Biochemistry of Food Spoilage -Ms.Ummeayman R.

What is spoilage?

Every food item that we eat is biological in origin, i.e. it comes from living organisms, thus it is bound to contain proteins , carbohydrates and fats and several metabolic activities would be carried out in them with the help of enzymes. These carbohydrates, fats and proteins are a source of energy. Since every living organism requires energy for survival, we consume food for procuring energy and similarly even microorganisms require energy, thus food becomes the target for the growth of some microorganisms. Food spoilage means the original nutritional value, texture, flavour of the food are damaged, the food becomes harmful to people and unsuitable to consume.

Various microorganisms may cause changes in the character of food, which may be classed as "positive" or "negative". Products of "positive" microbial transformations include cheese, yoghurt, and wine, which can be seen as increasing the nutritional value. "Negative" aspects of microbial growth include food deterioration and spoilage by decay, and food poisoning, mainly caused by different and less widespread bacteria. As they grow, micro-organisms release their own enzymes into the liquid surrounding them, and absorb the products of external digestion. This is the main basis of microbial food spoilage, which lowers the nutritional value of the medium they are growing in. Bacteria and moulds may also produce waste products which act as poisons or toxins, thus causing the renowned ill-effects.

Factors of Food spoilage:

Nutrients in food, their kind and proportions determine the type of organism that will grow. Also, microorganisms vary in their ability to use nutrients. The presence of easily utilizable nutrients will encourage faster growth and quicker damage. For example, a food with easily utilizable sugars will allow better growth than one which contains polysaccharides. Most foods contain enough peptides and amino acids that they can meet the nitrogen requirement of most organisms found in foods. Some organisms are also proteolytic and can grow on proteins found in the food. The mineral requirement of microorganisms is generally met by the food and this is not a limiting factor. Some foods may contain antibacterial substances which may prevent bacterial growth and food spoilage.

Other than the nutrients present in food, factors such as the pH, moisture content, oxidation reduction potential, etc., also influence microbial activity in foods. For example, each organism has an optimum pH for growth. Thus, both the growth as well as their survival in foods depends on the pH of the food material. Both yeasts and moulds can thrive in high acid foods like fruit, tomatoes, jams, jellies and pickles. Both are easily destroyed by heat. Processing high acid foods at a temperature of 100°C (212°F) in a boiling water canner for the appropriate length of time destroys yeasts and moulds.

Also, the concentration of the sugars will determine the type and extent of growth, since it affects both the osmotic pressure and the a_w. Generally, yeasts and molds are more resistant to high concentrations of sugar than bacteria. Bacteria generally prefer low acid foods like vegetable and meat. When the conditions for bacterial cell growth are unfavourable (e.g., low or high temperatures or low moisture content), several species of bacteria can produce resistant cells called endospores. Endospores are highly resistant to heat, chemicals, desiccation (drying out), and ultraviolet light. The endospores may remain dormant for long periods of time. When conditions become favourable for growth (e.g., thawing of meats), the endospores germinate and produce viable cells that can begin exponential growth.

Microorganisms have an absolute demand for water and the optimum level of moisture required for growth varies with the organisms. The water requirement is expressed in terms of available water or water activity (a_w), which is the vapour pressure of the solution divided by the vapour pressure of the solvent. This is equal to the vapour pressure of the solutions in water divided by vapour pressure of the water. Each organism has a maximal, optimal and a minimal aw for growth. Most bacteria grow well in a medium of aw activity around 0.995 to 0.998. Molds differ considerably in the optimal aw. For example, Rhizopus sp., has an optimal aw of 0.995-0.980, while Penicillium sp., and has an optimal aw of 0.9935. The a_w value of a food is affected by the vapour pressure of solutes such as sugars, salts, hydrophilic colloids or gels. An increase in the concentration of sugars and salts allows the water to be tied up and also causes the removal of water from the microbial cells. The a_w value of the food therefore, determines to considerable extent the type of organism that can grow in it.

The oxygen tension or partial pressure of oxygen and the reducing and oxidizing power of the food (O-R potential) influences the growth of organisms. In relation to oxygen, bacteria can be aerobic, anaerobic or facultative, while fungi are mostly aerobic, yeast are aerobic or facultatively anaerobic. A high O-R potential favours the growth of aerobic and facultative organisms. Most fresh animal and plant foods have a low O-R potential in their interior but have a higher O-R outside. Thus, a fresh piece of meat could support the growth of aerobic organisms in the exterior and the growth of anaerobic organisms inside.

Other than Microbial growth and destruction, food is spoiled by enzymes present within them. This self destruction is termed as autolysis. The most important mode of destruction is by enzymes .Enzymes are proteins found in all plants and animals. If uncooked foods are not used while fresh, enzymes cause undesirable changes in colour, texture and flavour. This is because, even though the vegetables and fruits have been plucked from the plants, their cells are still alive and continue the basic life process i.e. respiration.

Chemical changes causing Food Spoilage:

Food spoilage occurs in food products due to reaction or breakdown of the chemical components of the food, including its proteins, lipids, and carbohydrates. The rate at which the chemical reactions takes place depends on many factors, which are, water activity, temperature, pH, exposure to light or oxygen.

Protein degradation can involve reactions with protein and other ingredients brought about by enzymatic activity. Protein hydrolysis is achieved by enzymes collectively called proteases. Proteases bring about the cleavage of long protein chains and form fragments of amino acids. Enzymes hydrolyzing peptide bonds in the interior of the amino acid chain are called endo-peptidases whereas proteases hydrolyzing peptide bonds at either the amino- or carboxy- terminal end of the protein are called exo-peptidases. One of the spoilage causing protease is 'Protease plasmin'. Plasmin can survive pasteurization temperature and can cause degradation of dairy proteins in milk and cause coagulation and gelatinization. Other protease can act on the proteins in meat and cause the meats to become mushy. Degradation of meat protein is also brought about by the oxidation of proteins; overexposure to oxygen can cause myoglobin and oxymyoglobin to oxidize into metmyoglobin, causing the change in meat colour from bright red to brown which renders the meat not appealing to the consumer.

Putrefaction is also protein degradation, where decomposition of animal proteins is carried out especially by anaerobic microorganisms described as putrefying bacteria. Putrefaction usually results in the formation of amines such as putrescine and cadaverine.
Formula of putrefaction: Protein foods + proteolytic microorganism→ amino acids +ammonia+ hydrogen sulphide.

Enzymatic activities in fruits and vegetables can cause browning and softening of tissues. Typically these reactions are catalyzed by phenol oxidase enzymes, which react with phenol compounds and oxygen to form undesirable brown pigments. Another form of browning which happens due to non enzymatic activity is Millard Browning. This non enzymatic browning occurs due to reaction between proteins (amino acids) and reducing sugars. This is associated with loss in nutritional value along with the browning and change in the texture of food products. The essential amino acid lysine, which readily reacts with reducing sugars, is quickly lost.

Carbohydrates makeup the largest proportion of any fruits and vegetables and so a larger percentage of food spoilage is due to the degradation of the carbohydrate content of these foods. Vegetable cells, as plant cells, have rigid cell walls and are glued together by various polysaccharides such as cellulose, hemicellulose, and pectin. Once vegetables are harvested from the fields, the cells, now deprived of nutrient supplies normally obtained from soils and the air, go into senescence, or aging. The most noticeable structural change in senescent vegetables is softening, or loss of texture. Softening is caused by natural enzymatic reactions that degrade the plant cell walls. A large group of enzymes is involved in the senescence stage, including cellulase, pectinase, hemicellulase, proteinase, and others. After these enzymes break open the cells, chemical oxidation reactions take place and the vegetables develop off-flavours and loss of nutritional value. Broken cells are also much more easily subject to microbial attacks, which quickly lead to spoilage. In addition, even though the vegetables may be packaged or bagged, the plant cells continue to respire, or break down carbohydrates for energy needs.

Lipid spoilage most often occurs due to oxidation reactions or action of lipolytic enzymes and other hydrolytic reactions .Lipid oxidation is the most important degradation method in fats and oils and occurs in many foods containing fats and oils or in fried foods. During this reactions, oxygen attacks unsaturated fats to form colour changes, off-flavour and sometime toxic substances. The number and location of double bonds on the fatty acids and triglycerides is one factor that affects the rate and extent of oxidation. Light and heat are other important factors as they increase the rate of oxidation. Catalase and peroxidase are the two most important oxidizing enzymes that can cause darkening in diced and sliced vegetables. A simple heat treatment (Blanching) is used to inactivate these enzymes.

Atmospheric oxygen reacts with food components and cause rancidity. Rancidity is the term used for the deteriorative changes of fat with time and it results in undesirable flavour and odour. Hydrolytic rancidity occurs in foods when the lipid (fat) is hydrolyzed by the water contained in food to fatty acids. Some of the liberated fatty acids are volatile and some have very unpleasant odours and flavours. When rancidity occurs due to air, it is termed as Oxidative rancidity. The oxidation of acylglycerols which occurs in air, without the presence of enzymes, is called autoxidation. Among the products of autoxidation are hydroperoxides, ROOH. These have no taste, but they decompose easily to form aldehydes, ketones and acids, which give oxidised fats and oils their rancid flavours. It can be slow down by addition of antioxidants.

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