CC 9; UNIT 4. MICROBIAL FOOD SPOILAGE

Part 1: Introduction to food spoilage microorganisms

by

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Dear students in this chapter on Introduction tofood spoilage microorganisms you will learn abouthow food gets spoilt and the important microbes involved in the spoilage of food

In this chapter we deal with the following aspects

- ✓ Introduction
- ✓ Food Spoilage and General Principles Underlying Spoilage of Food
- ✓ Microbes involved in Spoilage of Foods
- ✓ Major Food Borne Infections/ Intoxications

Introduction:

Foods are not only nutritious to human beings, but are also for microorganism which grow on them. The presence of food poisoning organisms and spoilage of food are very important for the consumer in terms of food safety and consumer health. Today the emphasis is on total quality of foods. This means, that not only food should be nutritionally balanced but should be microbiologically safe too. In this chapter, we will understandthe general principles of microbial spoilage of food and food poisoning microorganisms.

What is Food Spoilage: we refer to food as spoilt when a food "looks bad," which means that there is

- Microbial growth in the form of mycelia or colonies visible on surface,
- Development of cloudiness in liquids,
- Changes in food color

Food spoilage causestextural changeslike:

- Slime formation primarily due to surface accumulation of microbial cells,
- Tissue softening due to enzymatic degradation (e.g. soft rot in veggies)
- Changes in taste and odor like ammonia, amines, sulfides or organic acids.

<u>General Principles for the Spoilage of Food</u>

The numbers and typesof microorganisms in food are largely determined by:

- Environment from which the food is sourced.
- Microbiological quality of the food in its raw or unprocessed state (intrinsic factors).

- Sanitation during handling and processing.
- Effectiveness of packaging, handling and storage conditions in restricting microbial growth (extrinsic factors).

Since foods are of plant & animal origin, characteristics of plant & animal tissues that affect microbial growth needs to be understood. The plants and animals have evolved mechanisms of defence against the invasion and proliferation of microorganisms, hence, fresh fruits and vegetables if undamaged can effectually stay fresh and without contamination. However, during harvesting, packing and transportation the skin of the fresh fruits and vegetables gets damaged thus,inviting spoilage organisms. Knowledge about source of microorganisms and factors influencing microbial growth is essential for food microbiologists. Desirable growth conditions are needed for applicability of microorganisms for fermentation & single cell protein production and finally to understand undesirable conditions utilised for food preservation. The various sources through which microorganisms gain entry into the foods are shown in Table 1.

Microorganisms in food can be used for preservation like curd or behave as spoilage organisms. A number of intrinsic and extrinsic factors affect the microbial growth (Table. 2). Intrinsic or parameters within the food like pH, water activity (a_W), oxidation-reduction potential (Eh), nutrient content, antimicrobial constituents and biological structures play a major role in food spoilage. Extrinsic or environmental parameters affect both foods as well as microorganisms these parameters include temperature of storage, relative humidity of storage environment and concentration of gases in environment.
Let us learn about both the parameters

Intrinsic Parameters

Nutrients

Microorganisms need water, energy source, nitrogen, minerals, vitamins and growth factors in order to grow and function normally. Since foods are rich source of these compounds, they form a good media or environment for microorganisms to grow. Microbes which cannot use the resources present in that food do not grow in that environment. Among the various groups, molds or fungican grow in almost all the conditions, as they can utilise most of the nutrients present in food, followed by yeasts, gram-negative bacteria, and gram-positive bacteria. Many microorganisms present in food have the ability to utilize simple sugars and amino acids. Few others are able to utilize complex carbohydrates such as starches and cellulose as source of energy. Fats are the least favoured source of energy. The commonly utilised nitrogen sources by microorganisms are amino acids. However, almost all microbes utiliseproteins, peptides and nucleotides. In general, simple compounds are utilized first by a majority of microorganisms.

Water Activity (a_W)

Water is often the major constituent in foods. Even relatively ‘dry’ foods like bread and cheese usually contain more than 35% water. However, the water present in food which is available for the microbes to thrive on is explained as water activity.
Water activity is the partial vapor pressure of water in a substance divided by the standard state partial vapor pressure of water. In the field of food science, the standard state is most often defined as the partial vapor pressure of pure water at the same temperature.It can be simplified as

the ratio between the vapour pressure of the food, when in a completely undisturbed balance with the surrounding air, and the vapour pressure of pure water under identical conditions.
Water activity, in practice, is measured as Equilibrium Relative Humidity (ERH) and is given by the formula:

Water Activity (a_w) = ERH / 100

Various organisms thrive at varied water activity a few are listed in table 3.

pH and Buffering capacity
The pH, or hydrogen ion concentration, [H+], of natural environments varies from about 0.5 in the most acidic soils to about 10.5 in the most alkaline lakes. The range of pH over which an organism grows is known as the pH range for that organism. This range can be divided into 3 regions. Minimum pH, below which the organism cannot grow, the maximum pH, above which the organism cannot grow, and the optimum pH, at which the organism grows the best. Microorganisms which grow at an optimum pH well below neutral range (7.0) are called acidophiles. Those which grow best at neutral pH are called neutrophiles and those that grow best under alkaline conditions are called alkalophiles. In general, bacteria grow well in the pH range of 6.0- 8.0, yeasts 4.5-6.5 and filamentous fungi 3.5-6.8. However, there are exceptions like lactobacilli and acetic acid bacteria which have an optima between pH 5.0 and 6.0. Some of the pH requirements of the various organisms are listed in Table 4.

Redox Potential (Eh)
Microorganisms display varying degrees of similarity to Oxidation-Reduction potential of their growth medium. The O/R potential is a measure of the tendency of a chemical species to acquire or release electrons and thereby be reduced. When an element or compound looses electrons, it is called as oxidized, while a substrate that gains electrons gets reduced. Thus, a substance that readily gives up electrons is a good reducing agent, while one that readily gains electrons is a good oxidizing agent. When electrons are transferred from one compound to another, a potential difference is created between the two compounds and is expressed in as millivolts (mV). If a substance is more highly oxidized, the more positive will be its electrical potential and vice versa. The O/R potential of a system is expressed as Eh. Aerobic microorganisms require positive Eh values for growth while anaerobic microorganisms require negative Eh values (reduced). The redox potential in a food is the result of several factors: redox couples present, ratio of oxidant to reductant, pH, production of toxins, availability of oxygen and microbial activity.

Extrinsic Parameters
Temperature of storage
Microorganisms have been found growing in virtually all temperatures. A particular microorganism will exhibit a range of temperature over which it can grow, in the same manner as pH taking the human body temperature as the central point they are classified as, organisms with an optimum temperature near 37 degrees are called mesophiles. Organisms with an optimum temperature between about 45 degrees and 70 degrees are thermophiles e.g, *Bacillus*,

Clostridium etc. Some archaebacteria with an optimum temperature of 80 degrees or higher and a maximum temperature as high as 115 degrees, are referred to as extreme thermophiles or hyperthermophiles. The cold-loving organisms are psychrophiles defined by their ability to grow below 15 to 0 degrees. Psychrotrophs are the main organisms which attack food stored in refrigerators eg. *Listeria*. The maximum damage is caused by mesophilic and psychrotrophic organisms in food.

Relative Humidity of the storage environment

Relative humidity and water activity are interrelated. When foods with low a_W are stored in environment of high humidity, water will transfer from the gas phase to the food and thus increasing the a_W of the food leading to spoilage. Temperature also plays a major role the modification of relative humidity. The general thumb rule is that, at higher temperature, lower is the relative humidity and vice-versa. Hence, it would be better to store food in conditions of low relative humidity to increase their shelf life. This can also be carried out by appropriately packing the food material. However, variations in storage temperature should be minimal to avoid surface condensation in packed foods.

Gaseous atmosphere
Oxygen is one of the most important gases which come in contact with food. This gas influence the redox potential which in turn affects the microbial growth. This understanding has led to designing of modified atmosphere packing which will be dealt in unit 9 (food preservation).

Microbial spoilage of food is due to the activity of these organisms on some of the constituents of food. They may be broadly be divided into 3 groups.

Fermentation:
Carbohydrate in foods +saccharolytic microorganisms = organic acids + alcohol + gases.
Putrefaction:
Protein in foods + proteolytic microorganisms = amino acids +amines+ ammonia+ H_2S.
Rancidity:
Fatty foods + lipolytic microorganisms = fatty acids + glycerol.

Microbes involved in Spoilage of Foods

Spoilage defects in foods.

As microbes are present everywhere they find ways and means to grow on food. However, as these foods provide a congenial environment for the microbes to grow they colonise. Such colonised microbes cause spoilage. The spoilage may be by changing the physical appearance of the food or flavour and taste (Chemical quality). The common spoilage defects that occur in different foods with some examples are shown in Table 5 and 6. The spoilage is not only by degradation of foods, but also by synthesis of various products like pigments and polysaccharides leading to discolorations and formation of slimes.

In general, it is considered that fresh fruits and vegetables are infected with fungi. Meat and egg products along with processed food are spoilt by yeast and bacteria. This is mainly due to the

presence of enzymes which break cellulose and pectin the major constituents in fresh fruits and vegetables. Whereas, protein degrading enzymes are common in bacteria, hence, they spoil milk, meat and fish products. Sugary substances are normally attacked by yeast as is in the case of fruit juices. However, there are exceptions like bread where even though it is a processed food spoilage is mainly by fungi.

Food with high amounts of fats are normally spoilt by bacteria, due to their capacity to produce lipolyticenzymes. They mainly belong to the group of lactobacillus.

Major Food Borne Infections/ Intoxications

What is food borne disease?

Safe, nutritious foods are essential to human health and well-being. However, food-borne diseases pose a significant problem worldwide. Foodborne disease is any illness resulting from the consumption of food contaminated with one or more disease-producing agents. These include bacteria, parasites, viruses, fungi and their toxic products. The World Health Organization (WHO) estimates that 1.5 billion cases of food-borne illnesses cause about 3 million deaths each year. More than 250 different food borne diseases have been described. These different diseases have many different symptoms, hence, indicating specific symptoms to food borne illness would be difficult. However, the first symptoms of food poisoning are nausea, vomiting, abdominal cramps and diarrhoea (table 7).

Foodborneinfection

Foodborne infection is caused by the ingestion of food containing live microbe which grow and establish themselves in the human intestinal tract. Some bacteria, viruses, and parasites cause foodborne illness via infection. The foodborne bacteria that cause infection are: *Salmonella* spp., *Listeria monocytogenes, Campylobacter jejuni, Vibrio parahaemolyticus, Vibrio vulnificus*, and *Yersinia enterocolitica*. The most common viral agents that cause foodborne disease are: Hepatitis A, norovirus, and rotavirus. The most common foodborne parasites are: *Trichinellaspiralis, Anisakis simplex, Giariaduodenalis, Toxoplasma gondii, Cryptosporidium parvum,* and *Cyclospora sp.*

Food borne intoxications

Foodborne intoxication is caused by ingesting food containing toxins formed by microbes. An intoxication results when a person eats food containing toxins that cause illness. Toxins are produced by harmful microorganisms, the result of a chemical contamination, or are natural part of a plant or seafood. Some bacteria cause an intoxication. Viruses and parasites do not cause foodborne intoxication. The foodborne bacteria that cause intoxication are: *Clostridium botulinum, Staphylococcus aureus, Clostridium perfringens*, and *Bacillus cereus*. Chemicals that can cause an intoxication include cleaning products, sanitizers, pesticides and metals (lead, copper, brass, zinc, antimony, and cadmium). Seafood toxins include ciguatera toxin,

scombroidtoxin, shellfish toxins, and systemic fish toxins. Plants and mushrooms can also cause an intoxication.

The major food toxin is produced by *Clostridium botulinum*known as botulin. It is so toxic that one microgram of the toxin can kill one lakh people. Hence in food processing industry the mere presence of one spore in 250 food packs call for the rejection of the complete batch.

Fungal toxins

Where conditions are right, fungi proliferate into colonies and produces toxins known as mycotoxin. The reason for the production of mycotoxins is not yet fully understood as they are not necessary for the growth or the development of the fungi. The production of toxins depends on the surrounding intrinsic and extrinsic environments and these substances vary greatly in their toxicity, depending on the organism infected and its susceptibility, metabolism, and defence mechanisms.

Types of fungal toxins

Aflatoxins are a type of mycotoxin produced by *Aspergillus* species of fungi, such as *A. flavus* and *A. parasiticus*. The term aflatoxin refers to four different types of mycotoxins produced, which are B_1, B_2, G_1, and G_2. Aflatoxin B_1, is a potent carcinogen and has been directly correlated to adverse health effects, such as liver cancer, in many animal species. Aflatoxins are largely associated with commodities produced in the tropics and subtropics, such as cotton, ground nuts, spices, pistachios, and maize.

Ochratoxin is a mycotoxin produced by *Penicillium* and *Aspergillus* species. *Aspergillusochraceus* is found as a contaminant of a wide range of commodities including beverages such as beer and wine. *Aspergilluscarbonarius* is the main species found on vine fruit, which releases its toxin during the juice making process.

Citrinin is a toxin that was first isolated from *Penicilliumcitrinum*, but produced by most of the species of *Penicillium* and several species of *Aspergillus*. Some of these species are used to produce human foodstuffs such as cheese (*Penicilliumcamemberti*), sake, miso, and soy sauce (*Aspergillusoryzae*). Citrinin is associated with yellowed rice disease in Japan and acts as a nephrotoxin in all animal species tested.

Ergot Alkaloids are compounds produced in the sclerotia of species of *Claviceps*, which are common pathogens of various grass species. Ergotism the human disease historically is known as St. Anthony's Fire.

Patulin is a toxin produced by the *P. expansum, Aspergillus*, *Penicillium*, and *Paecilomyces* fungal species. *P. expansum* is especially associated with a range of moldy fruits and vegetables, in particular rotting apples and figs.Although patulin has not been shown to be carcinogenic, it has been reported to damage the immune system in animals.

Fusarium toxins are produced by over 50 species of *Fusarium*which infect the grain of developing cereals such as wheat and maize.

Thus food is attacked by a number of microbes which indicates that what is good for us is also good for the microorganisms. The battle between man and microbes will continue in terms of food production, processing and preservation.

Conclusion: In this chapter we tried to understand the commonly occurring food spoilage organisms. The conditions which leads to their growth and proliferation on food determines the extent of spoilage. The conditions may be due to environmental or extrinsic or due to the original characters of the food or its handling and processing. The causative organisms need not to be present to call the food spoilt but the metabolites produced in the form of toxins can cause sickness. Quite often the food may not look spoilt externally but may carry these toxins which would cause the consumers to become sick. The Sources of Contamination may be Soil, water, air, human pathogens from manure (night soil). It can also come during harvesting both hand picking and machines picking which causes high damage if crop is ripe. Contamination may come from processing plant, packaging containers which are reused without any proper sanitization or during markets due to handling, cross-contamination.

Table 1: Sources of microorganisms found in foods

Sources
Microbes from soil and water
Microbes from air
Microbes on the surface of plant and plant products
Microbes on the surface of Food utensils and equipments
Microbes in animal feeds
Microbes on the surface of animal skin
Microbes on the Intestinal tracts of humans and animals
Microbes on Food Handlers (hands and cloths)

Table 2: Factors affecting the development of microorganisms in foods

Intrinsic Factors	**Extrinsic factors**
Nutrient content	Temperature
pH	Relative humidity
Redox potential	Gaseous atmosphere
Water activity	Antimicrobial, constituents & barriers

Table 3: Minimum water activity required for spoilage microorganisms

Microbial group	Minimum a_w
Bacteria	0.91
Yeasts	0.88
Molds/ filamentous fungi	0.80
Halophilic bacteria	0.75
Xerophilic fungi	0.65
Osmophilic yeasts	0.60

Table 4: pH ranges for the growth of different groups of microbes

	Minimum	Optimum	Maximum
Bacteria	4.5	6.5 – 7.5	9.0
Yeasts	1.5 – 3.5	4.0 – 6.5	4.0 – 6.5
Molds	1.5 – 3.5	4.5 – 6.8	8.0 – 11.0

Table 5: Various types of food spoilage caused by bacteria

Food	Types of Spoilage	Microorganisms involved
Bread	Ropy	*Bacillus subtilis*
Fresh Meats	Putrefaction	*Alcaligenes, Clostridium, Proteus vulgaris, Pseudomonasfluorescens*
Cured Meats	Souring	*Pseudomonas, Micrococcus.*
	Greening, slime	*Lactobacillus, Leuconostoc*
Fish	Discolorations,	*Alcaligenes, Pseudomonas, Flavobacterium*
Poultry	Slime, Odor	*Alcaligenes, Pseudomonas*
Eggs	Colorless& Green Rots	*Alcaligenes, Proteus, Pseudomonas, P. fluorescens*
Concentrated Juices	'Off' flavor	*Acetobacter, Lactobacillus, Leuconostoc*
Milk/ Cream	Ropiness	*Alcaligenesviscolactis, Micrococcus, Enterobacter, Lactobacillus, Streptococcus,*

		Bacillus
Milk/ Cream	Decomposition of fats	*Alcaligenes, Proteus, Pseudomonas, Micrococcus, Bacillus, Clostridium*
Milk/ Cream	Alkali formers	*Alcaligenesviscolactis, P. fluorescens*
Milk/ Cream	Off flavour	*Lactobacillus,Streptococcus, Leuconostoc*
vegetables	Soft rot	*Erwiniacarotovora, Pseudomonas*
fish	Off flavour	*Pseudomonas Acinetobacter-Moraxella*
Curd	slimy curd	*Alcaligenes*

Table 6: Common fungal spoilage of food

Food	**Types of Spoilage**	**Microorganisms involved**
Bread	Moldy	*Rhizopusnigricans, Penicillium*
Fresh fruits and vegetables	Soft rots	*Rhizopus, Erwinia*
	Gray& black mold	*Botrytis, Aspergillusniger*
Cured Meat	Moldy	*Rhizopus, Aspergillus, Penicillium*
Pickles, Sauerkraut	Film/ Pink Yeasts	*Rhodotorula*
Milk/cream	Decolourisation of fats	*Yeasts, molds,*
Fruits	Blue rot	*Penicillium,*
Onions	Black rot	*Aspergillus*
Onions	Sour rot	*Geotrichumcandidum*
Vegetables	grey mold rot	*Botrytis cinerea*
Grapes	Downy mildews	*Phytophora*

Table 7: Possible causes of food borne gastro intestinal disorders

• live microorganisms (Bacteria, viruses, fungi) or their toxins

• other microorganisms like algae, parasites, protozoa and their toxins

• Toxins naturally present or formed in foods e.g, toxic mushrooms, toxins in sea foods, red kidney bean poisoning, biological amines in cheese and fermented meats etc.

• Toxic chemicals which comes as contaminates, such as heavy metal and pesticide residues

• Allergy specific to individuals or inability to utilize some normal components of food due to metabolic disorders.

• Indigestion from over eating, eating foods with high fats and oils, high organic acids (sour food) or foods with high polyphenols (bitter foods)
