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Post Harvest food Spoilages, the factors affecting them and control

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Abstract
Foods consumed by human beings are subject to contamination by wide variety of microorganisms, as the foods contain a wide variety of substances that include carbohydrates, proteins, fats, minerals etc. The microorganisms include both beneficial and harmful types. The growth of these microorganisms in the foods bring about the spoilage of food, may induce toxicity or may bring about food borne infections. This review paper discusses about the type of food spoilages, food borne infections and the factors affecting them, which includes temperature, pH, oxygen availability, moisture content (a_w) and control etc.

Keywords: Spoilage, fruits, Vegetables, Rot, Temperature, Preservation.

1. Introduction
Food is subject to contamination by wide variety of microorganisms from various sources. The human food contains wide variety of substances of both plant and animal origin – carbohydrates, proteins, fats, minerals, water etc. Therefore food serves as an excellent medium for the growth of microorganisms such as bacteria, fungi, yeasts etc (Banwart GJ 1989). The growth of the microorganisms in the food brings about spoilage. Spoilage is the process in which food deteriorates to the point in which it is not edible to humans or its quality of edibility is reduced. Harvested foods are contaminated from the moment they are harvested to the point it reaches the consumer. Such contaminating microorganisms are responsible for the spoilage of the foods (Board R.G 1983). Not all the contaminants are spoilage causing, some of the microorganisms are harmless and may not bring about spoilage. On the other hand some microorganisms are responsible for food borne illnesses or infections (Cliver D.O 1990, Doyle M.P 1989). As such the microorganisms by themselves are not responsible for spoilage condition of foods, but the products of the microorganisms such as enzymes, acids, amines, H_2S etc are responsible for altered condition of the food. Due to food spoilage the nutritional value, texture, flavor of food are damaged (Jay 1991). Sometimes the foods may undergo without the mediation of microorganisms which may due to over ripening, endogenous enzymes such as those oxidizing phenolic compounds (browning) or pectinases enzymes which may cause softening. Insects infesting foods and rodents chewing on foods, Light causing degradation of pigments (photooxidation), fats, and proteins may cause off flavours and odours (Frazer W, Westhoff 1988). There are several factors affecting food spoilage- Temperature, pH, oxygen availability, available water, biological structures, antimicrobial substances etc (Meyer R.S, Grant MA, Luedecke LO, Leung HK 1989).

Humans have broader nutritional requirement and therefore the foods consumed by humans have range of ingredients such as –Carbohydrates, Proteins, Fats, Vitamins, Minerals, Water etc. Therefore food of humans serve as an excellent medium for the growth of wide range of microorganisms. These include – Bacteria, Fungi, Yeasts, Protozoa, etc. (Banwart 1989) the growth of the microorganisms in foods brings about biochemical changes in the food. This alters the condition of the food due to the metabolism of the microorganisms in the food and the release of metabolic products such as –acids, gases, amines, fatty acids etc. This alters the condition of the food that changes the taste, odour, appearance and makes it unfit for consumption by humans (Jay 1991). This is referred to as spoilage of foods.

Foods consumed by human beings are of different types with respect to their susceptibility to microorganisms. They are Perishable foods, Semi-perishable foods, Stable foods. Perishable

Table 1: Types of food Spoilages in general foods. (Tourns VH 2005, Loureiro V and Malfeito-Ferreira M 2003, Gram Dalgaard 2002)

Type of food	Spoilage	Causative agent
Vegetables	soft rot	*Erwinia carotovora*
Vegetables	Moldy	*Nigrosporum, Alternaria*
Fruits	Moldy	*Aspergillus, Mucor, Rhizopus*
Grapes	Grey mold rot	*Botrytis cinerea*
Papaya	Moldy	*Neurospora, Alternaria*
Banana	Cigar end rot	*Colletotrichum musae*
Bread	Moldy	*Rhizopus, Mucor, Aspergillus etc.*
Meat	greening	*Pseudomonas fluorescence*
Meat	Slimy	*Alcaligenes*
Poultry	Putrefactive	*Proteus*
Egg yellow	Red spot	*Serratia*
Milk	Ropiness	*Alcaligenes viscolactis*
Milk	Stormy fermentation	*Clostridium perfringens*
Butter	Rancidity	*Pseudomonas putrefaciens*
Fruit juice	Fermentative	*Yeasts*
Meat	Phosphorescence	*Photobacterium sp.*
Meat	Taint	*Lactobacillus, Alcaligenes*
Meat	Souring	*Lactobacillus sp.*
Meat	Rancidity	*Achromobacter sp.*
Milk	Rancidity	*Torula, Lipolytic yeasts*
Meat	Blue	*Pseudomonas pyocyanea*
Butter	Butyric	*Butyric acid spoilage*
Beer	sourness	*Lactic acid bacteria*
Bread	Red bread	*Serratia sp.*
Apples	Browning	*Monilia fructigena*
Citrus fruits	Moldy	*Penicillium expansum*
Pickles	Black pickle	*Bacillus sp.*

These are the common food spoilages which have reported. Such food spoilages are due to contamination of foods from various sources. Such food spoilages make the food unfit for consumption. Apart from this is also responsible for loss of large amount of agricultural produce. nearly 40-50% of the produce (Kantor L.S, Upton K, Manchester A and Oliveria V 1997). Such food spoilages can be prevented by adopting better preservation methods, so that the shelf life of the foods can be increased. Most of the food spoilages are due to aerobic microorganisms.

Canned food are the foods which are resistant to spoilages as they are highly processed under hygienic conditions. However some highly resistant forms of bacteria i.e spore formers which can tolerate boiling temperatures bring about the spoilage of canned foods. Some of the microorganisms which can bring about the spoilage of canned foods are Examples - *Clostridium thermoacidophilus* brings about the spoilage of high acid foods, *Bacillus stearothermophilus* are facultative aerobes and can survive under anaerobic conditions and high temperatures (Frazer W.C and Westhoff 1988). The resultant of canned food spoilage is the bulging and bursting of the cans. eg: Canned peas, Canned beans etc. Such spoilage organisms are aerobic or anaerobic spore formers and are highly resistant to boiling temperatures (100 ^{0}C) employed in the canning process.

The growth such spoilage containing microorganisms in foods brings about biochemical changes in the food product. Most of spoilage condition is due to those biochemical changes. They can be represented as follows:-

Carbohydrate (fermentation) $\longrightarrow$ acids, alchohols and gases such as CO_2, H_2.

Fats (lipolysis) $\longrightarrow$ fatty acids, aldehydes.

Proteins (proteolysis) $\longrightarrow$ amino acids $\longrightarrow$ amines or H_2S.

Microorganisms by themselves do not bring about the spoilage of foods, but the enzymes produced by the microbes are responsible for the spoilage condition of the foods (Banwart 1989).

Food borne infections:-Most of the spoilage causing microorganisms are not pathogenic or disease causing. On the contrary there are some microorganisms which only bring about spoilage but also cause infections or diseases in human beings. Such microbes alter the condition of food in such away that, they release several –toxins or other enzymes or any other virulence factors which affect the health. Hence such microorganisms transmit the infections via food.

Table 2: Food borne infections or diseases (Doyle M.P. 1989)

Name of the disease or infection	Causal Organism
Shigellosis	*Shigella sp.*
Gastroenteritis	*Salmonella enteritidis*
Typhoid	*Salmonella typhi*
Cholera	*Vibrio cholera*
Ulcers	*Helicobacter pylori*
Amoebic dysentery	*Entamoeba histolytica* (protozoa)
Jaundice	*Hepatitis A* (virus)
Salmonellosis	*Salmonella spp*
Bacillary dysentery	*Shigella dysenteriae*

The food borne infections are a result of the contamination of foods from various sources such as cooking personnel, water, improper cooking, utensils or storage containers, food handlers, storage conditions etc. The food borne infections or illnesses range from mild to severe to fatal form. Botulism is the most fatal form of food poisoning. The symptoms include- blurred vision, difficulty in swallowing and speaking, muscle weakness, nausea and vomiting. Dysentery is another most common symptom of food poisoning or infection. The characteristic symptom of most of the food borne infections is abdominal pain, diarrhea (Ashok Kumar et al 2011).

Apart from this some of the fungi also produce toxic effects on the foods. They are called Mycotoxins and the condition is called Mycotoxicosis. These toxins have an adverse effect on the human health. This can damage to Liver, Kidneys, and has various carcinogenic effects etc.

It has also been reported that some Algae also produce toxic effects and they cause Shell fish poisoning. Ex: *Gymnodium, Gonyulax* produce toxins.

Table 3: Food borne poisoning and the causal organisms

Name of the disease or infection	Causal Organism
Bacterial Toxins	
Botulism	*Clostridium botulinum (Botulinum toxin)*
Staph. Poisoning	*Staphylococcus aureus (Enterotoxin)*
Perfringens poisoning	*Clostridium perfringens (Lecithinase Enzyme)*
Mycotoxins (Mycotoxicosis) *	
Aflatoxin	*Aspergillus flavus*
Ochratoxin, Patulin	*Penicillium, Fusarium*

***Moreau, C 1979**

Sometimes the food may undergo spoilage by non-biological means and are called as Non microbiological spoilage of foods. This is due to some chemicals produced within the foods which may be of plant or animal origin. Some of the fruits may undergo spoilage by over ripening.

As such some do not undergo spoilage easily but sometimes due to damage to food mechanically. Apart from the spoilage by microorganisms much of the postharvest spoilages also occurs due to Rodents, insects (fly, fruit fly, bee, wasp, house flies etc). It has been reported that those spoilage accounts to about 30-40% of the postharvest spoilages (Diane G. Newell, Marion Koopmans, Linda Verhoel 2010).

Physical and chemical factors affecting the food spoilages are Temperature, pH, Available water(a_w), Physico-Chemical Properties, Chemical composition, Environmental conditions(Meyer RS, Grant MA, Luedecke Lo, and Leung HK, 1989), Biological structures, natural Antimicrobial substances in food (Ceylon E., Fung DYC 2004).

1) Temperature

Temperature is an important factor which influences the growth of the microorganisms. Temperature therefore influences the type of spoilage because different types of spoilages are brought about by the different microorganisms, which differ in their optimum temperature of growth. Based on this microorganisms are of the following types.

a) Psychrophiles

These microorganisms capable of growing at temperature of 4^0c are called Psychrophilic microorganisms. They can bring about the spoilage of refrigerated foods.eg:- *Pseudomonas sp* can bring about the spoilage of meat at 4 ^{0}c, making it Putrid. *Aspergillus sp*. can bring about spoilage of fruits and vegetables at about 4 ^{0}C.

b) Mesophilic

Microorganisms bring about the spoilage of foods at moderate temperatures. The temperature range is 20-45 ^{o}C. The optimum temperature is 30-45 ^{0}C. Most of spoilages and food borne infections are brought by Mesophiles.

c) Thermophiles

Thermophiles are those microorganisms which grow at high temperatures. The temperature range at which they can grow is 45-60^{0}C. The optimum temperature for thermophiles is 45 ^{0}C. eg:-Spoilage of canned foods is by *Clostridium thermocellum* is an anaerobic ,spore former. *Bacillus stearothermophilus* that brings about the spoilage of canned foods is an Gram positive, spore former, rod shaped bacteria.

2) Ph

PH is an important factor which influences the growth of the microorganisms. In terms of food spoilage the pH of the food influences the type of food spoilage which is determined by the microorganism. eg; pH of the vegetables is near neutral, therefore most spoilage of vegetables is brought about by bacteria. Whereas, pH of fruits is acidic range i.e below 7.0. , hence fungi thrive well and are responsible for most of the moldy fruit spoilages.

3) Moisture or available water

(a_w) is an important factor which influences the growth of the microorganisms., it varies from one food type to another. Eg; dry fruits contain less moisture content or a_w, so as cereal grains. Hence, such foods do not undergo spoilage easily, whereas foods such as fruits or vegetables undergo spoilage easily as they contain high a_w values.

4) Biological structures

The basic biological structure of food is responsible for the vulnerability or resistance of the food, e.g., the shell of egg protects the egg from spoilage, in case of any breakage of the shell, the microorganisms gain entry into the inner contents of the egg and bring the spoilage. Some fruits such as oranges, pineapple, litchi etc have thick fruit wall and protects the fruits from spoilage and damages.

5) Antimicrobial substances

Many foods have some intrinsic substances which are antimicrobial eg; Wine or beer contains alcohol which is antimicrobial, egg white contains lysozyme which inhibits bacterial growth, Capsicum contains capscisin which is antimicrobial. The presence of such antimicrobial substances provides protection against some spoilage causing microorganisms.

Control of spoilages/food contamination is by adopting certain measures such as preventing the entry of microorganisms in the food by maintaining hygienic conditions. Despite of all the precautions, foods get contaminated by undesirable microorganisms and undergo spoilage. Therefore by using food preservation methods food spoilage can be prevented and shelf life of foods can be increased. The preservation methods include both physical and chemical methods. The physical methods involve the use of physical agents to accomplish preservation of foods. The various physical agents commonly employed for preservation are:- Aseptic handling, High temperature or heat, Low temperature, Desiccation or Drying, and Radiations (Silva FVM and Gibbs P 2004).

1) Asepsis

Foods may get contaminated at various stages after harvest. After harvest the food is handled by many personnel, which may contaminate the food. Aseptic handling, covering or warping prevents primary contamination during handling. The environment in which the food is harvested or stored also influences the spoilage of foods.

2) High temperature or heat

This is the commonly and widely employed method of food preservation. This is an ancient method of food preservation. The application of high temperature or heat kills many spoilage causing microorganisms. The mechanism by which high temperature kills microorganisms is by denaturation of proteins or inactivation of enzymes. There are several methods which are employed in heat is an agent of destroying the spoilage causing microorganisms.

3) Pasteurization

This is one of the most commonly employed method of food preservation. In this method, a temperature below 100 ^{0}C is employed. The main principle involved in pasteurization is to destroy the spoilage causing microorganisms without affecting the aroma, flavor, taste of the food. Pasteurization method was devised by Louis Pasteur for prevention of wine spoilage. Later this method was widely employed for milk and its products such as Butter, Cheese etc. In the actual pasteurization process a temperature of 62.8 ^{0}C for 30 minutes is employed. It is also referred to as LTH (Low temperature holding) method. Later this method was modified and a temperature of 71.7 ^{0}C for 15 seconds was employed and is called HTST (High temperature short time) method (Silva FVM and Gibbs P 2004).

4) Canning

Canning is defined as the preservation of foods in sealed containers and usually implies heat treatment. In the process foods such as vegetables are immersed in boiling water at 100 ^{0}C and sealed under vacuum. However, some resistant form of microbes such as spore formers survive this process and bring about spoilage of canned foods (Sherraf TN, Wilkinson DM and Bain RS 2006).

5) Desiccation or drying

Foods contain moisture, which is essential for life. The concept of removal of moisture or drying has been employed since ancient times for prevention of growth of spoilage causing microorganisms. Various methods of drying are employed such as Sun drying, Vacuum drying, spray drying.

6) Anaerobiosis

It is a process in which the replacement of air by CO_2 or by an inert gas may bring about anaerobic conditions.eg; spores of aerobic bacteria do not germinate under anaerobic conditions.

7) Radiations

UV rays have a little penetrating power, and have been employed for the sterilization of the surface of meat. But it has been reported can cause hydrolysis of fats and may have limited applications. Gamma rays have been employed for the sterilization of packaged foods as they have high penetrating power. Gamma rays are widely employed for the sterilization of dry fruits, strawberries etc. However there are some objections in the use of gamma radiations for sterilization of foods as they can cause mutations, generation of free radicals, induce cancer (Boork and Frommh 2006),. . Therefore limited dose of radiations should be used and food should be pre-packed to prevent the effct of radiations. The materials recommended for packing of foods which are irradiated are Nitrocellulose, polythene film, Glassine paper, craft paper etc(CAC 1983)

In the chemical method of food preservation method, different chemicals are used for preservation of foods (Guynot ME, Ramos AJ, Sanchis V, Mains S 2005). Not all the chemicals can be used for the preservation of foods. According to FDA standards a chemical can be used for food preservation if it satisfies the following requirements.

a) The preservative should not have any toxic or poisonous effects on the humans.
b) It should not alter the condition of the food.
c) It should not have any carcinogenic effect on humans.
d) It should be effective at lower concentrations.
e) It should have a longer effect.

Mostly the Organic acids are commonly employed for food preservation. Citric acid is used as preservative in soft drinks. Vinegar is as preservative in Pickles. Sorbic acid is used in the preservation of Bread. Propionic acid is used as a preservative in Cheese. Benzoic acid is used as a preservative in Jams, Jellies etc.

Apart from these some other chemicals are also widely employed in food preservation.eg; Nitrates are used in the preservation of meats. Sulphur dioxide and sulphites are used for the preservation of wine and fruit juices.

Smoking is considered to be effective in the preservation of Meat, fish. The practice of exposing fish products to smoking has been practiced for many years. Smoking generates antimicrobial compounds such as cresols.

Salting

High salt concentration has reported to inhibit the growth of microorganisms. The application of salt on fish, meat has proved to be effective in preventing the spoilage. The use of high salt concentration in pickles is an effective preservative method.

Fermented foods as compared to the normal foods have longer shelf life, owing to the metabolic activities of the fermenting microorganisms resulting in the products such as acids, alcohols, amines etc which prevent the growth of spoilage causing microorganisms.eg; Beer, Wine, Curd, Pickles etc.

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