

UNIT 4 FOOD SPOILAGE

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4.1 INTRODUCTION

In the last unit, we learnt about the various organisms causing food spoilage and the factors influencing their growth. In this unit, we will try to understand what is meant by food spoilage, what factors are responsible for food spoilage, changes that are brought about by spoilage and how it differs from food to food.

Objectives

After studying this unit, you will be able to:

- explain what is spoilage and the factors that lead to spoilage,
- describe various chemical changes that occur in foods due to spoilage, and
- discuss, in detail, about spoilage of different foods.

4.2 FACTORS RESPONSIBLE FOR FOOD SPOILAGE

When do we consider a food to be spoiled? A food is considered to be spoiled when it becomes unacceptable for consumption as perceived by the individual, based on the organoleptic characteristics like smell, taste etc. The normal process of spoilage of foods by microorganisms has caused a greater concern than any other form. The microbial deterioration of a food is usually manifested by a change in the appearance, texture, odour, flavour or by slime formation. The appearance includes colour changes, formation of packets of gas or swelling and microbial growth, especially of that of moulds.

Microorganisms can cause a change in the character of food, which may be classified as positive or negative. Products of "positive" microbial transformations include cheese, yoghurt and wine, which can be seen as increasing the *nutritional value or keeping quality* of products with a short shelf life. "Negative" aspects of microbial growth include food deterioration and spoilage by *decay* and *food poisoning*, mainly caused by different and less widespread bacteria. As they grow, microorganisms release their own enzymes into the liquid surrounding them and absorb the products of

external digestion. This is the main basis of microbial food spoilage, which lowers its nutritional value. Bacteria and moulds may also produce waste products which act as poisons or toxins, thus causing the renowned ill-effects.

Spoilage, as you would realize, is quite a natural phenomenon. All foods undergo varying degrees of deterioration or spoilage that may be physical, chemical or biological. Spoilage results in losses in the organoleptic desirability, nutritional value, safety and aesthetic appeal. What are the factors which lead to food spoilage? Can we avoid them or slow them to a certain extent? These are the issues with which we are going to deal with. Let us begin with the factors that make a food unacceptable. These include:

- a) Growth and activities of microorganisms, principally bacteria, yeasts and moulds
- b) Activities of food enzymes, for instance, enzymatic browning
- c) Infestation by insects, parasites and rodents
- d) Chemical changes in a food, for instance, chemical oxidation of fats causing rancidity and non-enzymatic browning reaction.
- e) Physical changes, or the damages caused by freezing or drying etc.
- f) Presence of foreign bodies, and
- g) Physical abuse i.e. contamination with chemical agents.

You have now got a fairly good idea of the factors leading to spoilage. In the last unit we studied about the factors influencing the growth of microorganisms. All these factors too are important in the context of food spoilage.

But what is the criterion for classifying a food as unacceptable? How do we decide whether a food is spoiled or not? Well, you would notice that the concept of spoiled food is quite subjective and is closely associated with an individual's taste preference, ethnic origin and family background. The extent of chemical and bacteriological changes is associated with the decision about a food's acceptability. A food which might be unacceptable for some due to the above mentioned changes could be a delicacy for others. For instance, bananas that have become brown and sugary are considered overripe and therefore spoiled to many consumers but are perfectly acceptable to some.

You would have noticed that some food items deteriorate or spoil easily within a day or two as compared to others. In fact, based on the ease or quickness with which a food item gets spoiled, all foods can be categorized into the following three groups:

- *Non-perishable foods:* As the name suggests, these are the foods which do not spoil unless handled and stored carelessly and that can be stored at least for several months. Examples of non-perishable foods include cereals, pulses, sugar etc.
- *Semi-perishable foods:* Like the non-perishable foods, semi-perishable foods can survive without any perceptible sign of spoilage for a couple of weeks or for a few months. Here, of course, temperature and humidity of the environment makes a big difference. Examples in this category include cereal and pulse products like wheat flour, refined wheat flour, semolina, vermicelli, broken wheat, bengal gram flour (besan), potatoes, garlic, some fruits like apples, citrus fruits, fats and oils.
- *Perishable foods:* These are the foods which spoil easily within a day or two unless special methods are used to prevent such spoilage. Yes, all animal foods such as milk and milk products, meat and meat products, fish, poultry and eggs are included in this category. Most fruits and vegetables too fall in this category.

The classification presented above is practical, however, it is important to understand that there is nothing which would not spoil unless special care is taken. Even sugar and salt can absorb water and become soggy during conditions of high humidity like in rainy season. In a hot tropical country, like India, with the diverse environmental conditions – extreme temperatures and varying levels of humidity – there can be no absolute classification of food. The classification presented above is just a basic guide.

We have talked about food spoilage in this section. Are you aware of the changes taking place in food items, which render them as spoiled? The next section presents a detailed discussion on the chemical changes occurring during food spoilage and highlights the changes in specific foods and the organisms causing the spoilage. You will find this information very useful, not only from academic point of view, but also in terms of practical application in the day to day life. Read it carefully.

4.3 CHEMICAL CHANGES DUE TO SPOILAGE

A food item may have apparently looked safe and wholesome for you to eat, but the rumbling and grumbling in your stomach at night may have made you think, was the food really safe? Yes, very often the spoilage is not apparent on the surface of the food. It is the changes undergoing inside the food, not apparent to the naked eye, which might cause ill health.

The chemical changes that occur in a food due to spoilage depend primarily upon the composition of food. The changes vary depending upon the source of the food i.e. plant foods are primarily carbohydrate-rich, while animal foods are rich in proteins and fats, hence the changes will differ. Let us see what changes takes place with respect to the nutrients present in the food when bacteria acts upon them.

- *Degradation of Carbohydrates*

The carbohydrates that are naturally present in foods, you may already know, can be divided into monosaccharides, disaccharides, oligosaccharides and polysaccharides. Most commonly occurring carbohydrates are disaccharides and polysaccharides. Bacteria breakdown these carbohydrates to monosaccharides. This results in softening or liquefaction of the food.

- *Degradation of Fats*

Fats are the esters of glycerol and fatty acids and are called as 'glycerides'. Fats are susceptible to hydrolysis, oxidation and other chemical changes that produce both desirable and undesirable flavour changes in foods. The pure fat cannot be attacked by microorganisms. They need an aqueous phase to grow in foods like butter, creams and margarine. Microorganisms degrade fats into glycerol, free fatty acids, ketones and alcohols.

- *Degradation of Proteins*

Proteins are composed of amino acids combined by peptide linkages. The native proteins are resistant to attack by microorganisms. The other compounds like dipeptides and free amino acids in fresh meat, fish and poultry are readily used by microorganisms. Spoilage of the protein-rich foods may be evident before any significant amount of protein is degraded. The degradation of amino acids is of primary importance in the spoilage of protein foods. The products that are formed depend upon the following factors: (i) the type of microorganism (ii) amino acid composition of the material (iii) available oxygen, and (iv) type of inhibitors present. The anaerobic degradation of amino acids by microorganisms produces foul smell which is called as '*putrefaction*'. Aerobic degradation is called *decay*.

So far we have looked at the changes, in general context. We know each food varies in its nutrient content and hence the changes will vary. Milk, for example, is composed of carbohydrates, proteins and fat as compared to *chapatti*, which contains predominantly carbohydrates. Not only the nature of spoilage will differ but also the organisms causing the spoilage will vary. The next section focuses on spoilage of different foods, highlighting the organisms causing the spoilage and the factors influencing their growth in these foods.

Check Your Progress Exercise 1

- 1) Fill in the blanks:
 - a) The microbial deterioration of a food is usually manifested as a change in,, and
 - b) Bacteria breakdown complex carbohydrates to which results in of food.
 - c) Microorganisms require phase to grow in fatty foods.
 - d) Fats are degraded into,, and by microorganism.
 - e) Foods that spoil easily are called foods.
- 2) What do you understand by the positive and negative aspects of microbial growth?
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- 3) List a few factors that make a food unacceptable.
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4.4 SPOILAGE OF DIFFERENT FOODS

Earlier in the unit, we did present a general classification of foods based on the perishability. Let us now look at the consequences of spoilage of these foods, starting with a highly perishable food that is, 'meat', which owing to its ideal composition, is susceptible to microbial attack.

4.4.1 Spoilage of Meat

Meat is primarily the muscular tissue which is the edible portion of the carcass of animals. It contains all the essential nutrients in the ready form for microbial growth and also it has a high water content ($a_w = 0.99$), which is ideal, for most of the microorganisms, particularly bacteria.

What are the changes that occur in meat and lead to its spoilage? Well, it is surprising to note that the spoilage of meat depends mostly on the initial contamination of the animal. We had emphasized earlier that plants and animals have a natural microflora. In case of animals, except for the external surface and the gastrointestinal and

respiratory tracts, a healthy animal does not contain any microorganisms. But once the animal is slaughtered, the situation changes, as the body's defense mechanism is withdrawn and the slaughtered meat is subjected to biochemical changes. The enzymes present in the meat act upon the meat protein which makes the nitrogen compounds available for microorganisms. Immediately after the slaughter, the meat becomes stiff and rigid, which is known as *rigor mortis* (stiffening). Actually, the action of enzymes in tenderizing the meat is desired by many and is known as 'ripening'. If this autolysis (action of enzymes) is not stopped, the meat goes on to become sour.

What are the factors which influence the spoilage of meat? Can you list a few? Sure enough, you should be able to enumerate these having learnt about them earlier on. These important factors which lead to the growth of microorganisms in meat are highlighted next:

- **Initial microflora:** The initial microbial load on an animal clearly determines the keeping time under good preservation conditions. As such, the hygienic conditions of an animal are important for the reduction in the proliferation of microorganisms in the stored meat. The general sanitation of the abattoir also helps in reducing the contamination of fresh meat.
- **pH:** After the animal is slaughtered, the pH of the carcass drops from around 7.0 to 5.6, as the glycogen reserve in the muscles is used up slowly and lactic acid is formed. If the condition of the animal at the time of slaughter is abnormal due to excitement, stress etc., the available glycogen is used up rapidly thereby the desired reduction in pH does not occur and the pH remains around 7.0. This helps in the growth of microorganisms and the spoilage of meat results.
- **Oxidation-reduction potential:** You learnt earlier that the presence or absence of oxygen and the O-R potential of the food itself has a bearing on the type of organism which grows on a particular food. In the case of meat, after slaughter, the oxygen stored in the muscle gets reduced bringing down the oxidation reduction potential, while at the same time, it is higher at the surface of the meat. This condition is favourable to aerobic bacteria, yeasts and moulds while the internal conditions still being anaerobic, favours the growth of anaerobic bacteria. Under the anaerobic conditions, both the anaerobes and facultative anaerobes cause putrefaction. Putrefaction, as you know already, refers to *the decomposition of foods due to microbial action*. This is generally due to the growth of *Clostridium* spp. within the tissue, with the release of decomposition products like mercaptans, hydrogen sulphides, ammonia etc. The organism which is predominant in the decomposition of protein under anaerobic conditions is the *Clostridium perfringens*, which incidentally is a food borne disease causing organism. Under the aerobic conditions, apart from bacteria, yeasts and moulds also grow on meat. The growth of a particular microorganism depends on temperature, moisture and other conditions. The organisms principally responsible for the spoilage of meat are bacteria of the genera *Pseudomonas*, *Bacillus* and *Micrococcus*. The other common bacteria include *Corynebacterium*, *Escherichia* and *Aerobacter*.
- **Temperature:** Temperature has a profound impact on the spoilage of meat. The carcass meat held at temperatures above 20°C is subjected to the spoilage of anaerobic bacteria. Once the meat is minced, the aerobic and facultative anaerobic bacteria also grow, with an increase in the availability of oxygen, thereby increasing the oxidation-reduction potential. The spoilage is rapid at this stage.

Normally, the fresh meat is stored in refrigerators at chilling and freezing temperatures to enhance the shelf life. The danger to meat stored under refrigerated conditions is from the psychrotrophs like *Pseudomonas* spp. The *Pseudomonas* which is the predominant microflora, is limited to the surface and up to 3-4 mm underneath the exposed tissue, due to its strong aerobic characteristic. Apart from bacteria, fungi can

also grow on meat. Over an increased period of storage, the meat humidity on the surface layers gets dried and it will be susceptible to fungal attack due to a drop in water activity. Fungus growth is indicated by characteristic colours present on the surface. Table 4.1 gives the generally observed spoilage due to mould growth.

Table 4.1: Spoilage of meat by moulds

Features	Moulds involved
Whiskers	<i>Thamnidium chaetocladioides</i> Telegans, <i>Mucor mucedo</i> , <i>M. insitanicus</i>
White spots	<i>Sporotrichum carnis</i>
Black spots	<i>Cladosporium herbarum</i>
Green patches	<i>Penicillium expansum</i> , <i>P. asperulum</i>

After meat, let us learn about the spoilage of poultry and its products.

4.4.2 Spoilage of Poultry and Poultry Products

Poultry meat is the muscle tissue of chicken, ducks, turkey etc. The reference to poultry meat generally is the 'dressed chicken'. It is similarly considered along with the other meats. The spoilage organisms involved also follow more or less the same pattern. After processing, like evisceration (removal of the parts), the meat is generally stored under chill conditions. Under this storage temperature, the bacterial growth in poultry meat takes place on the surface. Once the spoilage takes place, off-odours are initially noticed and then followed by slime formation. Species belonging to *Pseudomonas* are the primary spoilage organisms in the meat held at 10°C or less. Above 10°C, *Micrococci*, *Alcaligenes* and *Flavobacterium* also grow.

Next, let us look at the spoilage of poultry products, specifically eggs.

Eggs

Most of the freshly laid eggs are sterile, although it may get contaminated through cracks in the shell. Washing also aids in the spoilage of eggs due to increased moisture on the surface of the shell. The bacteria which cause spoilage of eggs include species of *Pseudomonas*, *Micrococcus*, *Bacillus*, *Proteus*, *Alcaligenes*, *Flavobacterium* and *Salmonella*. The most predominant among them is *Pseudomonas*. Moulds found on eggs include *Penicillium*, *Aspergillus*, *Cladosporium*, *Mucor* and *Rhizopus*. But the spoilage is generally caused by bacteria than mould. Once the bacteria invade the inside of an egg, they develop characteristic odours and appearance. The common form of spoilage is known as *rotting*. How do we know whether an egg is rotten? Whether an egg is defective or not, could be identified by subjecting the egg to 'candling', which is a technique which involves rotating the egg in front of the candle light. This helps in identifying the cracks, rots etc. There are different types of rots characteristic to egg spoilage. The types of rots which are frequently encountered include:

- **Black rots:** The black rots are caused by bacterial species of *Proteus*, *Aeromonas* and *Pseudomonas*. The species of *Proteus* usually causes the black rot. The egg under this condition, when broken, gives a muddy dark brown appearance with putrid odour due to hydrogen sulphide.
- **Red rots:** This rot is caused by *Serratia marcescens* and is distinguished by a red colour.
- **Pink rots:** This is caused by the species of *Pseudomonas*.
- **Green rots:** *Pseudomonas fluorescens* is the causative organism of this rot, which fluoresces under the UV light.
- **Colourless rots:** *Acinetobacter*, *Alcaligenes* and *Pseudomonas* are responsible for this rot.

Of all the rots, the important ones are the green, colourless and black rots. Pink rots are not frequently encountered.

Next, spoilage of fish and other sea foods is discussed.

4.4.3 Spoilage of Fish and other Sea Foods

Fish and other marine foods are second only to meat and poultry as a staple animal food around the world. India is one of the important fish producing countries due to its vast sea coast and several inland water sources. Fish is a regular diet in populations residing in the coastal districts of various States in India. The demand for inland fish is greater when compared to marine fish, which is generally exported. Most of the fish is consumed fresh in India, although dried and salted fish is also used widely.

What are the factors and the organisms which influence spoilage of fish and other marine life? Let's find out.

Spoilage of fish

The spoilage of fish depends on several factors which include:

- i) *The type of fish:* Different types of fish are susceptible to spoilage due to shape and size. A fat fish is susceptible to spoilage due to the oxidation of unsaturated fats of their oils, whereas, the thin variety may get spoilt due to the rapid setting of rigor mortis (stiffening).
- ii) *The initial microflora:* The flesh and internal organs of fish are normally sterile at the time of catching but the external skin, gills and the intestine may contain bacteria depending on the environment it has been caught. If they are caught in polluted waters, the microbial load will be higher.
- iii) *The temperature of air and water source:* The type of microorganism on the fish depends greatly on the location. The fish from warm seas are contaminated with the mesophilic strains while the fish caught in cold regions contain psychrotrophs.
- iv) *Handling of the fish after being caught:* The handling process after catching the fish is also important to its spoilage. The fish after catching are held either as whole, beheaded or gutted (the intestines are removed). The spoilage pattern differs for each, the gutted fish keeping longer. The immediate storage pattern also plays a role. Sometimes, the fishes are piled, creating pressure on the lower layers of fish. If ice is used in preserving the fish, it also contributes to the microbial load, as ice is generally manufactured with unpotable water. The cross contamination from earlier catches, the nets used, boats, baskets or other containers used and their sanitary conditions also play a role.
- v) *Chemical changes in fish:* Similar to meat and poultry, the autolytic enzymes do play an active role in the deterioration of fish apart from the microorganisms. As lipids in fish contain high levels of polyunsaturated fatty acids (PUFA), the oxidative rancidity is more pronounced in fish than in the other animal products. In fish, the trimethylamine oxidé (TMAO) is reduced to trimethyl amine (TMA) due to the action of fish enzymes and bacterial action. The presence of TMA is considered as a test in assessing the spoilage of fish. This is also evident from the stale fishy odour.

So you have seen that normally the spoilage of fish is caused by the natural microflora of its habitat followed by the storage condition. In case of fish, the storage is by the cold process. The microorganisms causing spoilage of the fish are the *Pseudomonas* which is the predominant type of bacteria under condition, followed by *Acinetobacter*,

Moraxella and *Flavobacterium*. Are these organisms also responsible for spoilage of other sea foods? Let's find out.

Spoilage of other sea foods

The widely consumed sea foods are shrimps, oysters, crabs etc. The shrimps are commonly stored in chill conditions where the predominant organisms responsible for spoilage are the species of *Acinetobacter*, *Moraxella*, *Vibrio*, *Altermonas* and *Pseudomonas*. The oysters are spoiled at near freezing temperatures by *Pseudomonas* and *Moraxella* species. The oysters contain high levels of carbohydrate as glycogen, as such they are subject to different spoilage patterns. The crab meat is spoiled by *Pseudomonas*, *Acinetobacter* and *Moraxella* when held at chilled temperatures. *V. parahaemolyticus* is the predominant pathogen in fish and sea foods. Type of spoilage of fish and other sea foods are highlighted in Table 4.2.

Table 4.2: Types of spoilage of fish and other sea foods

Type of sea foods	Microorganisms	Spoilage effects
Fresh fish	<i>Pseudomonas</i>	Off-odour Hydrogen sulphide odour, Fruity odour
	<i>Acinetobacter</i>	
	<i>Moraxella</i>	
	<i>Pseudomonas</i>	
Salted fish	<i>Halobacterium</i>	Pink colour
Shrimps	<i>Pseudomonas</i>	Off-odour
Oysters	<i>Rhodotorula</i>	Pink colour

Check Your Progress Exercise 2

1) Fill in the blanks:

- a) Meat has a high activity which is ideal for the growth of microorganisms.
- b) An important microorganism that leads to fish spoilage under stored condition is.....
- c) species is the primary spoilage organism in the meat at 10°C or below.
- d) Oxidative rancidity is more pronounced in fish since high levels of are present in fish.
- e) The oysters are spoiled at near temperatures by *Pseudomonas*.

2) Define the following terms:

- a) Rigor mortis

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- b) Ripening

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3) List four important factors that are involved in meat spoilage.

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4) Mention 'rots' that are frequently encountered on eggs as a consequence of spoilage, along with the name of organism responsible for spoilage.

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5) Briefly describe chemical changes occurring in fish.

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From animal foods, we now move on to the plant foods and here we shall learn about the nature and organisms responsible for their spoilage. We start with fruits and vegetables.

4.4.4 Spoilage of Fruits and Vegetables

Fruits and vegetables are an integral part of daily diets of man all over the world. The spoilage of fruits and vegetables normally occurs after harvest. However, some plant pathogens cause spoilage even before harvesting. The post-harvest spoilage of fruits and vegetables occur mostly during packing, transport and storage, before being processed or consumed. Unlike other food products, the fruits and vegetables will be undergoing physiological changes for quite some time even after harvesting due to the process of ripening. During the ripening process, the autolytic enzymes are active, breaking down the carbohydrates. Apart from the enzymes, the microorganisms are also involved in causing the spoilage of the fruits and vegetables from pre-harvest to post-harvest stage. These are the fungi and bacteria. Let us get to know them.

Spoilage by fungi and bacteria

The dominant spoilage organisms in fruits are fungi, as their pH is low (normally 5), whereas the pH of vegetables is from 5.0 to 7.0, which makes them susceptible to both fungi and bacteria. The spoilage is affected through the formation of rot, which is due to the ability of fungi and bacteria to secrete pectolytic enzymes. The rot is characterized by the softening of the tissue due to the action of pectolytic enzymes. Most important moulds involved in the spoilage of fruits and vegetables are *Penicillium* and *Rhizopus*. The typical form of spoilage in case of both fruits and vegetables is clearly shown in the Figures 4.1 (a) and (b). Although bacterial spoilage of fruits and vegetables is less when compared to moulds, nevertheless, certain strains of bacteria still cause spoilage. The important organisms belong to *Erwinia* Spp. and *Pseudomonas* Spp. Among them, *Erwinia carotovora* is important. The types of fungal spoilage of certain fruits and vegetables are given in Table 4.3.

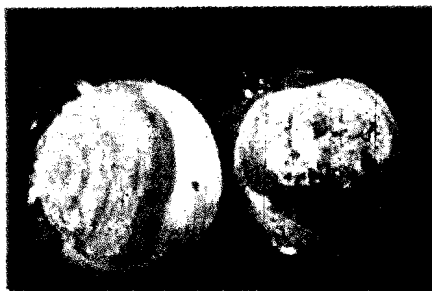


Figure 4.1(a): Spoilage in case of fruits and vegetables



Figure 4.1(b): A potato spoiled by the late blight fungus - *Phytophthora infestans*

Table 4.3: Fungi responsible for the spoilage of fruits and vegetables

Fruits and vegetables	Genus	Spoilage Effects
Majority of fruits and some vegetables	<i>Penicillium</i>	Blue rot
Several fruits and vegetables	<i>Rhizopus</i>	Soft rot
Several fruits and vegetables	<i>Sclerotinia</i>	Watery soft rot in vegetables, brown rot in fruits
Potato, tomato, citrus fruits and many vegetables	<i>Geotrichum</i>	Sour rot
Cabbage, cauliflower, potato, lemon, orange, apple and pear	<i>Alternaria</i>	Black rot

Next, we come to our staple food i.e. cereals and their products.

4.4.5 Spoilage of Cereals and Cereal Products

Cereals are the main source of energy to human beings. There are several varieties of cereals, of which wheat and rice are the major crops and staple food for the majority of people in India. In the preparation of different snacks and other varieties of foods, the cereals are the major ingredients. The cereal products, especially wheat, are extensively used in the food preparations like *chapati*, bread and other bakery products. Cereals, cereal flour etc., are generally stable due to their low water activity (a_w), hence, are considered as semi-perishable foods. You may recall reading about this earlier also. The spoilage of these commodities can take place only when they are stored in humid conditions or the product prepared contains high moisture. The spoilage organisms, in the case of cereals are usually *moulds* and followed by *yeasts* and *bacteria* as the moisture percentage increases. Occasionally, unseasonal rains occur at the time of harvest and standing of harvested grains of wheat, maize and sorghum are infected by moulds like *Aspergillus* and *Fusarium*.

Let us next discuss the spoilage of cereal products, starting with the most popular cereal product i.e. the bread, which we all perhaps consume almost everyday.

- *Bread*

Among the cereal products, bread assumes a prime position. It is a widely prepared cereal byproduct which is consumed all over the world. The spoilage of bread is mainly by moulds. Have a look at the Figure 4.2 to find out how a common bread mould looks like. The common spoilage moulds include *Rhizopus nigricans*, which produces the characteristic black spots. The *Penicillium expansum* or *Aspergillus niger* develops the green spots while the *Monilia sitophila* imparts the pink colour. The red or blood bread is caused by *Serratia marcescens*. The important spoilage problem in bread is the 'ropiness' which is caused by *Bacillus subtilis* or *Bacillus licheniformis*.

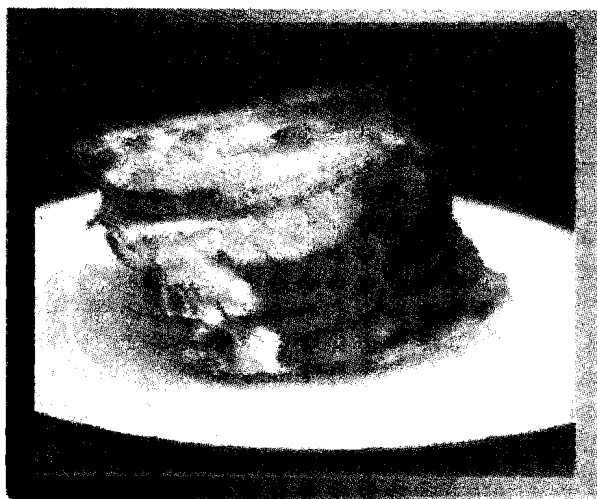


Figure 4.2: A mouldy loaf of bread

This occurs as the flour protein and starch in bread gets hydrolyzed which leads to stringiness in the bread. The spoilage of commercial bread has come down drastically due to the usage of preservatives like propionic acid. It has been found that *chapati*, which is the most common form of wheat preparation in India, when held in a polythene cover, keeps for nearly seven days inspite of the relative humidity being up to 90 to 95%. The *Aspergillus* spp. spoils *chapati* after this period.

- *Cakes, pastries and other bakery items*

Moulds are generally responsible for the spoilage of cakes and other bakery items. But the addition of several ingredients, like cream filling in pastries and other dairy products, eggs etc., can add up several spoilage organisms, as the water activity of these products is quite high. *Staphylococcus aureus* has been found frequently in pastries due to the addition of milk products. Due to the addition of high sugar icing, low pH topping like fruits, spoilage bacteria do not gain entry but ultimately yeasts or moulds can grow. The storage under refrigeration conditions below 5°C can help in reducing the risk of spoilage of pastries and cakes.

Having studied about fruits and vegetables above, which are classified as perishable foods, we move on to yet another perishable food i.e. milk and get to know about its spoilage and that of its products namely cheese, butter etc.

4.4.6 Spoilage of Milk and Milk Products

Milk is a wholesome food and so it is generally consumed in its basic form or with the addition of a beverage supplement. Milk is a basic food commodity for several milk-based preparations. It is important to know that the raw milk obtained from a healthy buffalo or cow is generally free from organisms. How then does the milk get spoiled? There are many factors that lead to spoilage of milk. Can you suggest a few?

Consider the following situation. The milk is normally procured from small farmers, collected in refrigerated containers and transported to the processing plants. Much before the milk is procured, the process of milking the cattle takes place. Now, can you suggest how milk can get spoiled at each of these stages? The first and foremost exposure is the milk obtained from an infested udder which can carry microorganisms, as cows and buffaloes generally suffer from mastitis. Apart from the udder, the other sources of spoilage organisms in milk could be through the handler, utensils, storage vessels and other process equipments etc.

Several microorganisms are encountered in raw milk, which includes the species of *Pseudomonas*, *Flavobacterium*, *Streptococcus* and *Lactobacillus*. The microorganisms impart several undesirable organoleptic changes in raw milk, the predominant ones being souring of milk and ropiness. The *Streptococcus lactis* is responsible for souring while the ropiness is caused by *Alcaligenes viscolactis*. The milk is normally procured from small farmers, collected in refrigerated containers and transported to the processing plants. As such, the spoilage organisms encountered in refrigerated milk are the *psychrotrophs*. The psychrotrophic bacteria enter the milk through soil, water, containers etc. If there is any delay in cooling, the bacterial load increases. The psychrotrophic bacteria produce enzymes such as proteases, lipases and other enzymes. The proteases while hydrolyzing the milk proteins, impart a bitter flavour. The lipases are responsible for the rancid off-flavour. Due to further processing like pasteurization, the organisms may die but the enzymes may remain unaffected. So can the pasteurized milk also get spoiled? Let us see how.

The spoilage of pasteurized milk

You would recall that pasteurization is one of the techniques to control and destroy the pathogenic, as well as, spoilage bacteria in milk and milk products. There are certain bacteria which can withstand pasteurization temperatures. They are 'thermoduric bacteria' which are heat-resistant. *Streptococcus thermophilis*, *Streptococcus faecalis*, *Corynebacterium lacticum* and *Micrococcus luteus* are some of the commonly found thermodurics. The spores of *B. cereus* are also found in pasteurized milk and they are also responsible for spoilage when held at normal temperatures. The spore formers especially *Bacillus subtilis* are responsible for the spoilage of Ultra High Temperature (UHT) processed milk. But generally the spoilage also results due to the enzyme activities.

Next, a word about the spoilage of milk products.

Spoilage of milk products

Butter, cheese, condensed milk etc. are some of the milk products commonly used in day to day life. What are the organisms which are responsible for their spoilage? Let's find out.

● *Butter*

Butter, which has a high content of fat, is subject to rancidity and microbial spoilage due to contaminated cream from which it has been prepared. The dominant microorganisms responsible for spoilage are the psychrotrophic bacteria due to the fact that butter is usually stored under refrigeration conditions. The putrid, proteolytic fruity flavours in butter are caused by the psychrotrophic bacteria. *Pseudomonas fluorescens* and *Pseudomonas fragi* are associated with the fruity odour in butter. They are both proteolytic and lipolytic i.e., they decompose proteins and fats. The presence of these organisms is due to the post pasteurization contamination through water and processing equipment. The surface taints and putrid flavours are caused by *Altermonas putrefaciens* and *Pseudomonas putrefaciens* which grows on the surface of butter.

● *Cheese*

Cheese is manufactured by souring or ripening of milk. The cheese is susceptible to abnormal fermentation which causes spoilage and abnormal physical appearance. In cheese, spoilage due to mould growth is encountered and especially species of *Penicillium*, *Cladosporium*, *Candida* and *Mucor* appear on the surface of cheese. Look at the Figure 4.3, where a spoiled cheese has been shown giving characteristic discolourations on the surface. The bacteria responsible for the spoilage of cheese

are encountered during the ripening stage of production. The spoilage due to *Pseudomonas* impart the slimy nature and the coliform bacteria are involved in the gas formation, the *Clostridium* spp and *Bacillus* spp are the chief gas forming bacteria. Yeasts also sometimes cause spoilage, *Rhodotorula* produces the pink colouration.



Figure 4.3: Cheddar cheese with aspirations to become blue cheese - various species of *Penicillium*, which can grow even in the refrigerator.

- *Sweetened condensed milk*

The sweetened condensed milk contains about 8% milk fat, 23% total milk solids and sweetened with the addition of a sweetener, usually sucrose, to prevent spoilage due to the lowered water activity (a_w). You would recall studying about water activity in Unit 2. A high a_w favours microbial growth in foods. The condensed milk is normally packed in small sealed cans. The cans keep for long periods without refrigeration. The spoilage of the canned condensed milk is due to the presence of osmophilic yeasts like *Torulopsis* spp or moulds, if the can is under-filled. The spoilage is evident by the swelling of the cans due to gas formation. The spoilage could be due to the entry of spoilage organisms via the canning equipment.

- *Spray-dried milk powder*

The milk which is concentrated by the process of spray drying contains about 40-45% total solids. Do you know how the dried milk powder is prepared? The milk is repasteurized and then atomized into a drying chamber of hot air where the hot air is made to flow, depending on the design, in the same, opposite or a combination of directions relative to the flow of the atomized milk particles. The drying air is heated to temperatures up to 150-260°C. The moisture is removed as particles move through the hot air and collect at the base of drying chamber. The dried powder is cooled to 38-40°C as it moves from the drier. The large clumps are separated in a 'sifter' and then packed.

The spoilage of dried milk depends upon the type of organisms present initially in the raw milk and the conditions of sanitation in the processing. *Micrococcus flavus* and *Bacillus subtilis* are the common thermophilic organisms found in raw milk which can withstand drying temperatures.

Let us now move on to the discussion on spoilage of frozen dairy desserts. Have you ever wondered how and which kind of microorganisms could spoil frozen products? Let us see this in the following section.

- *Frozen dairy desserts*

The frozen dairy desserts include ice cream, sherbet, ices and custards etc. The ingredients used in the preparation of these products are milk, cream, fruits, nuts, eggs and egg products and various additives like emulsifiers, stabilizers, colouring

substances etc. The spoilage of various frozen preparations could be due to microorganisms present in any of the ingredients used. The pasteurization process normally eliminates the microorganisms. The survivors will be only the spore formers. The spoilage is avoided if the pasteurized product is frozen promptly. The spoilage is usually due to the contamination or delay at the stage of freeze storage.

Ice creams are the most important frozen dairy products. The pathogens gain entry into ice creams due to faulty practices by way of using raw unpasteurized milk, eggs containing *Salmonella* spp. Insanitary handling while processing and improper storage practices etc. are other factors contributing to spoilage. The presence of *Staphylococcus aureus* enterotoxin, which withstands higher temperatures, has been found to be the principal reason for outbreaks involving ice creams.

Check Your Progress Exercise 3

1) Fill in the blanks:

- a) is the organism responsible for souring of milk while causes ropiness.
- b) Enzyme lipases cause off flavour and proteases lead to hydrolysis of milk
- c) The putrid, proteolytic fruity flavours in butter are caused due toand
- d) Bacteria that lead to spoilage of cheese are encountered during stage.
- e) Post-harvest spoilage of fruits and vegetables is caused due to
- f) in bread is caused by *bacillus subtilis* or *bacillus licheniformis*.
- g) The microorganism found more frequently in pastries due to the addition of milk product is

2) List the sources of spoilage of raw milk.

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3) Name a few thermophilic organisms.

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4) What causes the spoilage of canned condensed milk?

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We have focused on the spoilage of perishable, semi and non-perishable foods in our discussion so far. Certain beverages and other miscellaneous products like fats and oils, spices can also be subjected to deterioration. A knowledge of spoilage of these products which are an integral part of our daily diet is also crucial. The next section focuses on this aspect.

4.4.7 Spoilage of Soft Drinks, Fruit Juices, Fruit Preserves

We all consume soft drinks, fruit juices, as well as, preserves, which normally are available in the market as tetrapacks, cans, bottles etc. What microorganisms lead to their spoilage? Let us try to learn about them.

Soft drinks, fruit juices and fruit preserves are the unique products, as they are acidic by nature, to which antimicrobial ingredients are added. The soft drinks are of two types. One, *carbonated*, and the other one is *non-carbonated*. The carbonated soft drinks are manufactured by the absorption of carbon dioxide in the potable water containing flavours and colours. Other ingredients like sweeteners, foaming, emulsifying and stabilizing agents may also be added. The non-carbonated drinks, apart from the above ingredients, may contain fruit juices and vitamin C.

Do you know how these are prepared and what additives are used to preserve them?

The fruit juices are liquids, extracted from mature fruits. The bottled commercial fruit juices are diluted and blended with additives to give the required taste. The fruit preserves or jams are viscous or semi-solid products containing single fruit or mixed fruits. Other ingredients like jellying agents, pectin, gums etc., are added. The concentrated drinks are both with and without fruits. They have to be diluted appropriately before consumption, to suit the taste.

The above mentioned types of beverages contain either natural antimicrobial properties like the low pH, low water activity or added preservatives to enhance the shelf life. But the spoilage of these products still takes place. Yeasts and moulds are the principal organisms that can grow in soft drinks, juices and fruit preserves. Certain lactic and acetic acid organisms among bacteria also can grow. Let us see how these yeasts, moulds or bacteria can cause spoilage.

- *Spoilage by yeasts*

Yeasts dominate in the spoilage of fruit products which contain high acid content due to their ability to tolerate high acid environment. Yeasts are osmophiles but they can tolerate only high sugar environment but not salt. They also have the ability to grow anaerobically and have low nutritional requirements coupled with the ability to synthesize the nutrients required for growth and survival.

Among the types of yeasts, the ascospore-forming and heat-resistant organisms like *Saccharomyces cerevisiae* and *S. chevalieri* are found responsible for the spoilage in canned fruit products. The growth of yeast in a product results in the formation of CO₂, development of turbidity, clumping and flocculation (forming woolly cloudlike aggregations).

- *Spoilage by moulds*

Like yeasts, moulds also can tolerate high acid environment, sustain low water activity and grow with minimum nutrients. But majority of the moulds are strict aerobes which restrict their growth in fruit containing products due to low redox potential prevailing in them.

The moulds which have been found responsible for the spoilage of fruit products are *Penicillium notatum*, *Penicillium roquefortii*, *Cladosporium* spp or *Byssoschlamy*

spp. Moulds can also tolerate high temperatures, when compared to yeasts and as such they are found in pasteurized fruit products. The organisms include *Byssoschlamys fulva*, *Thermoascus aurantiacum* etc.

- Spoilage by bacteria

The *Lactobacillus* and *Leuconostoc* species have been reported in spoiled fruits and soft drinks. *Gluconobacter* species is also responsible for the spoilage of fruit products. The spoilage of fruit products due to lactic acid bacteria causes opalescence in soft drinks, gas bubbles and bursting of containers.

In the end, let us look at the spoilage of miscellaneous products.

4.4.8 Miscellaneous Products

Confectionery products namely sweetened products, fats and oils, spices are included under miscellaneous products here in this section. The spoilage of these products is described herewith.

- Confectionery products:** The confectionery products are sugar-based sweetened products to which cocoa, chocolate, fruits and milk products are added. The spoilage of confectionery products depends largely on the ingredients which are used in the preparation of a particular product. The main ingredients of confectionery apart from sugar are vegetable oil, milk and milk products, egg, edible gums, nuts, fruits, flavours, stabilizing agents etc. The major spoilage organisms include osmophilic yeasts like *Saccharomyces cerevisiae* and gas producing *Clostridium* spp. The main pathogen which can enter the confectionery products is *Salmonella*, as various confectionery ingredients like coconut, chocolate, milk, egg albumin, spices etc. are susceptible to contamination by *Salmonella*.
- Fats and oils:** Fats and oils form an integral part of several food preparations. The fats and oils are subjected to chemical changes. The chemical changes induced by autoxidation are generally referred to as 'rancidity'. It is a manifest with an accompaniment of off-flavours. Nevertheless, oils and fats are also spoiled by lipolytic microorganisms which also develop rancidity. The microbial enzymes hydrolyze fats to yield free fatty acids (FFA) and glycerol. The products like butter, margarine, vegetable oils, mayonnaise etc., are the chief vehicles for several food preparations. The bacteria which can spoil the oils and fats include *Pseudomonas*, *Bacillus*, *Achromobacter* and *Micrococcus*. The moulds which can affect them belong to the species of *Geotrichum*, *Penicillium* and *Aspergillus* etc.
- Spices and condiments:** Spices and condiments are used in the preparation of several foods. Spices are pungent and are natural additives used to impart flavours. They are substances obtained from plants. The principal spices include pepper, ginger, cloves, cinnamon, chillies etc. The spices are generally spoiled by moulds. Mycotoxins, like aflatoxins are found in pepper and chillies. Spices can act as vehicles of spores of microorganisms which can spoil the foods. This is due to the fact that spices are added to certain food preparations after the cooking process is over. The spore forming *Clostridium perfringens*, *Bacillus cereus* and *Salmonella* are implicated in various food borne diseases.

Check Your Progress Exercise 4

1) Fill in the blanks:

- Ascospore forming are responsible for spoilage of canned fruit products.

- b) Principal organisms that grow in fruit juices are and
- c) Moulds can tolerate high environment, sustain low and grow with minimum
- d) Moulds found in pasteurized fruit products are and
- 2) Define 'Rancidity'.
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- 3) Name three microorganisms that lead to the spoilage of:
- a) Confectionery Products
- b) Fats and oils
- c) Spices

4.5 LET US SUM UP

In this unit, we studied about food spoilage and the chemical changes that occur in major nutrient i.e., carbohydrates, fats and proteins, as a consequence to microbial spoilage. Next, we focused on various factors that lead to microbial growth and spoilage in a variety of foods groups such as meat, poultry, milk and its products cereals, fruits, and vegetables etc. Also we discussed a few characteristic signs and the chemical changes occurring in these food items because of the growth of microorganisms.

4.6 GLOSSARY

- Autolytic Enzymes** : autolytic (meaning "self-digesting") enzymes, are endogenous enzymes contained inside cells. The purpose of an autolytic enzyme is to break down the cell in which it is contained after that cell dies. Because the body is made up of fat, protein and carbohydrate, these enzymes are lipases, proteinases and amylase.
- Candling** : a technique which involves rotating the egg in front of a candle light; helps in identifying the cracks, rots etc.
- Decay** : aerobic degradation of amino acids.
- Mastitis** : refers to the inflammation of breast.
- Putrefaction** : the anaerobic degradation of amino acids by microorganisms to produce foul smell.
- Rancidity** : the chemical changes occurring in fats and oils induced by autoxidation.
- Rigor mortis** : stiffening of the meat, immediately after the slaughter.
- Ripening** : tenderizing the meat by the action of enzymes. It is a desirable process.

Rotting : the decomposition of food by the action of spoilage bacteria, fungi or viruses. When microbes eat food, they break down the proteins into smaller parts, generate acids, and poison the food with toxins that keep other microbes from growing in competition. "Rotten" food is waste and partially digested result from microbes!

4.7 ANSWERS TO CHECK YOUR PROGRESS EXERCISES

Check Your Progress Exercise 1

- 1)
 - a) appearance, texture, odour, flavour
 - b) monosaccharides, softening
 - c) aqueous
 - d) glycerol, free fatty acid, ketones, alcohols
 - e) perishable
- 2) Positive aspects of microbial growth are the increase in the nutritional value or keeping quality of products with a short shelf-life. Negative aspects of microbial growth include food deterioration and spoilage by decay, and food poisoning mainly caused by different and less widespread bacteria.
- 3) Growth and activities of microorganisms, activities of food enzymes, infestation, chemical and physical changes, presence of foreign bodies, and physical abuse are a few factors that make a food unacceptable.

Check Your Progress Exercise 2

- 1)
 - a) water
 - b) *Staphylococcus aureus*
 - c) *Pseudomonas*
 - d) PUFA
 - e) freezing
- 2)
 - a) Rigor mortis is the stiffening of meat immediately after slaughter.
 - b) The action of the enzyme in underlying the meat is known as ripening.
- 3) Initial microflora, pH, O-R potential, temperature are the four important factors that are involved in meat spoilage.
- 4) Rots that are frequently encountered on eggs along with microorganisms are:
Black Rots - *Proteus*
Red Rots - *Serratia marcescens*
Pink Rots - *Pseudomonas*
Green Rots - *P. fluorescens*
Colourless Rots - *Pseudomonas, Alcaligenes, Acinetobacter*
- 5) The autolytic enzymes in fish play an active role in deterioration. The Trimethylamine oxide (TMAO) is reduced to Trimethyl amine (TMA), which is indicator of fish spoilage.

Check Your Progress Exercise 3

- 1)
 - a) *Streptococcus lactis*, *Alcaligenes viscolactis*
 - b) rancid, proteins
 - c) *P. fluorescens*, *P. fragi*
 - d) ripening
 - e) *Pseudomonas*
 - f) Ropiness
 - g) *S. aureus*
- 2) Infested udder, handling practices, utensils and other equipments for collection and storage of milk are the sources of spoilage of raw milk.
- 3) *S. Thermophilus*, *S. faecalis*, *Cornyebacterium lacticum* and *Micrococcus luteus* are few thermoduric organisms.
- 4) The spoilage of canned condensed milk is caused by presence of osmophilic yeasts / moulds if the can is under filled or due to the entry of spoilage organisms through the canning equipment.

Check Your Progress Exercise 4

- 1)
 - a) yeast
 - b) yeasts, moulds.
 - c) acid, water activity, nutrition
 - d) *Byssochlamys fulva*, *Thermoascus aurantiacum*
- 2) Chemical changes in fats and oils induced by autoxidation are referred to as rancidity. It is characterised by off-flavour.
- 3)
 - a) *S. Cerevisiae*, *Clostridium* and *Salmonella*
 - b) *Pseudomonas*, *Bacillus*, *Penicillium*
 - c) Moulds, *Clostridium perfringens*, *Bacillus cereus*