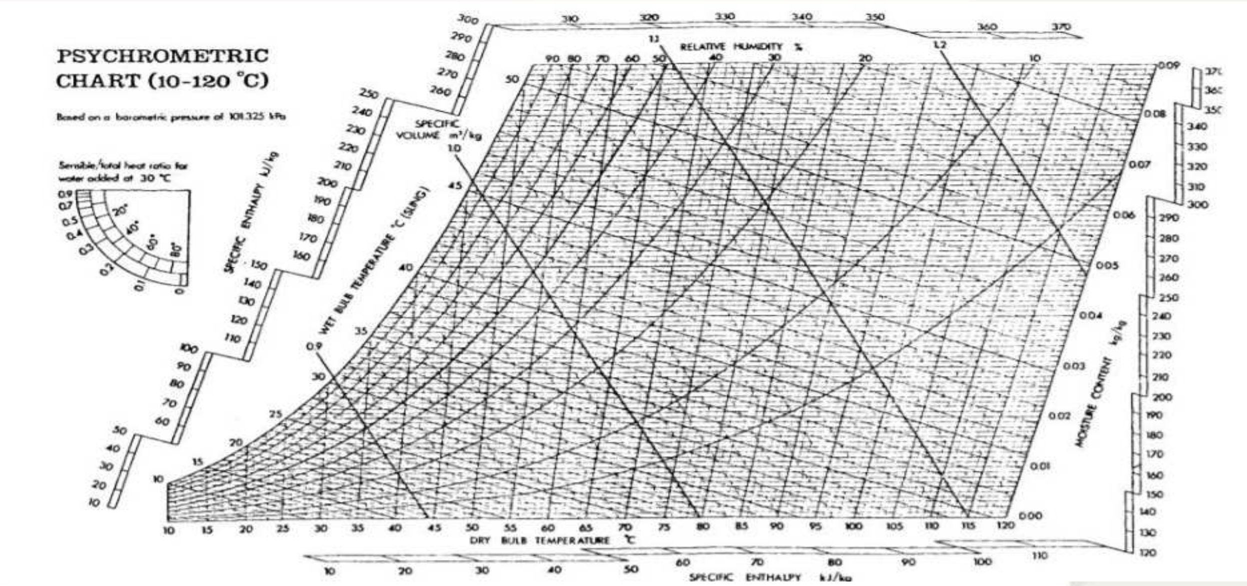


Fig 1. Psychometrics chart

Heat from drying air is absorbed by food and provides the latent heat needed to evaporate water from the surface. The temperature of the air, measured by a thermometer bulb, is termed the **dry-bulb temperature**. If the thermometer bulb is surrounded by a wet cloth, heat is removed by evaporation of water from the cloth and the temperature falls. This lower temperature is called the **wet-bulb temperature**. The difference between the two temperatures is used to find **the relative humidity** of air on the psychrometric chart. An increase in air temperature, or reduction in RH, causes water to evaporate more rapidly from a wet surface and therefore produces a greater fall in temperature. The **dew point** is the temperature at which air becomes saturated with moisture (100% RH) and any further cooling from this point results in condensation of the water from the air. Adiabatic cooling lines are the parallel straight lines sloping across the chart, which show how absolute humidity decreases as the air temperature increases.

8.3.1 Mechanism of drying

The third factor that controls the rate of drying, in addition to air temperature and humidity, is the air velocity. When hot air is blown over a wet food, water vapor diffuses through a boundary film of air surrounding the food and is carried away by the moving air (Fig. 2). A water vapor pressure gradient is established from the moist interior of the food to the dry air. This gradient provides the 'driving force' for water removal from the food.

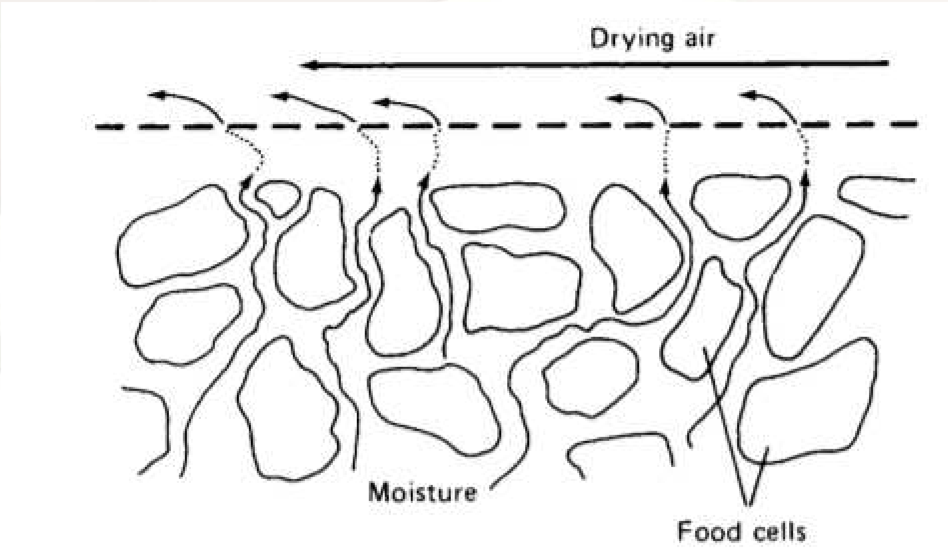


Fig. 2. Movement of moisture during dehydration of food.

The boundary film acts as a barrier to both heat transfer and water vapor removal during drying. The thickness of the film is determined primarily by the air velocity; if the velocity is low, the boundary film is thicker and this reduces both the heat transfer coefficient and the rate of removal of water vapor. Water vapor leaves the surface of the food and increases the humidity of the surrounding air, to cause a reduction in the water vapor pressure gradient and hence the rate of drying. Therefore the faster the air, the thinner the boundary film and hence the faster the rate of drying. In summary, the three characteristics of air that are necessary for successful drying when the food is moist are, 1. Moderately high dry bulb temperature, 2. A low RH, 3. A high air velocity.

Constant-rate period

When food is placed into a drier, there is a short initial settling down period as the surface heats up to the wet-bulb temperature (A–B in Fig. 3(a)). Drying then commences and, provided water moves from the interior of the food at the same rate as it evaporates from the surface, the surface remains wet. This is known as the constant-rate period and continues until a certain critical moisture content is reached (B–C in Fig. 3(a) and (b)). The surface temperature of the food remains close to the wet-bulb temperature of the drying air until the end of the constant-rate period, due to the cooling effect of the evaporating water. In practice, different areas of the food surface dry out at different rates and, overall, the rate of drying declines gradually towards the end of the 'constant'-rate period.

Falling-rate period

When the moisture content of the food falls below the critical moisture content, the rate of drying slowly decreases until it approaches zero at the equilibrium moisture content (that is the food comes into equilibrium with the drying air). This is known as the falling rate period. Non-hygroscopic foods have a single falling-rate period (C–D in Fig. 3(a) and (b)), whereas hygroscopic foods have two or more periods. In the first period, the plane of evaporation moves from the surface to inside the food, and water vapour diffuses through the dry solids to the drying air. The second period occurs when the partial pressure of water vapour is below the saturated vapour pressure, and drying is by desorption.

During the falling-rate period(s), the rate of water movement from the interior to the surface falls below the rate at which water evaporates to the surrounding air, and the surface therefore dries out (assuming that the temperature, humidity and air velocity are unchanged). If the same amount of heat is supplied by the air, the surface temperature rises until it reaches the dry-bulb temperature of the drying air. Most heat damage to food can therefore occur in the falling-rate period and the air temperature is controlled to balance the rate of drying and extent of heat damage. Most heat transfer is by convection from the drying air to the surface of the food, but there may also be heat transfer by radiation. If the food is dried in solid trays, there will also be conduction through the tray to the food. Calculation of heat transfer is therefore often very complex in drying systems.

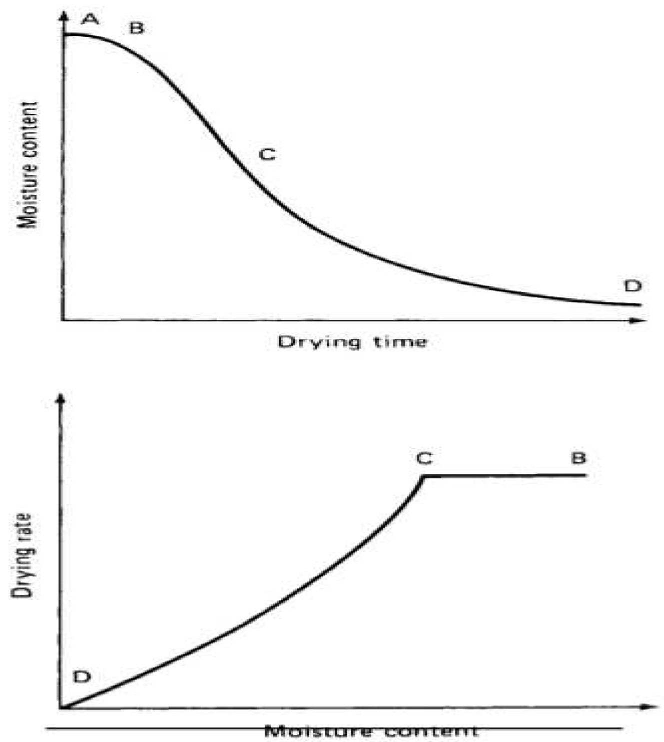


Fig. 3. (a) and (b) Drying curves. The temperature and humidity of the drying air are constant and all the heat supplied to the food surface by convection

The falling-rate period is usually the longest part of a drying operation and, in some foods (for example grain drying) the initial moisture content is below the critical moisture content and the falling-rate period is the only part of the drying curve to be observed. During the falling-rate period, the factors that control the rate of drying change. Initially the important factors are similar to those in the constant-rate period, but gradually the rate of water movement (mass transfer) becomes the controlling factor. Water moves from the interior of the food to the surface by the following mechanisms:

- liquid movement by capillary forces, particularly in porous foods
- Diffusion of liquids, caused by differences in the concentration of solutes at the surface and in the interior of the food.
- diffusion of liquids which are adsorbed in layers at the surfaces of solid components of the food
- Water vapor diffusion in air spaces within the food caused by vapor pressure gradients.

During drying, one or more of the above mechanisms may be taking place and their relative importance can change as drying proceeds. For example, in the first part of the falling-rate period, liquid diffusion may be the main mechanism, whereas in later parts, vapour diffusion may be more important. It is therefore sometimes difficult to predict drying times in the falling-rate period. The mechanisms that operate depend mostly on the temperature of the air and the size of the food pieces. They are unaffected by the RH of the air (except in determining the equilibrium moisture content) and the velocity of the air. The size of food pieces has an important effect on the drying rate in both the constant-rate and falling-rate periods. In the constant-rate period, smaller pieces have a larger surface area available for evaporation whereas in the falling-rate period, smaller pieces have a shorter distance for moisture to travel through the food. Calculation of drying rates is further complicated if foods shrink during the falling-rate period. Other factors which influence the rate of drying include:

- The composition and structure of the food has an influence on the mechanism of moisture removal. For example, the orientation of fibers in vegetables (e.g. celery) and protein strands in meat allow more rapid moisture movement along their length than across the structure. Similarly, moisture is removed more easily from intercellular spaces than from within cells. Rupturing cells by blanching or size reduction increases the rate of drying but may adversely affect the texture of the rehydrated product. Additionally, high concentrations of solutes such as sugars, salts, gums, starches, etc., increase the viscosity and lower the water activity and thus reduce the rate of moisture movement.
- The amount of food placed into a drier in relation to its capacity (in a given drier, faster drying is achieved with smaller quantities of food). In practice, the rate at which foods dry may differ from the idealized drying curves described above for these reasons.

References

1. Handbook of Industrial Drying, Third Edition (Advances in Drying Science and Technology by Arun S. Mujumdar.

Course Name	Fundamentals Of Food Technology
Lesson 9	Classification of dryers (Spray dryers, drum dryer and freeze dryers)
Content Creator Name	Dr Mohammed Wasim Siddiqui
University/College Name	Bihar Agricultural University, Bhagalpur
Course Reviewer Name	Dr. Jagmohan Singh
University/college Name	Sher-E-Kashmir University Of Agricultural Sciences And Technology Of Jammu ,Jammu

9.1 Introduction

There are different types of dryers available to meet the wide range of requirement of food and dairy industry. Depending on the quantity of moisture present initially and the final moisture content to be retained in the food, the type of drier, air supply temperatures etc are chosen. The dryers can also be classified as per the scale of operation, source of energy, the physical state of the feed

9.2 Classification of dehydration systems

Dehydration systems can be classified as per the scale of operation.

1. Domestic Open sun drying
    - Solar drying
2. Small scale Roller dryingTunnel drying
    - Cabinet/ Tray
    - Trough drying
    - Microwave drying
    - Dielectric
3. Medium and Large scale Spray
    - Fluidized bed
    - Freeze
    - Puff
    - Vacuum
    - Bin
    - Pneumatic
    - Rotary
    - Tower

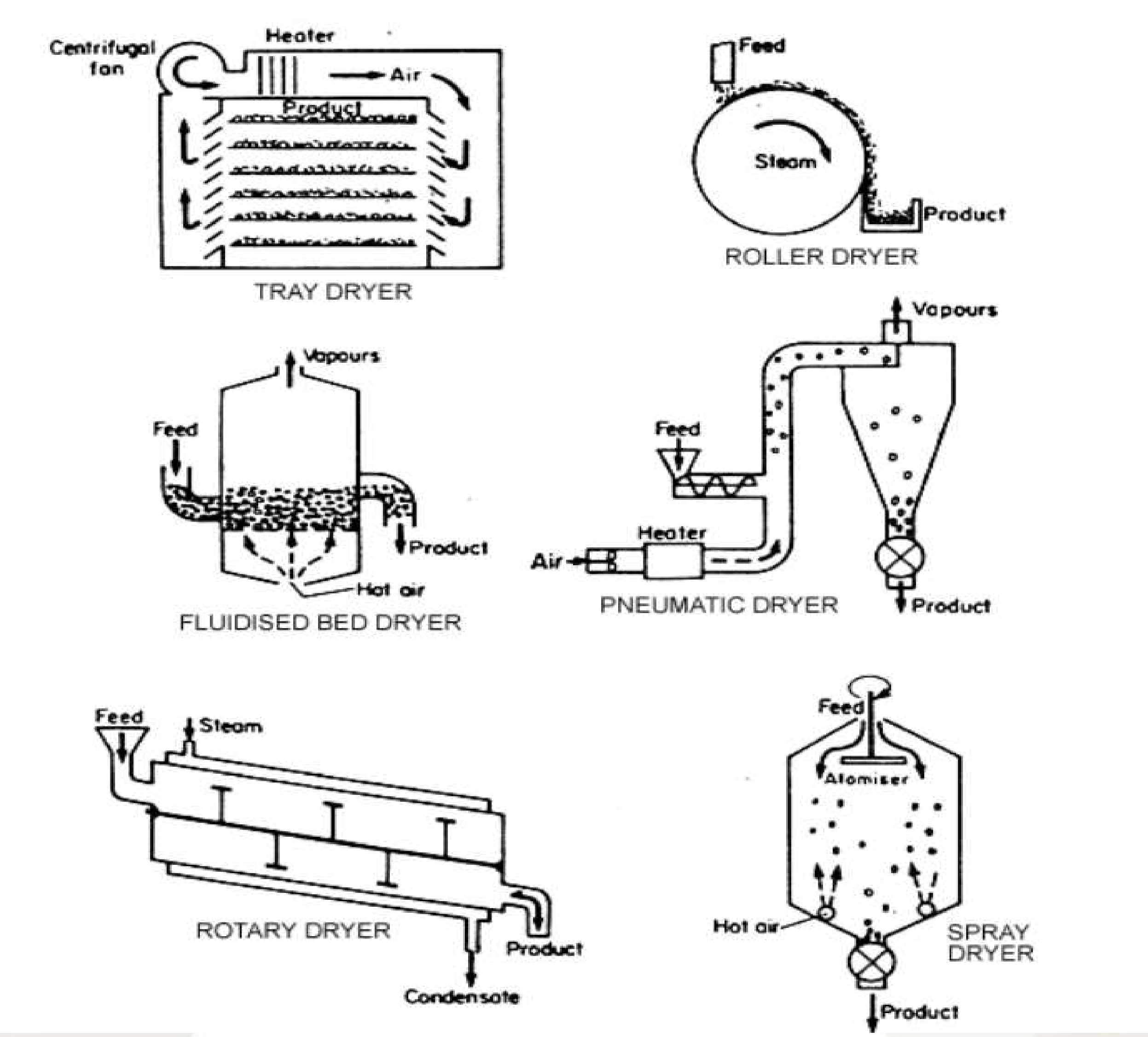


Fig. 1. Showing different types of drying equipment

9.3 Drum Drying

The drum dryer is an indirect type dryer in which the milk to be dried is maintained in a thin film on a rotating steam heated drum. The milk being dried is spread over the outside surface of the dryer. Clinging to it and drying continues as the hot drum rotates. At the end of a revolution, the drum comes to a 'doctor blade' which scrapes the dried film from the drum, when the product has made about three-quarter of a complete rotation on the drum surface. The process is also known as roller drying or film drying.

Drum drying requires less space and is more economical than spray dryers for small volumes. The ratio of steam consumption to water evaporation is from 1.2 to 1.6:1. The major disadvantages are that the product may have a scorched flavour, and solubility is much lower (85%) because of protein denaturation.

9.3.1 Classification of drum dryers

The drum dryers may be classified according to:

1. Number of drums (a) single drum, (b) double drum, or (c) twin drum.
2. Pressure surrounding the product (a) atmospheric, and (b) vacuum.
3. Feeding arrangement: (a) nip feed, (b) splash feed, (c) dip feed or (d) roller feed.
4. Material of construction: (a) alloy steel, (b) stainless steel, or (c) chrome, or nickel plate steel Fig. 5 shows different tpes of drum dryers and their feed mechanisms.

9.3.2 Construction of drum dryers

The double drum atmospheric dryer is most commonly used in the dairy industry (Fig. 1). Liquid is fed at about 70 ºC from a trough or perforated pipe into a pool in the space above and between the two rolls. Heat is transferred by conduction to the liquid, which is partly concentrated in the space between the rolls. Subsequently, all the liquid is vapourized as the drum turn, leaving a thin layer of dried product which is scraped off by doctor blades into conveyor below.

Water vapour above the dryer has a lower density than the air surrounding the unit, and will rise. Vaporized moisture is removed through a vapour hood above the drums. The lower edge of the hood is formed into a trough to drain away moisture which may accumulate because of condensation. Adequate air flow must be over the drum surface to carry away moisture.

The different feeding arrangements are shown in Fig: 2 . Dip feed is the simplest type of feed, suitable for materials with a high rate of sedimentation. Dip feed is used for certain suspensions of solids, usually with recirculation of material in the tray. Roller feed is suitable for glutinous materials such as starch. The product may be placed in its natural form or condensed before it is fed to the dryer. Milk is usually precondensed (not more than 30%) for single drum units, and preheated for double drums.

The doctor blade, a sharp hard flexible knife, scrapes the dried material from the drum. The blades are made of spring steel if the surface of the drum is hard and for soft drum bronze is used. The blades are positioned at an angle of 15 to 30º with the surface. The conveyor for each drum discharges the product into for sizing the dried product.

The inside of drum is heated with steam at 3-6 kg/cm2. Drum temperatures of below 130 ºC is suggested, as the product temperature approaches the temperature of the steam. The drums used are 60 to 120 cm in diameter, and upto 360 cm in length. Drums are carefully machined, inside and outside, otherwise a difference in thickness will change heat transfer rate and drying will not be uniform. The speed of the drums is adjustable from 6 to 24 rpm. The speed is important as it affects the thickness of milk film and the time of solid contact with metal. The speed of the drum depends upon the concentration of the milk and the final moisture content. Both drums turn at the same speed.

The time that the solid is in contact with metal is 3 s or less. The product is removed after 3/4 to 7/8 of a revolution of the drum has taken place. The thickness of the film is quite critical in controlling the operation. It is important that the material be spread evenly over the drum in order to have a uniform product. The surface tension and the rheological properties of the material controls this.

The spacing between the drum affects the film thickness. One drum of a double drum dryer is mounted on a stationary bearing and the other on a movable bearing to adjust the spacing between the drums. The spacing between the drums is about 0.5 to 1.0 mm. If the clearance is below this, there will be product damage.

As the heat is removed from steam, it is condensed. The condensate moves to the bottom of the drum and must be removed by a pump or siphon. Flooding of the inside with condensate reduces the heat transfer rate. The drying capacity is proportional to the active drum area.

9.3.3 Rate of evaporation in drum dryers

The rate of moisture removal by a drum dryer is essentially a constant rate of water evaporation as the product is continuously fed between the drums and the dried product is removed. The equation governing the rate of evaporation in a drum dryer is:

rate of evaporation = ts – ta

Where,

Ts=latent heat of vaporization.

Ta= the mean temperature difference between the roller surface and the product.

The overall coefficient is from 1000 to 1800 kcal/hr m2 c under optimum condition, although it may be only 1/10th of these values when conditions are adversed. Since the thickness of drum wall is small compared to the diameter of the drum, the area A can be regarded simply as the outer surface area of the drum. The U depends on hs , k and hp and other coefficients.

Where,

hs : equivalent film coefficient of steam, Kcal/ hr m^2c

x: thickness of metal , m

k : thermal conductivity of metal, kcal/ m hr c

hp : equivalent film coefficient of product

hc : convection coefficient

hr: radiation coefficient

he : evaporation film coefficient

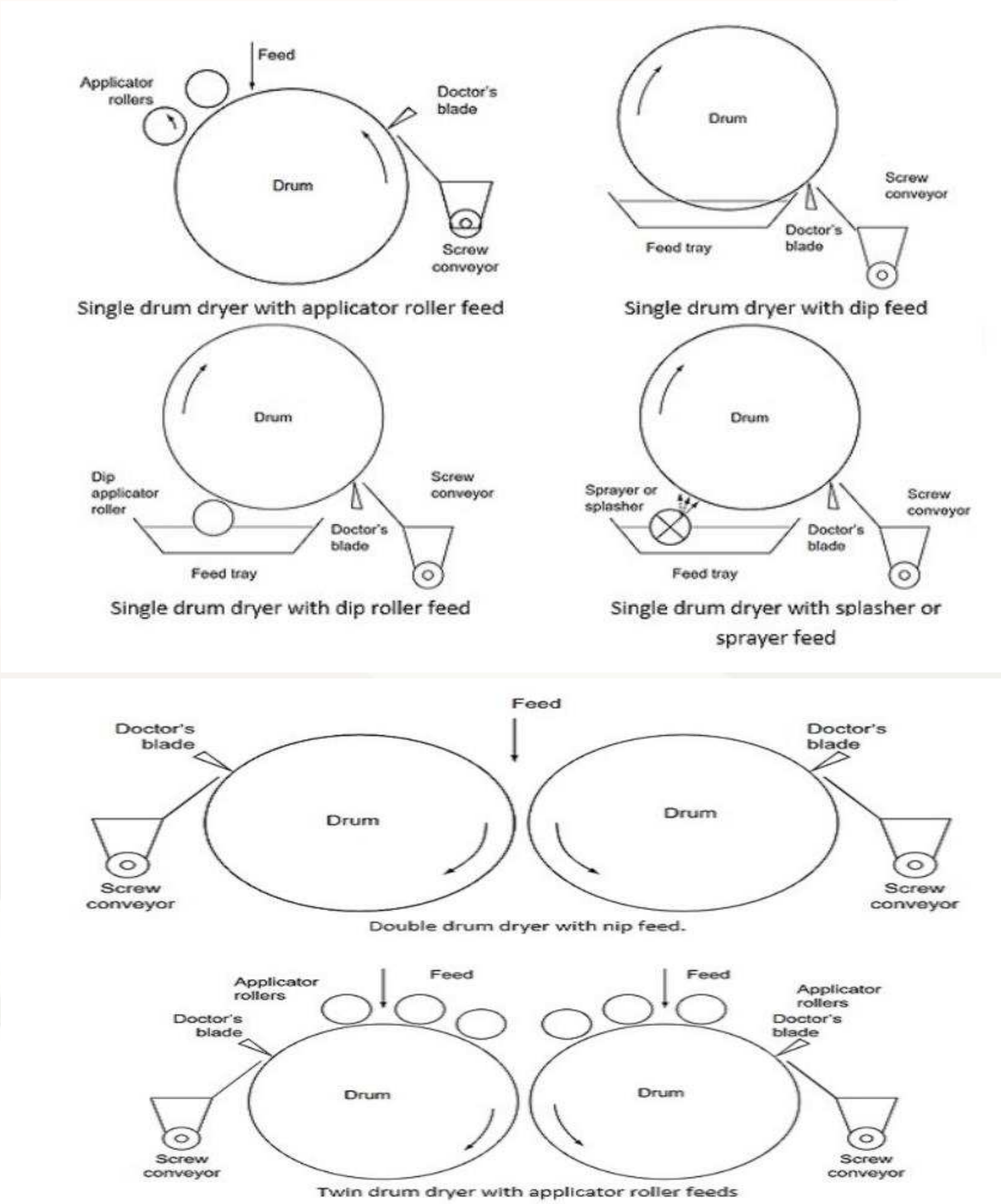


Fig. 2. Different types of drum drier

The factor having the greatest effect on U is the condition of the liquid film and the drum speed. Drying rates for drum dryers can be extremely high when thin film of low viscosity is evaporated, and it is thus permissible to use high temperature. In addition to assuring the adequate heat transfer the drying system must provide for removal of water vapour. If the speed of a particular drum is measured, then the U value and the moisture content of the product will be increased, if the conditions are unchanged. The overall thermal efficiency of drum dryer is 35 – 80 %.

The proportion of dry matter (TS) is given by:
During the evaporation of a product from the original moisture content x0 containing amount of water mwo to a final moisture content x containing an amount of water mw, the following amount is removed. Calculated as a fraction of the water originally present, the following is obtained:

9.4 Spray Drying
Spray drying is the transformation of feed from a fluid state into a dried particle form by spraying the feed into a hot drying medium. Spray drying is considered to be one of the best methods for drying of food materials. This method is applied to fluids of high moisture content and high viscosity or of a slightly paste like character. The major advantages of spray drying are:

Advantages of spray drying

i. High production rate
ii. Gentle drying
iii. Short drying period
iv. Superior flavour, appearance, and solubility of product
v. Continuous single step operation
vi. Uniform product
vii. Plant can be easily automated
viii. No product contamination
ix. High thermal efficiency

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Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

9.4.1 Processing of Spray drying:

A conventional spray dryer consists of the following main components (Fig. 3).

1. Drying chamber
2. Hot air system and air distribution
3. Feed system
4. Atomizing device
5. Powder separation system
6. Pneumatic conveying and cooling system
7. Fluid bed after-drying/cooling
8. Instrumentation and automation

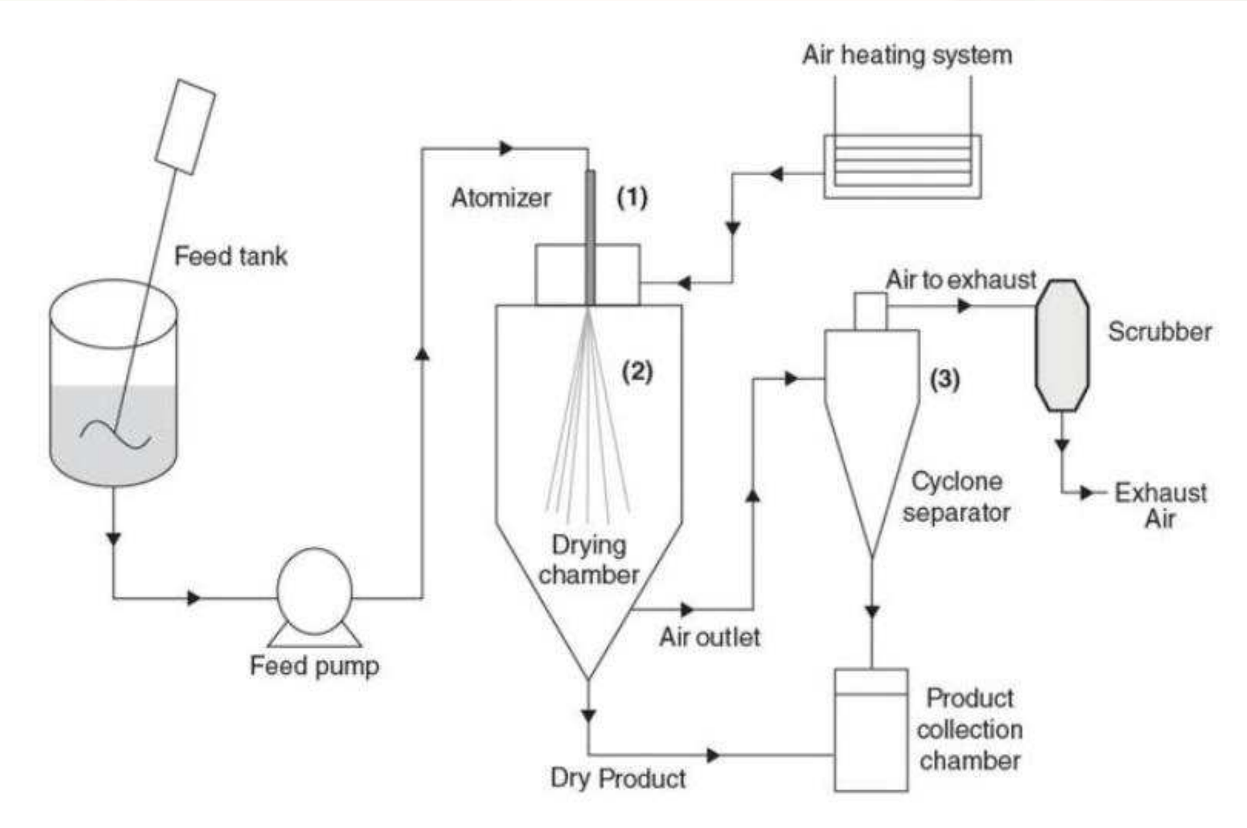

Fig 3. Components of a spray drier

9.4.2 The spray dryer consists of mainly four components:

1. Heating of the drying air: air heaters with accompanying fans, air filters dampers and ducts.
2. Atomization of feed into a spray: atomizer with feed supply system of pumps, tanks and feed pretreatment equipment.
3. Contacting of air and sprays and drying of sprays: drying chamber with air disperser, product and exhaust air outlets.
4. Recovery of dried products and final air cleaning: complete product recovery with product discharge, transport and packing, air exhaust system with fans, wet scrubbers, damper and duct.

9.4.3 Classification of Spray Dryers

Spray dryers are mainly classified according to:
1. Method of atomization :(a) pressure atomization (b) centrifugal atomization, (c) pneumatic atomization
2. Method of heating air (a) steam (b) furnace oil, (c) electricity
3. Position of drying chamber (a) vertical (b) horizontal
4. Direction of air flow in relation to product flow (a) counter current (b) co current (c) mixed current
5. Pressure in dryer (a) atmospheric (b) vacuum.
Shape of the bottom of the chamber (a) flat bottom (b) conical bottom

9.5 Freeze Dryers

The material is held on shelves or belts in a chamber that is under high vacuum. In most cases, the food is frozen before being loaded into the dryer. Heat is transferred to the food by conduction or radiation and the vapor is removed by vacuum pump and then condensed. In one process, given the name accelerated freeze drying, heat transfer is by conduction; sheets of expanded metal are inserted between the foodstuffs and heated plates to improve heat transfer to the uneven surfaces, and moisture removal. The pieces of food are shaped so as to present the largest possible flat surface to the expanded metal and the plates to obtain good heat transfer. A refrigerated condenser may be used to condense the water vapor.

9.5.1 Principle

The fundamental principle in freeze-drying is sublimation, the shift from a solid directly into a gas. Just like evaporation, sublimation occurs when a molecule gains enough energy to break free from the molecules around it.

The water vapor pressure of a food is held below 4.58 torr (610.5 Pa) and water is frozen. When the food is heated solid ice sublimes into vapor without melting. The pressure in food dried cabinet is below the vapor pressure at the surface of ice and a vacuum pump is present in the cabinet which removes the vapor and let it condense on refrigeration coils. Food products are dried in 2 stages: first by sublimation to 15% moisture content and then by evaporative drying (desorption) of unfrozen water to 2% moisture content. The rate of drying depends on resistance of the food to heat transfer and to a lesser extent on resistance to vapor flow from sublimation.

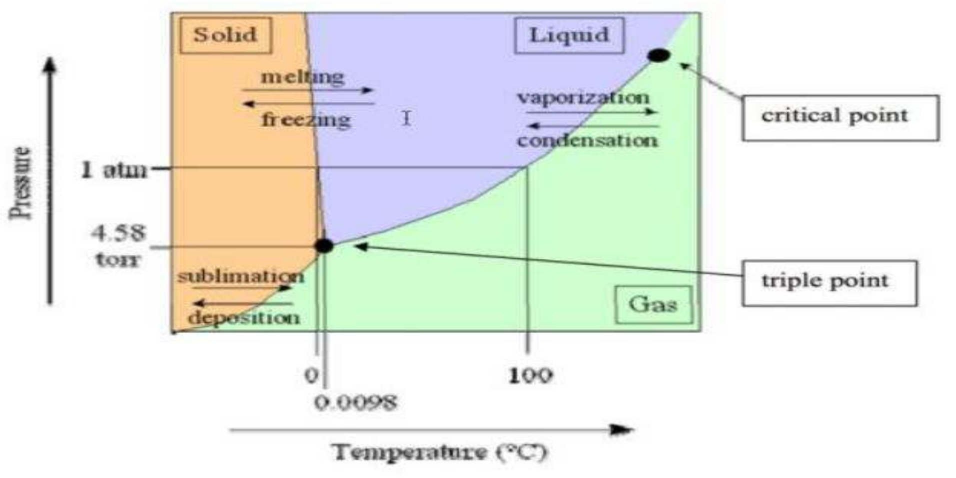

Fig.4. Phase diagram showing the sublimation of ice during freeze drying

9.5.2 Properties of Freeze Dried Food Products

1. The moisture content of freeze dried food product is below 3%.Freeze dried product is lighter in volume/weight.
2. There is very good retention of volatile flavor and aroma components with the process.
3. Freeze drying causes very little change in chemical components of food. There is very minute difference in the nutritive value of fresh food and freeze dried food product.

9.5.3 Freeze Drying Process

1. **Freezing–**It is most critical process in whole freeze drying process. The product to be freeze dried is cooled below its triple point (lowest temperature at which liquid and solid phases of product coexist) which ensures the sublimation. Freezing is done rapidly in order to lower the material to its eutectic point quickly to avoid the formation of ice crystals. Generally the freezing temperature is between -50 to -80 degree Celsius. In lab, it is often done by placing the product to be frozen in freeze drying flasks and the flasks are rotated in a bath called shell freezer which is cooled by mechanical refrigeration, dry ice and methanol or liquid nitrogen.
2. **Primary Drying (Sublimation) -** In this process temperature and pressure should be below the triple point of water, i.e., 0.0098 degree Celsius and 4.58 m of Hg. So, in this process pressure is lowered and enough heat is supplied for the water to sublimate. The heat supplied is latent heat of sublimation. In this process moisture is removes up to 98-99%.Pressure is controlled by applying partial vacuum. The condenser plates resolidifies the water vapor into ice. Driving force for sublimation is vapor pressure difference between the evaporating surface and the condenser.
3. **Secondary Drying (Desorption)**-It aims to remove unfrozen water molecules which could not be able to convert in ice and sublime. In this process temperature is raised higher, around 50 degree Celsius to break all physico-chemical interactions (to remove bound water) that

have formed between water molecules and frozen material. Generally, Pressure is kept lowered to around 50 mm of Hg. Rate of secondary drying is slow and it takes around 10-12 hours.

4. **Packing-**After drying, vacuum is replaced by filtered dry air or any inert gas such as nitrogen to establish atmospheric pressure. At the end of all these operations moisture content reaches 0.5%-4%.

9.5.4 Basic Components of Freeze Drying-

- **Freeze Drying Chamber**-It contains the trays to hold the food during drying and heaters to supply latent heat of sublimation.
- **Refrigerated Condenser**-A condenser is a pipe coil system which condenses all the vapours from the product. The sublimated ice is accumulated in condenser and is manually removed at the end of the operator. In lab scale, the condenser is cooled by means of carbon dioxide or liquid nitrogen .The refrigeration system should be able to maintain temperature of condenser substantially below temperature of product.
- **Refrigeration Unit**-During the freeze drying process, water contained in the material passes 3 stages. The product should be cooled, frozen and subjected to sublimation. During this stage heat must be applied to product to compensate for the sublimation.
- **Vacuum Pump**-It sucks all the air present in freeze drying chamber and maintains vacuum inside it.

9.5.5 Advantages of Freeze Drying

- Since the water is removed from the food product it becomes very light and hence becomes easy for transportation(portable)
- Nutritional qualities and sensory characteristics of freeze dried product is retained.
- The products do not require refrigeration hence can last for months or years.
- Thermolabile food products can easily be dried.

9.5.5 Disadvantages of Freeze Drying-

- Freeze dried food products are quite expensive due to specialized equipment needed for this process.
- The food product is prone to oxidation, due to high porosity and large surface area. Hence the product is packed in vacuum or in inert gas.

9.5.6 Shelf Life of Freeze Dried Foods

Since, the moisture present in freeze dried products is upto 2-3% ,therefore, these products can be stored for much longer period of time.In case of freeze dried fruits and vegetables it can be stored upto 25 years and freeze dried meat and meat products can lasts for several months Simply dehydrated fruits and vegetables can last for atmost 15 years.

9.5.8 Food types suitable for freeze drying

- Coffee
- Fruits and juice
- Vegetables
- Meat
- Fish and seafood
- Eggs
- Dairy

Small fruits and vegetables can easily be freeze dried whereas whole fruits and whole vegetables would not be suitable. It also applies to meat products, large meat pieces are difficult to freeze dry whereas small meat chunks can be dried very well.

References

Handbook of Industrial Drying, Third Edition (Advances in Drying Science and Technology by Arun S. Mujumdar (Editor)

Course Name	Fundamentals Of Food Technology
Lesson 10	Effect of cooking methods on food
Content Creator Name	Dr Mohammed Wasim Siddiqui
University/College Name	Bihar Agricultural University, Bhagalpur
Course Reviewer Name	Dr. Jagmohan Singh
University/college Name	Sher-E-Kashmir University Of Agricultural Sciences And Technology Of Jammu ,Jammu

Designed and developed under the aegis of NAHEP Component-2 Project "Investments In ICAR Leadership In Agricultural Higher Education"
Division of Computer Applications, ICAR-Indian Agricultural Statistics Research Institute

Objectives:

1. To get a better idea about various methods of cooking of food
2. How cooking affects food quality in terms of appearance, taste and shelf life.

Glossary

Conduction- is heat transfer through stationary matter by physical contact. (The matter is stationary on a macroscopic scale—we know there is thermal motion of the atoms and molecules at any temperature above absolute zero.) Heat transferred between the electric burner of a stove and the bottom of a pan is transferred by conduction.

Convection- is the heat transfer by the macroscopic movement of a fluid. This type of transfer takes place in a forced-air furnace and in weather systems, for example.

Radiation- Heat transfer by radiation occurs when microwaves, infrared radiation, visible light, or another form of electromagnetic radiation is emitted or absorbed. An obvious example is the warming of the Earth by the Sun. A less obvious example is thermal radiation from the human body.

10.1 Introduction

Cooking: The process of subjecting foods to the action of heat is termed as cooking.

Objectives of cooking

1. improves the taste and food quality

For ex. roasting of groundnut and coffee seeds, frying of onions and papads, cooking meat with spices, frying cashew nuts in ghee, etc.

2. Destruction of microorganisms

Harmful micro-organisms cause infections or produce toxins. Eg. Clostridium botulism and Salmonella. Some moulds produce toxin. Aspergillus flavus produces aflatoxin in groundnuts, cereals and spices. Cooking helps to destroy the harmful microorganisms eg in cooked meat.

3. Improves digestibility

Cooking softens the connective tissue of the meat and the coarse fibres of cereals, pulses and vegetables so that the digestive period is shortened and

Gastro Intestinal tract is less subjected to irritation. Cooking improves the texture and hence it becomes more chewable. Cooking also bursts the starch digestion is easier, rapid and complete. When dry heat is applied to starches they are converted to easily digestible dextrins. Cooking increases the access to enzymes and improves digestibility.

4. Increases variety

By cooking, same food can be made into different dishes, for eg. rice can be made into plain, bular, lemon rice, biriyani or combination with pulses into idli, wheat can be made into chapatis, bun, paratha or halwa.

5. Increase consumption of food

Cooking improves the texture and makes the food chewable. Improvement in texture and flavour by cooking increases the consumption of food to meet our nutritional requirement.

6. Increase availability of food

Raw egg contains avidin which binds biotin making biotin unavailable to the body. By cooking, avidin gets denatured and biotin is available to the body. Toxin substances from khesari dhal can also be removed by boiling in and throwing away the water. By reducing phytic acid, oxalic acid the availability of minerals can be enhanced.

7. Concentration of nutrients

This may be due to removal of moisture or using combination of foods or due to cooking procedures ex. Sweets, dehydrated foods, dry fruits.

Foods can also be cooked by microwaves.

Limitations of cooking

- Thiamine and vitamin C which is heat sensitive, may be lost during cooking.
- Water soluble vitamins are leached into the water during cooking. Vitamin
- A content may be reduced due to oxidation and heat.
- Quality of protein may be reduced due to destruction of certain amino acids during cooking eg. bread crust has less quality of protein compared to the crumb.

Methods of Cooking

- Heat may be transferred to the food during cooking by conduction, convection, radiation or by the energy or microwaves – electronic heat transfer.
- Water or steam and air or fat or combination of these is used as cooking media.
- Moist heat involves water and steam.
- Air or fat are used in dry heat.

10.2 Classification of cooking methods

10.2.1. Moist heat methods

Moist Heat Method

- Boiling
- simmering
- poaching
- stewing
- blanching
- steaming
- pressure
- cooking

10.2.2. Dry heat

- Roasting
- grilling / broiling
- toasting
- baking
- sautering
- frying

III. Combination methods

- Boiling is generally used in combination with simmering or other methods, e.g. cooking rice, vegetables or dhal.

Advantages

- It is the simplest method. It does not require special skill and equipment.
- Soluble starches can be removed and rice grains are separated.
- Protein gets denatured, starch gets gelatinized and collagen gets hydrolysed.
- Uniform cooking can be done.

Disadvantages

- Loss of nutrients: If excess water is used in cooking and the water is discarded 30-70% water soluble nutrients may be lost. To prevent the loss, cooked water should be used in soups, rasam, sambar and dhal. Some protein may be lost if vegetables are cooked in water containing salt and the cooking water is discarded. There is considerable loss of nutrients especially sodium, potassium and calcium due to leaching.
- Loss of colour: Water soluble pigments, like betalains from beetroot may be lost.
- Time consuming: Boiling may take time and fuel may get wasted.
- Loss of flavour and texture: Boiled foods are not considered tasty because flavour compounds are leached into the water or volatile compounds gets evaporated. Over boiling of food may make the food mashy. Last modified: Monday, 18 June 2012, 7:16 AM.

Boiling

- Boiling is cooking foods by just immersing them in water at 100oC and maintaining the water at that temperature till the food is tender.
- Foods that are cooked by boiling are rice, eggs, dhals, potatoes, meat, sago and beet root.
- Boiling can be done with excess of water (eggs, potatoes) or with sufficient water (dhal, upma).

Simmering

- When foods are cooked in a pan with a well-fitting lid at temperature just below the boiling point 82 – 92oC of the liquid in which they are immersed the process is known as simmering.
- It is a useful method when foods have to be cooked for a long time to make it tender as in the case of cheaper cuts of meat, fish, cooking custard, kheer, vegetablesand carrot halwa.
- This method is also employed in making soups.

Advantages

- Foods get cooked thoroughly
- Scorching or burning is prevented
- Losses due to leaching is minimum

Disadvantages

- There is loss of heat sensitive nutrients, due to long period of cooking.
- Takes more time and more fuel.

Poaching

- This involves cooking in the minimum amount of liquid at a temperature of 80-85C, that is below the boiling point.
- Foods generally poached are eggs, fish and fruits.
- For poaching eggs, the addition of little salt or vinegar to the cooking liquid lowers the temperature of coagulation.
- Eggs cook quickly by poaching

Advantages

- Very quick method of cooking.
- Easily digestible since no fat is used.

Disadvantages

- It is bland in taste.
- Water soluble nutrients may be leached into the water.

Stewing

This is a gentle method of cooking in a pan with a tight fitting lid, using small quantities of liquid to cover only half the food. The food above the liquid is cooked by the steam generated within the pan. The liquid is brought to a boiling point and then the heat applied is reduced to maintain the cooking at simmering temperature ie. 98°C. Stewing is a slow method of cooking taking 2-4 hours depending upon the nature and volume of the foods being stewed.

This method is generally used for cooking cheaper cuts of meat along with some root vegetables and legumes all put in the same cooking pot and cooked in stock or water.

The larger cooking time and lower temperatures enable tougher meat fibres to become soft.

The cooking of meat and vegetables together make the dish attractive and nutritious since no liquid is discarded.

Apples can also be cooked by this method.

Advantages

- Retention of nutrients.
- Flavor is retained e.g. in making Oondhya.
- The vegetables are stewed by which flavour is retained.

Disadvantages

- Time consuming.

Steaming

- This method requires the food to be cooked in steam.
- This is generated from vigorously boiling water or liquid in a pan so that the food is completely surrounded by steam and not in contact with the water or liquid.
- Hence the food gets cooked at 100oC.
- Steaming is generally done in idli cooker.

There are 2 types of steaming

a. Wet steaming

- Here the steam is in direct contact with the food e.g. idli.

b. Dry steaming

- Here double boiler is used for cooking the food.
- Double boiling is cooking in a container over hot or boiling water.

- This process is used for such preparations as sauces and custards where temperatures below boiling point are desirable.
- The food is placed in a utensil which is kept in another utensil containing water.
- When the water is heated or boiled the food gets cooked.
- Recipes made by steaming are idli, dhokla, rice (or) ragi puttu, idiappam, appam,
- kolukattai and custards.

Advantages

1. It does not require constant attention.
2. Nutritive value is maintained because there is no leaching and cooking time is less.
3. Easily digestible since not much fat is added. It is good for children and patients.
4. There is less chance for burning and scorching.
5. In double boilers sudden increase in temperature in making custards and overflow of milk can be avoided.
6. Texture of the food is better and becomes light and fluffy.
7. Steamed foods have good flavour.

Disadvantages

1. Special equipment is required.
2. Many foods cannot be prepared by this method eg. rice.

Pressure cooking

- A relatively small increase in temperature can drastically reduce cooking time and this fact is utilized in pressure cooker.
- In pressure cooking, escaping steam is trapped and kept under pressure so that the temperature of the boiling water and steam can be raised above 100oC and reduce cooking time.

Advantages

1. It takes less time to cook.
2. Different items may be cooked at the same time.
3. Fuel is saved.
4. Requires less attention.

5. Nutrient or flavour loss may be less.
6. Food is cooked thoroughly by this method.
7. There is an indication for the completion of cooking.
8. There is less chances for scorching or burning.

Disadvantages

1. Thorough knowledge of using the equipment is required.
2. There may be mixing of flavours.
3. Foods may be undesirably soft.
4. Foods cooked in pressure cooker are rice, dhal, vegetables and meat.

10.2.2. Dry heat methods

a. Air as medium of cooking

Grilling (or) Broiling

Toasting

Pan broiling (or) Roasting

Baking

b. Fat as a medium of cooking

Fat as a medium of cooking

- In this method either **air or fat** is used as the medium of cooking.

Air as medium of cooking

Grilling (or) Broiling

- Grilling consists of placing the food below (or) above (or) in between a red hot surface.
- When under the heater, the food is heated by radiation only.
- This results in the browning of foods.
- Then the heat is more slowly conducted through the surfaces of the food downward.
- As heating is mostly superficial, grilled foods are usually reversed or rotated.
- If the food is above the heater, heat is transmitted to the food through convection currents as well as radiations.
- This will consequently increase efficiency.

- Foods cooked by grilling are cob of the corn, papad, brinjal, phulkas and sweet potato.
- The term toasting is used to describe a process by which bread slices are kept under the grill or between the two heated elements to brown from both sides of the bread at the same time.

Dry heat methods

This can be adjusted to give the required degree of brownness through temperature control.

Advantages

1. Quick method of cooking.
2. Less or no fat is required.
3. Flavour is improved.

Disadvantage

1. Constant attention is required to prevent charring.
2. Reduce protein quality due to browning and loss of lysine.

Pan broiling (or) Roasting

When food is uncovered on heated metal or a frying pan the method is known as pan broiling. e.g. groundnuts and chapathi.

Advantages

1. Improves the colour, flavour and texture of the food.
2. Reduces the moisture content of the food and improves the keeping quality e.g. rava.
3. It is easy to powder e.g. cumin seeds and coriander seeds after roasting.
4. It is one of the quick methods of cooking foods.

Disadvantages

1. Constant attention is required
2. Losses of nutrients like amino acids occur when the food becomes brown

Baking

1. Here the food gets cooked by hot air.

2. Foods baked are generally brown and crisp on the top, soft and porous in the centres, e.g. cakes, pudding and breads.
3. The principle involved in baking is the air inside the oven is heated by a source of heat either electricity (or) gas and wood in the case of tandoori.
4. The temperatures that normally maintained in the oven are 1200C – 260oC.
5. Foods prepared by baking are custards, pies, biscuits, pizzas, puffs, buns, bread, cakes, tandoori chicken, meat and fish.

Advantages

1. Flavour and texture are improved.
2. Variety of dishes can be made.
3. Uniform and bulk cooking can be achieved e.g. bun and bread.

Disadvantages

1. Special equipment and skill are required.
2. Source of trans-fat if hydrogenated fats are used.

Fat as a medium of cooking

Sautering: This method involves cooking in just enough of oil to cover the base of the pan (greasing the pan) e.g. dosa. The food is tossed occasionally or turned over with a spatula to enable all the pieces to come in contact with the oil and get cooked evenly. Sometimes the pan is covered with lid, reducing the flame and allowing the food to be cooked till tender in its own steam. The product obtained in cooking by this method is slightly moist, tender but without any liquid or gravy. Foods cooked by sautéring are generally vegetables used as side dishes in a menu. The heat is transferred to the food mainly by conduction.

Frying: Two types: Shallow fat frying and deep fat frying.

a. Shallow fat frying: Here the food is cooked in larger amounts of fat but not enough to cover it. Heat is transferred to the food partially by conduction by contact with the heated pan and partially by the convection currents of the foods. This prevents local burning of the food by keeping away the intense heat of the frying pan. e.g. paratha, chapatti, cashewnuts, potatoes, fish, cutlets and tikkis.

b. Deep fat frying: Food is totally immersed in hot oil and cooked by vigorous convection currents and cooking is uniform on all sides of the foods. Cooking can be rapidly completed in deep fat frying because the temperature used is 1800 – 220oC. In most foods, this high temperature results in rapid drying out of the surface and the production of a hard crisp surface, brown in colour. The absorption of fat by the food increases the calorific value of the food. Fats when heated to smoking point decompose to fatty acids and glycerol followed by the decomposition of glycerol to acrolein, which causes irritation to the eyes and nose. Generally 10% of oil is absorbed but larger amount of fat is absorbed when oils are used repeatedly. Samosa, papad, chips, poori, muruku, pakoda, bajji and bonda are made by deep fat frying.

Advantages

1. Taste is improved, along with the texture.
2. Increases the calorific value.
3. Fastest method of cooking.
4. In shallow fat frying the amount of oil consumption can be controlled.
5. Fried foods have greater shelf life.

Disadvantages

6. Sometimes the food may become oily or soggy with too much absorption of oil.
7. More attention is required while cooking and care should be taken to avoid accidents.
8. The food becomes very expensive.
9. Fried foods take long time to digest.
10. Repeated use of heated oils may produce harmful substances and reduce the smoking point.

10.2.3. Combination of cooking methods

Combination of cooking methods

Braising: Braising is a combined method of roasting and stewing in a pan with a tight fitting lid. The meat should be sealed by browning on all sides and then placed on a lightly fried bed of root vegetables. Stock or gravy is added to 2/3 of the meat. Flavourings and seasonings are added and allowed to cook gently.

Many food preparations are made by not only single method but by a combination of cooking methods.

- Vermicelli payasam - Roasting and simmering
- Vegetable curry - Sautering and simmering
- Upma - Roasting and boiling
- Meat cutlet - Boiling and deep frying
- Vegetable pulav - Frying and simmering

Microwave cooking: In microwave cooking heat is generated within the food and the dramatic reduction in cooking time is the main advantage of this method of cooking.

Microwave cooking

The essential component of a microwave oven is a magnetron which converts electrical energy into microwave energy. The microwaves can be absorbed, transmitted or reflected.

They are reflected by metals and absorbed by food. When food is kept in the cavity of the microwave oven for cooking, the microwaves generated by the magnetron strike the food and the metal walls of the oven. Microwaves that strike the metal walls are reflected and bounced back so they disperse throughout the oven and accomplish uniform heating of the food.

Advantages

- They cook many foods in about ¼th of the time necessary on a gas burner.
- There is no wastage of energy.
- It saves time in heating frozen foods. Thawing can be done in minutes or seconds.
- Only the food is heated during cooking. The oven or the utensil does not get heated except under prolonged heating periods.
- Flavour and texture do not change when reheated to a microwave oven.

- Loss of nutrients is minimized.
- After cooking in a microwave oven washing dishes is much easier as food does not stick to the sides of the vessels.
- Food gets cooked uniformly.
- Preserves the natural colour of vegetables and fruits.

Disadvantages

- Due to short period of cooking, food does not become brown and crispness unless the microwave has a browning unit.
- It is not possible to make chapathi or tandoori rotis in it. It cannot cook soft or hard boiled eggs
- Deep frying cannot be done.
- The short cooking time may not give a chance of blending of flavours as in conventional methods.
- The operator should be careful in operating the microwave oven since any exposure to microwave oven causes physiological abnormalities.
- If the food is greater than 80mm the control portion is out of range of the microwave radiation will only heat by the normal slow process of conduction. It will be relatively uncooked while the extension accessible to microwave is cooked in minutes or seconds.

Course Name	Fundamentals Of Food Technology
Lesson 11	Food Fermentation Technology
Content Creator Name	Dr Mohammed Wasim Siddiqui
University/College Name	Bihar Agricultural University, Bhagalpur
Course Reviewer Name	Dr. Jagmohan Singh
University/college Name	Sher-E-Kashmir University Of Agricultural Sciences And Technology Of Jammu ,Jammu

Objective

1. Give a basic idea about fermentation and its various aspects.
2. How fermentation is important for food industry.

Glossary

Fermentation:

1. Preservation methods for food via microorganisms (general use).
2. Any process that produces alcoholic beverages or acidic dairy products (general use).
3. Any large-scale microbial process occurring with or without air (common definition used in industry).
4. Any energy-releasing metabolic process that takes place only under anaerobic conditions (becoming more scientific).
5. Any metabolic process that releases energy from a sugar or other organic molecules, does not require oxygen or an electron transport system, and uses an organic molecule as the final electron acceptor (most scientific).

11.1 Definitions of Fermentation

To many people, fermentation simply means the production of alcohol: grains and fruits are fermented to produce beer and wine. If a food soured, one might say it was 'off' or fermented.

General principles of fermentation processes

In fermentation, the first process is the same as cellular respiration, which is the formation of pyruvic acid by glycolysis where net 2 ATP molecules are synthesized. In the next step, pyruvate is reduced to lactic acid, ethanol or other products. Here NAD+ is formed which is re-utilized back in the glycolysis process (fig-1).

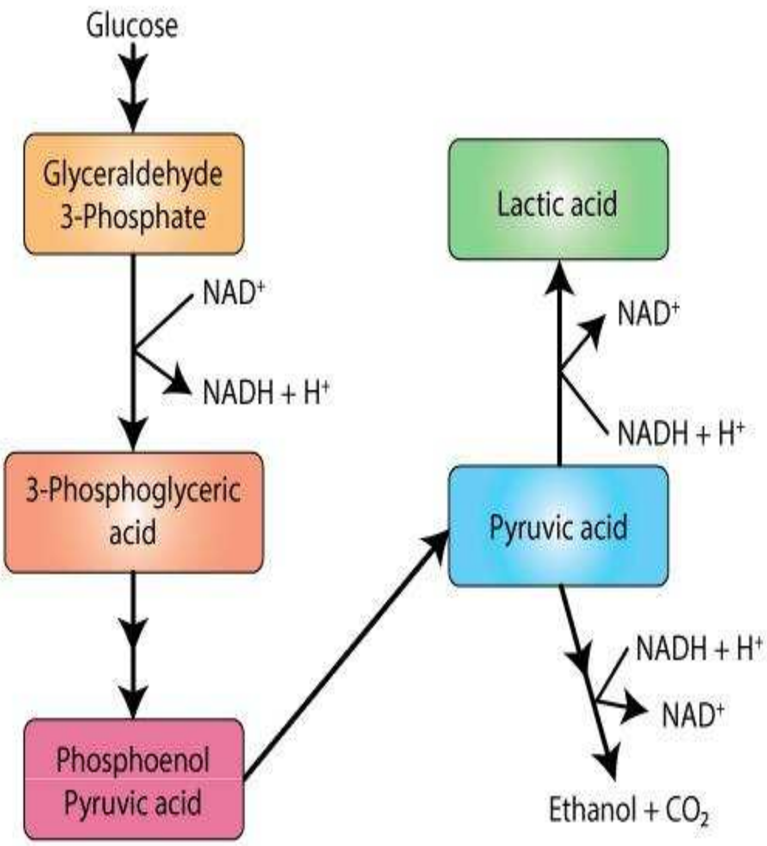

Fig-1 fermentation process

Fermentation is a metabolic process that converts sugar to acids, gases or alcohol. It occurs in yeast and bacteria, and also in oxygen-starved muscle cells, as in the case of lactic acid fermentation. Fermentation is also used more broadly to refer to the bulk growth of microorganisms on a growth medium, often with the goal of producing a specific chemical product like enzyme, vaccines, antibiotics, food product/additive etc. French microbiologist Louis Pasteur is often remembered for his insights into fermentation and its microbial causes. The science of fermentation is known as **zymology.** Fermentation takes place in the lack of oxygen (when the electron transport chain is unusable) and becomes the cell's primary means of ATP (energy) production. It turns NADH and pyruvate produced in the glycolysis step into NAD+ and various small molecules depending on the type of fermentation. In the presence of O2, NADH and pyruvate are used to generate ATP in respiration. This is called oxidative phosphorylation, and it generates much more ATP than glycolysis alone. For that reason, cells generally benefit from avoiding fermentation when oxygen is available, the exception being obligate anaerobes which cannot tolerate oxygen. The first step, glycolysis, is common to all fermentation pathways:

$C_6H_{12}O_6 + 2\ NAD^+ + 2\ ADP + 2\ Pi \rightarrow 2\ CH_3COCOO^- + 2\ NADH + 2\ ATP + 2\ H_2O + 2H^+$ where, Pyruvate is CH_3COCOO^-

Pi is inorganic phosphate

Two ADP molecules and two Pi are converted to two ATP and two water molecules via substrate-level phosphorylation. Two molecules of NAD+ are also reduced to NADH. In oxidative phosphorylation the energy for ATP formation is derived from an electrochemical proton gradient generated across the inner mitochondrial membrane (or, in the case of bacteria, the plasma membrane) via the electron transport chain. Glycolysis has substrate-level phosphorylation (ATP generated directly at the point of reaction). Humans have used fermentation to produce food and beverages since the Neolithic age. For example, fermentation is used for preservation in a process that produces lactic acid as found in such sour foods as pickled cucumbers, kimchi and yogurt, as well as for producing alcoholic beverages such as wine and beer. Fermentation can even occur within the stomachs of animals, such as humans.

Examples of Fermentation

Fermentation does not necessarily have to be carried out in an anaerobic environment. For example, even in the presence of abundant oxygen, yeast cells greatly prefer fermentation to aerobic respiration, as long as sugars are readily available for consumption (a phenomenon known as the Crabtree effect). The antibiotic activity of hops also inhibits aerobic metabolism in yeast. Fermentation react NADH with an endogenous, organic electron acceptor. Usually this is pyruvate formed from the sugar during the glycolysis step. During fermentation, pyruvate is metabolized to various compounds through several processes:

1. Ethanol fermentation, like alcoholic fermentation, is the production of ethanol and carbon dioxide

2. Lactic acid fermentation refers to two means of producing lactic acid:

- Homolactic fermentation is the production of lactic acid exclusively
- Heterolactic fermentation is the production of lactic acid as well as other acids and alcohols. Sugars are the most common substrate of fermentation, and typical examples of fermentation products are ethanol, lactic acid, carbon dioxide, and hydrogen gas (H2). However, more exotic compounds can be produced by fermentation, such as butyric acid and acetone. Yeast carries out fermentation in the production of ethanol in beers, wines, and other alcoholic drinks, along with the production of large quantities of carbon dioxide. Fermentation occurs in mammalian muscle during periods of intense exercise where oxygen supply becomes limited, resulting in the creation of lactic acid.

11.1.1 Ethanol fermentation

The chemical equation below shows the alcoholic fermentation of glucose, whose chemical formula is $C_6H_{12}O_6$. One glucose molecule is converted into two ethanol molecules and two carbon dioxide molecules:

$C_6H_{12}O_6 \rightarrow 2\ C_2H_5OH + 2\ CO_2$.

C_2H_5OH is the chemical formula for ethanol.

Before fermentation takes place, one glucose molecule is broken down into two pyruvate molecules. This is known as glycolysis.

11.1.2 Lactic acid fermentation

Homolactic fermentation (producing only lactic acid) is the simplest type of fermentation. The pyruvate from glycolysis undergoes a simple redox reaction, forming lactic acid. It is unique because it is one of the only respiration processes to not produce a gas as a byproduct. Overall, one molecule of glucose (or any six-carbon sugar) is converted to two molecules of lactic acid: C6H12O6→2CH3CHOHCOOH It occurs in the muscles of animals when they need energy faster than the blood can supply oxygen. It also occurs in some kinds of bacteria (such as Lactobacilli) and some fungi. It is this type of bacteria that converts lactose into lactic acid in yogurt, giving it its sour taste. These lactic acid bacteria can carry out either homolactic fermentation, where the end-product is mostly lactic acid, or **Heterolactic fermentation**, where some lactate is further metabolized and results in ethanol and carbon dioxide (via the phosphoketolase pathway), acetate, or other metabolic products, e.g.:

$C_6H_{12}O_6 \rightarrow CH_3CHOHCOOH + C_2H_5OH + CO_2$

If lactose is fermented (as in yogurts and cheeses), it is first converted into glucose and galactose (both six-carbon sugars with the same atomic formula): $C_{12}H_{22}O_{11} + H_2O \rightarrow 2\ C_6H_{12}O_6$ Heterolactic fermentation is in a sense intermediate between lactic acid fermentation, and other types, e.g. alcoholic fermentation. The reasons to go further and convert lactic acid into anything else are:

- The acidity of lactic acid impedes biological processes; this can be beneficial to the fermenting organism as it drives out competitors who are unadapted to the acidity; as a result the food will have a longer shelf-life (part of the reason foods are purposely fermented in the first place); however, beyond a certain point, the acidity starts affecting the organism that produces it.
- The high concentration of lactic acid (the final product of fermentation) drives the equilibrium backwards (Le Chatelier's principle), decreasing the rate at which fermentation can occur, and slowing down growth
- Ethanol, that lactic acid can be easily converted to, is volatile and will readily escape, allowing the reaction to proceed easily. CO2 is also produced, however it's only weakly acidic, and even more volatile than ethanol.
- Acetic acid (another conversion product) is acidic, and not as volatile as ethanol; however, in the presence of limited oxygen, its creation from lactic acid releases a lot of additional energy. It is a lighter molecule than lactic acid, that forms fewer hydrogen bonds with its surroundings (due to having fewer groups that can form such bonds), and thus more volatile and will also allow the reaction to move forward more quickly.
- If propionic acid, butyric acid and longer monocarboxylic acids are produced (see mixed acid fermentation), the amount of acidity produced per glucose consumed will decrease, as with ethanol, allowing faster growth.

11.1.3. Acetic acid Fermentation

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Vinegar is produced by this process. This is a two-step process.

The first step is the formation of ethyl alcohol from sugar anaerobically using yeast.

In the second step, ethyl alcohol is further oxidized to form acetic acid using acetobacter bacteria. Microbial oxidation of alcohol to acid is an aerobic process.

$$C_2H_5OH(ethanol) + O_2 \xrightarrow{acetobacter} CH_3COOH(acetic\ acid) + H_2O$$

11.1.4. Butyric acid Fermentation

This type of fermentation is characteristic of obligate anaerobic bacteria of genus clostridium. This occurs in retting of jute fibre, rancid butter, tobacco processing and tanning of leather. Butyric acid is produced in the human colon as a product of dietary fibre fermentation. It is an important source of energy for colorectal epithelium. Sugar is first oxidized to pyruvate by the process of glycolysis and then pyruvate is further oxidized to form acetyl-CoA by the **Oxidoreductase** enzyme system with the production of H_2 and CO_2. Acetyl-CoA is further reduced to form butyric acid. This type of fermentation leads to a relatively higher yield of energy. 3 molecules of ATP are formed.

$$C_6H_{12}O_2 \xrightarrow[butyricum]{clostridium} C_4H_8O_2 + 2CO_2 + 2H_2$$

11.2 Application of fermentation in pickling, curing and other processes

Fermented pickles, often called brine pickles. Dill pickles and sauerkraut are examples of this group. Changes occur in the flavor and the color of the foods, and the acidity increases as the curing process takes place. Fermented pickles undergo a curing process for several weeks in which fermentative bacteria produce acids necessary for the preservation process. These bacteria also generate flavor compounds which are associated with fermented pickles. Initial fermentation may be followed by the addition of acid to produce such products as half dills or sweet gherkins.

Fermentation is used in processing industry for making fermented food products. Fermented foods are foods and beverages that have undergone

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controlled microbial growth and fermentation. Fermentation gives unique and desirable taste, aroma, texture and appearance to the foods.

There are thousands of different types of fermented foods, including:

- cultured milk and yoghurt
- wine
- beer
- cider
- tempeh
- miso
- kimchi
- sauerkraut
- fermented sausage.

Course Name	Fundamentals Of Food Technology
Lesson 12	Novel food processing technologies
Content Creator Name	Dr Mohammed Wasim Siddiqui
University/College Name	Bihar Agricultural University,Bhagalpur
Course Reviewer Name	Dr.Jagmohan Singh
University/college Name	Sher-E-Kashmir University Of Agricultural Sciences And Technology Of Jammu ,Jammu

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Objective

1. To give a clear concept about different novel processing methods.
2. How these methods are helpful than conventional methods.

Glossary

Novel food processing methods- these are non-thermal methods of processing, which helps in retention of nutritional quality of food.

It also prevent microbial spoilage and improves shelf life.

High-pressure processing- whereby products are held at pressures typically between 300 and 600 MPa for up to 10 minutes.

Pulsed electric field- the food to be processed is exposed to a pulsed high voltage field for less than 1 second.

Cold plasma- applications in the sanitization of the surface of fresh produce, liquid products (e.g., juice), as well as equipment surfaces used in food processing and food packaging.

Ultrasound- Sound waves exceeding the audible frequency range i.e. greater than 20 kHz are termed as 'Ultrasound'.

Irradiation- The process of exposing food to an ionizing radiation is called "Irradiation".

12. Introduction

The need for novel processing technologies in the food industry is a direct result of consumer demand for fresh, high quality and healthy products that are free from chemical preservatives and yet are safe. The trend towards the use of "natural" ingredients, (colors, flavors or preservatives) although technically challenging, has created the need for research into milder and more energy efficient but equally effective processing technologies that are able to preserve the structure and thus, function and benefits of novel ingredients whilst at the same time maintaining the nutritional and other food product qualities. Improvement of product quality has always been the main goal of food and beverage manufacturers. The novel methods used in food processing, include high-pressure processing, cold plasma, pulsed electric field, supercritical carbon dioxide, irradiation, and ultrasound. Novel processing technologies such as high-pressure processing (HPP), pulsed electric field (PEF) and cold plasma are thought to be among the most promising of novel technologies.

12.1 High Pressure Processing (HPP)

HPP is a non-thermal pasteurization technique whereby products are held at pressures typically between 300 and 600 MPa for up to 10 minutes. The advantages of HPP over the conventional thermal processing techniques involve reduced process times and thus reduced heat damage, as well as retention of product flavor, texture, color and vitamins. However, microbial spore survival during processing requires this technique to be used in conjunction with another hurdle such as low pH or refrigeration.

HPP is shown to inactivate pathogenic and spoilage bacteria, yeasts, molds and viruses; however, its efficacy is limited against bacterial spores and enzymes. Factors such as the type of microorganism, food composition, pH and water activity are shown to affect its microbial inactivation efficiency. HPP wasn’t used in the commercial preservation of foods until 1990 but has since been used successfully while the number of commercial applications is growing worldwide. HPP has been employed in the processing of a number of liquid and semi-solid foods such as fruit juices, purees, smoothies, jellies and guacamole. High capital expenditure and limited throughput are its main current limitations.

12.2 Pulsed Electric field (PEF)

Recognized for its ability to inactivate bacteria present in liquid food products at low temperatures, PEF is a food preservation technique whereby the food to be processed is exposed to a pulsed high voltage field for less than 1 second. Studies have shown that PEF processing results in better retention and storage stability of carotenoids, phenolic compounds and flavonols, in comparison to thermal processing. It can be industrially implemented to produce juices that better resemble the freshly squeezed, mainly with regards to their aroma profile.

PEF has the potential to replace thermal techniques for the pasteurization and sterilization of liquid foods due to the retention of the products' nutritional value, sensory characteristics, safety and overall quality profile, yet at lower operational costs. Others believe that PEF could be a suitable technique for use with additional processes/hurdles such as mild thermal treatment or control via pH/water activity. Studies have shown that combining the PEF treatment at moderate temperatures with the presence of an antimicrobial, effective against both Gram-positive and -negative pathogenic bacteria, would significantly enhance process efficiency, reduce the number of pulses and outlet temperature and lead to significant energy cost savings.

PEF efficacy towards microbial inactivation mainly depends on the intensity of the electric field, the pulse width, treatment time (number of pulses times pulse duration), pulse wave shape, temperature (operational temperatures of 50–60oC result in increased microbial inactivation) and product conductivity. High conductivity foods are not thought to be suitable for treatment with PEF, neither are those with a high salt content or liquid products containing particulates. PEF lethality is also affected by the lifecycle stage of the target micro-organisms with rapidly growing and dividing microbial populations being the most sensitive while those in stationary or lag phases showing some resistance.

12.3 Cold Plasma

Plasma is defined as the fourth state of matter that is energetically distinguishable from solids, liquids and gases and can either be thermal or non-thermal, depending on the conditions in which they are created. Plasma is a source of different antimicrobial substances including UV photons, charged particles, and reactive species such as superoxide, hydroxyl radicals, nitric oxide and ozone. Very high temperature and/or pressure conditions, thus a significant level of power, are required to obtain thermal plasmas, whereas non-thermal plasma use significantly less power as they may be generated by electric or magnetic discharges and can be obtained at lower pressures, thus generating significant industrial interest. Although a relatively unexplored decontamination technology, cold plasma has found applications in the sanitization of the surface of fresh produce, liquid products (e.g., juice), as well as equipment surfaces used in food processing and food packaging. Cold plasma is thought to be an effective alternative to thermally based microbial inactivation methods having comparable microbial inactivation properties against major pathogens while having little or no effect on the product's nutritional or other quality. However, cell density has been shown to affect the efficacy of cold plasma processing with upper cell layers acting as physical barriers to underlying cells in complex bacterial multilayer structures (e.g., bacterial biofilms), thus potentially affecting the practical application of the technique to the food industry.

The need for enhanced food safety and quality, without compromising the nutritional and sensory characteristics of foods, has created an increasing interest in low-temperature innovative food processes. These emerging technologies mainly rely on physical processes that use ambient or moderately elevated temperatures and short treatment times to inactivate microorganisms. Given that factors affecting the efficacy of the different processes, mainly related to the properties of the food matrix to be processed, can lead to significant variability in their efficacy, it would be difficult to apply a one-for-all-rule on the application of these mild processing conditions. More research is required to establish and expand the industrial applications of the different technologies and overcome high capital costs that may delay industrial adoption.

12.4 Microwave heating

Microwave is an electromagnetic wave within the frequency band of 300 MHz and 300 GHz. These waves find applications in variety of areas which include telecommunications, medical, and other scientific fields

(Richardson, 2001). In relation to food industry, microwaves are used for thawing of frozen foods, pasteurization, drying, and pre-cooking (meats like beef). This is primarily due to the advantages that microwave heating provides over other heating methods which include efficient heating, less time to start, easy for mass commercialization and food with better nutritional and sensory qualities (Decareau and Peterson, 1986; Sun, 2005). But, microwaves of all the frequencies cannot be used for the food applications. There are two specific frequencies that are dedicated to the industrial applications (food industry) which are 915 MHz and 2.45 GHz (most commercial ovens) (Tewari, 2007; Doona, 2010). There are two main principles involved in the microwave heating of food. The first and the most important is the “dipole rotation” and the second one is the “ionic polarization” or “ionic conduction.” For the dipole rotation to occur the presence of polar molecules is very important. The most common polar molecules found in food is the water molecule that is randomly oriented all over food. But, in the presence of an electric field (like microwave), the molecule tries to align itself to the orientation of the field appropriately. In a microwave, the field alternates at a very high frequency (2450 MHz) and when the polar molecule is present, after aligning themselves to the field, the resulting interactions between the fast moving (rotating) polar molecules and the other molecules in food produces friction resulting in the heating effect. The ionic polarization occurs in the presence of high concentrations of ions in the food. Under the influence of the electric field, the ions in food collide with each other and thus dissipate their kinetic energy which is converted to thermal energy on collision. In fact, it is said that the temperature of food can be raised by about 10C per second with the high intensity of heat produced in microwave processing. Thus, the microwave processing generates heat instantly and the amount of heat generated is highly dependent on the local composition and the overall homogeneity of the food product. Moreover, the heat transfer rate within the food relies on the composition (presence of water) and on the geometry of the food. There are a wide variety of changes caused due to the generation of heat in food during microwave processing. Some of them include gas/water vapor generation (baking), starch gelatinization (corn, potatoes, etc.,), protein denaturation (milk & egg), surface browning (Millard Reaction in baking), caramelization (due to sugar dehydration), and enzyme inactivation. They can also effect the textural and organoleptic properties of the food. This suggests that the microwave processing does have an effect on the components of food.

12.5 Ultrasounds

Sound waves exceeding the audible frequency range i.e. greater than 20 kHz are termed as 'Ultrasound'. When the acoustic waves propagate through a medium, they generate compressions and rarefaction (decompressions) in the medium particles. This, in turn, produces a high amount of energy, due to turbulence, and increase in mass transfer. The underlying principle is the reflection and scattering of sonic waves analogous to light waves. Ultrasound is an emerging sustainable technology that enhances the rate of several processes in the food processing industry, and their efficiency. It can also be applied in combination with temperature (thermosonication) and pressure (manosonication) to produce a synergistic effect, which further enhances its efficacy. Based on the intensity and frequency ultrasound waves used in food application can be categorized into two categories: low and high-intensity ultrasound.

The low intensity or high-frequency ultrasound waves also described as diagnostic waves and have a characteristic frequency greater than 100 kHz and intensities below 1 W/cm^2. These waves can be utilized for evaluating the structure (shape, size, and dimensions) of the food product, determining the composition of fresh food commodities such as meat and poultry, raw and fermented fisheries. The principle of operation of low energy ultrasound that it effectively exploits the interaction between matter and high-frequency sound waves to obtain detailed information in context to the structure, dimensions, and composition of the product through which it disseminates.

Table 1. Application of ultrasound in basic unit operations.

Applications	Principle	Products	Advantages
Filtration	Vibrations	Liquid food products eg. Juices	Increases membrane permeation. Requires less time. Enhances filtration process
Freezing / Crystallization	Uniform Heat Transfer	Milk products Fruits & Vegetables Meat	Improves freezing by better preservation of the microstructure. Requires less time and small crystal size. Improved diffusion. Rapid decrease in temperature.
Thawing	Uniform heat Transfer	Frozen products	Reduction in thawing time. Preserve color Inhibit lipid oxidation. Improved product quality. Reduced product dehydration
Brining/Pickling		Cheese, meat, fish etc	Low water activity and longer shelf life Required less sodium chloride Uniform distribution of salt in less time
Drying	Uniform Heat Transfer	Dehydrated Food Products	Intensification of mass transfer. Shorter processing time. Enhanced organoleptic properties. Increased drying rate due to less resistance.

Applications	Principle	Products	Advantages
Foaming	Dispersion of gas bubbles	Protein	Increases the foaming capacity Reduces the foam stability and water retention capacity
Degassing / Deaeration	Agitation	Carbonic beverages, aqueous solutions.	Reduces the bottles broken and beverage overflow Less time required
Cooking	Uniform Heat Transfer	Meat Products Vegetables	Requires less time Improved nutrient retention. Improved rate of heat transfer. Enhances organoleptic properties. Improved tenderization
Emulsification	Cavitation Phenomenon	Emulsions eg. Mayonnaise	Enhances rheological properties Improves emulsion stability Requires less time
Cutting	Cavitation Phenomenon	Soft Products eg. Cheese, Bread	Accuracy in cuts Requires less time Clean cuts with minimized product loss
Sterilization / Pasteurization	Uniform Heat Transfer	Milk, Juice	Reduced processing time Efficient microbial inactivation Low temperature requirements Low energy requirements

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Applications	Principle	Products	Advantages
Extraction	Diffusion	Food and plant material	Increase the efficiency of extraction Reduces the time of extraction Less solvent required
Rehydration	Absorption	Dried vegetables, grains etc.	Reduction in time of rehydration

12.6 Irradiation

The process of exposing food to an ionizing radiation is called “Irradiation.” Though wide range of ionizing radiations is available, the treatment with gamma-radiation is widely employed over the others. These rays are emitted through the radio isotopes Cobalt—60 and Cesium—137 (Farkas, 2006). These are primarily used for increasing storage duration by destroying the surface pathogens present on the food. By varying the dosage of radiation, various other desired effects are achieved which can be extension of shelf life, microbial destruction, and reduction in the losses of produce during storage. The process of irradiation is also environmentally safe and is an energy efficient process which adds to its marketability. The radiation in the ranges of 2–7 kGy (medium dosage level) can eliminate the surface pathogens in the food products without affecting the organoleptic and nutritional qualities of the food. Researchers also mentioned when irradiation is used in combination with other processing treatments, even a low or medium level exposure would actually decrease the chances of the microorganisms to survive in the end product.

12.7 Dense gases – Supercritical carbon dioxide

Supercritical carbon dioxide (SCCO2) is already widely used by the food industry. The goal of using this technique is to extract desirable or unwanted food ingredients, to reduce microbiological activity, and to reduce enzyme activities. SCCO2 can be used to remove caffeine from coffee beans; it is also suited to remove key aroma compounds from roasted coffee beans, and to add these compounds to the produced coffee powder. This technique improves the quality of the soluble coffee to a remarkable extent. SCCO2 is able to penetrate membranes of micro-organisms, and after being distributed in the micro-organisms, CO2 is converted to carbonic acid if the Wa value is sufficiently high. The result of this conversion is a decrease of the pH value, and subsequently a reduction of microbial metabolism. An additional damage of the membranes occurs through extraction of lipid components by SCCO2. Knorr reported that microbial activities of Saccharomyces rouxii are already strongly reduced after treatment with SCCO2 for 20 min at aw values ranging from 0.62 to 0.91 and almost totally eliminated after 30 min treatment (Knorr 1998).

12.8 Applications of novel processing techniques

Some examples of existing and intended applications of novel processing techniques may show the wide variety of benefits they bring. To preserve and/or to decontaminate macro- or micro-ingredients, micro-organisms, ready-to-eat meals or packaging material in order to extend the shelf life, high hydrostatic pressure, pressure-assisted freezing, high-voltage arc discharge, ultrasonics and high-intensity pulsed light can be used. Using high hydrostatic pressure or high-intensity electric-field pulses, whole foods, micro- and/or macro-ingredients can be modified, for example gelatinization can be improved. High hydrostatic pressure and high-intensity electric-field impulses can also be used to induce stress, for example to increase the biosynthetic activities of micro-organisms, cell cultures or algae. An important goal in producing foods is mass-transfer modification by extraction or expression in whole foods, micro-organisms, cell cultures, algae, raw materials for macro- or micro-ingredients or food waste. This aim can also be achieved by using techniques such as high hydrostatic pressure, high-intensity electric-field pulses and ultrasonics. Non-thermal processes such as membrane processes (ultrafiltration and reverse osmosis) can be used to preserve and modify liquids, whilst biotechnical processes like fermentation or enzymes serve to transform foods in order to preserve or modify them. Although novel processing techniques appear to be increasingly important in the food industry, there have been hardly any research projects that deal with the effect of these new techniques on the allergenic potency of treated food. Some experiments, however, have been undertaken to investigate the effect of HP treatment on allergenic potential. The results show that the influence of this treatment on allergenic potential is low, which is an astonishing result because not only HP treatment but also the other methods mentioned above modify the food proteins. It is, however, known from many other experiments that the modification of proteins may influence the allergic potency of foods.