Growth and survival of microorganisms in food

Factors affecting the growth of microorganisms in fish

Foods meant for human consumption are rarely sterile, and contain several microorganisms. Microorganisms associated with food include natural micro-flora of raw material and organisms that are introduced during harvesting / handling, processing, storage and distribution.

The microbial load in food depends on factors such as:

- Nature of the food
- Storage environment
- Properties of organisms in foods
- Effects of processing

Generally, micro-flora associated with food has no effect and food is consumed without objection and no adverse consequences. But in some instances associated microorganisms manifest their presence leading to spoilage, food borne illness or Transformation of properties of food in a beneficial way (Ex. Fermentation).

Factors affecting microbial growth in foods

Microorganisms associated with food and their growth is affected by several factors. These are broadly grouped into 2 types.

1. Intrinsic factors: Includes physicochemical properties of food such as,

- Nutrients
- pH and buffering capacity
- Redox potential
- Water activity / moisture content
- Antimicrobial constituents

2. **Extrinsic factors:** Include conditions of storage environment such as,

- Relative avidity
- Temperature of storage
- Gaseous atmosphere
- Presence / activities of other organisms

Nutrient content

Microorganisms associated with foods derive nutrients as source of energy, nitrogen, water, vitamins, minerals etc. for their growth and energy needs from foods. Nature of nutrient availability

favor growth of different microorganisms. Ability of microorganisms to utilize nutrients favors their growth on foods, while inability to utilize nutrients reduces microbial growth.

Ex. Saccharolytic microorganisms grow well on cereals using carbohydrates as carbon source.

- Proteolytic bacteria grow well on fish and meat.
- Diverse microbial group are associated with fruits containing variety of sugars (sucrose, fructose etc) favoring a variety of microorganisms and yeasts.
- Generally, foods where nutrients are easily available (fish/meat) support high microbial load and activity. Foods with low water content are protected against microbial invasion.

pH and buffering capacity

The acidity and alkalinity of an environment affects growth and metabolism of microorganisms as the activity and stability of macromolecules, enzymes and nutrient transport is influenced by pH. Generally, bacteria grow fast at pH 6-8. But bacteria that produce acids have optimum pH between pH 5 and 6 (Ex: Lactobacillus and Acetic acid bacteria). Yeast grows best at pH 4.5-6.0 and Fungi at 3.5 – 4.0.

In low pH foods (Ex. Fruits), spoilage is mainly by yeasts and fungi than bacteria. Fishes with pH around neutrality (6.5-7.5) favour bacterial growth and spoil rapidly than meat (pH: 5.5 – 6.5). Ability of low pH to restrict microbial growth has been employed as a method of food preservation (Ex: use of acetic and lactic acid).

Buffering capacity refers to the ability of foods to withstand pH changes. Microorganisms have ability to change pH of the surrounding environment to their optimal level by their metabolic activity. Decorboxylation of aminoacids releases amines which increases surrounding pH. Deamination of aminoacids by enzyme deaminases release organic acids causing decease in pH. Thus, protein rich foods like fish and meat have better buffering capacity than carbohydrate rich foods.

Moisture content ($a_{w)}$

Moisture content of the food affects microorganisms in foods, and the microbial types present in foods depends on the amount of water available. Water requirement for microorganisms is described in terms of water activity (a_w) in the environment and is defined as the ratio of the water vapor pressure of food substrate to the vapor pressure of pure water at same temperature.

$a_w = P/P_o$
P = vapour pressure of water in substrate
P_o = vapour pressure of solvent (pure water)
aw is related to relative humidity (RH)
RH = 100 x a_w

Water activity of solutes and requirements of certain microorganisms

- a_w of pure water: 1.0
- NaCl solution (22 %): 0.86
- Saturated NaCl solution: 0.75
- Bacteria generally require higher value of aw than fungi
- G^{-ve} bacteria require higher aw than G^{+ve} bacteria
- Most spoilage bacteria do not grow at a_w below 0.91
- Spoilage molds grow at a_w of 0.80
- Halophilic bacteria grow at a_w of 0.75
- Xerophilic and osmophilic yeasts grow at of 0.61

Microorganisms like halophiles, osmophiles and xerophiles grow better at reduced aw. Microorganisms can not grow below aw 0.60, and in such situations spoilage of food is not microbiological but due to chemical reactions (Ex: oxidation).

Relationship between aw, temperature and nutrition

- Growth of microorganisms decreases with lowering of a_w
- The range of a_w at which the growth is greatest occurs at optimum temperature for growth
- The presence of nutrients increases the range of a_w over which the organisms can survive

Redox potential (Oxidation – Reduction potential / O-R potential/ Eh)

Microorganisms show varying degree of sensitivity to O-R potential (Eh) of growth medium. Redox reaction occurs as a result of transfer of electrons between atoms or molecules. O-R potential of a substrate is defined as the ease with which the substrate loses or gains electrons. Substrate is oxidized when it loses electrons and is called as good reducing agent. Substrates that gain electrons become reduced and are good oxidizing agents.

Cu ------> Cu + e

Oxidation may also achieved by addition of oxygen.

2 Cu + O_2 -------> 2 CuO

Transfer of electros from one compound to another creates a potential difference between two compounds and is measured by an instrument and expressed as millivolts (mv). Highly oxidized substances have more electric potential (positive potential) and reduced substances negative electrical potential. Zero electric potential when oxidation and reduction are equal. O/R protential of a system is expressed by Eh. Aerobic microorganisms require positive Eh for growth and anaerobes, negative Eh. Reducing conditions in food is maintained by -SH groups in meat and ascorbic acid and reducing sugars in fruits and vegetables.

Factors influencing O/R potential of a food

- The characteristic of O/R potential of the original food.

- Poising capacity – (Resistance to change in potential of food)
- Oxygen tension of the storage atmosphere of food
- Access that the atmosphere has to the food
- Microbial activity

Eh requirement of microorganisms

- Aerobic microorganisms require oxidized condition (+ Eh) for growth. Ex. *Bacillus sp*
- Anaerobes require reduced condition (-Eh). Ex. *Clostridium sp*
- Microaerophils are aerobes growing at slightly reduced condition. Ex. *Lactobacillus, Campylobacter*.
- Facultative anaerobes have capacity to grow both under reduced and oxidized condition. Eg. Yeasts.
- Plant foods have positive Eh (fruits, vegetables) and spoilage is mainly caused by aerobes (bacteria and molds).
- Solid meat and fish have negative Eh (-200 mv), and minced meat positive Eh (+200 mv).

Microorganisms and Eh of food

- Microorganisms affect Eh of food during growth. Aerobes reduce the Eh of environment due to oxygen utilization. Growth medium becomes poorer in oxidizing and richer in reducing substances.
- Microorganisms reduce Eh by releasing metabolites. Hydrogen sulphide released by anaerobic microorganisms reacts with oxygen and creates reduced condition.
- Presence or absence of appropriate quantity of oxidizing/ reducing agents in the medium influences growth and activity of all microorganisms.

Antimicrobial constituents and barriers

All foods have one or the other mechanism to prevent or limit potentially damaging effects by microorganisms through protective physical barriers to infection (Ex. skin, shell, and husk) and antimicrobial components. Natural covering of some foods provide excellent protection against entry and subsequent damage by spoilage microorganisms. These include outer covering of fruits, outer shell of egg, skin covering of fish and meats.

The outer covering is usually composed of macromolecules and these are resistant to degradation and create inhospitable environment for microorganisms due to low aw and shortage of readily available nutrients.The antimicrobial substances such as short chain fatty acids in animal skin and essential oils in plant surfaces help to prevent entry of microorganisms.

Physical damage to outer barrier allows microbial invasion and cause spoilage. Some foods are resistant to attack by microorganisms and remain stable due to the presence of naturally occurring substances which have antimicrobial property. Many plant species possess essential oils which are antimicrobial.