UNIT 1 MICROBIOLOGY OF FOODS

Structure

1.1 INTRODUCTION

The first unit in this course introduces you to the discipline called food microbiology. In this unit, we will try to understand the historical aspects and development of food microbiology over the years. Food microbiology, as a discipline, has evolved to accommodate various modern developments. We will look at the role of microbiology in biotechnology and see how efficiently a microorganism can be improved by bio-engineering. Further, we will understand the role of microorganisms in preparing different fermented products and discuss other uses of microorganisms in the food industry.

Objectives

After studying this unit, you will be able to:

- understand the history and historical development of food microbiology,
- describe what is biotechnology and its role in the food industry,
- enumerate the various fermented food preparations produced by the use of microorganisms, and
- discuss other uses of microorganisms in the food industry.

1.2 FOOD MICROBIOLOGY – BASIC CONCEPT

We start our learning of food microbiology by first understanding what is microbiology. Microbiology is *the branch of biology that deals with microorganisms and their effects on other living organisms*. Microorganism, as you may already know, is a microscopic organism, such as a bacteria, virus, algae, fungus, protozoan etc. So why do we need to study and learn about these microbes? Microbes can spoil the foods, can cause food borne diseases and interestingly, some of them are useful. The relationship between microorganisms and food has been a subject of study for long and has been recognized as a separate area of study referred to as '*food microbiology*'. It is, in fact, a branch of microbiology concerned with the relationships between

microorganisms and food. *Food microbiology concerns with the interactions between microorganisms, food and us the community.* It covers food borne disease, food hygiene, food spoilage, fermented foods and beverages, use of microorganisms to produce food ingredients and processing aids, microbiological aspects of quality control, conventional and novel methods for the microbiological analysis of foods and aspects of food legislation. Food microbiology therefore, is a vast field of study in itself. Let us look at the origin of this field of study, next.

1.3 HISTORY OF FOOD MICROBIOLOGY

The microorganisms were first observed using primitive microscopes as early as the late 1600s. The science of microbiology is barely 150 years old. A dramatic development and broadening of the subject of microbiology has taken place since World War II.

It is extremely difficult to pinpoint the precise beginnings of man's awareness of the presence and role of microorganisms in foods, evidence available at this time indicates that this knowledge preceded the establishment of microbiology as a science. The era prior to this may be further divided into what has been called as man's 'food gathering period' and the 'food producing period'.

The food-gathering period may be from origin of man to 10,000 years ago. During this period, man was presumably carnivorous in his eating habits, with plant foods coming into his diet later in this period. The food producing period dates from 10,000 years ago to present time. Between 3000 BC and 1200 BC, the Jews employed salt in the preservation of various foods. The use of curds involving fermentation of milk was known in India since the Vedic period. The epic *Mahabharath* dating 5000 BC contains references to milk products like curd and butter.

It is presumed that man first encountered problems of spoilage and food poisoning early in the period with the advent of prepared foods. The problem of disease transmission by food and faster spoilage due to improper storage both made their appearance.

The first man to suggest the role of microorganism, in spoiling food was *A. Kiremer*. In 1658, he examined decaying bodies, meat, milk or other solutions and saw what he referred to as "worms" invisible to the naked eye. Subsequently, *L. Pasteur* (1837) was the first man to appreciate and understand the presence and role of microorganisms in food. In 1860, he employed heat to destroy undesirable organisms present in wine and beer.

So then, starting from 150 years ago till date, food microbiology, as a discipline, has evolved to accommodate various modern developments. We learnt that microorganisms can cause food spoilage and disease, though not all microorganisms are harmful. Some organisms play a beneficial role in nutrition and well being of humans. This aspect has been studied and great advancements have been made in this area. Some of the recent developments in food microbiology are discussed next:

a) *Probiotics:* The word 'Probiotic' is a Greek word and it means "for life". It refers to *microorganisms and their culture products, which contribute to the intestinal microbial balance, thus benefiting the host by protecting against disease or improvising its nutrition*. It is well known that probiotics, like lactobacillus, assist in the digestion of lactose, inactivate toxins, bind cancer causing chemicals, modulate the gut flora and reduce cholesterol absorption in the gut. We will read about probiotics in greater details in the Advance Nutrition Course in Unit 11.

b) *Biotechnology:* You must have heard the word 'biotechnology'. In today's world, it is one of the most extensively used branches of science to develop/ generate better quality foods in the market. Biotechnology is *a series of enabling technologies that involve the manipulation of living organisms or their sub-cellular compounds to make or modify products to improve plants or animals or to develop microorganisms for specific uses*. If these specific uses are meant to enhance the production, processing and distribution of safe, nutrition foods, then it is *"food biotechnology"*. Microorganisms including bacteria and moulds have been used for the production of fermented meat, vegetable products as well as wine, beer etc. and for producing food additives like flavour enhancers, stabilizers, colours and preservatives. However, with the advert of newer genetic engineering techniques developed in the last 30 years, tremendous developments have taken place in food biotechnology. Genetically engineered crops, processing and ingredients are gaining a regular approval and are entering the markets. Let us learn more about this new, interesting branch of science geared towards developing better quality of food in the next section.

1.4 ROLE OF MICROBIOLOGY IN BIOTECHNOLOGY

The word biotechnology is derived from the word *"bio"* meaning 'life or living systems', while the word "*technology*" is defined as 'scientific methods for achieving a practical purpose'. *Biotechnology, hence, is the use of biological processes to make or change a product.* Biotechnology is not new to the food sector, since human beings have been exploiting microorganisms for the production, processing and preservation of foods for centuries. Biotechnology is also used to genetically modify plants or animals and control particular attributes. How is this done? Let us look at some of the uses of biotechnology through genetically modifying foods and improving the nutritional status of the population.

Genetically Modified Foods

Modern biotechnology techniques are now used by the scientists to be able to identify individual genes that control particular characteristics. The selected gene can be transferred to another plant or animal to bring about a desired change. We have talked about 'genes' here. What are genes? Genes are composed of specific lengths of deoxyribonucleic acid (DNA) strands intertwined in a spiral called as the double helix as shown in Figure 1.1. You may recall reading about DNA in the Nutritional Biochemistry Course, Unit 2, as well. It is this DNA which gives the individual characteristics to all plants and animals. For e.g. the colour of a flower's petals, fair or dark skin complexion or the brown or blue coloured eyes.

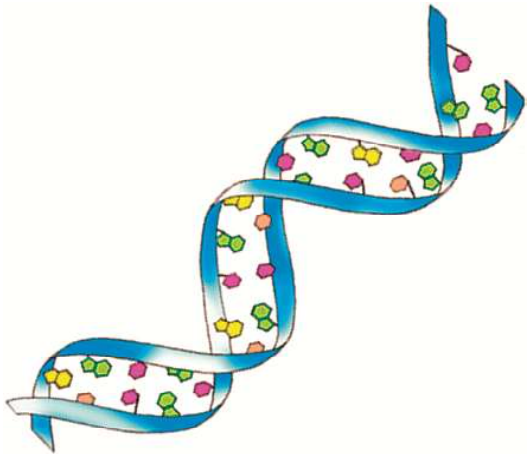

Figure 1.1: Double helical structure of DNA

The use of biotechnology and understanding the nature of DNA has led to what we call as *'genetic modification'. It is a technique of changing by inactivating, deleting or inserting genes to produce a desired characteristic*. In this technique, selected individual genes are transferred from one organism (microbes, plant or animal) to another organism. When genes are transferred from one species to another, transgenic organisms are produced. Foods produced by genetically modified technique are called *Genetically Modified* or *GM Foods*. The term *'Recombinant technology'* or '*Biotechnology'* is often used to describe genetic modification process.

What is the genetic modification process? Let us next briefly review the process. Initially, the gene that carries the desirable characteristic is identified. Then a gene from a second strain carrying the desired trait is inserted, which produces a genetically modified variety which is identical to the original variety with the improved desirable characteristics.

The first GM plants were created in 1983. Since then a variety of crop plants such as maize, soybean, rice, rapeseed (mustard), tomato, cotton, potato etc have been modified by this technique. What are the benefits of genetic modification? Among the many benefits of genetic modification, reduction in the use of pesticides or herbicides, higher yields, better quality food, foods with greater shelf life, nutritional improvement and enhancement in processing qualities are some of the important benefits of genetic modification. Let us understand this concept better by looking at the benefits of genetically modifying a few of the food items:

a) *Tomatoes:* It was discovered in the Nottingham University in the UK that it is possible to slow down the softening process of tomatoes by genetically modifying the tomato plant. This helped to increase the shelf-life of tomato, keeping it fit to eat for longer and reducing waste during processing.

b) *Maize:* The European corn was made pest-resistant by inserting a gene from the naturally occurring soil bacterium *Bacillus thuringiensis*. The gene produces a protein that acts as an insecticide, but is harmless to other creatures.

c) *Golden rice:* The natural varieties of rice do not provide vitamin A. Vitamin A deficiency, as you may already know, could lead to blindness, decreased immunity to diseases and deaths of more than a million children. So, the scientists in Switzerland genetically enhanced rice to be rich in β-carotene (a precursor of vitamin A, to be converted to vitamin A in the body) by re-engineering the genes that imparts yellow colour to daffodils. Interesting isn't it!

d) *Vaccines:* In US, foods such as potatoes, tomatoes and bananas that can carry vaccine for the infectious liver disease – Hepatitis B, have been successfully produced on a small scale. Feasibility studies are being conducted to investigate whether these modified crops would help to deliver the vaccines to people living in developing countries. If the positive outcomes are indicated in these studies, it would help to save lives of many millions.

In India, so far 3 hybrids of *cotton* containing Bt gene produced by Mahyco/Monsanto has been approved for commercialization by the Genetic Engineering Approval Committee (GEAC) in 2002. One variety of cotton, again containing Bt gene produced by *rasi seed* was allowed seed production for one hybrid. Other GM crops undergoing field trials include:

- Mustard containing barnase-bar star gene, produced by the company Proagro and another variety produced by Jawahar Lal Nehru University, Delhi.
- Rice and brinjal with Bt gene and tomato by the Indian Agricultural Research Institute, New Delhi.

- Potato containing lysine protein gene from amaranth plant by Jawahar Lal Nehru University, New Delhi.

Besides the benefits, apprehensions about the use of genetically modified foods have been expressed and you will study about them in the next Unit. In fact, because of these apprehensions, the Government of various countries have introduced legislations to cover the development, release, cultivation, sale, import etc. of these foods. We will get to know more on this topic subsequently.

So far we have looked at the benefits of genetically modifying a few of the food items. We saw how corn was made pest-resistant by inserting a gene from the naturally occurring soil bacterium. Likewise, microorganisms have other beneficial roles as well. Microorganisms i.e. bacteria, yeasts and moulds have been used since the beginning of the recorded history for the production of fermented dairy, cereal, meat and vegetable products, as well as, for fermenting the beverages such as wine and beer. Many ingredients used in foods as vitamins, stabilizers, flavour and flavour enhancers, colours and preservatives are produced by microbes.

Next, we shall briefly focus on a variety of fermentation food preparations, method of preparation and microorganisms involved in this process. This information will help you understand the role of microorganisms in food fermentation and in the food industry. But first, let us take a break and recapitulate what we have learnt so far.

Check Your Progress Exercise 1

1) State whether the following statements are true or false. Correct the false statement.

   a) All microbes are harmful, since they spoil foods and cause food-borne diseases.

   b) Man was primarily carnivorous during the food-gathering period.

   c) A. Kiremer was the first one to discover microorganisms in food.

2) What is food microbiology? What areas does it cover?

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3) Define the following terms:

   a) Probiotics

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   b) Biotechnology

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   c) Genetic modification

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1.5 ROLE OF MICROORGANISMS IN FERMENTED FOODS

Fermentation is one of the oldest forms of food preservation technologies in the world. Indigenous fermented foods such as bread, cheese and wine have been prepared and consumed for thousands of years and are strongly linked to culture and tradition, especially in the rural households and village communities.

The development of fermentation technologies is lost in the mists of history. Anthropologists have suggested that it was the production of alcohol that motivated primitive people to settle down and become agriculturists. Some even think that the consumption of fermented foods is pre-human. The first fermented foods consumed probably were fermented fruits. Hunter-gatherers would have consumed fresh fruits but at times of scarcity would have eaten rotten and fermented fruits. Repeated consumption would have led to the development of the taste for fermented fruits. There is a reliable information that fermented drinks were being produced over 7,000 years ago in Babylon (now Iraq), 5,000 years ago in Egypt, 4,000 years ago in Mexico and 3,500 years ago in Sudan.

Bread-making probably originated in Egypt over 3,500 years ago. Several triangular loaves of bread have been found in ancient tombs. Fermentation of milk started in many places with an evidence of fermented products in use in Babylon over 5,000 years ago. There is also evidence of fermented meat products being produced for King *Nebuchadnezer* of Babylon. China is thought to be the birth-place of fermented vegetables and the use of *Aspergillus* and *Rhizopus* moulds to make food. The book called "*Shu-Ching*" written in the *Chou dynasty* in China (1121-256 BC) refers to the use of "*chu*"- a fermented grain product.

Having looked at the history of fermentation, let us review and see what is fermentation? Fermentation is the *slow decomposition process of organic substances induced by microorganisms, or by complex nitrogenous substances (enzymes) of plant or animal origin*. It can be described as a biochemical change, which is brought about by the anaerobic or partially anaerobic oxidation of carbohydrates by either microorganisms or enzymes.

You know that microorganisms are naturally found in foods, since there is no environment where some type of microbes cannot live. These microbes either living or dead and their cellular byproducts all have specific uses in some foods. These include such products as fermented food products. Fermented foods use microbes to convert the original food into a fermented product by the use of specific microbes. These microorganisms use the original product for growth and reproduction, and in the process, they excrete byproducts into the environment surrounding themselves and the food. *These byproducts plus the part of the original product that is not consumed is the fermented food*. Fermented foods include fermented dairy, meat, fish, cereals, fruits, vegetable products etc. They may be fermented separately or in conjunction with each other to produce the desirable end product.

From our discussion, so far, it is evident that, fermentation involves the introduction of the desirable microbes into the original product. Some of the common microbes used in food fermentation are highlighted herewith.

- *Lactococcus lactis* — used in dairy fermentation.
- *Steptococcus thermophilus* — used in dairy fermentation.
- *Leuconostoc* sp. — used in wine making, dairy fermentation.
- *Pediococcus* sp. — meat fermentation, vegetable fermentation, ripening of some cheeses.

- *Lactobacillus* sp. — meat fermentation, vegetable fermentation, dairy fermentation, sourdough bread.
- *Bifidobacterium* sp. — added to dairy products to promote intestinal health.
- *Propionibacterium* sp. — Swiss cheese.
- Yeasts — bread, beer, wine, liquors.
- Moulds — ripening cheeses, soy sauce.
- *Lactobacillus delbruekii*, subspecies *bulgaricus* and *streptococcus thermophilus* — making of yogurt.

Although fermentation of foods has been in use for thousands of years, it is likely that the microbial and enzymatic processes responsible for the transformations were largely unknown. It is only recently that there has been a development in the understanding of these processes and their adaptation for commercialization. Let us now get to know about a few of the fermented food preparation used commercially. We shall begin our study on fermentation products with the baked preparations.

1.5.1 Fermented Baked Preparations

In baked products such as bread and bun, the yeast *Saccharomyces cerevisiae* which is popularly known as "baker's yeast", helps by raising the dough giving it the texture and also adding flavours. The different ingredients added gives distinctly different tastes to each of the products. The *naan,* which is popular in India, is made from maida (refined wheat flour) to which salt, yeast or curd is added. It is kneaded vigorously for 15 minutes adding vegetable oil for softening. It is allowed to ferment for 30 minutes – 1 hour. It is then baked rapidly for 5 to 10 minutes. Intense heat causes centre of the dough to expand rapidly and create a central pouch. *Saccharomyces cerevisiae* is mainly responsible for leavening by carbon dioxide production.

1.5.2 Fermented Vegetable Foods

We all consume vegetables either in raw or cooked form as salad preparations, soup, dry vegetables and curry or as stuffing in a variety of snacks. But, do you know, we can even consume these by making fermented products. Can you think of any such food item? Yes, of course, it is pickles which all of us relish sometimes or the other. Let us learn about these fermented vegetable products and see which microorganisms are involved in their preparation.

i) *Sauerkraut*

Sauerkraut is a fermented fresh cabbage product. It is popular in USA and Europe. The main organism which is involved in the fermentation of this pickle is lactic acid bacteria, *Leuconostoc mesenteroides* followed by *Lactobacillus plantarum.*

ii) *Cucumber pickle*

Cucumber pickle is a fermentation product of fresh cucumbers. Several lactic acid bacteria are involved in the preparation of this pickle. *Lactobacillus plantarum* is the most important organism required for the fermentation of cucumber pickle.

Next, we shall look at the commonly consumed fermented soya products.

1.5.3 Fermented Soyabean Products

Do you enjoy Chinese food? If you have tried making it at home, you would have realized that soya sauce is a basic ingredient in Chinese cooking. In fact two of the most commonly consumed soya products are tempeh and soya sauce. We will briefly focus on the preparation of these products.

i) *Tempeh*

Tempeh is a highly popular soyabean preparation in Indonesia. The chief organism in this preparation is the species belonging to mould *Rhizopus oligosporus.* The soyabean mash is wrapped in a banana leaf or a plastic box and the mash is inoculated with tempeh fungus by the addition of a portion of previous batch and allowed to ferment for about 24-48 hours at a temperature 30-40°C, until there is a good mycelium growth. This is then sliced and prepared as per the taste, such as roasting or frying. The taste of the tempeh is considered to be bland, but it is highly nutritious.

ii) *Soya sauce*

Soya sauce is a very popular preparation of Japan which has received wide acceptance in many countries. This is prepared by inoculating an *Aspergillus* species, mostly *Aspergillus oryzae* in a mixture of soaked and steamed soya bean with roasted wheat in the ratio of 2:1. The mixture is allowed to be incubated for 3 to 5 days. Subsequently, it is subjected to various processing with *Lactobacillus* bacteria and the yeast *Saccharomyces rouxii.* After 3 months, the final product is filtered, pasteurized and bottled for use.

We will learn more about the fermented soya products in the Principles of Food Science Course, Unit 11.

1.5.4 Fermented Dairy Products

A large number of fermented dairy products are available in our markets. These are prepared at our homes as well. How are they made and what are the microorganisms involved in their preparation?

The fermented dairy products assume greater importance in the human diets in India, as invariably, the diets mostly include milk byproducts especially the cheese, butter, yogurt, *dahi* etc. A variety of bacterial yeasts and moulds are involved with the fermentation of dairy products. We will begin our discussion with cheese.

i) *Cheese*

There are several varieties of cheese manufactured all over the world. All types of cheese are the byproducts of lactic fermentation of milk. There are several varieties of cheese which are classified as hard, semi-hard and soft cheese. These are prepared with culturing of the milk either with bacterial or mould species. Among the several varieties, the popular ones are *cheddar cheese* and *swiss cheese* which are known as 'hard cheese' whereas *roquefort* cheese (blue cheese) is a semi-soft cheese and the soft variety is the *camembert cheese.* The cheddar cheese originated from England and was adopted in USA, the colour of which ranges from white to orange-yellow, depending upon the colour added. The curing is done with the help of *Streptococcus* and *Lactobacillus.* The cheese is without the gas holes (the eyes), which characterizes the Swiss cheese. The Swiss cheese is cultured with the help of a mixed culture, *L. bulgaricus*, *Streptococcus thermophilus* and *Propionibacterium shermanii* which imparts the characteristic eye formation. The roquefort cheese is prepared by the inoculation of curd with *Penicillium roqueforti* and the camembert cheese is produced by the fermentation with *Penicillium camemberti.*

ii) *Dahi* and *Yogurt*

Dahi or curd is the Indian variety, a version of yogurt and is widely used in the daily menu of an average Indian. Several organisms are involved in the preparation of *dahi* which contains lactic acid. Yogurt is the preparation with the action of two organisms, *Streptococcus thermophilus* and *Lactobacilius bulgaricus.* The ideal ratio of these two organisms is 1:1 for best results. In common usage, *dahi*

refers to 'the domestically prepared fermented milk using a starter of the previous day' while yogurt refers to the 'industrially produced fermented milk using a particular bacteria as the starter.'

iii) *Butter*

The microorganisms which are involved in the preparation of butter are *Streptococcus lactis* and *Streptococcus cremoris* which convert the lactose in the milk to lactic acid. Then the organisms like *Streptococcus diacetilactis, Leuconostoc dextranicum* and *Leuconostoc citrovorum* are involved in imparting the aromatic flavours to the butter. The preparation of commercial butter involves aging of cream overnight at 5-10°C and culturing for 15-16 hours with bacteria.

Check Your Progress Exercise 2

1) Fill in the blanks:

a) *Saccharomyces cerevisiae*, popularly known as ..... i s used in the fermentation of dough by raising the dough and giving it ..... and ..... .

b) A few fermented dairy products are ....., ...,.....and ..... .

c) *Dahi* is ..... prepared while yogurt is ..... prepared.

d) Roquefort cheese is prepared by inoculation with ..... bacteria and camembert cheese with ..... bacteria.

e) Organisms ....., ... and .....are involved in imparting aromatic flavours to the butter.

2) Match the following:

	A		B
a)	Sauerkraut	i)	*Rhizopus oligosporus*
b)	Soya sauce	ii)	Soyabean and roasted wheat product
c)	Tempeh	iii)	Fermented fresh cabbage
d)	Yoghurt	iv)	*S.thermophilus* and *L.bulgaricus*
e)	Butter	v)	*S.lactis* and *S.cremoris*

1.5.5 Other Fermented Food Preparations

In this section, we shall discuss food preparations that involve a combination of raw food products, which on fermentation, give appetizing and nutritious preparations. Can you list a few of such fermented food products which are formed by combination of raw food materials. Yes, these include *idli, dosa, vada, dhokla* etc. Let us get to know about these fermented products, starting with idli – a salty sponge cake, prepared from cereal and pulse.

i) *Idli*

Idli is prepared from rice and black gram dal. They are cleaned, washed and ground in equal proportions and left overnight for fermentation. The microorganisms involved in this preparation are *Leuconostoc mesenteroides,* which grows first in the batter followed by *Streptococcus faecalis* and *Pediococcus cerevisiae.* Once the batter rises sufficiently, it is steam-cooked and served.

ii) *Vada*

Vada is prepared by soaking black gram *dal* in water for sometime, and then ground to paste. It is then left to ferment at 23-32°C for 3-12 hours, usually overnight. It is then made into balls and deep fried in vegetable oil. The Black gram paste is fermented by lactic acid bacteria, with heterofermentative *Leuconostoc mesenteroides* being the major organism. The organism produces carbon dioxide which aerates the product.

iii) *Dosa*

Dosa is a light, shallow-fried, thin pan-cake. It is prepared from fermenting rice and black gram overnight. The aeration of batter is caused by lactic acid bacterial fermentation by *Streptococcus faecalis* with carbon dioxide production by *Leuconostoc mesenteroides.*

iv) *Bhatura*

Bhatura is prepared from refined wheat flour, salt and sometimes with pepper, cumin or turmeric and made into dough with water. Curd is used as a starter and the dough is fermented at 20-30°C overnight. It is rolled and flattened into discs and deep fried in vegetable oil. The major organisms involved in fermentation are *Streptococcus* and *Lactobacillus* species, introduced by curd.

v) *Dhokla*

Dhokla is similar to idli, where rice and Bengal gram dal are used in making it yellow-coloured. *Leuconostoc mesenteroids* and *Streptococcus faecalis* are the bacteria involved in the fermentation. The batter is poured into large sheets, then steamed and cut into pieces and seasoned.

Apart from helping man in preparing his foods, the microorganisms have contributed to a great extent in perpetuating man's desire for alcoholic beverages, which are the products of plant fermentation. Now let us see how these alcoholic products are prepared.

1.5.6 Economically Important Fermentation Products

Alcoholic drinks fall into two broad categories: wines and beers. Wines are made from the juice of fruits and beers from cereal grains. Primitive wines and beers have been produced, with the aid of yeasts, for thousands of years, although it was not until about four hundred years ago that microorganisms associated with the fermentation were observed and identified. It was not until the 1850's that *Louis Pasteur* demonstrated unequivocally the involvement of yeasts in the production of wines and beers. Since then, the knowledge of yeasts and the conditions necessary for fermentation of wine and beer has increased to the point where pure culture fermentations are now used to ensure consistent product quality. Originally, alcoholic fermentations would have been the spontaneous events that resulted from the activity of microorganisms naturally present. These non-scientific methods are still used today for the home preparation of many of the world's traditional beers and wines. Let us learn about these products.

i) *Beer*

Beer is an alcoholic product, produced by brewing. It is a principal malt beverage where the fermentation of carbohydrates to alcohol takes place. Barley is used in the preparation of beer. Yeasts play a major role in the preparation of beer. *Lager beer* is produced by *Saccharomyces uvarum,* which settles at the bottom of the fermenting vat and is known as the 'bottom yeast'.

ii) *Ale*

Ale is produced by the strains of *S. cerevisiae,* which is collected at the top and is called as the 'top yeast'.

iii) *Rice beer*

Rice beer is a low-alcohol beverage made from rice, which is more popular in North Eastern India. The rice is milled, water is added and cooked. It is cooled and then the starter is added and fermented for 18 hours at 20-28°C. Rice beer is then decanted from the solid residue, which often is used as a breakfast cereal.

The starter introduces a mixture of moulds and yeasts. The rice starch is broken down to sugars by amylase enzymes of moulds of *Rhizopus, Mucor* and *Aspergillus* species. The yeasts of *Endomycopsis* and *Hansenula* then convert the sugars to ethanol and carbon dioxide. The ragi starter contains moulds, yeasts and lactic acid bacteria. It is produced by fermenting rice or other starchy powders. This is used as a starter for several fermented foods.

iv) *Wine*

Wine is one of the oldest and well-known fermented alcoholic beverages produced by the fermentation of good and sound grapes which is further processed, known as *aging*, before consumption. Although there are other fruit wines, they are not as popular as grape wine. The grape fruits are crushed to give a "must". The fermentation of "must" is initiated by yeasts *Kloeckera apiculatus* and *Metschnikowia pulcherrima* together with the yeasts of *Torulopsis, Candida* etc. The main fermentation is by the yeasts, *Saccharomyces cerevisiae* and *S. uvarum* or *S. bayanus* which converts sugars to ethanol and carbon dioxide.

v) *Champagne*

Champagne is a product of secondary fermentation. Fresh must, yeast and sugar are added to the wine selected for champagne preparation.

vi) *Distilled liquor products*

The distilled alcoholic products of interest are rum, brandy and whisky. These products are manufactured from the distillation of yeast fermentations of sugar cane juice, molasses, grains and grain products.

a) *Rum*

Rum is an alcoholic distillate of fermented sugarcane juice or molasses.

b) *Brandy*

An alcoholic beverage produced after distillation from fruit wines/grape wine. The brandy is produced by distilling grapes or other fruit wines.

c) *Whisky*

Whisky is produced by distilling the fermented mash of wheat, barley, malt and other grains with *Saccharomyces cerevisiae*.

After learning about the economically important fermented products, we move on to studying the other uses of microbes in the industry.

1.5.7 Other Uses of Microbes in Industry

Here in this section, we shall study about the different microbes used in the food industry to manufacture the products of commercial value namely vinegar citric acid, antibiotics etc.

i) *Vinegar*

If the alcohol produced by the fermentation process is further oxidized to acetic acid by the acetic acid-producing bacteria, the product is vinegar. Vinegar is made by different processes. It can be made from fruit juices, starchy vegetables, malted cereals, sugars and alcohol. Vinegar is widely used as a preservative in food preparation.

ii) *Enzymes*

Enzymes are the *protein substances produced by the living cells which catalyzes a biochemical reaction.* They accelerate a specific chemical reaction.

Enzymes, which are known as *biocatalysts*, are very useful in the manufacturing of several products of commercial value. The enzymes are widely used for the manufacture of alcoholic beverages etc. The enzyme α-amylase used in bread-making, is commercially prepared from *Aspergillus oryzae*. The amyloglucosidase, used as a substitute for malt in the production of beer and spirits, is commercially prepared from *Aspergillus niger*. Pectolytic enzymes are produced from a number of fungi for use in fruit processing. Cellulase enzyme used for removing cellulose cloud and clarifying juices is produced from the mould *Trichoderma viride* and proteases used in cheese-making from *Aspergillus niger*.

iii) *Amino acids and Vitamins*

The importance of amino acids and vitamins in human health is well-recognized. Several microbes have been used for their productions which are biologically suitable. Yeast is one of the best sources of the vitamin B complex. A number of preparations of high potency vitamin B-complex made from dried yeast and yeast extracts are available in the market. Riboflavin, one of the B-group vitamins, is produced from the yeast *Eremothecium ashbyii.* Ergosterol, the precursor of vitamin D is synthesized by a number of moulds and yeasts. β-carotene is produced commercially by fermentation using the fungus *Rhodotorula.*

iv) *Citric acid*

Citric acid is one of the widely used chemical which finds applications in several divergent industries such as pharmaceuticals, flavouring extracts in food preparations, dyeing etc. Citric acid is produced by the mould *Aspergillus niger,* which converts sugars to citric acid where molasses is generally the raw material.

v) *Antibiotics*

Apart from giving man several food products, certain microorganisms, especially moulds have given products which are life-saving. The antibiotics are *the products of living organisms, which in small proportions could be acting as inhibitory agent for the growth of other microbes*. The discovery of Penicillin produced by *Penicillium notatum* by *Sir Alexander Fleming* in 1929 has triggered off the manufacturing of modern antibiotics. There are over 600 antibiotics derived from bacteria and over 150 from fungi. The genus *Streptomyces* has yielded a wide range of useful antibiotics such as streptomycin, aureomycin, chloromycetin and terramycin.

From our discussion above, it is evident that there is a tremendous scope and potential for the use of microorganisms towards meeting the growing world demand for food, through an efficient utilization of available natural food and feed stocks and the transformation of waste materials.

Check Your Progress Exercise 3

1) Fill in the blanks:

   a) Bottom yeast produces ....., while top yeast produces .....

b) A low-alcohol beverage is ..... .

c) Ragi starter is produced by ..... of rice or other starchy powders

d) The additives in champagne preparation are ..... , ...and ..... .

e) Whisky is produced by the distillation of fermented mash of wheat malt and other grains with ..... .

2) Name a few fermented products which involve the use of *Leuconostoc mesentroides* as one of the microorganisms that aid in fermentation.

..... , ... , ...

3) How is vinegar prepared?

.....

.....

.....

4) What are antibiotics? Name a few antibiotics.

.....

.....

.....

1.6 LET US SUM UP

In this unit we started our study of food microbiology by first understanding the concept and historical development of the discipline. The modern development in the field of microbiology with respect to biotechnology and probiotics was highlighted.

Further, we studied about various fermented preparations belonging to different food groups such as vegetables, pulses, cereals, milk etc. The discussion involved a brief description of the method of preparation and the organism used for fermentation. Further, preparation of commonly consumed beverages differing in the alcoholic contents was described. Finally, a few other uses of microbes in food industry were discussed. These included vinegar and citric acid, preparations as antibiotics, and in amino acids and vitamin synthesis.

1.7 GLOSSARY

Antibiotics : products of living organisms, which in small proportions could act as inhibitory agents for growth of other microbes.

Baker's yeast : *Saccharomyces cerevisiae*, which helps in raising the dough giving it the texture and flavours.

Deoxyribonucleic acid (DNA) : a large molecule that contains genetic coding information within each cell.

Enzymes : protein substances produced by living cells which catalyze a biochemical reaction.

Microorganism : a microscopic organism such as a bacteria, virus, alga, fungus, protozoan etc.

Probiotics : microorganisms and their culture products which contribute to the intestinal microbial balance.

1.7 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

1) a) False, Some microbes are useful for example microbes present in the intestinal flora which protect against disease

   b) True

   c) True

2) Food microbiology is a branch of microbiology concerned with the relationship between microorganisms and food. It covers food borne diseases, food hygiene, food spoilage, fermented foods and beverages, use of microorganisms to produce food ingredients, microbiological aspects of quality control, microbiological analysis of food and food legislation.

3) a) Probiotics refers to microorganisms and their culture products which contribute to the intestinal microbial balance, thus benefitting the host by protection against disease or improvising the nutrition.

   b) Biotechnology is a series of enabling technologies that involve the manipulation of living organisms or their sub-cellular compounds to make or modify products to improve plants or animals or to develop microorganisms for specific uses.

   c) Genetic modification is a technique for copying individual genes and transferring them to another living organism in order to incorporate or delete specific characteristics.

Check Your Progress Exercise 2

1) a) baker's yeast; texture, flavours.

   b) cheese, *dahi*, yogurt and butter.

   c) domestically, industrially .

   d) *Penicillium roqueforti, Penicillium camemberti.*

   e) *Streptococcus diacetilactis, Leuconostoc dextranicum, Leuconostoc citrovorum.*

2) a) - iii)

   b) - ii)

   c) - i)

   d) - v)

   e) - iv)

Check Your Progress Exercise 3

1) a) larger beer, ale b) rice beer

c) fermentation d) must, yeast, sugar

e) *S. cerevisiae*

2) *Idli, Vada, Dosa, Dhokla*

3) Vinegar is produced by the oxidations of alcohol to acetic acid by acetic-acid producing bacteria. It can be made from fruit juices, starchy vegetables, malted cereals, sugars and alcohol.

4) Antibiotics are the products of living organisms which in small proportions could act as inhibitory agent for growth of other microbes e.g. streptomycin, aureomycin, chloromycetin and terramycin.