COURSE TITLE: FOOD AND INDUSTRIAL MICROBIOLOGY
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MICROBIAL SPOILAGE OF CEREALS AND BAKERY FOODS

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Primary sources of microorganisms

- Soil and water
- Plant and plant products
- Food utensils
- Gut of animals and humans
- Food handlers
- Animal hides
- Air and dust
- Animal feeds

Roles of microorganisms found in food

- Spoilage, fermentation, food production.
- Microorganisms are used in brewing, winemaking, baking, pickling and other food-making processes.
- They are also used to control the fermentation process in the production of cultured dairy products such as yogurt and cheese. The cultures also provide flavour and aroma, and inhibit undesirable organisms.

What is 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 becomes reduced

- Any change which renders a product unacceptable for human consumption.

- Spoilage is a complex event in which a combination of microbial and biochemical activities may create abnormal end products.

- One of the major reason that led to preservation.

Microbial growth in food depends on
-Characteristics of a product
-The way processed
-The way stored
-Modes of preservation and processing
Factors affecting growth -Intrinsic parameters -Extrinsic parameters

Pre-harvest

- climatic factors
- environmental conditions
- field microflora (mostly Gram-negative bacteria; "field" fungi - *Alternaria* and *Fusarium* spp.)

Harvesting

- contaminated equipment
- unsanitary handling
- harvesting after rainfall
- grain damage at harvest
- inefficient pre-drying

Transport

- contaminated equipment
- unsanitary handling

Storage and processing

- poor storage hygiene
- birds, insects and rodents contamination
- storage microflora (mostly spore-forming and lactic acid bacteria; "storage" fungi - *Aspergillus* and *Penicillium* spp.)

Major Quality-Loss Mechanisms

Microbiological	Enzymatic	Chemical	Physical	Mechanical
Microorganism growth	Browning	Color loss	Collapse	Bruising due to vibration
Off-flavor	Off-flavor	Flavor loss	Controlled release	Cracking
Toxin production	Color change	Non-enzymatic browning	Crystallization	Damage due to pressure
		Nutrient loss	Recrystallization	
		Oxidation-reduction	Phase changes	
		Rancidity	Flavor encapsulation	
			Shrinkage	
			Transport of component	

Spoilage Factors

The grains are having low moisture content due to this they are less susceptible to spoilage and have higher shelf-life. The spoilage mainly occurs due to fungal growth when food is stored at high temperature and high humidity. Before packaging the whole grains should be properly fumigated to reduce microbial load and increases the storage life. The factors influencing the quality of cereals are:

Moisture content above 12 to 13 percent may cause spoilage problem in cereals.

Low moisture grain showed molds growth and high moisture content in food may cause growth of yeasts and bacteria.

Total no of microbial load, physical damage and temperature of storage

Aspergillus, Penicillium, Mucor, Rhizopus, Fusarium are some common molds : produce mycotoxin.

Lactic acid bacteria, Coliform, Acetobacter spp, Micrococci and Bacillus are some species responsible for causing spoilage

Mojor group of microorganisms and the characteristics of spoilage

	Spoilage Agents	Properties of Colony
Moulds	*Penicillium* spp.	Blue/green, flat, spread rather slowly
	Aspergillus niger	Black, fluffy, spreading with sporeheads often clearly visible
	Aspergillus flavus	Olive green
	Aspergillus candidus	Cream
	Aspergillus glaucus	Pale green
	Cladosporium spp.	Dark olive green, flat, spread slowly
	Neurospora stophila	Salmon pink, fluffy and fast spreading
	Rhizopus nigricans	Grey/black, very fluffy and fast spreading
	Mucor spp.	Grey
Bacteria	*Bacillus subtilis* or *Bacillus licheniformis*	Irregular shape, white and dull colour
Yeasts	*Hyphopichia burtonii*	Slow growth on bread surface, low, white, spreading colonies
	Pichia anomala	
	Scopsisfi buligera	
	Pichia burtonii	Very fast growth on bread
	Zygosaccharomyces bailii	Smooth, round, convex and white to cream coloured
	Torulaspora delbrueckii	
	Pichia membranifaciens	
	Candida parapsilosis	

Spoilage by molds

Molds ➡ major spoilage problem in bakeries ➡ losses of raw materials and end products.

Molds favor the presence of water bakery products with a high water activity (a_w) level such as bread, cakes and creams.

Spoilage types for typical bakery products *Rhizopus stolonifera*

Rhizopus nigricians is probably the most well-known mold causing spoilage type in bread called‘bread mould’. It grows at a water activity (a_w) of 0.91 or higher and can be recognized by its black sporangium, where spores are formed.

Penicillium and *Aspergillus* are well-known species produces mycotoxins (e.g. Ochratoxin that damages kidney and liver). They are also frequently used in the development of medicine or food additives (e.g. enzymes). *Penicillium cycolium* is the most common type of *Penicillium* species found in bakery products and can produce Penicillic acid above a water activity of 0.87, while the mould can already grow at a water activity (a_w) of 0.80 or higher.

Water activity level and the spoilage types

Water activity (a_w)	Products	Spoilage types
0.99	Moist cakes (e.g. carrot cake)	Moulds and yeast, bacterial spoilage (e.g. "rope")
0.97 - 0.90	Plain cakes	Moulds and yeast
0.95 - 0.90	Moist cakes (e.g. carrot cake)	Moulds and yeast, bacterial spoilage (e.g. "rope")
0.89 - 0.80	Plain cakes	Moulds and yeast
0.79 - 0.70	Fondants, fruited cakes	Osmophilic yeasts, xerophilic moulds and osmophilic yeasts
0.69 - 0.60	Some dried fruits, heavily fruited cakes	Specialized xerophilic moulds and osmophilic yeasts, sugar-tolerant yeasts
< 0.6	Biscuits, chocolate, some dried fruits	No microbial spoilage

Some important spoilage defects of bread are because of the growth of overgrowth of different moulds, mos and yeast as follows-

Green spored mold	--	*Penicillium expansum*
Bread mold	--	*Rhizopus stolonifer*.
White cottony mycelium and black spots		
Red bread mold	--	*Neurospora sitophila*
Ropiness of homemade Breads	--	*Bacillus subtilis (Bacillus mesentericus).*
Ropyness	--	*due to hydrolysis of flour protein by proteinase of the bacillus and capsulation of bacillus*
Chalky bread	--	chalk like white spots due to yeast like fungi *Endomycopsis fibuligera* and *Trichonospora variable*
Red bread	--	Pigmentation by Serratia marcescens.

Spoilage by bacteria

Bacteria also have a potential to contaminate baked products. The spores of *Bacillus subtilis* for example are heat resistant and will not be killed by the baking process. Several *Bacillus* species can contribute in the process that makes bread "ropy" like *Bacillus cereus*. Warm humid conditions are perfect for the spores to germinate and grow, forming the characteristic stringy brown mass with the odor of fruit. This microorganism has also been implicated in food poisoning outbreaks from cream filled bakery products.

Food poisoning is caused by the fact that *Staphylococcus aureus* produces enterotoxins under appropriate conditions. Other bakery ingredients, such as egg (products), chocolate, desiccated coconut and cocoa powder were found to be contaminated with *Salmonella*.

Salmonella is part of the enterobacteria family, same as *Escherichia Coli*, These bacteria can live with or without the present of oxygen. *Salmonella* and in particular *E.coli* can cause big complications in small quantities, due to the Shiga toxin production, mainly related to *E. coli*. This toxin can lead to thrombosis, destruction of red blood cells and kidney failure·

Spoilage by yeasts

Next to molds and bacteria, yeast also involved in the spoilage of bakery products.

Problems caused by yeasts can be divided into two types.

The first type are visible yeasts which grows on the surface of the bread in white or pinkish patches. Surface spoilage on bread is mainly caused by *Pichia burtonii*,
whereby white spots are visible leading to the term "chalk" bread.

In order to manage microbial growth and (post-baking) contamination is the main concern for retaining bread quality and it is important to have a good quality control system. The next steps to minimize the spoilage by adopting strategies to prevent contamination, destruction or entry of contaminants and ways to control the growth of contaminants should be known to operating personals.

In cereal grains loss in quality and quantity during storage is caused by

- Fungi
- Insects
- Rodents
- Mites Fungi (molds)

are the major cause of spoilage in grain.

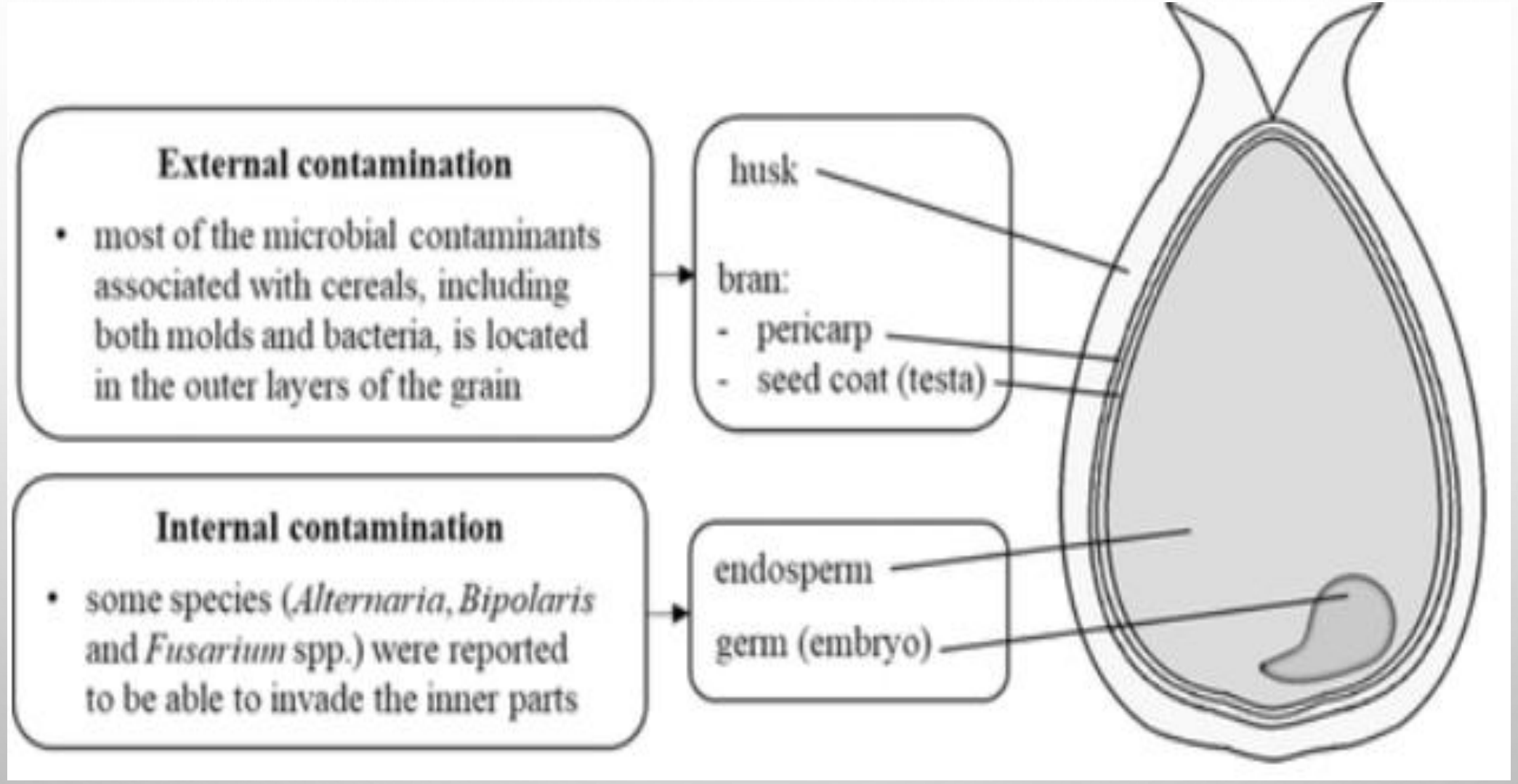
Fungi impair feed quality in at least two ways :

- They may alter the nutritional quality of feeds by destroying important nutrients such as vitamins.
- They may produce mycotoxins that are harmful to animals.

Losses caused by fungi in cereal grains are related to

- Decrease in germination
- Heating and mustiness
- Possible production of toxins
- Discoloration of the seed
- Biochemical changes
- Loss in dry matter

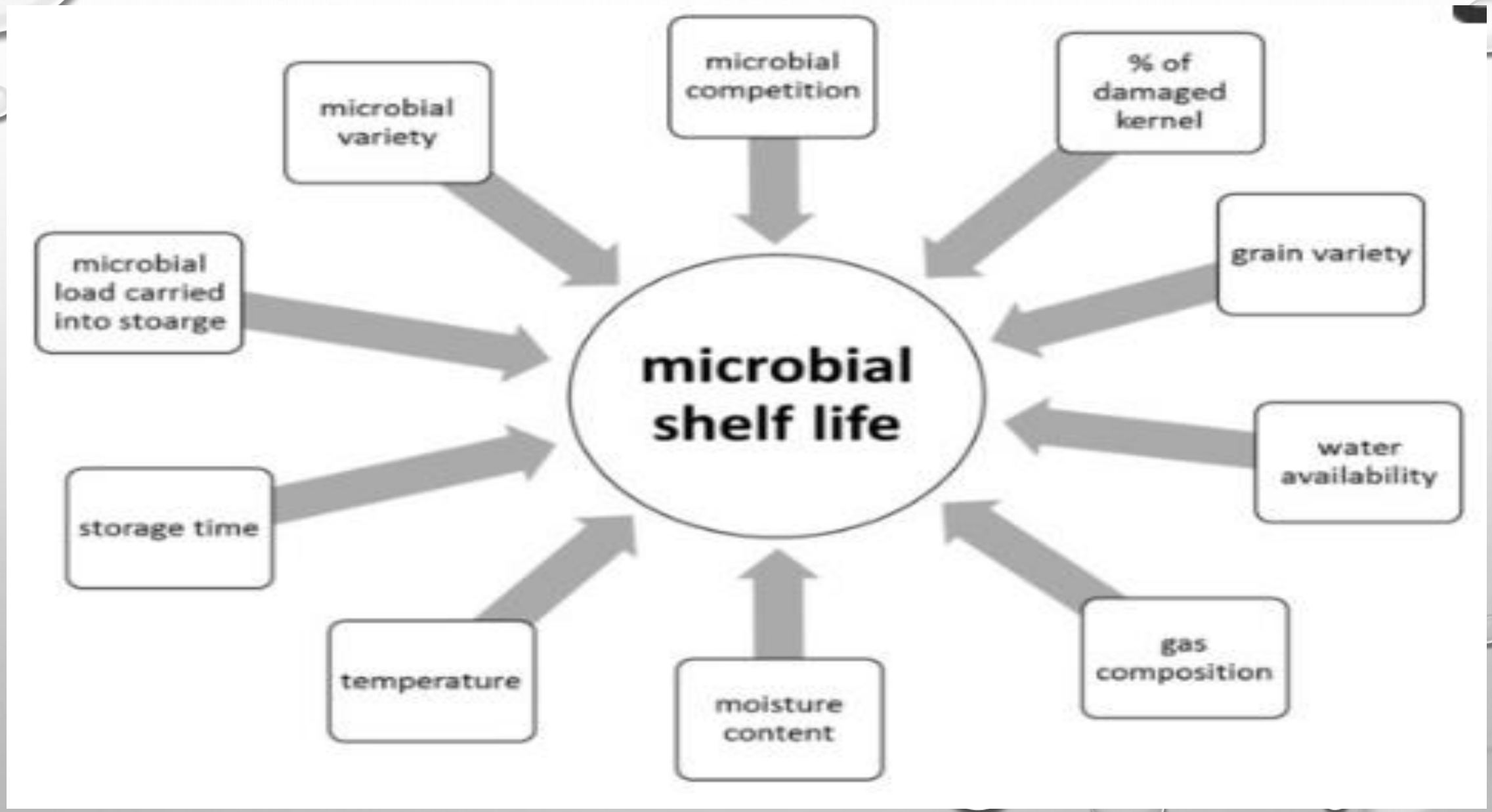
Microbial contamination within a cereal grain



Current methods and technologies used for cereal grains preservation

Method/technology	Description	Limitation
Pesticides	Chemicals designed to prevent and control the occurrence of pests causing harm to crops - molds (fungicides), weeds (herbicides) and insects (insecticides)	• High environmental impacts • Direct negative impact on human health • Increasing resistance against pesticides
Drying	Grains are dried to a low moisture content	• Lack of uniformity of the process • Over-drying may damage the grains and cause economic losses as well as increase mycotoxin contamination
Chlorine and hypochlorite	Due to their oxidizing capacity, chlorine and hypochlorite treatments are one of the most widely used processes for microbial control	• Low inactivation of fungal spores on cereal grains&&generation of toxic by-products after the treatment
Irradiation	Exposing food to a certain amount of ionizing radiation	• Can negatively modify the quality and technological properties of cereals and cereal products
Ozone	Triatomic oxygen formed by addition of a free radical of oxygen to molecular oxygen	• The cost of treatment can be relatively high due to complex technology

Factors influencing the microbial shelf-life of cereal grains during storage



Aflatoxins are the most widely isolated mold that produced the toxin: *Aspergillus Flavus*. *Aspergillus Flavus* produces Aflatoxin B1 and B2 and will only be formed between a temperature range of 7.5 – 40°C. Substantiated evidence suggests that aflatoxins are carcinogenic, especially in liver where the toxin will first pass after absorption in the intestinal tract.

The exposure risk to human is directly through cereal grains or indirectly through food of animal origin (e.g. milk and eggs).

Tolerable daily intake (TDI) levels are determined on 1.0 µg/kg bodyweight a day. Its adverse effects are nausea, vomiting, headache, dizziness, diarrhea and fever.

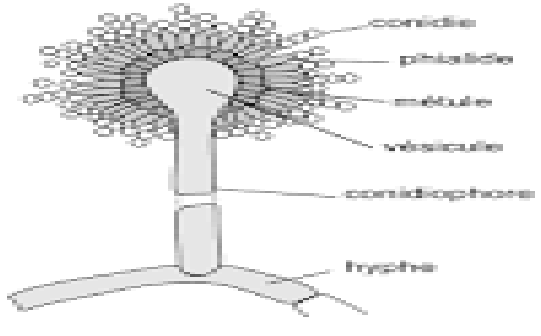
Highest levels were observed in wheat, maize and oat grains and derived products.

Besides the molds that grow at a relatively high water activity, there are molds that can grow in bakery products with a low water activity, such as fruited cakes and fondants, called Xerophilic molds.

Mold spores are generally killed by the baking process. However, no effect observed on mycotoxins formed during cultivation and storage of raw materials. Mycotoxins, are very stable compounds that can resist temperatures between 200-300°C.

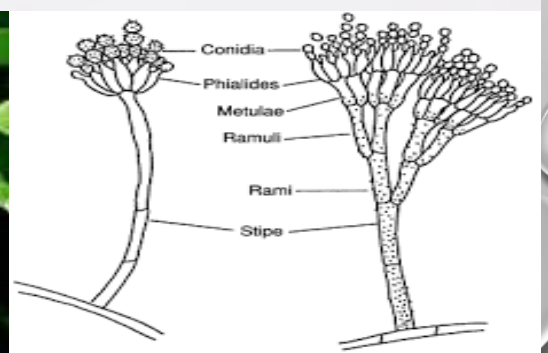
Aspergillus

- Can live in high **osmotic concentration** (high sugar, salt, etc.) environment
- Like highly **aerobic** condition
- Use **carbon-rich substrates**(monosaccharides-glucose, polysaccharide-amylose)
- Live in **starchy foods, plants and trees**
- *Aspergillus* spp. cause disease on many grain crops, especially maize, and some variants synthesize mycotoxins, including **aflatoxin**.
- Aspergillosis (fever, cough, chest pain, or breathlessness-Pulmonary aspergillosis)



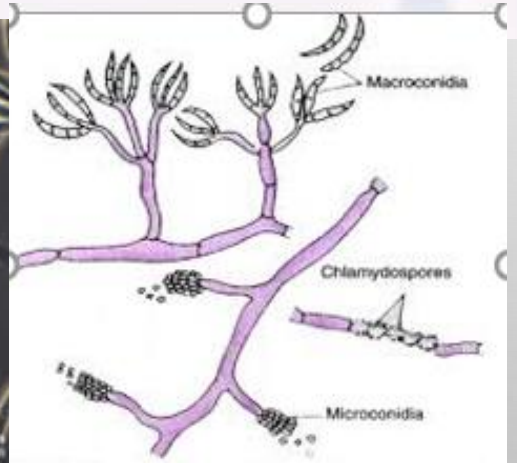
Penicillium

- **Thallus** consists of a **highly branched network** of multinucleate, septate, usually colorless hyphae
- Many-branched **conidiophores** sprout on the mycelia, bearing individually constricted conidiospores.
- The **conidiospores** are the main dispersal route of the fungi, and often are green in color.
- *Penicillium* **growth** can still occur indoors even if the relative **humidity is low.**



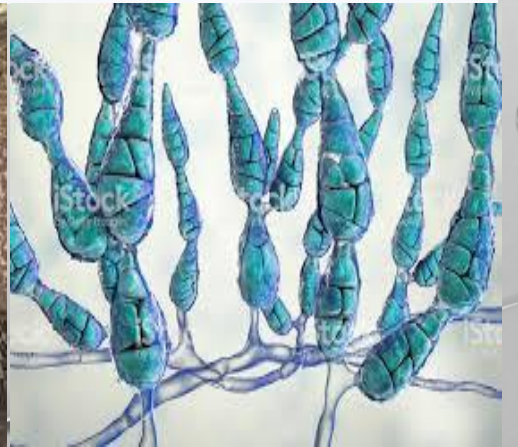
Fusarium

- widely distributed in **soil** and associated with **plants**
- Some **species produce mycotoxins in cereal crops** that can affect human and animal health if they enter the food chain.
- The main toxins produced by these *Fusarium* species are **fumonisins** and **trichothecenes**.



Alternaria

- The club-shaped spores are **single or form long chains**.
- Can grow thick colonies which are usually **green, black, or gray**
- Grow on **skin** and **mucous membranes**, including on the **eyeballs** and within the **respiratory tract**
- **Allergies** are common, but serious infections are rare.
- **Alternariosis**



THANK YOU