

A study material for M.Sc. Biochemistry (Semester: IV)
Students
on the topic (EC-1; Unit IV)

Spoilage of Common Foods

The process of degradation of food due to
Microorganisms

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Spoilage of common foods

Food spoilage means that the original food nutrition, texture, flavour, color etc. are lost and food becomes unsuitable and harmful for consumption. It is a process in which food deteriorates to the point in which its quality of edibility reduces.

Relevance of the study

The ever increasing global population result in increased demand of good quality and safe food for healthy living. However, food spoilage is a deterrent which is also a factor leading to food insecurity in various regions of world. It results in economic loss to both producers and consumers. A report from Food and Agriculture Organisation of United Nations has stated that one third of food produced for human consumption is either spoiled or wasted. The second sustainable developmental goal (goal-2:zero hunger) aims to end hunger. Food spoilage, therefore, constitutes a global problem that requires attention and study.

Among the various causes microbes which are ubiquitous are one of most concerned common cause of food spoilage. As they are unseen by naked eye except molds, colonization of exposed food by bacteria and yeasts remain unnoticed.



Fig 1. some spoiled foods.

Effects of food spoilage

Changes in nutritional value

- Decomposition of proteins, carbohydrates, vitamins.

Changes in organoleptic features

- Color, flavour, taste, unpleasant odour or smell.

Injurious effects

- Toxins, biogenic amines
- Metabolites of microbes
- Pathogen microbes

Spoilage signs and symptoms

When microbes manifest on food they become apparent and can be detected by undesired sight, smell, touch changed color and odor etc.

- **Odour**- Foul smell due to putrefaction. Off flavors.
- **Slimy texture on food** - Occurs primarily due to surface accumulation of microbial cells.
- **Discoloration**- blue or green spots on fruits and cheese (due to mouldy growth)
- **Souring-production of acid**. E.g. sour milk due to production of lactic acid.
- **Gas formation**-Meat becomes spongy, swelling or bubbling of canned packages.

Classification of food spoilage

- **Perishable food**-spoils readily without preservation methods(milk, fish, meat, eggs etc.)
- **Semi-perishable foods**-Remain unspoiled for longer periods(potato, apples etc.)
- **Non-perishable foods**- they are stable food and can be stored without preservation methods (sugar, flour, dry beans etc.)

Main causes of food spoilage:

It can be result of natural decay or contamination by microorganisms.

1. Physical factors

- Temperature, **aw**, mechanical effects.
- Inappropriate handling, storage and transport

TABLE- I Water activity of some foods of plant origin.

Foods	Water activity
Fruit and vegetables	0.97- 0.98
Bread	0.96-0.97
Fruit Jam	0.82 - 0.94
Flour, rice, bean and peas	0.80 - 0.87
Stewed fruits	0.60 - 0.65
Pastes, spices	0.20 - 0.60

Source: www2.univet.hu/sc1/feltoltott/428_1306839856.doc

TABLE-II Minimum water activity requirement of some organisms

Group of microorganism		Minimum a_w
Bacteria	Most Gram-negative	0.97
	Most Gram-positive	0.90
	Halophilic	0.75
Yeasts	Most yeasts	0.88
	Osmophilic	0.62
Fungi	Most filamentous	0.80
	Xerotolerant	0.71
	Xerophilic	0.61

Source: www2.univet.hu/sc1/feltoltott/428_1306839856.doc

TABLE –III Minimum water requirement of some spoilage fungi

Group	Species	Minimum a_w
Field fungi	<i>Fusarium culmorum</i>	0.89
	<i>Fusarium graminearum</i>	0.89
	<i>Alternaria alternate</i>	0.88
	<i>Cladosporium herbarum</i>	0.88
Storage fungi	<i>Penicillium aurantiogriseum</i>	0.82
	<i>Penicillium brevicompactum</i>	0.80
	<i>Aspergillus flavus</i>	0.78
	<i>Aspergillus candidus</i>	0.75
	<i>Eurotium amstelodami</i>	0.71
	<i>Willemia sebi</i>	0.69

Source: www2.univet.hu/sc1/feltoltott/428_1306839856.doc

2. Biological factors

- Microbiological (Bacteria, yeasts, moulds)
- Macrobiological Parasites, insects, birds, rodents damage.

3. Chemical, Biochemical factors:

- **Enzymatic changes**
 - Enzymatic changes involving oxygen \Rightarrow oxidation process(e.g. rancidity of fats and oils)
 - Activity of endogenous tissue enzymes(foods of animal or vegetable origin)

In pasta, the yellow color is related to the carotenoid content and the level of lipoxygenase activity of semolina. The red component is instead the result of Maillard reaction during drying. Finally, brownness depends on phenolics and PPOs.

Non enzymatic reactions. The Maillard Reaction (browning) is a type of non –enzymatic browning which involves the reaction of simple sugars (carbonyl groups) and amino acids (free amino groups). Non–enzymatic browning causes spoilage during the storage of dry milk, dry whole eggs and breakfast cereals.

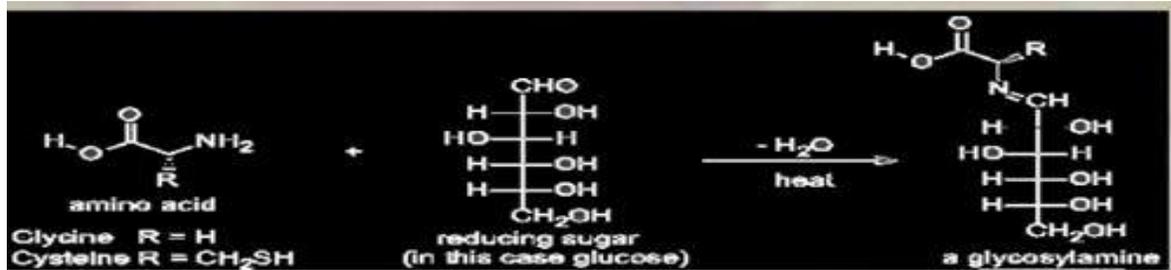


Fig. 2. Non enzymatic chemical change.

- **Rancidity:** Rancidity is the development of unpleasant smells in fats and oils, which are often accompanied by changes in appearance and texture.

Two types of rancidity:

- Hydrolytic rancidity
- Oxidative rancidity (Auto- oxidation)

Factors affecting spoilage (fig-3) The genesis of association is influenced by Extrinsic , intrinsic and implicit parameters

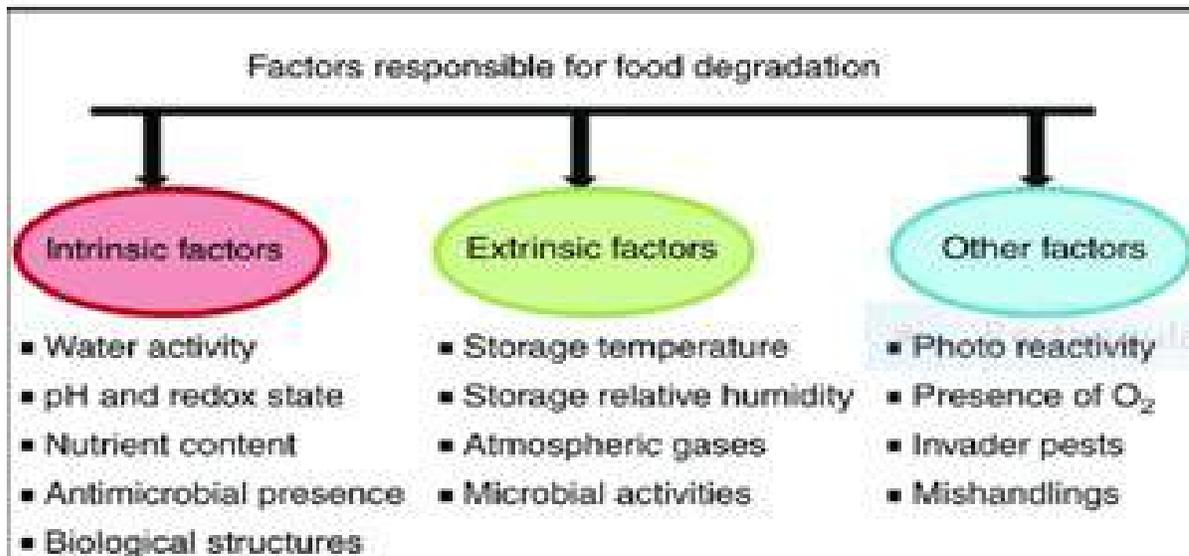


Fig.3. Different factors affecting spoilage

(1) **Extrinsic factors** External factors that affect microbial growth in foodstuffs. They include:

- Temperature, relative humidity, atmosphere composition of gases.
- Processing effects.
- Hygiene, cleaning ,disinfections.
- Microbial activities

(2) **Intrinsic factors:** They are inherent in foodstuffs. They include:

- Physical-chemical properties: **a_w**, redox state, Hydrogen ion concentration(pH), Moisture content, antimicrobial substances.
- Chemical composition: Nature of nutrient content, vitamins, inhibitors.
- Biological structure
- Antimicrobial presence.

Hydrogen ion concentration (pH)- It has been well established that most organisms grow best at pH values around 7.0

(6.6-7.5), while few below 4.0. Bacteria tend to be more fastidious in their relationship to pH than molds and yeasts. With respect to pH minima and maxima of microorganisms. **Fig 4** is a tentative value which can fluctuate in relation with other growth parameter.

TABLE 34

Product	pH	Product	pH
Vegetables		Fruits	
Asparagus (boiled and stalks)	5.7-6.1	Apples	3.9-3.3
Beans (string and Lima)	4.6 & 5.5	Bananas	4.5-4.7
Beets (sugar)	4.7-4.4	Figs	3.9
Broccoli	6.5	Grapefruit (juice)	1.8-2.0
Brussels sprouts	6.3	Limes	6.2-6.7
Cabbage (green)	5.4-6.0	Melons (iceberg)	3.6-4.3
Carrots	4.9-5.2; 6.0	Oranges (juice)	2.8-4.6
Cauliflower	5.6	Pineapples	3.2-3.6
Celery	5.7-6.0	Watermelons	3.4-4.5
Corn (sweet)	7.3	Citrus	
Eggplant	4.5		
Lettuce	6.0		
Onions	3.6-3.8		
Onions (red)	5.3-5.8		
Parsley	5.7-6.0		
Parsnip	5.3		
Potatoes (tubers & sweet)	5.3-5.6		
Pumpkin	4.8-5.2		
Rhubarb	3.1-3.4		
Squash	5.5-6.0		
Squash	5.0-5.4		
Turnips (whole)	4.2-4.3		
Turnips	5.2-5.5		

Fig.4. approximate pH growth ranges of some food spoilage organisms.

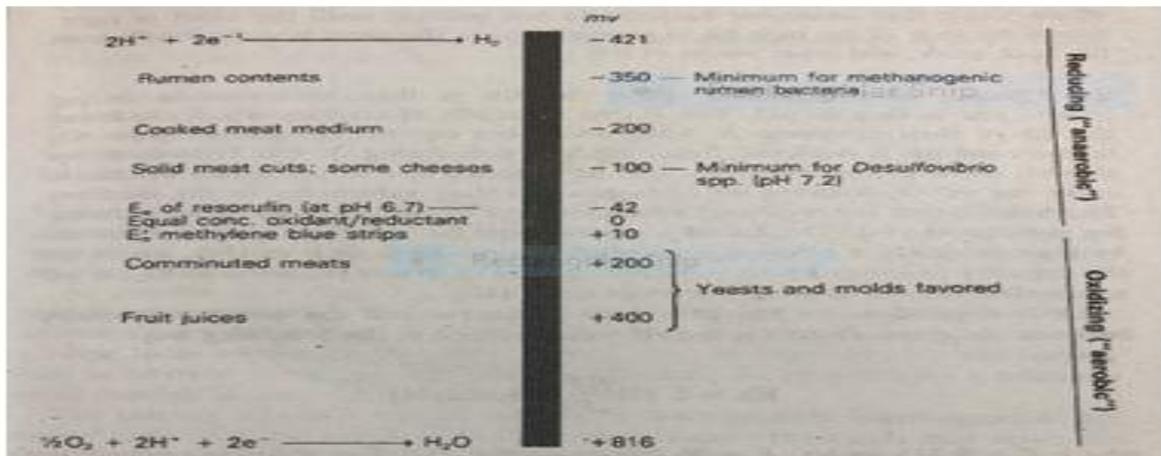


Fig . 5.- Approximate pH values of some fruits and vegetables

Product	pH	Product	pH
Dairy products		Fish and shellfish	
Butter	6.1-6.4	Fish (most species)*	6.6-6.8
Buttermilk	4.5	Clams	6.5
Milk	6.3-6.5	Crabs	7.0
Cream	6.5	Oysters	4.8-6.3
Cheese (American mild and cheddar)	4.9, 5.9	Tuna fish	5.2-6.1
Meat and poultry		Shrimp	6.8-7.0
Beef (ground)	5.1-6.2	Salmon	6.1-6.3
Ham	5.9-6.1	White fish	5.5
Veal	6.0		
Chicken	6.2-6.4		

*Just after death.

Fig.6 –Approximate pH values of Dairy, Meat, Poultry and Fish products

Water activity (aw)- Water requirement of organism is defined in term of water activity(aw)It is defined as water vapor of food substrate to vapor pressure of pure water at same temperature. p/p_0 . This is related to relative humidity (R.H). $R.H=100 \times aw$. Pure water has aw of 1.0, NaCl solution has aw of 0.86. Bacteria (gram positive require aw of 0.91, gram negative need higher aw than gram positive, spoilage molds as low as 0.85, as such yeasts and mold grow over wider range of aw compared to bacteria.

Oxidation reduction potential (O/R,Eh): O/R potential of a substrate is the ease with which the substrate loses or gains electrons. When an element or compound loses electrons, the substrate is said to be oxidized, while the substrate which gains electrons becomes reduced. Aerobic microbes require positive Eh values (oxidized) for growth eg. *Bacillus*, while anaerobes require negative Eh values (reduced) eg. *Clostridium* Eh about -200mv. When an electron is transferred from one compound to another, a potential difference is created between two compounds. This difference is measured and expressed as millivolts(mv).

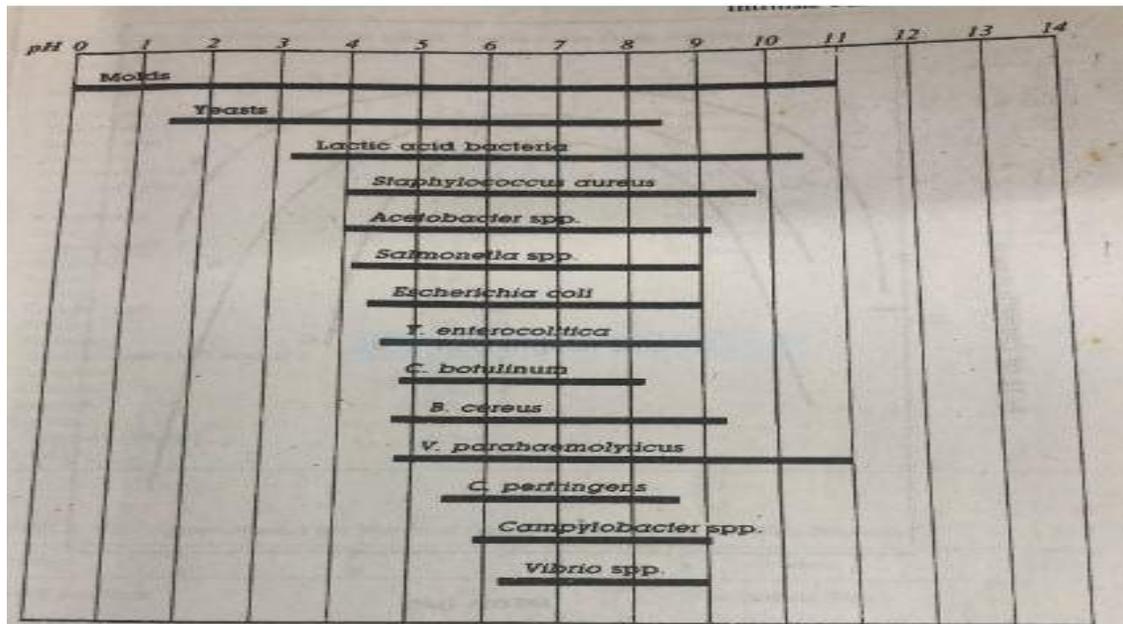


Fig.7 Schematic representation of oxidation reduction potentials relative to the growth of certain microorganism

(3) Other factors

- Photo reactivity
- Presence of oxygen
- Invader pests
- Mishandling
- Reproductive potential

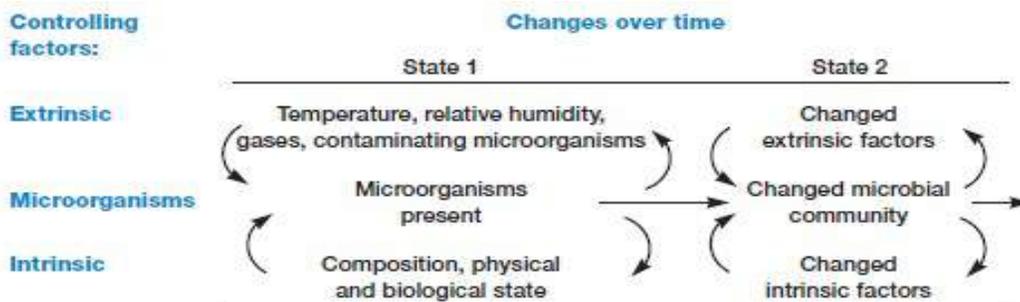


Fig 8: A variety of intrinsic and extrinsic factors can influence microbial growth in foods. Time related successional changes occur in the microbial community and the food.

Spoilage of various food commodities

▪ **Cereal and its products:**

Cereals are one of the most important sources of food (FAO, 2002) . Cereals are important in human nutrition as a source of protein, dietary fiber, and carbohydrates, as well as providing

such as, magnesium, zinc, and micronutrients E and B complex –vitamins. Some common cereals are: corn (maize), wheat, barley, rice, oats, rye etc. ♦ Cereal products derived from cereal grains such as wheat, rye, and oat flours and semolina, cornmeal, corn grits, doughs, breads, breakfast cereals, pasta, snack foods, dry mixes, cakes, pastries, flour dough and tortillas. Toxigenic fungi are a major problem in cereal crops as they produce a multitude of toxic metabolites contaminating plants and food products.

- Common phytogetic microorganisms include bacteria (e.g. Pseudomonadaceae, Micrococcaceae, Lactobacillaceae and Bacillaceae), yeasts (e.g. Candida, Cryptococcus, Pichia, Sporobolomyces, Rhodotorula, Trichosporon) and filamentous fungi (e.g. Alternaria, Aureobasidium, Cladosporium, Epicoccum, Fusarium, Helminthosporium, Claviceps). Additionally, potential secondary infections can occur post-harvest. Common microorganisms infecting grains in storage include xerophilic *Aspergillus glaucus* group, and *Penicillium* spp., where the most important parameter for mould germination is the minimum aw of 0.68 (14% moisture) High incidence of mycotoxin infections in cereals have been observed worldwide. • Mycotoxins, such as Fusarium toxins, Alternaria toxins, and the ergot alkaloid groups, are common contaminants of cereal grains

MILK AND MILK PRODUCTS

- Milk contains few bacteria when it leaves the udder of healthy cow. Contamination starts from the animal especially the exterior of the adjacent areas. Bacteria found in manure, soil & water may enter from this source. Microorganisms from milking machine, when milking by hand, contamination from dairy utensils & milk contact surfaces like milk oil or milking machines, bulk milk cooler. Hands & arms of the milker, flies, the air around milk parlor. Other sources tanker-truck, transfer pipes, sampling utensils separators, homogenizers, coolers, glass bottles.

Milk is highly perishable food. Milk is an excellent culture medium for many kinds of microorganisms. Spoilage occurs when microorganisms degrade carbohydrates, proteins, fats of milk and produce spoilage. The genera found in cold stored milk include, *Alcaligenes*, *Acinetobacter*, *Aerobacter*, *Alcaligenes*, *Flavobacterium* as well as some members of *Enterobacteriaceae*.

MILK PRODUCTS

Microbial spoilage occurs quite readily in dairy products like butter, milk, cream, cheese. Milk is an excellent medium for a variety of microbial spoilage. Fresh as well as refrigerated raw milk contains several bacteria belonging to the genera of *Streptococcus*, *Leuconostoc*, *Lactobacillus*, *Pseudomonas*, *Bacillus*, *Microbacterium*, *Propionibacterium*, *Micrococcus*, etc.

Spoilage type	Organisms involved	Signs of spoilage
Souring	<i>Lactobacillus sp.</i> <i>Streptococcus sp.</i>	Sour milk, Curd formation
Proteolysis	<i>Pseudomonas sp.</i> , <i>Bacillus sp.</i> , <i>Bacillus subtilis</i> , <i>B. cereus var. mycoides</i> , <i>Pseudomonas putrefaciens</i> , <i>p. viscosa</i> , <i>Streptococcus</i> , <i>liquefaciens</i> , and <i>proteus spp.</i>	Bitterness
Sweet curdling	<i>Bacillus sp.</i> <i>Proteus sp.</i> <i>Micrococcus sp.</i>	Alkaline pH Curd formation
Lipolysis	<i>Pseudomonas sp.</i> , <i>Pseudomonas fluorescens</i> , <i>Achromobacter lipolyticum</i> ; yeasts, e.g., <i>Candida lipolytica</i> ; and moulds, e.g., <i>Penicillium spp.</i> , <i>Geotrichum candidum</i> .	Rancid odour
Gas production	<i>Clostridium sp.</i> <i>Coliform bacteria</i> , Certain yeasts, e.g., <i>Torula cremoris</i> , <i>Candida pseudotropicalis</i> , and <i>Torulopsis sphaerica</i>	Gassiness
Ropiness	<i>Alcaligenes sp.</i> , <i>Klebsiella sp.</i> , <i>Enterobacter sp.</i>	Stringy or slimy milk
Red rot	<i>Serratia marcescens</i>	Red coloration

Fig 8: Organisms involved in the spoilage of Milk and Milk products

MEAT

The healthy inner flesh meat contains few or no microorganisms although they have been found in lymph nodes, bone marrow & even flesh. Normal slaughtering practices would remove the lymph nodes from edible parts. Contamination comes from external sources during bleeding, handling and processing. During bleeding, skinning and cutting the main sources of microbes is the exterior of the animals (hide, hoofs and hair) and the intestinal tract.

- Knives, clothes, air, hands and clothing of the workers can serve as intermediate source of containments.
- During handling contamination comes from cart, boxes, and contaminated meat, from air and from personals.
- Grinders, sausages stuffers, slicing, casing and ingredients are the sources.

PRODUCT	MICRO-ORGANISMS ISOLATED
FRESH & REFRIGERATED MEAT	BACTERIA:- <i>Pseudomonas</i> , <i>Aeromonas</i> , <i>Micrococcus</i> , & <i>Alcaligenes</i>
	MOLDS:- <i>Cladosporium</i> , <i>Geotrichum</i> , & <i>Mucor</i>
	YEASTS:- <i>Candida</i> , <i>Torulopsis</i> , & <i>Rhodotorula</i>
PRECESSED & CURED MEATS	BACTERIA:- <i>Lactobacillus</i> & other lactic acid bacteria, <i>Bacillus</i> , <i>Micrococcus</i> , & <i>Staphylococcus</i>
	MOLDS:- <i>Penicillium</i> , <i>Aspergillus</i> , <i>Rhizopus</i>
	YEASTS:- <i>Candida</i> , <i>Torula</i> , <i>Torulopsis</i>

Fig 9: Microbes isolated from Spoiled meat

Micro flora coming from the animal's lymph nodes, intestinal tract, hide, processing equipments, cause fresh meat to spoil. In meats microbial spoilage occurs due to bacteria from internal sources such as *Mucor*, *Rhizopus* and *Thamnidium*. they produce whiskers on beef, *Penicillium* produces green patches, *Clostridium* causes black spots.

Meat is one of most perishable foods. Thus its preservation is very difficult. Raw meat is subjected to change by its own enzymes and by microbial actions and its fat may be oxidised chemically. microbe contamination varies in aerobic and anaerobic conditions.

FRUITS AND VEGETABLES

· Spoilage occur during storage, transportation while waiting to be processed, washing, mechanical damage, processes such as trimming, peeling, cutting, coring add to contamination.

Diseases in fruits and vegetables are generally caused because of microbial spoilage. Bacterial soft rot commonly occurring in fruits is due to the *Erwinia carotovora* and *P. marginalis*. These microbes break down the pectin thereby giving rise to soft, mushy consistency with a bad odour and a water-soaked appearance. Vegetables, for example carrot, celery, beet, garlic, onion, potato, cabbage, tomato, watermelon are affected by this disease.

Watery soft rot of vegetables or sour rot is caused by *Geotrichum candidum*. It occurs in vegetables like bean, carrot, lettuce, cabbage, onion, garlic, radish. Similarly *Rhizopus* soft rot is caused by *R. Stolonifer* in vegetables like cabbage, cucumber, pumpkin, carrot, radish and watermelon, thereby making them soft and mushy. Other important microbes causing diseases in the vegetables are bacterial blight of celery, black rot of cabbage and cauliflower, ring rot of potato, bacterial speck of tomatoes etc

Sr. No.	Type of spoilage	Spoilage Microorganism
1.	Bacterial soft rot	<i>Erwinia caratovora, Pseudomonas sps</i>
2.	Gray mold rot	<i>Botrytis cinerea</i>
3.	Rhizopus soft rot	<i>Rhizopus nigricans</i>
4.	Anthrachose	<i>Collectotrichum lindemuthianum</i>
5.	Alternaria Rot	<i>Alternaria tenuis</i>
6.	Blue mold rot	<i>Penicillium digitatum</i>
7.	Downey mildew	<i>Phytophthora bremia</i>
8.	Watery soft rot	<i>Sclerotinia sclerotiorum</i>
9.	Stem end rots	<i>Alternaria, Phomopsis, Fusarium</i>
10.	Black mold rot	<i>Aspergillus niger</i>
11.	Black rot	<i>Alternaria, Ceratostomella, Physalospora</i>
12.	Pink mold rot	<i>Trichothecium roseum</i>
13.	Fusarium rots	<i>Fusarium sps</i>
14.	Green mold rot	<i>Cladosporium, Trichoderma</i>
15.	Brown rot	<i>Sclerotinia</i>
16.	Sliminess	<i>Saprophytic bacteria</i>

Fig 10: Microorganisms involved in the spoilage of Fruit and Vegetables

Spoilage of fishes and other sea-foods-

Fish is highly perishable due to :high moisture content,ambient temperature, availability for growth of microorganisms.



Fig 10: Microorganisms involved in the spoilage of Fish and Sea products

Microbial flora of living fish depends on the water in which they live. Slime on the outer surface of fish contains *Pseudomonas*, *Acinetobacter*, *Moraxella*, *Alcaligenes*, *Micrococcus*, *Flavobacterium*, *Corynebacterium*, *Sarcina*, *Serratia*, *Vibrio* and *Bacillus*.

Bacteria on fish from northern waters are mostly psychrophils, where as fish from tropical water are mesophiles: they have bacteria like *Aeromonas*, *Lactobacillus*, *Brevibacterium*, *Alcaligenes* and *Streptococcus*. Intestine of fish from both the sources includes bacteria of genera *Aeromonas*, *Lactobacillus*, *Brevibacterium*, *Alcaligenes*, *Pseudomonas*, *Flavobacterium*, *Vibrio*, *Bacillus*, *Clostridium* and *Escherichia*.

Salt Fish (Marine Fish) have Halophilic bacteria, such as , *Serratia*, *Micrococcus*, *Bacillus*, *Alcaligenes*, *Pseudomonas* and others. These bacteria cause discolorations, a red colour being common.

Molds are the chief spoilage organisms on smoked fish. Marinated (sour pickled) fish should present no spoilage problems unless the acid content is low enough to permit growth of Lactic Acid bacteria or the entrance of air permits mold growth.

Thanks
