MICROBIAL SPOILAGE OF VEGETABLES

Introduction

Vegetables form an integral part of diet due to their role in providing various types of vital nutrients such as carbohydrates, minerals, vitamins, roughage etc. Vegetables being a part of fresh produce, contain high moisture which makes them highly perishable foods and hence more prone to spoilage. Microorganisms gain entry into vegetables from various sources. These sources include:

- Soil
- Water
- Diseased plant
- Harvesting and processing equipments
- Handlers
- Packaging and packing material
- Contact with spoiled vegetables

The conditions in which vegetables are stored and transported after harvesting also contribute to rate of spoilage. Other than microbial, sources, the spoilage of vegetables can also occur due to the activity of native enzymes.

Types of Spoilage in Vegetables

The microbial spoilage of vegetables is predominately of following types Spoilage due to pathogens. The plant pathogens which infect stem, leaves, roots, flowers and other parts or the fruit itself.

Spoilage due to saprophytes

Vegetables have general microflora inhabiting them. These organisms under certain conditions can grow on these vegetables and spoil them. The list of these organisms is given in Table -1.

Table - 1 Normal microflora of vegetables

Bacteria	Fungi
Alcaligens	Alternaria
Bacillus	Aureobasidium
Erwinia	Botrytis
Micrococci	Fusarium
Pseudomonas	Penicillin
Lactic acid bacteria	Rhizopus

There are certain secondary invaders which may enter the healthy food or grow after growth of pathogens. It is well known that plant diseases are mostly caused by fungi. Thus most of the spoilage causing pathogens in vegetables is fungi.

Fungi have specific characteristics when spoiling food as it leads to mushy areas which may be water soaked. The fungi produce characteristic spores which may be pigmented. The pigmentation helps in identification of the type of spoilage by fungi. The bacterial diseases too cause spoilage of vegetables but to a lesser extent.

Table - 2 The major types of spoilages by pathogens in vegetables

Type of Spoilage	Causative organisms	Symptoms
Bacterial soft rot	*Erwinia carotovora* *Pseudomonas marginalis* *Clostridium*	Water soaked appearance, soft-mushy, bad odor
Alternaria rot	*Alternaria tenuis*	Greenish brown to black brown spots
Rhizopus soft rot	*Rhizopus sp*	Cottony mold growth with small black dots
Blue mold rot	*Penicillim digitatum*	Bluish green color
Downy mildew	*Phytophthora, Bremia*	White woolly mass
Black mold rot	*Aspergillus niger*	Brown to black mass, referred as smut
Fusarium rot	*Fusarium*	
Sliminess or souring	*Saprophytic bacteria*	
Stem end rots	*Diplodia* *Alternaria* *Phomopsis*	Involve stem ends
Watery soft rot	*Sclerotenia sclerotinium*	

Spoilage in vegetables is largely affected by composition of vegetable. The non acidic foods are thus spoiled by bacterial rot while acidic foods with dry surfaces are more prone to mold spoilage. The product on which organism grows and types of organisms growing largely determine the character of spoilage.

Bacterial Soft Rot Caused by *Erwinia carotovora* and *Pseudomonas* such as *P. marginalis*. *Bacillus* and *Clostridium* spp. are also implicated.

Breaks down pectin, giving rise to a soft, mushy consistency, sometimes a bad odour and water soaked appearance. Vegetables affected onions, garlic, beans, carrot, beets, lettuce, spinach, potatoes, cabbage, cauliflower, radishes, tomatoes, cucumbers, watermelons.

Soft rot in tomato caused by *Erwinia carotovora*. Blue mould rot in tomato caused by *Penicillium* spp. *Penicillium, Cladosporium, Rhizopus, Aspergillus* spp. are responsible for various defects in vegetables. Gray mold rot – caused by *Botrytis cinera* in vegetables. Favoured by high humidity and warm temperature

Table -3 Examples of fungal spoilage of vegetables

Examples of Commodities Most Affected	**Genus**	**Type of Spoilage**
Most vegetables especially carrot, lettuce, celery, cabbage	*Botrytis*	Grey mould rot
Most vegetables. Especially carrot, lettuce, legumes, *Brassica* spp.	*Sclerotinia*	Watery soft rot
Legumes, carrot, *Brassica* spp.	*Rhizopus*	Soft rot
Tomato, cucumber, asparagus, potato	*Fusarium*	Dry rots
Tomato, potato, carrot	*Phytophthora*	Brown rots (blight)
Tomato, potato, beetroot Cucumber, legumes	*Phoma* *Pythium*	Dry brown, black rots Cottony leak

Some common Fungal Fruit and Vegetable Spoilage Conditions, Etiologic Agents, and Typical Products Affected

Common Fungal Fruit/ Vegetable Spoilage Conditions	Etiologic Agents	Typical Products Affected
Black rot cabbage	*Aspergillus niger, Alternaria*	Onions,
Black rot	*Ceratocystis fimbriata*	Sweet potatoes
Blue mold rot	*Penicillium digitatum*	Citrus fruits
Dry rot	*Fusarium* spp.	Potatoes
Gray mold rot	*Botrytis cinerea*	Grapes, many others
Green mold rot	*Penicillium digitatum*	Citrus fruits
Rhizopus soft rot	*Rhizopus stolonifer*	Sweet potatoes, tomatoes
"Smut" (black mold rot)	*Aspergillus niger*	Peaches, apricots
Sour rot	*Geotrichum candidum*	Tomatoes, citrus fruits

MICROBIAL SPOILAGE OF FRUITS AND FRUIT JUICES

Introduction

Fruits are natural sources of minerals, vitamins besides carbohydrates and other essential substances. Naturally fresh fruits and juices made out of them contain high amount of water thereby making them highly prone to attack by microorganisms. While most of the fruits are naturally provided with coatings and coverings in the form of skins, but these are fragile enough to be easily disturbed by various biological and mechanical factors. Like vegetables, fruits being produce of plants get contaminated through different sources by a variety of microorganisms which may play significant role in their spoilage. These are soil, water, diseased plant, harvesting and processing equipments, handlers, packaging and packing material and contact with spoiled fruits.

Microorganisms Associated with Spoilage in Fruits and Juices

The microorganisms associated with fruits depend on the structure of fruit. The fruits contain different organic acids in varying amounts. **The types of acids which are predominately found are citric acid, malic acid and tartaric acid. The low pH of fruits restricts the proliferation of various types of organisms.** The pH and type of acids found in different fruits is given in Table -1.

Table -1 Type of acid associated with fruits and their pH

Fruit	Type of Acid	pH
Apple	Malic, citric, lactic	3.3–4.1
Watermelon	Citric, malic	5.8–6.0
Banana	Citric, malic, tartaric	4.5–5.2
Grape	Tartaric, malic	3.0–4.5
Plum	Malic, quinic	2.8–4.6
Pineapple	Citric, malic	3.2–4.0
Guava	Citric, malic, lactic	3.0–3.2
Lemon	Citric	2.2–2.4
Mango	Citric, tartaric	3.3–3.7
Orange	Citric, malic	3.0–4.0
Papaya	Citric, malic, ketoglutaric	4.5–6.0

Due to the low pH, a large number of microorganisms are restricted to grow on fruits. Fungi are most dominating organisms to grow on fruits because of the ability of yeasts and molds to grow under acidic conditions. A small number of bacteria which are aciduric (ability to resist acidic conditions) also grow. Also the dry conditions prevailing on the skin and surface do not allow the growth of certain microorganisms. Besides, these plants also produce certain antimicrobial components too.

Despite the high water activity of most fruits, the low pH leads to their spoilage being dominated by fungi, both yeasts and molds but especially the latter.

Yeasts

Yeasts are unicellular fungi which normally reproduce by budding. Of the 215 species important in foods, about 32 genera are associated with fruits and fruit products . Only a few species of yeasts are pathogenic for man and other animals. None of the pathogenic species are common contaminants of fruits and fruit products. Fruit that has been damaged by birds, insects, or pathogenic fungi usually contain very high yeast populations. The yeasts are introduced into the exposed tissue, often via insects and are able to use the sugars and other nutrients to support their growth. Types of yeasts growing in fruits depend upon the nature of the fruit and the strain of yeast. Growth of a strongly fermentative type such as certain strains *of Saccharomyces cerevisiae* may produce sufficient CO2 (90 lb/in. or more) to burst the container,. Growth of some species in a clear fruit juice may produce only slight haze and sediment. While carbon dioxide and ethanol are the predominant metabolic products of yeasts, other products such as glycerol, acetaldehyde, pyruvic acid, and a keto glutaric acid are also formed. Oxidative yeasts such as species of *Brettanomyces* produce acetic acid in wines and other fruit products. Although yeasts produce hydrolytic enzymes which degrade pectins, starch, and certain proteins, enzymatic activity is usually much less than that exhibited by other aciduric microorganisms, molds in particular.

Molds

These are filamentous fungi which are important group of microflora of fruit products due to following reasons

1. Some of the members are xerophilic, thereby having potential to spoil foods of low water activity such as dried fruits and fruit juice concentrates.
2. Some of the species have heat resistant spores such as ascospores which can survive the commercial pasteurization treatments that are given to most fruit products.
3. Growth of molds on processing equipment such as wooden tanks can result in the generation of off flavors in wines, juices, and other fruit products.
4. Mold infected raw fruit may become soft after processing because pectinases were not inactivated by the thermal treatment.

5. The metabolic products of many molds are toxic to humans. Of these toxins, mycotoxins are important components. Molds are aerobic microorganisms, but many of them are very efficient scavengers of oxygen. Due to this property of molds, processed fruits, including those hermetically sealed in cans or glass, are susceptible to spoilage. In case of limited vegetative growth, evidence of spoilage may be the changes produced by fungal enzymes such as the breakdown of starch or pectins while in case of heavy growth, colonies develop in the headspace or as strands throughout a beverage or similar product. *Penicillium italicum* (blue mold) and *Penicillium digitatum* (green mold) seen in oranges, lemons and citrus fruits.

Bacteria

Various groups of bacteria have ability to grow on fruits and its juices. These bacteria by virtue of their diversity in metabolism row on fruits and produce different types of compounds. The major group of bacteria which are involved are:

- Lactic acid bacteria
- Acetic acid bacteria
- Spore formers

Lactic acid bacteria

The lactic acid bacteria are Gram positive, catalase negative organisms which can grow under anaerobic conditions. These are rod shaped (lactobacilli), or cocci (pediococci and leuconostocs). The homo fermentative species produce mainly lactic acid from hexose sugars. The heterofermenters produce one molecule of lactic acid, one molecule of carbon dioxide, and a two carbon compound, which is usually acetic acid or ethanol or a combination of the two.

Growth of lactic acid bacteria in juices and other fruit products cause the formation of haze, gas, acid, and a number of other changes. Certain hetero fermentative lactobacilli lead to slime in cider. The lactobacilli and leuconostocs that are present in citrus juices generate acetyl methyl carbinol and diacetyl compounds that give the juices undesirable, butter milk like flavor. Some strains, being extremely tolerant to ethanol grow in wines. *Lactobacillus fructivorans* can grow in appetizer and dessert wines containing as much as 20% ethanol. Lactic acid bacteria have the ability to decarboxylate malic acid to lactic acid. This malolactic fermentation is often desirable in high acid wines because the acidity is reduced and desirable flavors are produced.

Acetic acid bacteria

These are Gram negative, aerobic rods having two genera, viz. *Acetobacter* and *Gluconobacter*. Both of these species oxidize ethanol to acetic acid under acidic condition, *Acetobacter* species can oxidize acetic acid to carbon dioxide thus, the genus is called as over oxidizer. Because the bacteria are obligate aerobes, juices, wines, and cider are most susceptible to spoilage while held in tanks prior to bottling. Some strains of *Acetobacter pasteurianus* and *Gluconobacter*

oxydans produce microfibrils composed of cellulose, which leads to formation of flocs in different fruit juice beverages.

Spore formers

Spores are heat resistant, so role of organisms producing spores is important in heat treated juices and beverages. Variuos spore formers such as *Bacillus coagulans, B. subtilis, B. macerans, B. pumilis, B. sphaericus* , and *B. pantothenticus* have been found to grow in different types of wines. Some of these organisms have also been involved in canned fruits. Spore forming bacilli that actually prefer a low pH have been responsible for spoilage of apple juice and a blend of fruit juices.