MICROBIAL SPOILAGE OF FOOD IN INDUSTRY: A REVIEW

Supported by tetfund TERTIARY EDUCATION TRUST FUND

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Received: April 29, 2019 **Accepted:** June 30, 2019

Abstract: Food spoilage is a metabolic process that causes foods to be undesirable or unacceptable for human consumption due to changes in sensory characteristics. Spoilage organisms are not initially a basic part of foods they commonly exists in water, soil air, animals and handling personnel. Healthy living plants and animals are able to prevent the action of bacteria, yeast and mould on its tissues, but immediately they are slaughtered or harvested their defenses depreciate and their tissues become prone to spoilage microbes. The growth of microorganism in food causes alterations in the foods physical appearance as a result of metabolic action. Some of this changes result in food spoilage and food poisoning which are undesirable, the most important factors that affect microbial growth in foods are the intrinsic environment of food as well as the extrinsic environment in which the food is stored and proper regulation of these factors are the key to the measures of control of variety of food produce in industry.

Keywords: Bacteria, food, industry, moulds, spoilage, yeast

Introduction

Microbial food spoilage takes place once undesirable microorganisms exist in food which makes the manufactured foods product undesirable to the consumers (Petruzzi *et al.*, 2017; Houghton, 2016). All manufactured foods have their standard characteristics that make a peculiarity from the others, such as its appearance, consistency odour, taste and aroma. Any alteration in any of these features makes the food uncertain or unaccepted (Amal, 2017; Seems, 2015). Bacteria, yeasts, and moulds are minute forms of plant life that use the soluble components of food in their life developments, or that secrete enzymes that bring about disintegration of food tissue, which renders several of the constituents soluble and accessible to the microorganisms (Aryris, 2016). Regulating the temperature throughout the storage of the food is one of the most significant factors that delay the signs of spoilage of foods. Storage at low temperature slows the activity and growth of microbes since microorganisms have an optimal temperature for their growth causing unacceptable changes in the foods.

Spoilage Microorganism

Bacteria

They are the most abundant microorganisms found on earth. Spore forming bacteria are usually associated with spoilage of heat-treated foods because their spores can survive high processing temperatures. Gram-positive bacteria may be strict anaerobes or facultative (capable of growth with or without oxygen) (Seema, 2015). Some spore-formers are thermophilic, preferring growth at high temperatures (as high as 55ºC). Some anaerobic thermophiles produce hydrogen sulphide (*Desulfotomaculum*) and others produce hydrogen and carbon dioxide (*Thermoanaero bacterium*) during growth on canned or hermetically sealed foods kept athigh temperatures, for example, soups sold in vending machines. Other thermophiles (*Bacillus* and *Geobacillus* spp.) causes a flat sour spoilage of high or low pH canned foods with little or no gas production, and one species causes ropiness in bread held at high ambient temperatures. Mesophilic anaerobes, growing at ambient temperatures, cause several types of spoilage of vegetables (*Bacillus* spp.); putrefaction of canned products, early blowing of cheeses, and butyric acid production in canned vegetables (Andress and Harrison., 2014) and fruits (*Clostridium* spp.); and "medicinal" flavors in canned low-acid foods (*Alicyclobacillus*). Psychrotolerant sporeformers produce gas and sickly odors in chilled meats and brine-cured hams (*Clostridium* spp.) while others produce off-odors and gas in vacuum-packed, chilled foods and milk (*Bacillus* spp.). It is important to take proper consideration when heating or cooling product during food processing. If the food product is not heated or cooled appropriately i.e. the product stays for too long in a temperature range that is favorable to bacterial growth, the spores will change to a vegetative state and start reproducing (Urmila *et al.*, 2017).

Moulds

They are multiple cell organisms forming tubular filaments. Molds demonstrate branching and reproduce by means of fruiting bodies, called spores, which are borne in or on aerial structures. Their mycelia, or intertwined filaments, may resemble roots (Urmila *et al.*, 2017). They are many times larger than bacteria and longer than yeasts. Molds are able to grow within a wide range of water activity values, pH values, and temperatures (Synder and Woroba, 2018) by using a large number of substrates such as carbohydrates, organic acids, proteins, and lipids. Consequently, molds are able to grow on acidic products such as fruits or fruits juices (Lahlali *et al*., 2005) and on foods with intermediate moisture levels such as bread and bakery products where other microorganisms such as bacteria cannot grow. Molds also can grow in cereals, beverages, dairy products, and fermented products and thus are associated with the spoilage of a wide range of foods (Seema, 2015). Some of the most common genera of molds found in food are: *Aspergillus*, *Alternaria*, *Fusarium*, *Geotrichum*, *Mucor*, *Penicillium* and *Rhizopus*.

Yeast

Yeasts are single-cell, microscopic living bodies, usually egg-shaped. They are smaller than molds, but larger than bacteria. Yeasts reproduce mainly by budding. A small bud forms on the parent yeast cell, gradually enlarges, and then breaks off into another yeast cell (Urmila *et al.*, 2017).Yeasts are important in food because of their ability to cause spoilage (Lucille, 2017). Many are also used in food bioprocessing. Some are used to produce food additives. Yeast typically spoil high acid, low pH, and high salt or weak organic acid products. Though they can spoil various types of food products they are mostly commonly found in fruits and cereals (Francois and Katia, 2012). Several important genera include *Saccharomyces*, *Pichia*, *Rhodotorula*¸ *Torulopsis* and *Zygosaccharomyces* (Ray, 2005). They also cause spoilage of food, producing alcohol and CO_2. They form pigment and discoloration of foods such as meat, fish, and sauerkraut. They cause spoilage of milk they also spoil fruit juice concentrates and acid foods. They tend to form pellicles on the surface of liquids.

Factors that affect the growth of microorganism in food

The ability of microorganisms to grow or multiply in a food is determined by the food environment (intrinsic environment of food) as well as the environment in which the food is stored (extrinsic environment).

Intrinsic Parameters

I. **pH:** Most microorganisms grow best at pH values around 7.0 (Jehan, 2012). At pH (6.6-7.5) Moulds and yeasts are capable of growing at a lower pH than bacteria, in addition Gram-negative bacteria are more sensitive to low pH than are Gram-positive bacteria and pathogenic bacteria being the most fastidious (Jay, 2005; Ray, 2005). On the basis of pH, foods can be grouped as high-acid foods (pH below 4.6) and low-acid foods (pH 4.6 and above) (Jehan, 2012). Fruits, soft drinks and vinegar all fall below the point at which bacteria normally grow. Fruits generally undergo mold and yeast spoilage, and this is due to the capacity of these organisms to grow at pH values <3.5, which is below the minimal pH for most food spoilage and all food poisoning bacteria (Neeraj and Sharma, 2007).

II. **Water activity *(aw):*** Is a measure of the availability of water for biological functions and relates to water present in a food in free form) (Ray, 2005). The free water in a food is essential for microbial growth. It is necessary to transport nutrients and remove waste materials, carry out enzymatic reactions, synthesize cellular materials and partake in further biochemical reactions; for instance hydrolysis of proteins to amino acids (Ray, 2005). The water necessities of microorganisms had been described in terms of the water activity *(aw)* in the surroundings. Bacteria want higher values of *aw* for growth than fungi, with gram-negative bacteria having higher requirements than gram positives (Jehan, 2012). Each microbial species (or group) has an optimum, maximum, and minimum *aw* level for growth. The minimum *aw* values for growth of microbial groups are as follows: Most Gram-positive bacteria 0.90 and Gram-negative bacteria 0.93, most molds 0.80 and most yeasts 0.88 (Barnard, 2018).

III. **Nutrient content:** Microorganisms of importance in foods require water, source of energy, source of nitrogen, vitamins, related growth factors and minerals (Hammond *et al*., 2015; Garnier *et al*., 2017). Moulds have the lowest requirement, followed by yeasts, gram-negative bacteria, and gram positive bacteria (Hamad, 2012). As sources of energy, food borne microorganisms may utilize sugars, alcohols, and amino acids. Some few microorganisms are able to utilize complex carbohydrates such as starches and cellulose as sources of energy by first degrading these compounds to simple sugars. Fats are used also by microorganisms as sources of energy, but these compounds are attacked by small number of microbes in foods. Microorganisms may require B vitamins in low quantities, and almost all natural foods have a large quantity for those organisms that are unable to synthesize their essential requirements. In general, gram-positive bacteria are the least synthetic and must therefore be supplied with one or more of these compounds before they will grow (Neeraj and Sharma, 2007). The gram-negative bacteria and molds are able to synthesize most or all of their requirements. Consequently, these two groups of organisms may be found growing on foods low in vitamins B (Garnier *et al*., 2017).

IV. **Oxidation-reduction potential:** The O/R potential of a substrate may be defined generally as the ease with which the substrate loses or gains electrons. (Granier *et al*., 2017) When an element or compound loses electrons, the substrate is said to be oxidized, whereas a substrate that gains electrons becomes reduced. Therefore, a substance that readily gives up electrons is a good reducing agent, and one that readily takes up electrons is a good oxidizing agent. The O/R potential of a system is expressed by the symbol Eh. Aerobic microorganisms require positive Eh values (oxidized) for growth such as some members of the genus *Bacillus*, whereas anaerobes require negative Eh values (reduced) such as the genus *Clostridium* (Jay *et al.*,2005*)* Some bacteria actually grow better under slightly reduced conditions, and these organisms are often referred to as *microaerophiles.* Examples of microaerophilic bacteria are Lactobacilli and Campylobacters. Some bacteria have the capacity to grow under either aerobic or anaerobic conditions. Such types are referred to as facultative anaerobes. Most molds and yeasts encountered in and on foods are aerobic, although a few tend to be facultative anaerobes. Plant foods, especially plant juices, tend to have positive Eh values, aerobic bacteria and molds are the common cause of spoilage of products of this type. Solid meats have negative Eh values, an aerobic bacteria are the common cause of spoilage of products of this type.

The stability of some foods against attack by microorganisms is due to the presence of certain naturally occurring substances that have been shown to have antimicrobial activity. Some species are known to contain essential oils that possess antimicrobial activity. Among these are eugenol in cloves, allicin in garlic, cinnamic aldehyde and eugenol in cinnamon, cow's milk contains several antimicrobial substances, including lactoferrin, lysozyme and the lactoperoxidase system. Eggs contain lysozyme, Ovotransferrin and conalbumin, provides fresh eggs with antimicrobial system. The organic acids found in fruits, vegetables show antibacterial and some antifungal activity (Neeraj and Sharma, 2007).

I. **Antimicrobial substances**

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i) Temperature of storage: Microorganisms important in foods are divided into three groups on the basis of their temperature of growth: thermophiles (grow at relatively high temperature), mesophiles (grow at ambient temperature), and psychrophiles (grow at cold temperature) (Ray, 2005). Therefore, it would be well to consider at this point the temperature growth ranges for organisms of importance in foods as an aid in selecting the suitable temperature for the storage of different types of foods. Temperature of storage is the most important parameter that affects the spoilage of highly perishable foods. Examples of psychrotrophs found most commonly on foods are those that belong to the genera *Pseudomonas* and *Enterococcus*. These organisms grow well at refrigerator temperatures and cause spoilage of meats, fish, poultry, eggs, and other foods normally held at this temperature. In a study conducted by Altunatmaz *et al*. (2012) on the detection of airborne psychrotropic bacteria and fungi in food storage refrigerators, it was detected that out of the 48 refrigerators sampled took all

containing milk sample.They were foundas *Penicillium* (29.0%), *Aspergillus* (12.0%), *Mucor* (9%), *Cladosporium* (8%), *Botyrtis* (7%), and *Acremonium* (6%) and 42 (87.5%) tested positive for psychrotrophic bacteria or fungi. Only 4 meat-containing refrigerators (33.3%) were found to be free of microorganisms in air samples. According to the researchers, psychrotrophic bacteria flora was found dominant in meat containing refrigerators (Ayudil *et al*., 2006 & Col, 2006). Most psychrotrophic bacteria are found in specie *Acinetobacter, Aeromonas, Bacillus, Clostridium, The mouds isolated from air samples were broadly represented by 17 general.* The moulds isolated from air samples were broadly represented by 17 genera. In total, 172 mould and 4 yeast (*Candida krusei*) isolates were obtained from 48 samples. *Penicillium italicum* was the most frequently detected species, found in 12.6% of 86 air samples, and followed by *Botrytis cinerea* (5.8%), *Mucor rasemosus* (5.8%) and *Rhizopus oryzae* (5.8%). Several researchers have reported the frequency of *Penicillium*, *Aspergillus*, *Mucor* and *Cladosporium* in food processing air samples (Asefa *et al*., 2008; Kure *et al*., 2008; Salustiano *et al.*, 2003; Soresen *et al*., 2008). In addition, Asefa *et al.* (2009) and Sørensen *et al.* (2008) also reported *Penicillium* spp. as one of most predominant moulds in food processing areas.

ii) **Relative humidity of environment:** The Relative Humidity (RH) of the storage environment is important both from the stand point of *aw* within foods and the growth of microorganisms at the surfaces. When the *aw* of a food is set at 0.60 (Ray, 2005), It is important that this food be stored under conditions of RH that do not allow the food to pick up moisture from the air and increase its own surface and subsurface *aw* to a point where microbial growth can occur. When foods with low *aw* values are placed in environments of high RH the foods pick up moisture (Neeraj and Sharma, 2007). Foods with a high *aw* lose moisture when placed in an environment of low RH. Foods that undergo surface spoilage from molds, yeasts, and certain bacteria should be stored under conditions of low RH. Wrapped meats such as whole chickens and beef cuts tend to suffer much surface spoilage in the refrigerator before deep spoilage occurs, due to the generally high RH of the refrigerator.

iii) **Presence and concentration of gases in the environment:** Carbon dioxide (CO_2) is the single most important atmospheric gas that is used to control microorganisms. Ozone (O_3) is the other atmospheric gas that has antimicrobial properties. It has been shown to be effective against a variety of microorganism, but because it is a strong oxidizing agent, it should not be used on high-lipid-content foods since it would cause an increase in rancidity (Ray, 2005). By employing proper sanitary measures and preventing contamination of water to be used.

Microbial spoilage of some selected food in industry

Spoilage of raw meat in industry: Fresh meats from food animals and birds contain a large group of potential spoilage bacteria that include species of *Pseudomonas*, *Acinetobacter*, *Moraxella*,*Shewanella*,, *Aeromonas*, *Escherichia*, *Enterobacter*, *Serratia*, *Hafnia*, *Proteus*, *Brochothrix*, *Micrococcus*, *Enterococcus* and *Clostridium*, including yeasts and molds. The predominant spoilage flora in a meat is determined by nutrient availability, oxygen availability, storage temperature, pH, storage time of the product, and generation time of the microorganisms present in a given environment (Ray, 2005), the Pre-slaughter husbandry practices (e.g., free range vs. intensive rearing), Age of the animal at the time of slaughter, Sanitary handling during slaughter, processing and distribution, Preservation controls, type of packaging, Consumer handling and storage (Cerveny *et al*., 2009).

Spoilage of diary product in industry: Raw milk contains many types of microorganisms coming from different sources. The average composition of cow's milk is protein 3.2%, carbohydrates 4.8%, lipids 3.9%, and minerals 0.9%. Microbial spoilage of raw milk can potentially occur from the metabolism of lactose, proteinaceous compounds, fatty acids (unsaturated), and the hydrolysis of triglycerides. If the milk is refrigerated instantly after milking and stored for days, the spoilage will be mainly caused by Gram-negative psychrotrophic rods, such as *Pseudomonas*, *Alcaligenes*, *Flavobacterium* spp., and some coliforms (Ray, 2005). Spoilage bacteria may originate on the farm from the environment or milking equipment or in processing plants from equipment, employees, or the air (Doyle, 2007).

Raw milk kept for a long time for example will get sour, bacteria that survived pasteurization grow in the milk and produce acid from the carbohydrates lactose in it. The spoilage will occur more rapidly if the milk is held at room temperature than refrigerated. The sour taste is due to the presence of lactic acid, acetic acid, butyric acid and other food acids (Houghton, 2016).

Spoilage of canned food in industry: Canned foods are sterilized before being placed on grocery shelf, but if the sterilization has not been successful, contamination or food spoilage may occur. Swollen cans usually contain gas produced by member's clostridium (Andress and Harrison, 2014). Sour spoilage without gas is commonly due to members of the genus bacillus. The type of spoilage id called flat sour spoilage. Lactobacilli are responsible for acid spoilage when they break down the carbohydrates in foods and produce detectable amount of acid (Houghton, 2016).

Spoilage of cereal and bakery product in industry: Cereal grains are exposed to a range of bacteria, molds and yeasts in the course of their growth, harvesting, drying and storage (Doyle, 2007). Molds are the most significant pollutants because of the low moisture levels in grains, effective drying and good storage facilities are essential to avoid their growth (Saranraj and Sivasakthivelan, 2015). Microbial inhabitants reduce during milling and storage of grain. The appearance of grains and flours can be change due to mold spoilage; some species can produce toxic secondary metabolites called mycotoxin (Cook and Johnson, 2009). Molds are also the primary spoilage organisms in baked goods, with *Aspergillus*, *Penicillium*, and *Eurotium* being the most frequently isolated genera. Freshly baked bread does not comprise of viable molds but become polluted upon exposure to air and surfaces (Cook and Johnson, 2009). *Bacillus* spores are heat resilient and can survive baking in the inner of bread loaves and then develop and start increasing as the bread cool down. Certain strains cause a defect called ropiness, a soft sticky texture caused by starch degradation and slimy exopolysaccharides often accompanied by a fruity odor storage (Doyle, 2007). Yeasts may also be involved in spoilage of some breads and fruitcakes, causing a chalky appearance on surfaces and off odors (Saranraj and Sivasakthivelan, 2015). High sugar content and low water activity of cakes also favors molds over other spoilage microbes but some species of yeasts and bacteria (*Bacillus* and *Pseudomonas*) may also attack cakes.

Spoilage of fruit, beverages and vegetables in industry: When fruits and vegetables are ripe the cell wall get weaken and decreases the amounts of antifungal chemicals in it and physical damage during harvesting causes breaks in outer

protective layers of fruits and vegetable that spoilage organisms can exploit (Doyle, 2007). Molds are tolerant to acidic environments and low water activity and are involved in spoilage of citrus fruits, apples, pears, and tomatoes, onions. *Penicillium, Botrytis*, and *Rhizopus* are frequently isolated from spoiled fruits. Yeasts and some bacteria, including *Erwinia* (Doyle, 2007) and *Xanthomonas*, can also spoil some fruits mainly fresh cut packaged fruits (Barth *et al*., 2009).

Fruits juices generally have relatively high levels of sugar and a low pH and this favors growth of yeasts, molds and some acid-tolerant bacteria which can survive heating. Spoilage may be manifested as surface pellicles or fibrous mats of molds, cloudiness, smoky taint and off-flavors. Lack of oxygen in bottled and canned drinks limits mold growth. *Saccharomyces* and *Zygosaccharomyces* are resistant to thermal processing and are found in some spoiled juices. *Alicyclobacillus* spp., an acidophilic and thermophilic spore-forming bacteria, has emerged as an important spoilage microbe, causing a smoky taint and other off-flavors in pasteurized juices *Propionibacterium cyclohexanicum* (Neeraj and Sharma, 2007). Lactic acid bacteria can spoil orange and tomato juices, and some pseudomonads and enterobacteriaceae also spoil juices.

Control of Microbial Food Spoilage in Industry

i) Good industrial practices with firm consideration to sanitation and hygiene can hinder establishment of many microbes which is one of the most significant step in controlling the spoilage process.
ii) Delaying the lag phase can decrease the growth rate of certain microbes by managing the environment of the food thereby delaying their spoilage. For example, some microbes grow slowly or not at all at low temperatures and refrigeration can prolong spoilage.
iii) Several microbes need a high water activity and hence keeping foods such as grains and cereal products dry will aid to preserve them.
iv) Managing the atmosphere during storage in packaging can retard or prevent the growth of some microbes. Several types of modified atmosphere packaging (MAP) have been developed to retard growth of pathogenic and spoilage organisms.
v) Thermal processes are being established to destroy spoilage microbes such as: high pressure, processing of fruits, juices, meat and fish irradiation of fruit and meat
vi) Formulation of processed foods may include compounds that alter the water activity or pH of foods, thereby limiting growth of many organisms.
vii) Antimicrobial compounds, Organic acids and Bacteriocins can help control bacteria, molds and yeast when added to foods or packaging to inhibit growth of many spoilage organisms e.g. bakery products, meat, juices, vegetable and other foods
viii) Chitosan integrated into foods or used as a coating for fruits and vegetables inhibits growth of some spoilage bacteria and yeasts
ix) A number of herbs, essential oils, and spices have proven some inhibitory action against spoilage microbes in a variety of foods. Thyme, oregano, vanillin, and cinnamon are the most commonly substances use.
x) Good hygienic design following, HACCP guidelines which is applied to food safety will guarantee high degree of assurance on food that will be free of pathogenic microorganisms or their toxins.

Conclusion

Microbes are able to establish and develop in the processing environment and on food products which pose a potential problem in term of food safety and quality in industry. This can be from bacteria, yeast or mold which are responsible for food spoilage. To guarantee the safety of food product in industry there is need for manufacturers of food product ensure proper control of production, packaging, storage and distribution practices which will minimize the risk of product spoilage.

Conflict of Interest

Authors declare that there is no conflict of interest related to this study.

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