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Intrinsic and Extrinsic Factors that Affect Microbial Growth in Different Foods





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What is Food Spoilage?

Food spoilage is a process or change which renders a product undesirable or unacceptable for consumption. This complex ecological phenomenon is the outcome of the biochemical activity of microbial processes which will eventually dominate according to the prevailing ecological conditions.

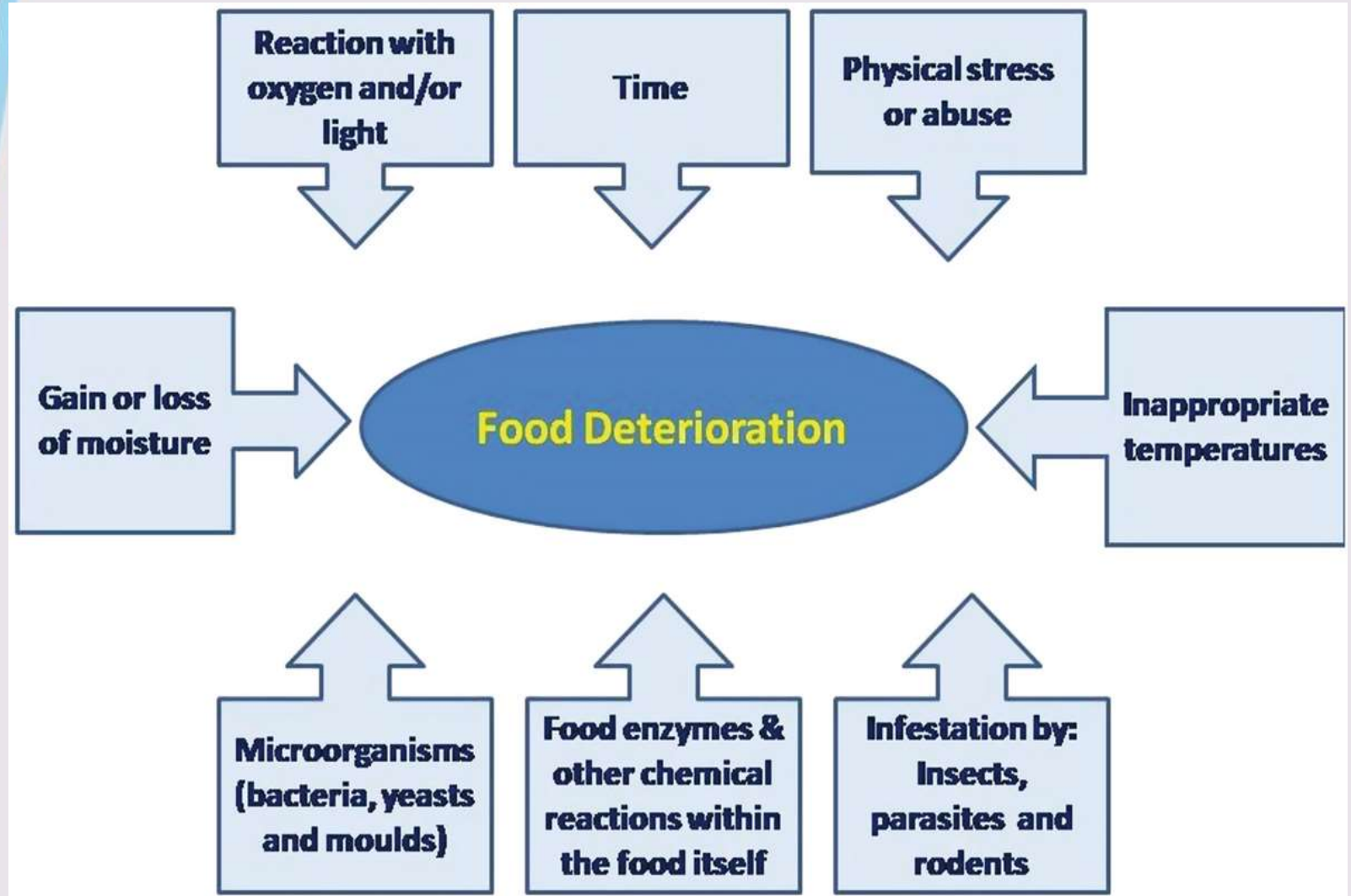




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Major Causes of Food Spoilage





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Primary Sources of Microorganisms in Food

Sources of microorganisms in food

The primary sources of microorganisms in food include:

1. Soil and water
2. Plant and plant products
3. Food utensils
4. Intestinal tract of man and animals
5. Food handlers
6. Animal hides and skins
7. Air and dust



Food	Type of Spoilage	Microorganisms involved
Bread	Mouldy	<i>Rhizopus nigricans</i> <i>Penicillium</i> spp. <i>Aspergillus niger</i>
	Ropy	<i>Bacillus subtilis</i>
Maple sap and syrup	Ropy	<i>Enterobacter aerogenes</i>
	Yeasty	<i>Saccharomyces</i> <i>Zygosaccharomyces</i>
	Pink	<i>Micrococcus roseus</i>
	Mouldy	<i>Aspergillus</i> <i>Penicillium</i>
Fresh fruits and vegetables	Soft rot	<i>Rhizopus</i> <i>Erwinia</i>
	Gray mold rot	<i>Botrytis</i>
	Black mold rot	<i>A. niger</i>
Pickles, sauerkraut	Film yeasts, pink yeasts	<i>Rhodotorula</i>
Fresh meat	Putrefaction	<i>Alcaligenes</i> <i>Clostridium</i> <i>Proteus vulgaris</i> <i>Pseudomonas fluorescens</i>
Cured meat	Mouldy	<i>Aspergillus</i> <i>Rhizopus</i> <i>Penicillium</i>
	Greening, slime	<i>Lactobacillus</i> <i>Leuconostoc</i>
Fish	Discoloration	<i>Pseudomonas</i>
	Putrefaction	<i>Alcaligenes</i>
Eggs	Green rot	<i>P. fluorescens</i>
	Colorless rots	<i>Pseudomonas</i> <i>Alcaligenes</i>
	Black rots	<i>Proteus</i>
Concentrated orange juice	"Off" flavor	<i>Lactobacillus</i> <i>Leuconostoc</i> <i>Acetobacter</i>
Poultry	Slime, odor	<i>Pseudomonas</i> <i>Alcaligenes</i>

Microorganisms involved in food spoilage (Other than Canned Foods)



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Factors influencing microbial growth in food

Intrinsic Factors

Nutrients
pH and buffering capacity
Redox potential
Water activity
Antimicrobial constituents
Antimicrobial structures

Intrinsic factors are present in food system together and exert effects on microbial growth in combination, either favorably or adversely

Environmental factors

Relative humidity
Temperature
Gaseous atmosphere

Factors important for microbial growth in a food include the environmental conditions in which it is stored.

Implicit factors

Specific growth rate
Mutualism
Antagonism
Commensalism

Properties of the organisms themselves, how they respond to their environment and interact with one another.

Processing factors

Slicing
Washing
Packing
Irradiation
Pasteurization

Food undergoing different processing or treatment factors

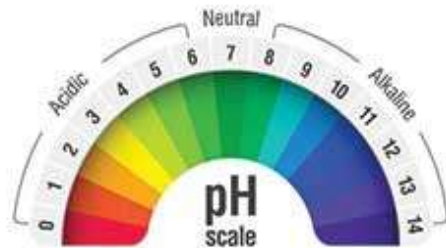
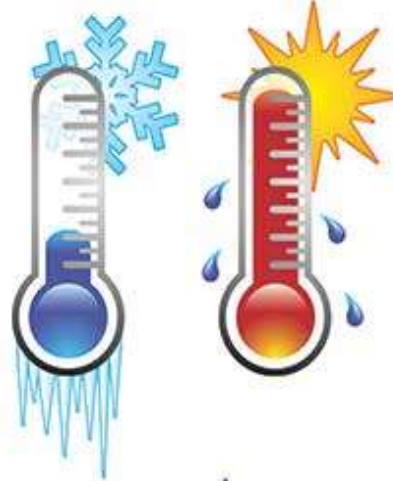


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Factors affecting microbes in foods

- Extrinsic factors
- Intrinsic factors





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Nutrient content:

- 1. Microbial growth is accomplished through the synthesis of cellular components and energy.**
- 2. The necessary nutrients for this process are derived from the food nutrients (carbohydrates, proteins, lipids, minerals, and vitamins).**
- 3. Example: meat is rich in protein, lipids, minerals, and vitamins but poor in carbohydrates. Foods from plant sources are rich in carbohydrates but poor sources of proteins, minerals, and some vitamins.**



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pH and buffering capacity:

- pH is equal to negative logarithm of the hydrogen ion activity. The acidity or alkalinity of an environment has a profound effect on the activity and stability of macromolecules, so growth and metabolism of micro-organisms are influenced by pH.**
- Grouped as high-acid foods (pH below 4.6) and low-acid foods (pH 4.6 and above).**
- Fruits, fruit juices, fermented foods and salad dressings are high-acid (low-pH) foods, whereas vegetables, meat, fish, milk and soups are low-acid (high-pH) foods.**

Product	pH
Citrus fruits	2.0-5.0
Soft drinks	2.5-4.0
Apples	2.9-3.3
Bananas	4.5-4.7
Beer	3.5-4.5
Meat	5.6-6.2
Vegetables	4.0-6.5
Fish (most spp)	6.6-6.8
Milk	6.5-6.8
Wheat flour	6.2-6.8
Egg white	8.5-9.5
Fermented shark	10.5-11.5



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1. Grow at an optimum pH well below neutrality (7.0) are called acidophiles.
2. Grow best at neutral pH are called neutrophiles.
3. Grow best under alkaline conditions are called alkalophiles.
4. Bacteria grow faster in pH range of 6.0- 8.0, yeasts 4.5-6.5 and filamentous fungi 3.5-6.8.

Microbe	Minimum	Optimum	Maximum
Most 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



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Redox Potential:

- 1. This measures the potential difference in a system generated by a coupled reaction in which one substance is oxidized (loss of electrons) and a second substance is reduced (gain of electrons) simultaneously.**
- 2. Redox potential of food is influenced by its chemical composition, specific processing treatment given, and its storage condition.**
- 3. Fresh foods are in a reduced state because of the presence of reducing substances (ascorbic acid, reducing sugars, and $-SH$ group of proteins). Processing, such as heating, can increase or decrease reducing compounds and alter the Eh.**



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Couple	E_0 (mV)
$\frac{1}{2} O_2 / H_2 O$	+820
Fe^{3+} / Fe^{2+}	+760
Dehydroascorbic acid / ascorbic acid	+80
Methylene blue ox/ red	+11
Pyruvate/ lactate	-190
$NAD^+ / NADH$	-320

Redox potential is the result of several factors: redox couples present, ratio of oxidant to reductant, pH, availability of oxygen and microbial activity.

Some important redox couples and their standard redox potential (Eh) values

Redox potential of some foods

Food	Eh(mV)	pH
Raw meat	-200	5.7
Minced meat	+225	5.9
Whole wheat	-350	6.0
Ground grain (Barley)	+225	7.0
Fruit juices	+300 to +	3.0-5.5
Grape	+410	3.8
Lemon	+380	2.2



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Water Activity (a_w):

- 1. Measure of availability of water for biological functions and relates to water present in a food in free form.**
- 2. In a food system, total water is present in free and bound forms. Bound water is not available for biological functions.**
- 3. The a_w (p/p_0 ; p is the partial vapor pressure of food and p_0 is the partial vapor pressure of pure water at the same temperature).**
- 4. Measured as equilibrium relative humidity (ERH) by dividing ERH by 100.**
- 5. Water activity scale extends from 0 (bone dry) to 1.00 (pure water).**
- 6. Most foods have water activity in range of 0.2 for very dry foods to 0.99 for moist fresh foods.**



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Applications of Water Activity

**Maintaining
chemical stability
of foods**

**Minimizing non-
enzymatic
browning
reactions**

**Prolonging desired
activity of
enzymes and
vitamins in foods**

**Optimizing
physical
properties of foods
such as texture**



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Water activity	Microorganisms grow at this a_w and above	Food examples
1.00 – 0.95	<i>Pseudomonas, E. coli, Proteus, Shigella, Klebsiella, Bacillus, Clostridium perfringens</i> & some yeasts	Highly perishable fresh foods & canned fruits, vegetables, meat, fish, milk, eggs; foods containing up to 40% (w/w) sucrose or 7% NaCl.
0.95 – 0.91	<i>Salmonella, Vibrio parahaemolyticus, Clostridium botulinum, Serratia, Lactobacillus, Pediococcus</i> , some molds and yeasts	Some cheeses (cheddar, Swiss), cured meats; some fruit juice concentrates; bread; high moisture prunes; foods containing 55% (w/w) sucrose or 12% NaCl
0.91 – 0.87	Many yeasts like <i>Candida, Torulopsis, Hansenula, Micrococcus</i>	Fermented sausages; sponge cakes; dry cheese; margarine; foods containing 65%(w/w) sucrose (saturated) or 15% NaCl
0.87 – 0.80	Most molds, <i>Staphylococcus aureus</i> , most <i>Saccharomyces spp</i> , <i>Debaromyces</i>	Most fruit juice concentrates, sweetened condensed milk, flour, rice, pulses containing 15-17% moisture, salami
0.80 – 0.75	Most halophilic bacteria, Mycotoxigenic <i>Aspergilli</i>	Jam, Marmalade, Soy sauce
0.75 - 0.65	Xerophilic molds, <i>Saccharomyces bisporus</i>	Rolled oats containing 10% moisture; Fudge; marshmallows; Jelly; Some dried fruits; Nuts, Peanut Butter
0.65 - 0.60	Osmophilic yeasts, few molds	Dried fruits containing 15-20% moisture; Honey
0.50	No microbial proliferation	Pasta containing 12% moisture; spices containing 10% moisture
0.40	No microbial proliferation	Whole egg powder containing 5% moisture
0.30	No microbial proliferation	Cookies, biscuits crackers, bread crusts etc. containing 3- 5% moisture
0.20	No microbial proliferation	Whole milk powder containing 2-3% moisture, Dried vegetables containing 5% moisture, Corn flakes containing 5% moisture, Instant coffee



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A food having a_w of 0.85 or below, it is generally considered as non-hazardous. This is because below a_w of 0.91, most pathogens such as *Clostridium botulinum* cannot grow. *S. aureus* can be inhibited by a_w of 0.91 under anaerobic conditions but under aerobic conditions, it requires minimum a_w value of 0.86.

Minimum water activity values of spoilage microorganisms

Microbial group	Minimum a_w	Examples
Most bacteria	0.91	<i>Salmonella</i> spp. <i>Clostridium botulinum</i>
Most yeasts	0.88	<i>Torulopsis</i> spp.
Most molds	0.80	<i>Aspergillus flavus</i>
Halophilic bacteria	0.75	<i>Wallemia sebi</i>
Xerophilic molds	0.65	<i>Aspergillus echinulats</i>
Osmophilic yeasts	0.60	<i>Saccharomyces bisporus</i>



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Dried or Low Moisture Foods

- Contain **<25%** moisture and final water activity between **0.0 and 0.60**. e.g., Dried egg powder, milk powder, crackers and cereals.
- Stored at room temperature without any secondary method of preservation.
- Shelf stable and do not spoil as long as moisture content is kept low.

Intermediate Moisture Foods

- Foods contain between **15% and 50%** moisture content and have water activity between **0.60 and 0.85**.
- Require added protection by secondary methods (pasteurization, pH control, refrigeration, preservatives).
- Include dried fruits, cakes, pastries, fruit cake, jams, syrups and some fermented sausages.
- Usually spoiled by surface mold growth.





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Antimicrobial Constituents

1. **Natural covering of foods like shell of eggs and nuts, outer covering of fruits and testa of seeds, hide of animals provide protection against entry and subsequent spoilage by microorganisms.**
2. **Antimicrobial compounds such as short chain fatty acids (on animal skin) or essential oils (on plant surfaces).**

Essential constituents	Characteristics
Eugenol in cloves and cinnamon, allicin in garlic, thymol in sage	Antimicrobial activity
Lactoferrin, lactoperoxidase and lysozyme in milk	Antimicrobial activity
Ovatransferrin, avidin, lysozyme and ovoflavoprotein in hen's egg albumin	Antimicrobial activity
Hydroxycinnamic acid derivatives (p-coumaric, ferulic, caffeic and chlorogenic acids) in fruits, tea and other plants	Antibacterial and antifungal activity



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Temperature of storage

Microbial growth is accomplished through enzymatic reactions. Within a certain range, with every 10 C rise in temperature, the catalytic rate of an enzyme doubles. Because temperature influences enzyme reactions, it has an important role in microbial growth in food.

<i>Group</i>	<i>Temperature (°C)</i>		
	<i>Minimum</i>	<i>Optimum</i>	<i>Maximum</i>
Thermophiles	40–45	55–75	60–90
Mesophiles	5–15	30–40	40–47
Psychrophiles (obligate psychrophiles)	–5 to +5	12–15	15–20
Psychrotrophs (facultative psychrophiles)	–5 to +5	25–30	30–35



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Gaseous atmosphere

- 1. Oxygen comprises 21% of the earth's atmosphere and important gas in contact with food under normal circumstances.**
- 2. The inhibitory effect of CO₂ on microbial growth is applied in modified-atmosphere packing of food and is an advantageous consequence of its use at elevated pressures (hyperbaric) in carbonated mineral waters and soft drinks.**
- 3. The storage of foods in atmosphere containing 10% of CO₂ is referred as "Controlled Atmosphere".**
- 4. Molds and oxidative Gram-negative bacteria are most sensitive to CO₂.**



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Relative humidity

1. 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 a_w of the food leading to spoilage by the viable flora.
2. Foods that undergo surface spoilage from molds, yeasts, and some bacteria should be stored in conditions of low relative humidity to increase their shelf-life.
3. Done by proper wrapping of the food material also.



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Implicit Factors

Organism specific growth rate:

The organism with the highest specific growth rate are likely to dominate over time. Eg., many molds can grow perfectly well on fresh meat but they grow more slowly than bacteria and are therefore out-competed.

Mutualism:

Growth of one organism stimulates the growth of another (e.g., interaction of the starter cultures in yoghurt fermentation).

Commensalism:

An association between two organisms in which one benefits and the other derives neither benefit nor harm. One increase the availability of nutrients to others by degrading a food component into more readily assimilable compounds.

Antagonism:

Microorganisms may be antagonistic towards one another producing inhibitory compounds or sequestering essential nutrients such as iron.