UNIT 10 FERMENTATION, METHOD OF FERMENTATION AND INDUSTRIAL SIGNIFICANCE

Structure

10.0 OBJECTIVES

After studying this unit, you should be able to:

- state the meaning of biotechnology and fermentation;
- infer the historical importance of different varieties of fermented foods prepared all over the world from various agricultural commodities;
- know the nutritional significance and beneficiary effects of fermented foods and their classification;
- describe the general methods in fermentations for the cultivation of microorganisms;
- state the importance of aerobic and anaerobic fermentations; and
- discuss the difference between solid state fermentation and submerged fermentation.

10.1 INTRODUCTION

In recent years, biotechnology and information technology have been given much importance. It is believed that these areas of Science and Technology would help to improve the standard of living as well as the life span all over the world. Biotechnology is the integrated use of biochemistry, microbiology and chemical engineering to achieve industrial application of microorganisms and tissue culture. Unlike material sciences, in biotechnology the key of any process or activity is the biological source viz., microorganisms (bacteria,

yeasts, fungi and virus) plants and animals. If we scan the books and journals, we find most of the processes are based on microbes through fermentation. These microorganisms produce newer types of products (vitamins, antibiotics, hormones, amino acids, enzymes, beverages, fuels and solvents, life saving drugs) or convert raw food stuffs (cereals, pulses, fruits, vegetables, animal, fish, poultry and dairy products) into palatable, nutritious and processed foods with longer shelf life.

Fermentation is the oldest word used for biotechnology from time immemorial when nothing was known about microorganisms or technology. Bread-making, cheese manufacture and production of wine and alcoholic beverages are the certain examples. *Fermentation can be defined as the chemical modification of organic compounds or raw materials or agricultural commodities with the aid of enzymes produced by microorganisms*. With respect to foods, it is the transformation of physical structure and chemical constituents (carbohydrate, proteins, fats and nucleic acids) by microorganisms and their enzymes under aerobic (presence of oxygen) or anaerobic (absence of oxygen) conditions. Examples are wine from grapes, cider from apples, beer from malted barley, whisky, gin, rum, pickles, curds, idli and dosai, bread and nan, cheese and lactic beverages.

10.2 HISTORY OF FOOD FERMENTATIONS

When we go through several books and research articles we find a number of definitions of fermentation. The most frequently used names were: respiration, fermentation, putrefaction, decay, digestion, dissimilation and ferment. However, the major developments in the twentieth century in the field of microbiology, molecular biology, chemical engineering and biochemical engineering and biochemistry have resolved this confusion.

If we look at the human's civilization, the man has passed through several stages viz., hunting, gathering food to this stage of collective cultivation and processing of foods. During the early stages, sun-drying, salting and fermentation were practiced and in certain pockets especially in tribals and rural areas in India and other countries, these are in vogue sometimes singly or in combinations.

The Egyptians, Sumarians, Babylonians, Assyrians and Indians knew the technique of alcoholic beverages production. Indians were used to *Ashwas* and *Arishtas*. Drinking wine was common in the Roman Empire throughout Europe and North Africa. Mead was prepared from honey. Idli, dosai and other fermented foods were introduced in South Indian dietary system since time immemorial. Soy sauce, miso and tempeh were known to Chinese as early as 1000 BC and the techniques were passed on to Japan around 600 AD. Fermented dairy products such as curds and butter milk are referred in early Sanskrit literature. The word fermentation comes from the Latin word *ferveo* meaning to boil. From this *fermentum* was derived which means yeast or leaven. The evolution of bubbles due to carbon dioxide production was noticed in alcoholic fermentation and hence this name was given. Louis Pasteur in France in 1861 was first to declare that a group of microorganisms viz., yeasts are responsible for fruits and grains fermentation for the manufacture of wine and beer. He also described that along with desirable type of microorganisms, undesirable types also grew in the ferment and also these were responsible to spoil the quality of final product. He was first to suggest heating at 62.8^{o}C for

30 minutes (pasteurization) to eliminate the undesirable microorganisms from the fruit juice before fermentation.

10.3 MICROBIOLOGY AND BIOCHEMISTRY

As you have become aware, food fermentations started with the development of man's civilization purely due to necessity. During those days nothing was known about science and technology of fermentation and also causitive agents viz., microorganisms and their enzymes responsible for it. It was also not known that these microorganisms fall under two categories: **useful** producing life saving drugs, chemicals and fermented foods and products and **harmful** causing spoilage of the products and responsible for many deadly diseases (Cholera, typhoid, plague, small pox etc.). These became evident after the discovery of microorganisms and their systematic scientific studies in the middle of nineteenth century when Louis Pasteur established their role in fermentations and human and animal diseases. In India, food prepared if left over night outside, gets spoiled due to the growth of microorganisms. Microorganisms spoil the food by damaging the structure, colour, and chemical and physical characteristics both in raw as well as processed foods. Bread (*Rhizopus nigricans, Aspergillus niger, Penicillium notatum)* fresh fruits and vegetables (*Rhizopus* and *Erwinia)* Pickles (*Rhodotorula, Candida, Pichia),* meat (*Alcaligenes, Clostridium, Proteus vulgaris, Pseudomonas fluorescens),* fish (*Flavobacterium, Alcaligenes)* eggs (*Pseudomonas fluorescens)*, orange juice (*Lactobacillus, Leuconostoc, Alcaligenes)* and poultry (*Pseudomonas, Alcaligenes)* are spoiled by a number of microorganisms and thus become unfit for consumption.

Some bacteria such as *Salmonella* spp., *Shigella dysenteriae, Vibrio cholerae, Clostridium botulinum, Clostridium perfringens, Listeria* spp. and *Campylobacter* spp. produce toxins causing food poisoning. *Aspergillus flavus, Pencilllium citrinum, Fusarium graminarium* and many strains and species of fungi in under humid and hot conditions grow on agricultural commodities and food materials and produce different types of toxins which are deleterious to human and animal health.

The growth and activity of microorganisms thus are important in controlling the quality and safety of food. Both harmful and useful microorganisms grow in their environmental and ecological conditions in food commodities, food preparations and processed foods and other systems and produce enzymes, metabolites and toxins depending on nutritional and physical factors. These factors are water activity, pH, temperature, chemical constituents and the buffering compounds. In natural fermentation (without addition of microorganisms, inoculum or starter culture) and controlled fermentation (addition of starter culture/s), microorganisms bring about many chemical and structural changes in organic constituents of foods and thus check the growth of pathogenic microorganisms. Examples are lactic acid producing bacteria, alcoholic fermentations, oxidation of alcohol to acetic acid, production of other organic acids and amino acids and nucleotides and changes in cellulose, hemicellulose, pectins, gums, fats and proteins.

Lactic acid producting bacteria have been used since time immemorial all over the world in preserving and modifying foods such as cereals (idli, dosai, nan) milk (curds), cheeses and fermented meat and fish.

The lactic acid bacteria convert available carbohydrate to lactic acid where by lowering the pH and changing the conditions suitable for the growth of yeast. Some times propionic acid is also produced which acts as a preservative. They also produce flavour compounds e.g. diacetyl, acetaldehyde and acetoin. This action of lactic acid producing bacteria is observed in the production of many traditional and indigenous foods from fruits and vegetables, legumes, cereals, milk, meat, poultry and fish etc. The acids developed by the organisms during the processing of foods contribute to the flavour of the final product and also act as preservatives preventing the growth of undesirable pathogenic and spoilage microorganisms.

Some of these lactic acid producing bacteria produce lactic acid only or acetic acid, formic acid and ethyl alcohol. The organisms producing only lactic acid are known as *homofermentative* and those producing lactic acid with other compounds are *heterofermentative*. Lactic bacteria normally isolated from vegetable fermentations are: *Lactobacillus plantarum, Lactobacillus brevis, Pediococcus cerevisiae, Leuconostoc mesenteroides* and *Lactococcus lactis.*

10.4 NUTRITIONAL VALUES OF FERMENTED FOODS

It is clear now that early man or our ancestors used to store fruits, vegetables, seeds, cereals and even fish and meat for the lean period when the supply of these commodities were scarce. The first reason was storage in order to check the spoilage. The other reason was to improve the nutritional quality and also palatability and acceptability. Certain flavours such as sweet, sour, alcoholic, meat like are obtained in the final fermented products through microorganisms by fermentation. Soybeans and many legumes are difficult to digest and therefore many fermented products are prepared in the oriental countries e.g., China, Japan, Indonesia and African Countries. Besides flavours, these fermentation also increase the levels of vitamins and also amino acids. In general the important beneficial changes obtained through fermentation are:

- Improvement in the profile of flavours, aromas and textures in food substrates.
- Preservation through lactic acid, alcohol, acetic acid and alkaline fermentations.
- Enrichment with essential amino acids, essential fatty acids and vitamins.
- Detoxification of certain toxic constituents during food fermentations.

10.5 NUTRITIONAL QUALITY OF FERMENTED VEGETABLES AND FRUITS

When we consider this aspect of fermentation, most of the vegetables e.g., cabbage (Sauerkrauts and Korean Kimchi), cucumber, green olives, carrots, onion and various others (tomato, pepper, green peas, cauliflower and mustard leaves) are fermented in European countries. Relatively few vegetables are fermented in India. However, the beneficial effect of fruits and vegetables is as follows:

10.5.1 Beneficial Dietary Effects

As reported by nutritionists and health experts, fermented vegetables are rich in fibre, vitamins and minerals. We all are fully aware regarding the

importance of fibre in our dietary system. Many intestinal and heart problems are associated with less consumption of fibre especially the processed foods. There are several benefits in consuming fermented vegetables with live lactic acid producing bacteria:

Lactic acid bacteria if taken along with fermented vegetables or fruits in the diet lower the blood serum cholesterol level.

These bacteria produce a number of metabolites which are beneficial to human health.

They help in preventing tumor formation in the body due to stimulation of factors responsible for immunity.

Lactic acid producing bacteria inhibit the formation of carcinogenic compounds in the gastrointestinal tract.

They reduce the growth and enzyme production by the intestinal bacteria e.g., enterobacters.

These bacteria and fermented foods if taken as a food, change the microflora by eliminating pathogenic and undesirable organisms in our intestine and colon.

10.5.2 Protection of Vitamin C in Fermented Vegetables

In India, we do not include fermented vegetables in our dietary system. However, in Europe, North America and Korea, cabbage and several other vegetables are fermented and higher levels of vitamin C is found in them due to its synthesis by microorganisms.

10.5.3 Mineral Preservation in Fermented Vegetables

The fermented vegetables in a meal help higher assimilation of iron. Iron bioavailability is better in lactic acid producing bacteria fermented carrots.

10.5.4 Reduction in Nitrate Content

Due to the widespread use of nitrogenous fertilizers, high quantities of nitrates are sometimes found in food products. This nitrate which is harmless as such, is reduced and converted into nitrites which finally gets transformed into highly carcinogenic nitrosamines. During lactic acid fermentation of vegetables, nitrites are converted into NO_2 which goes out as a gas.

10.5.5 Improved digestibility

Many indigestible compounds responsible for gas and flatulence and also sulphur compounds in garlic or onion are broken down to inoccous break down products.

10.6 POSSIBLE HARMFUL EFFECTS

a) A number of amines are formed during the fermentation of cabbage, carrot, pepper and turnip etc., and thus their higher concentrations cause unpleasant flavour to the final product or toxic effect. Ingestion of certain amines can cause headaches, fever and vomiting almost similar to

microbiological food poisoning. Histamine, tyramine, putrescine, and cadaverine are normally noticed in the fermented vegetable products.

b) During the fermentation process D(-)lactic acid is also produced depending on the type and number of lactic acid producing bacteria. D(-) form of lactic acid is not assimilated in the body and thus gets eliminated by the kidney in the form of salts which results in the loss of calcium and magnesium. Normally D(-) lactic acid concentration in the fermented vegetables is low without having any adverse effect on the human health. However, care is needed to restrict the quantity in the meals.

Check Your Progress Exercise 1

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. Explain why a knowledge of biotechnology is useful in understanding microorganisms in fermentations.

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2. What do you understand by fermentation?

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3. Highlight the importance of harmful and useful microorganisms in the spoilage and improvement of food quality.

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4. List the beneficial changes in food commodities by fermentations.

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5. What are the attractive nutritional characteristics of fermented fruits and vegetables?

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10.7 CLASSIFICATION OF FERMENTED FOODS

It is important to know about different varieties of fermented foods prepared and consumed all over the world depending upon the agricultural and food raw materials produced in that region. These fermented foods can be classified into the following categories:

i) Fruit and Vegetable products
ii) Beverages (alcoholic and non-alcoholic)
iii) Cereal products
iv) Milk Products
v) Fish Products
vi) Products from Legumes
vii) Meat products
viii) Starch Crop products

i) Fruits and Vegetable Products

You are now fully convinced that the fermentation of food commodities was practiced by the early man and by trial and error many technologies were developed. Vegetables have been preserved throughout the world by fermentation. Examples are cabbage (Sauerkraut, Korean Kimchi), radish, mustard leaf, gherkins and cucumbers, ginger onion, chilli and bambooshoots (Malaysian pickles), carrot, turnips and peppers. In India, relatively very few vegetables are fermented and preserved for consumption. Among fruits, olives are commercially fermented and consumed in European countries as an appetizer.

ii) Beverages (alcoholic and non-alcoholic)

Beverages are produced in large quantities in all regions of the world. We normally find two types of beverages which are common everywhere. The first group comprises of alcoholic beverages in which fermentation plays a major role in contributing the flavour and chemical and physical characteristics of the fermented products. Beer and wine fall under this category. After fermentation further distillation is done and thus a variety of products termed 'spirits' such as whisky, gin, brandy, rum etc., are produced.

The second category of beverages are non-alcoholic e.g., coffee, cocoa and tea. All of them involve fermentation. India is a major producer of tea and coffee. If you look at the worlds map, you find an interesting observation

that these are based on the type of agricultural crops cultivated in that particular area depending on the geographical and climatic conditions. The colder countries of Europe including Britain, Scandinavia, Netherlands and Poland consume beer which is manufactured mostly from barley. The southern countries of Europe grow grapes extensively and produce different varieties of wine. These beverages have spread to many countries wherever the European settled e.g. Northern America (The United States of America, Canada), Australia and South Africa. Rice beer in Indian sub-continent, sorghum beer in Africa, sake (rice) in Japan and a variety of alcoholic beverages are produced in different parts of the world. In Europe and North America apples are used for cider production. In warmer climate in Africa, Asia, Oceania (Australia and New Zealand), the Indian subcontinent and South America the sweet liquid sap of palm trees is fermented to wine. In India, it is known as '*Toddy*'. Cashew apple pulp is extensively is used for the preparation of Feni in Goa.

The alcohol content of most of the fermented materials varies between 5-18%. Its concentration is increased in the range of 35-55% by distillation and thus brandy, whisky rum and gin are manufactured. Consumption of excessive amounts of alcoholic beverages leads to intoxification and loss of body control. Therefore it is prohibited in many countries and also many religions of the world.

In contrast to alcoholic beverages, the non-alcoholic beverages most widely consumed throughout the world are coffee, tea and cocoa and these are largely produced in India especially in southern part of the country. The tea leaves are fermented as such by the natural microorganisms. In the case of coffee and cocoa the pulp surrounding the beans are removed by the natural fermentation. This process contributes to the flavour of the final product. Bacteria, yeasts and moulds are involved in the fermentation of these commodities.

iii) Cereal Products

Cereals are the major staple food in every parts of the world. These are wheat, rice and maize. The most popular fermented cereal product is bread which is consumed in every region. It is done by fermenting wheat flour dough with the yeast *Saccharomyces cerevisiae*. Lao-Chao is a fermented rice product of China prepared by natural fermentation containing strains of *Rhizopus oryzae,Rhizopus chinensis* and *Endomycopsis* species etc., Puto of Philippines, Ang-Kak of China, Ragi of Indonesia, Tape-Ketan of Indonesia, Ogi of Nigeria, Injera of Ethopia and Banku of Ghana are produced extensively and consumed regularly in these countries. In India, mixed fermented preparations of rice and pulses and other commodities are idli, dhokla, khaman, papad and jalebies etc., Ambali, bhatura, kulcha and warri are also Indian fermented foods prepared and used in different parts of the country.

iv) Milk Products

Milk products have been included in our diets since time immemorial. In early days, natural fermentation of milk was the best method of preserving milk. Dahi and Chhanchh (butter milk) are important ingredients of every day's meal all over the country. The other products are youghurt, cultured milk acidophilus milk, cheese, Srikhand, Kefir and Kumiss etc.,

Fermented milk products have therapeutic properties along with their nutritional characteristics, wholesomeness and good flavour and digestibility. These qualities are introduced in the product by a number of lactic acid producing bacteria e.g. *Lactococcus lactis* subsp. *lactis, Lactococcus lactis* sub-sp. *cremoris* (cultured butter milk, sourcream, cottage cheese, other soft and hard cheeses), *Lactococcus lactis* sub-sp. *diacetylactis* (sour cream, butter, cheese, butter milk), *Streptococcus thermophilus (*yoghurt*, Lactobacillus delbrueckii* sub-sp. bulgaricus (yoghurt, kefir, kumiss, bulgarian butter milk), *Lactobacillus acidophilus* (Acidophilus butter milk).

Realising the health giving properties of fermented milk products, different varieties of preparations are being marketed all over the world. These are acid alcohol fermented milk products, high acid fermented products, medium acid fermented products, low acid fermented products and whey based beverages.

v) Fish Products

The fermented fish products are popular in some countries. Philippine fish sauce and Vietnamese Nuoc-mam are prepared by fermenting sardines, shrimps and small sea fish etc., Malaysian budu is consumed as a condiment on rice and as a flavouring ingredient in various dishes. Baloa baloa is a fermented rice shrimp mixture of Phillipine and consumed by most of the people.

vi) Legumes Products

Pulses constitute an important component of diet after cereals in Asian countries, especially in India. In India we consume tur or arhar, black gram, green gram, Bengal gram, lentils and a range of beans. Soybeans is also gaining popularity in India. Legumes are rich in proteins, and also in oil and carbohydrates. Unlike cereals, their digestibility is poor and therefore, they are fermented to different products in oriental countries e.g., China, Japan, Indonesia, Malysia, Thailand and several African Countries. Majority of these pulses and beans contain oligosaccharides such as stachyose and verbascose which cause flatus in the intestine. Trypsin inhibitors are also present in these agricultural commodities. Fermentation stimulates these undesirable constituents. Thus the fermentation improves digestibility, nutritional quality and textural characteristics of the fermented products. Tempeh, sufu, soybean milk, soy sauce, natto, bangkrek, khaman, warries and mixed fermented foods containing cereals and pulses e.g., idli, dosai, dhokla etc., are consumed in different regions of the world.

vii) Meat Products

There are not many fermented meat products. These products are dry and semi-dry sausages. In the United States of America, the commercial sausages are Genoa and Salami. Among the popular European brands (dry) are summer sausage, cervelet, thurunger, and Teewurst. Semi-dry-sausages are turkey sausage, fermented frankfurter and Frischwurst etc., In Europe and Western World, fermented sausages are preferred whereas in India, their consumption is almost negligible. The lactic acid producing bacteria e.g., *Lactobacillus plantarum, L. sake, L. curvatus, Pediococcus acidilactici, P. pentosaceus, Lactococcus lactis* are mainly responsible for

fermentation of meat. The safety and shelf life of the products are important because these products are contaminated easily and frequently by pathogenic microorganisms.

viii) Starch Crop Products

Cassava (tapioca) is a major food crop cultivated in several African Countries. It is a staple food to most of the people. It contains cyanogenic glucosides and therefore it must be processed. During fermentation, the cyanide content is reduced completely. Gari, lafun, fufu, peujeum, poi and tape are some of the products. Maize, Sorghum and millets are used for the preparation of fermented products like ogi, uji, koko fube and chika etc.

10.8 GENERAL METHODS OF FERMENTATION

The purpose and importance of food fermentation in our life including food preservation, textural modification and nutritional improvement, has already been highlighted earlier. In recent years, the fermentation industry stands next to information technology (IT) and software industries. It is therefore, pertinent to know general method's used in fermentation for the production of fuels, food and pharmaceutical products and life saving drugs.

There are two distinct types of fermentation which are commonly used for the above-referred purpose. These are:

a) Aerobic fermentation

b) Anaerobic fermentation

Aerobic Fermentation

These are carried out under the aerobic conditions in the presence of oxygen which is required for the growth and product formation by the microorganisms. Majoirty of the fermentations such as antibiotics, single cell protein, enzymes and amino acids come under this category. As listed above, the key of these fermentations is the microorganism/s and raw materials (ingredients) and cultural (pH, temperature, humidity and water content) and nutritional characteristics influence the product formation significantly. In many of the fruit and vegetable and agricultural commodities fermentations, the microorganisms grow at very low moisture level whereas in others contrary to this, it is carried out at very high levels of moisture in the range of 85-90% with adequate supply of oxygen. The former is termed as the solid-state fermentation (SSF) and the latter is called as the submerged culture fermentation.

Solid-State Fermentation (SSF)

SSF refers to the growth of microorganisms on solid materials without the presence of free liquid. It is considered to be economical since low moisture content is used and also does not require expensive equipments e.g, sophisticated fermentors. It is extensively practiced in the oriental food fermentations (miso, tempeh, soysausce, natto), secondary metabolites, enzymes, organic acids and composting etc. Although solid-state fermentation is a simpler and less expensive process of growing microorganisms, recovery of the final product adds finally to the cost during the down stream processing

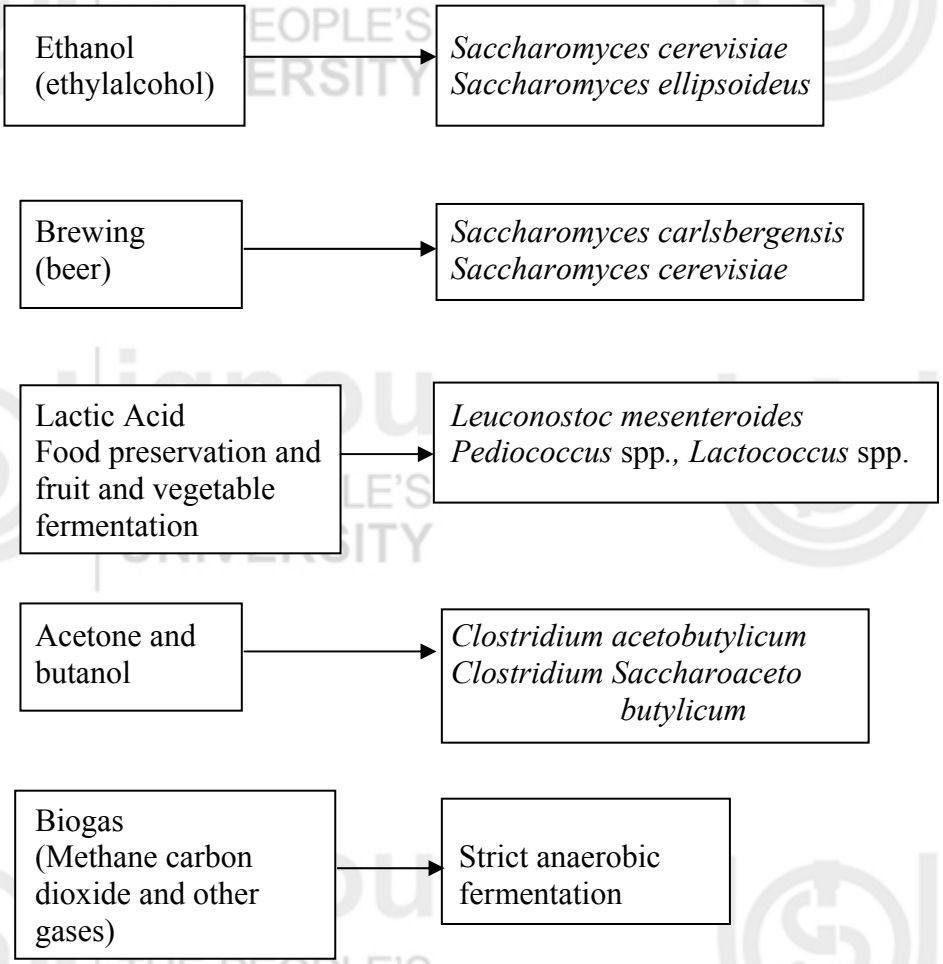
step. However it is widely followed for food and feed enrichment, food and feed enzymes production and composting and waste minimization.

Submerged Culture Fermentation

This method of fermentation has been practised for several years for the production of life saving drugs, enzymes, amino acids and organic acids by bacteria, yeasts, fungi and actinomycetes etc. Oxygen is supplied by either shaking or bubbling air through the liquid medium. Agitation, aeration and temperature affect the fermentation. Batch culture or continuous culture methods are followed for the production of fermented products - commercially.

Anaerobic Fermentation

These are carried out by strict anaerobes or facultative anaerobes such as bacteria and yeasts in the absence of oxygen. Examples of anaerobic fermentation are:



10.9 PRE-REQUISITES FOR INDUSTRIAL FERMENTATIONS

After knowing these preliminary information about the fermentations, it is necessary to know what are the important points to be considered before starting laboratory or industrial scale fermentation.

a) Microorganism/s is the key for any fermentation whereas fermentor is the heart of the process. The choice of a good medium/substrate/raw-material is virtually as important as selecting a right type of strain or microorganism

for the success of fermentation. The medium serves the following purposes:

i) It supplies nutrients for growth.
ii) It supplies nutrients for energy.
iii) It supplies nutrients for building of cell substance.
iv) It is required for the production of final product.

Nutrients needed for the growth and product formation are:

i) Carbon compounds derived mostly from starch, sugar and molasses.
ii) Nitrogeneous compounds.
iii) Inorganic salts.
iv) Water.
v) Vitamins.
vi) Growth factors.
vii) Precursors of fermentation products.
viii) Dissolved oxygen and other gases.
ix) Buffers.
x) Antifoam substances.
xi) Lysate of dead cells.

b) As you have become familiar that fermentation is a microbiological processes hence a potent strain of fungi; yeasts and bacteria is required for desired results. The choice depends upon many factors, the most important being the nature of the raw material. The youghurt preparation requires a strain of *Lactobacillus delbrueckii* sub sp. *bulgaricus* and *Streptococcus salvarius* subsp. *Thermophilus* and milk whereas *Leuconostoc mesenteroides, Lactobacillus, plantarum* and *Pediococcus cerevisiae* become predominant in cabbage for sauerkraut fermentation. In the mixed natural fermentation, it is not possible to control the number and type of microorganisms. Contrary to this in controlled fermentations such as alcoholic beverages, brewing and life saving drugs, an ideal microorganism is needed having the following characteristics:

i) The strain should grow profusely either in liquid or solid state conditions.
ii) The strain should be a pure culture and free of phages.
iii) The strain can be stored for a long period without any genetic change.
iv) The strain should always produce the predictable amounts of metabolite.
v) The strain should be amenable to strain improvement.

c) In nature, microorganisms exist as a mixed culture system and based on the chemical and physical characteristics of the substrate and environmental factors, one or two organisms dominate and thus desired fermentation is achieved. But in monoculture system, these have to be eliminated by sterilization using dry heat, moist heat (autoclaving), radiation and filteration. Sometimes tyndallization and pasteurization are also practiced depending on the nature of substrate and final product. For pharmaceutical

and chemical productions, this step has to be strictly followed as per need of the process.

d) The next step followed is the inoculum preparation and then fermenter has to be inoculated containing cooled sterilized medium at the rate of 1-10%. The fermentation is carried out by controlling all the parameters strictly for a certain period and thereafter the product is obtained by filteration, purification, concentration and drying. The quality of product is monitored at this stage.

10.10 COMPUTER APPLICATIONS IN FERMENTATIONS

The computer application is gaining importance in fermentation industries. It serves two distinct purposes: i) evaluation of fermentation parameters and their impact on the synthesis of desired product in the cell; ii) on line fermentation control especially at the production scale.

Computers find wide acceptability in high valued low volume product formation mainly costly life saving drugs and chemicals. It is used for data acquisition such as information on pH, temperature, viscosity, aeration rate and O_2 and CO_2 content. It also helps in data analysis.

Check Your Progress Exercise 2

Note: a) Use the space below for your answer.
b) Compare your answers with those given at the end of the unit.

1. List the important varieties of fermented foods consumed all over the world.

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2. Define ‘Aerobic’ and ‘Anaerobic’ fermentation and cite some examples.

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3. Compare the solid-state fermentation (SSF) and submerged culture fermentation.

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4. What are the requirements of fermentation? Illustrate the significance of microorganism in the fermentation.

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5. Provide an account of computer applications in industrial fermentations.

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10.11 LET US SUM UP

Biotechnology has emerged as an important tool to improve the life of people. It implies the application of microorganisms, plants and animals. Fermentation is an important aspect of biotechnology and it has been in practice since time – immemorial. Both harmful (pathogenic) and useful (beneficial) microorganisms grow on different commodities and environment when physical (water activity, pH, temperature, humidity) and nutritional factors become favourable for their growth. These microorganisms modify the textural and chemical characteristics of food materials and thus make them highly nutritious and palatable. They enrich some of these agricultural food commodities with vitamins, minerals, amino acids and essential fatty acids. These fermented foods are classified into several categories based on the raw materials used for fermentation (fruits and vegetables, cereals, milk and fish and meat products etc.)

The methods of fermentation normally employed are solid state fermentation (SSF) and submerged culture fermentation both aerobic (presence of oxygen and anaerobic (absence of oxygen) conditions. In nature many microorganisms grow together thus mixed culture fermentation takes place whereas in industries one (monoculture) or two microorganisms with improved strains are used and their growth conditions are strictly monitored. Computers are employed in fermentation industries for different purposes.

10.12 KEYWORDS

Fermentation : Fermentation is the chemical transformation of the constituents of raw materials with microorganisms and their enzymes.

Harmful microorganisms : Spoilage and pathogenic microorganisms.

Useful microorganisms : Beneficial microorganisms (wine and beer producing, curd, cheese and bread making and ethanol production).

Homofermentative : The microorganisms only producing lactic acid.

Heterofermentative : Those microorganisms produce lactic acid along with acetic acid, formic acid and ethanol.

Aerobic fermentation : It is carried out in the presence of oxygen.

Anaerobic fermentation : Microorganisms grow in the absence of oxygen (Ethylalcohol, lactic acid, acetone, acetic acid, butanol).

Solid state fermentation (SSF) : Microorganisms grow on solid materials without the presence of free liquid.

Submerged culture fermentation : Microorganisms grows in the liquid medium in the presence of oxygen mostly.

10.13 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1. Your answer should include the following points:

   - Emerging area of Science and technology.
   - Application of microorganisms, plants and animals.
   - Production of chemicals, value added products, food materials, medicines etc., commercially.
   - A boon to people all over the world.
   - A myriad of chemicals and products are produced by only microorganisms unlike plants and animals.

2. Your answer should include the following points:

   - Change in chemical and physical characteristics of the raw materials.
   - A process in which innumerable strategic chemicals (ethanol, medicines, harmones, vitamins) are produced by microorganisms.
   - Production of bread, curds, cheese, wine, beer, whisky, rum and brand etc.,

3. Your answer should include the following points:

   - Causing fatal infectious and contagious diseases to human being, animals and plants.
   - Commercially producers of alcoholic beverages of different types from varieties of agricultural commodities, bread, lactic acid fermentation, amino acids, vitamins and antibiotics.

4. Your answer should include the following points:

   - Improves the shelf life of fruit and vegetables.
   - Improves the organoleptic quality.
   - Improves the nutritional quality and health benefits in foods.
   - A good method of storage of agriculture and food commodities.
   - Cheapest and simplest method of preservation.

5. Your answer should include the following points:

   - Fermented fruits and vegetables taken along with lactic acid bacteria lower the cholesterol level in blood.
   - Lowers the number of cardiovascular diseases.
   - Lactic acid producing bacteria present in foods inhibit the formation of carcinogenic compounds.

Check Your Progress Exercise 2

1. Your answer should include the following points:

   - Fruits and vegetables, alcoholic and non-alcoholic beverages, cereals, milk products, fish products, products from pulses, legumes, meat products, starch crop fermented products.

2. Your answer should include the following points:

   - Growth of microorganisms in the presence of oxygen.
   - Growth of microorganisms in the absence of oxygen.
   - Ethanol, beer, acetone, butanol, biogas (aerobic).
   - Enzymes, aminoacids, vitamins and organic acid (anaerobic).

3. Your answer should include the following points:

   - Growth of microorganisms on solid materials for examples grits of cereals, fruits and vegetables, wheat and rice bran etc.,
   - The moisture content is usually maintained around of 32-35% (SSF: Solid state fermentation).
   - Tray fermenters are conventionally used (SSF).
   - Fermentation is carried out in a liquid medium containing 85% moisture (submerged).
   - Sophisticated expensive fermenters along with other equipments are needed (submerged).

4. Your answer should include the following points:

   - Microorganisms are responsible for the conversion of constituents into the desired product.
   - Needs highly potent strains of microorganisms.
   - A good medium for the growth of culture.

- The medium should have optimum quantity of carbon source, nitrogen source, vitamins, minerals, water, pH and oxygen.

5. Your answer should include the following points:

- Monitoring the functions of fermenters during operation.
- Data acquisition and data analysis.

10.14 SOME USEFUL BOOKS

1. Steinkraus, K.H. (1995) Hand Book of Indigenous Fermented Foods, Second Edition, Marcel Dekker, New York.

2. Campbell-Platt, G. (1987) Fermented Foods of the World, Butterworths, London.

3. Wood, B.J.B. (1985) Microbiology of Fermented Foods Vol. 1&2, Elsevier Applied Science Publishers.

4. Reed, G. and Nagodawitana, T.W. (1995) Biotechnology, Second Edition, VCH, New York.