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Importance of Extending the Shelf Life of the Meat

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Abstract

The shelf life of the meat and the meat products is the storage time until spoilage, which is a complex condition in which the combination of biological and physicochemical activities may interact and make the product unacceptable for human consumption.

Maximum acceptable microbial level and/or unacceptable off-odor and off-flavor identify the exact point of spoilage, which is strictly dependent on the initial numbers and types of contaminating microorganisms, their growth, lipid oxidation, and autolytic enzymatic reactions. The Meat and the fish, due to their physic-chemical characteristics, are excellent basic nutrients for microbial activity. Indeed the pH, aw (activity water), and high moisture values can support the growth of a wide variety of microorganisms.

Keywords: The shelf life, meat, meat products, lipid oxidation, autolytic enzymatic reactions.

Introduction

Usually, the initial microbial count of the meat and the cooked meat products is about 23 log CFU/cm2 or g, and for fresh meat and meat and fish products about 45 log CFU/cm2 or g. The microbial species originate from the physiological status of the animal during the farming, slaughtering, harvesting, fishing, processing, transportation, preservation, and storage conditions. Food contamination occurs after the heating process that is often used to prolong the shelf life either of meat or fish products. It is estimated that only 10% of the bacteria initially present are psychrotolerant and may grow in cold storage and that the fraction causing the spoilage is even lower **[1,2,3,4,5,6,7]**. During the storage, the temperature, the gaseous atmosphere, the pH, the NaCl, and the packaging are important factors affecting the selection, the growth rate, and the activity of certain bacteria. The initial mesophilic bacterial count on the meat and the cooked meat products is about lo' to 10' cfu,/cm' or gram, consisting of a large variety of species. Only 10% of the bacteria initially present are able to grow at refrigeration temperatures, and the fraction causing spoilage is even Iower. Since the meat products are heated to a temperature of 65 to 75" C, most vegetative cells are killed and post-heat treatment recontamination determines the shelf-life. The surface contamination of the cut meat and the meat products will determine the potential shelf life. During the storage, environmental factors such as the temperature, the gaseous atmosphere, the pH, and the NaCl will select certain bacteria, and affect their growth rate and activity. The shelf life of refrigerated meat and meat products can range from days to many months. The bacteria are able to grow and cause spoilage during the storage of the meat, the cooked and the cured meat products **[8,9,10,11,12,13,14]**.

Causes of Meat Spoilage

Caused by the physical, chemical, and biological agents, including microorganisms such as bacteria, yeast, and mold, the action of enzymes in meat such as lipases and proteases, the chemical reactions in the foods such as browning and oxidation, the physical changes introduced by the freezing, the drying, and the application of the pressure. 'The Several agents are implicated in meat spoilage, the microorganisms are the most common cause of the quality deterioration in the foods of animal origin'. The spoilage organisms break down fat, carbohydrates, and protein in the meat resulting in the development of off-flavors, slime formation, and discoloration, thereby rendering the meat disagreeable for consumption. It is estimated that microbial spoilage is responsible for 25% of the postharvest food loss globally **[15,16,17,18,19,20, 21]**.

The Meat

The Environmental Influence on Bacterial Growth and Shelf Life

The Growth to high numbers is a prerequisite for the spoilage. The expected shelf life and growth ability of different bacteria under various environmental conditions. The Microbiome of the spoiled meat, Microbial spoilage can be defined as the biochemical changes in meat brought about by dominant microorganisms that make up a significantly higher proportion of the microbial community associated with meat. The overall composition of the spoilage microflora is diverse and primarily determined by the environment in which the animals are raised, and the postharvest and processing environment of meat. These spoilage organisms are conventionally grouped as the Gram-negative rods, the Gram-positive spore formers, the lactic acid bacteria (LAB), the other Gram-positive bacteria, the yeast, and the molds. The meat products are not commonly degraded by the yeast due to their inability to produce extracellular proteases. Some exceptions to this include

Yarrowia lipolytica, Rhodoturola, Cryptococcus, Pichia, and Saccharomyces in fresh and refrigerated meat and poultry. Similarly, the mold found on the meat that could play a role in the spoilage includes Alternaria, Aspergillus, Fusarium, Rhizopus, and Cladosporium **[22,23,24,25,26,27,28]**.

The Microflora of Fresh Meat

The muscle tissue in healthy living animals is essentially sterile. Thus the initial microbial load and composition of the fresh meat are primarily influenced by the physiological status of the animal at the time of slaughter, the spread of microbes during slaughter, and the slaughterhouse environment. Following sacrifice, the main contamination of the meat occurs when the carcass is opened and the offals are removed. For instance, bacteria from the intestines, lymph nodes, skin, hide, handlers, cutting knives, and the processing facility can potentially contaminate the meat. These microorganisms acquired by the meat can be termed the slaughterhouse microbiome, which is a combination of the microbial population in the facility and the animal's gut. Mills and colleagues demonstrated that Carnobacterium spp. found on lamb carcasses were linked to the meat processing environment. Spoilage bacteria and the meat quality. Further, investigations of microbial prevalence revealed that the core microbiota at the slaughterhouse consisted of Staphylococcus spp., Streptococcus spp., Brocothrix spp., Psychrobacter spp., Acinetobacter spp., and LAB. 'On the other hand, Proteobacteria especially Pseudomonas spp'. and members of Enterobacteriaceae were found to dominate the carcass microflora **[29,30,31,32,33,34,35]**.

The Packaging

Three different packaging types are in use: air, vacuum, and modified atmospheres. Modified atmospheres contain different levels of oxygen and carbon dioxide, balanced with inert nitrogen. The Packages containing up to 80% oxygen and 20% carbon dioxide (High oxygen-modified atmospheres) will reduce the color. 'The deterioration of the retail cuts of the meat, but will only slightly increase the shelf life, compared to aerobic storage'. The Pork is generally stored aerobically or in modified atmospheres, and beef in a vacuum or modified atmospheres due to the need for tenderization during extended storage. Transitions between the different packaging types may be performed for retail cuts. The shelf life of the meat increases in the order: of air, high oxygen-modified atmospheres, vacuum, no oxygen-modified atmospheres, and 100% CO2, P.wudomonm spp. dominate on the aerobically stored meat, and due to a high growth rate the shelf life is a matter of days. The shelf life may be attained in pure CO2, The time needed to reach 10' bacteria/cm' and off odour. was 10 days in air, and 40 days in 100% CO2 for pork stored at 4°C. 'The effect of CO2 is enhanced by a low storage temperature, due to increased solubility of the gas'. On pork loins stored under CO2, at ~ 1.5" C, a maximum bacterial number of 10(2) cfu/cm (2)" was reached after 63 days. Shelf life extension by CO2 results from an immediate selection, as opposed to a gradual one in a vacuum pack, of lactic acid bacteria growing at a reduced rate **[36,37,38,39,40,41,42]**.

The Temperature

The lowest cold storage temperature for the meat is - 1.5" C and the minimum growth temperature of the psychrotrophic bacteria is - 3°C. Decreasing refrigeration temperatures decreases bacterial growth, and affects the composition of the bacterial flora. In the vacuum-packaged beef, a bacterial count of about 10(7) cfu/cm2 was reached after 14 weeks at - 1.5'C, but as early as after three weeks at 4°C. The growth of enterobacteria was drastically reduced at - 1.5C, but a transition to 4°C initiated the growth **[43,44,45,46,47,48,49]**.

The Product Composition

The meat pH and the availability of the nutrients affect the selection and the growth of the bacteria. Normally, the muscle pH decreases post-mortem to values between 5.4 and 5.8. A high ultimate pH (> 6.0; dark firm dry meat, dark firm dry) may be the result of stress of the living animal. The Adipose tissues also have a higher pH than normal meat. The meat contains about 0.2% glucose and 0.4% amino acids. In the adipose tissue and the high-pH meat, the levels of the bacterial nutrients are lower. The High pH meat and the adipose tissue spoil more rapidly than the normal pH meat since the amino acids are rapidly attacked. Vacuum-packed pork has a shorter shelf life than beef, even though the lactic acid bacteria dominate both types of meat. The Glycogen and the glucose decrease at a faster rate in the pork than in the beef, leading to an earlier initiation of the amino acid degradation in the pork. In addition, the Enterobacteriacae~ are developed better on the pork than on the beef. The pink color of the cooked, cured meat products is the result of the addition of the nitrite and/or nitrate prior to the heating, and the subsequent formation of the nitrosohaemochrome. The Nitrite has an inhibitory action on the growth of several microorganisms, such as the Enterobucferiuceue and the B. thermosphacta, but not on the lactic acid bacteria **[50,51,52,53,54,55,56]**.

The Bacteria are Associated with the Spoilage of the Meat Products

The Lactic acid bacteria are the major bacterial group associated with the spoilage of refrigerated vacuum or MA-packaged cooked, cured meat products. At the time of the spoilage, some products contained a 'pure' culture of only one species, while in others a mixture of the lactobacillus spp. and the Leuconostoc spp. was found. The great diversity of the bacteria isolated from the spoiled meat products. The genus/species of the lactic acid bacteria responsible for the spoilage depend on the product composition (product-related flora) as well as the manufacturing site. The Lactic acid bacteria spoil the refrigerated meat products by causing defects such as sour-off flavors, discoloration, gas production, slime production, and a decrease in PH **[57,58,59,60,61,62,63]**.

The Off-odors and the Off-Flavors

The Off devours in the vacuum or the MA-packaged cooked meat products are typically described as sour and acidic. The dominating bacteria, lactic acid bacteria, produce acids such as lactic acid. acetic acid and formic acid: the levels depending on genus species and growth conditions. The Meat products stored aerobically or vacuum packaged using a film with a relatively high permeability to oxygen may be in addition to sour and acid flavors. Develop a slightly sweet, cheesy obnoxious Odor, This is also found in the meat products that have initially been stored anaerobically and subsequent to opening the package in an aerobic atmosphere. An aerobic atmosphere induces the formation of acetoin in B. thermofecta lactobacillus spp. and Corynebacterium spp. **[64,65,66,67,68,69,70]**.

The Discoloration

The Bacteria producing H2O2 may cause a green discoloration through the oxidation of the nitrosohaemochrome to the choleomyoglobin, frequently seen as green spots. Exposure to the air is necessary for the formation of H2O2. The bacterial greening in the Centre of the meat products is caused by the bacteria surviving the cooking process which after exposure to air starts to produce H2O2. The high heat resistance, W.viridescens has been demonstrated to survive regular heat processing in sausage processing, being able to survive for more than 40 minutes at 68°C. The surface greening is caused by bacteria which contaminate the product after cooking. The Homofermentative Lactobacillus spp., the heterofermentative Lactobacillus spp., the Leuconostoc spp., and the C. divergens are able to form H2O2. Other bacteria that have been associated with greening are Elzterococcus spp. and Pediococcus spp. **[71,72,73,74,75,76,77]**.

The Gas Production

Clostridium spp. has been associated with the production of large amounts of gas (H2, and CO2,) in the vacuum packaged beef, accompanied by foul-off odors. The Gas production (CO2) by lactic acid bacteria without extensive off odours may be associated with vacuum-packaged beef and pork **[78,79,80,81,82,83,84]**.

Heat Processed Meat Products

The Environmental Influences on Bacterial Growth and Shelf Life

The microbiological stability of the cooked, the cured meat products depends on the extrinsic factors, mainly the packaging method and storage temperature, and on intrinsic factors, such as the product composition **[85,86,87,88,89,90]**.

The Packaging

The Cooked meat products are chill stored. The vaccum pack or MA-packs are also distributed unpacked, i.e. stored in an aerobic atmosphere. In the retail shops slicing is performed after the opening of packages, with subsequent storage in an aerobic atmosphere. During the aerobic storage of the cooked, the sliced meat products a mixed florrt composed of the bacillus spp., the micrococcus spp, and the lactobacillus spp. is recorded to dominate. In addition, the psuedomonus spp. may increase up to 10^5 Cfui\g. The cured, the raw meat products, the B. thermophacta, the Moraxella spp\ psychrobacter spp., and the Pseudmonus spp. were retrieved. In addition, good growth of yeast occurred. Vacuum packaging is frequently used for cooked meat products. The combination of the microaerophilic conditions, the presence of the curing salt, and the nitrite favors the growth of the psychotropic lactic acid bacteria **[91,92,93,94,95,96,97]**.

The Temperature

On the vacuum or the MA-packaged meat products the dominance of lactic acid bacteria is unaltered by the refrigeration temperature used, but the growth rate is affected. Inoculation studies with the lactic acid bacteria on the vacuum-packaged Bologna type sausage demonstrated that with a decrease in temperature from 7°C to 2" C, the growth of lactic acid bacteria was retarded almost twofold; from 7°C to 0°C about fourfold. For meat products, the storage temperature is an important factor influencing the shelf life **[98,99,100,101,102,103,104]**.

The Analysis of the Spoilage

The Bacterial Indicators

The maximum level of bacteria reached during refrigerated storage of the meat is $1O^7$ to 10^9 cfu\cm^2 and of the meat products about $1O^7$ to 10^9 cfu /g. The correlation between bacterial numbers, in particular lactic acid bacteria, and sensorial spoilage is imprecise, which makes it difficult to use bacterial levels as an estimate of spoilage. The probability that 10^7 lactobacillus lus spp\g meat products would cause overt spoilage is about 10%. The times between reaching bacterial counts of 10^7 cfu\ig, and that of evident spoilage, were 19 days and one month of storage at 4°C and 2°C respectively. A similar situation is also valid for vacuum-packaged beef. The storage at 4°C off odours occurred one week after achieving a count of 10^7 cfu\cm'. However, at - 1.5°C off odors were pronounced as early as four weeks before a count of 10^7 cfu/cm^2 **[105,106,107,108,109,110,111]**.

The Chemical Indicators

As an alternative to bacterial determinations, n-lactate, acetoin, tyramine, pH value, and headspace gas composition have been suggested as chemical indicators of bacterial spoilage in meat and meat products. 'The use of such spoilage indicators is, however, dependent on the product composition. The occurrence of the slime and the decrease in the pH of the meat products will depend on the presence of the fermentable carbohydrates'. The drop of the pH from 6.3 to 5.6 was observed in the Bologna-type sausage, while in the liver Sausage, the pH dropped to five. The type and the amount of the bacterial end products formed were dependent on the type of bacteria growing on the meat. The o-lactate and acetate indicated high numbers of lactobacillus sp. while D-lactate and ethanol indicated high numbers of Leuconostoc sp. **[112,113,114, 115, 116,117,118]**.

The Microbiological Spoilage of the Meat

'Meat and meat products are ideal growth media for the animal-borne as well as the environmental sources of the microbes'. The skin and the intestinal contents are the primary sources of the animal-borne microbes in the meat. The Muscle glycogen lactic acid from the anaerobic glycolysis along with minor quantities of glucose and glucose-6-phosphate are some of the molecules available for microbial utilization. Glucose is the first source of energy, which is metabolized more rapidly by obligate aerobic pseudomonads than by facultative anaerobes such as the B. thermosphacta and the oxidative strains of the Shewanella putrefaciens. The Pseudomonads are predominantly seen during spoilage as a result of their faster growth rate along with a higher affinity for oxygen. The glucose reserves are depleted; lactate is the next energy source utilized both under aerobic and anaerobic conditions, followed by the amino acids. 'The sensorial meat spoilage development is due to the metabolic activity of the meat surface microbiota on the nutrient substrates such as the sugars, the fatty acids, and the' free amino acids favoring the release of the undesirable volatile organic compounds (VOCs), including the alcohol, the aldehydes, the ketones, the esters, and the volatile fatty acids. The Aerobic bacteria such as the pseudomonads oxidize the glucose and the glucose-6-phosphate to form the D-gluconate, the pyruvate, and the 6-phosphogluconate. The Odoriferous metabolites derived from amino acids such as sulfides, methyl esters, and ammonia are usually the first manifestation of the spoilage of chilled meat and poultry. The microorganisms commonly involved in putrefaction include the P. fragi, the S. putrefaciens, the Proteus, the Citrobacter, the Hafnia, and the Serratia **[119,120,121,122,123,124]**.

The Alcohols

The Alcohols are produced by the spoilage microbes during the chilling of the fresh meat when stored aerobically and under the vacuum packaging and MAP. Microbial metabolism favors the breakdown of proteins and amino acids, reduction of the ketones, and the aldehydes derived from the lipid peroxidation to produce a variety of alcohols. The Alcohols associated with the spoilage of the meat stored aerobically and in the vacuum packaging include methyl-1-butanol, 1-octen-3-ol, 2-ethyl-1-hexanol, 2, 3-butanediol, butanol, 1-heptanol, 1-hexanol, and 3-phenoxy-1- Propanol, whereas 1-octen-3-ol is associated with MAP meats. The spoilage organisms, the Pseudomonas spp., and the Carnobacterium spp. are predominantly involved in the production of alcohols, and some of the compounds generated are indicative of possible off-odor in the meat **[125,126,127,128,129,130]**.

The Aldehydes

The production of aldehydes by the spoilage organisms is known to impart sharp acidity to the fatty flavor of the meat. The Acidic flavors are commonly attributed to the short-chain aldehydes, whereas an increase in the aldehyde chain length with varying degrees of unsaturation contributes to the fattiness. The Aldehydes are derived from triglyceride hydrolysis, the oxidation of the unsaturated fatty acids, or the lipid auto-oxidation. The aldehydes can be generated from the imide intermediates of the amino acid transamination reactions. The species mainly contributing to the off flavors by the aldehyde production include the Pseudomonas spp., the Carnobacterium spp., and the Enterobacteriaceae spp. The hexanal, the nonanal, the benzaldehyde, and the 3-methyl butanal are aldehydes seen in naturally spoiled meat, which at the detectable threshold levels are known to generate the fresh green fatty aldehydic grass leafy, fruity sweaty odor, the fatty and the green herbal odor, the volatile almond oil and the burning aromatic taste, and the cheese and the pungent apple-like odor, respectively. Exceedingly higher concentrations than detectable odor threshold values are known to produce very unpleasant and rancid aromas in the meat. The aldehydes are known to produce off flavors in fresh as well as spoiled meat, correlating their presence with the spoilage bacteria is difficult due to their low concentration and oxidation to acids during the early storage phase, the Spoilage bacteria and the meat quality **[131,132,133,134,135]**.

The Ketones

The Ketones are generated either via chemical or microbial spoilage, and they are produced in the fresh meat stored under varying atmospheric conditions. Lipolysis and microbial alkaline degradation or dehydrogenation of secondary alcohols are some of the putative routes for ketone production in fresh meat. The aldehydes, the Pseudomonas spp., the Carnobacterium spp., and the Enterobacteriaceae are also known to be primarily associated with volatile ketones from spoiled meat. The Acetoin and the diacetyl are major ketones that contribute to the cheesy odor and the butter, the sweet, the creamy, and the pungent caramel flavor, respectively. Acetoin is known to be generated from the glucose catabolism by the B. thermosphacta, the Carnobacterium spp., and the Lactobacillus spp. and also by the microbial breakdown of aspartate **[136,137,138,139]**.

The Esters

The Esters are predominantly seen in fresh meat stored aerobically and their production is attributed to P. fragi, which is considered the major ester producer. Microbial esterase activity favors the esterification of alcohols and carboxylates found in meat resulting in a fruity off flavor. Some of the volatile esters produced from naturally spoiled meat or an inoculated model meat system include ethyl acetate, ethyl butanoate, ethyl-3- methylbutanoate, ethyloctanoate, ethyl hexanoate, and ethyl decanoate **[5,6,7,8,9,10,11]**.

The Volatile Fatty Acids

Volatile fatty acids are another group of compounds that originate from fresh meat following the hydrolysis of triglycerides and phospholipids. Amino acid degradation or the oxidation of ketones, esters, and aldehydes are other plausible reaction pathways for their production. B. thermosphacta and Carnobacterium spp. are associated with the production of volatile fatty acids in fresh meat. B. thermosphacta are known to produce 2- and 3-methylbutanoic acid from aerobically stored fresh meat, wherein isoleucine, leucine, and valine act as precursors for amino acid degradation. These acids provide a pungent, acid, and Roquefort cheese odor and a sour, stinky, feet, sweaty, and cheese odor, respectively, in aerobically stored fresh meat. Butanoic acid is produced by LAB via the breakdown of amino acids through the Stickland reaction, or by Clostridia through butyric fermentative metabolism in vacuum-packaged meats. Butanoic acid is known to produce a rancid, sharp, acid, cheesy, butter, and fruity odor in spoiled meat **[31,32,33,34,35,36]**.

The Sulfur Compounds

The Volatile sulfur compounds are produced by spoilage microbes as a result of the degradation of sulfur-containing amino acids (methionine and cysteine) producing compounds such as dimethylsulfide, dimethyldisulfide, dimethyltrisulfide, and methyl thioacetate. The Pseudomonads are commonly associated with the production of volatile sulfur compounds which generate a wide variety of odors providing sulfurous, cooked onion, vegetable, radish-like, and savory meaty odors. The Biogenic amines are also a consequence of meat spoilage by bacteria producing amino acid decarboxylases. The primary end product of bacterial amino acid metabolism in meat includes putrescine and cadaverine. Production of these amines leads to the development of putrefying odors associated with spoiled fresh meat **[68,39,70,71,72,73]**.

The Factors Affecting Microbial Meat Spoilage

The Spoilage of the meat is principally caused by the growth and degradation of the nutrients in the product by a diverse group of microorganisms. The composition of this microflora is dependent on the product itself and the processing and storage conditions. In general, the factors that influence microbial proliferation in meat are grouped into three categories. The Intrinsic parameters include the physical and chemical composition of the substrate, water activity, pH, nutrient availability, initial microflora, and presence of natural antimicrobial substances. The Extrinsic parameters are the storage and handling environment specifically temperature, humidity, and atmosphere conditions (aerobic, anaerobic, and MAP). The Implicit parameters constitute the synergistic and antagonistic effects of the factors mentioned above on the development and establishment of the spoilage microflora. The Intrinsic factors, The Meat composition, and antimicrobial hurdles Like higher animals, microorganisms also require energy for their growth and survival, essential nutrients and components for the constitution of cells. They acquire these molecules from their substrate or surrounding food environment. In this regard, meat and muscle foods, in general, are rich in proteins, lipids, minerals, and vitamins, but poor sources of carbohydrates. This nutrient composition and availability select for the growth and survival of certain groups of microbes (initial microflora) over others. Further, the initial breakdown of these macromolecules to simpler molecules paves the way for microbial succession by organisms that in turn feed on these metabolites. Beyond nutrient availability, and the presence of growth factors, natural and added inhibitors select for specific strains. These antimicrobial hurdles include food additives, preservatives, natural antimicrobials, and bioprotective cultures that are incorporated into food to improve shelf life and promote food safety **[134,135,136,137,138,139]**. The meat pH Postmortem pH of meat is determined by the amount of lactic acid produced from glycogen during anaerobic glycolysis and is an essential determinant for the growth of spoilage microbes. After slaughter, muscle pH reduces typically to 5.4 \5.8, which can inhibit spoilage microbes to a certain extent. The Meat from stressed animals produces a pH greater than or equal to 6.0 (dark, firm, and dry meat), and this makes it an ideal environment for microbes to multiply, eventually resulting in spoilage. The presence of lipid (adipose tissue) 320 Chapter 17 and high pH favor rapid bacterial proliferation, utilization of nutrients, and eventual spoilage of the meat. The Water activity is High, The moisture content and low solute concentrations tend to provide a favorable environment for microbial growth on meat. The Water activity (aW) of a solution is defined as the ratio of its vapor pressure to that of pure water at the same temperature, and it is inversely proportional to the number of solute molecules present. The Spoilage molds and yeast are more tolerant to higher osmotic pressures than bacteria. The Bacteria tend to grow at an aW ranging from 0.75 to 1.0, whereas yeast and molds grow slowly at an aW of 0.62. Dried products (aW of less than 0.85), which are stored and distributed at ambient temperatures do not support growth and toxin production bacteria such as Staphylococcus aureus and Clostridium botulinum. The microbe population in curing salt solutions such as bacon brines has a shift in population toward osmotolerant and halotolerant organisms. For instance, certain Lactobacillus spp. can tolerate high sugar concentrations generally used in the ham-curing brine. They are capable of growing on cured unprocessed hams and produce polysaccharides with associated deterioration in flavor and appearance. The Extrinsic factor, The Temperature is a major factor that controls bacterial growth. An understanding of time and temperature management to control spoilage microbes is essential to improve the shelf life of a product. Based on the survivability of microbes at different temperatures, they can be classified as psychrotrophs, mesophiles, and thermophiles, whose tolerability includes the following temperature range: 2C 7C, 10C 40C, and 43C, v66C, respectively. The Aerobic spoilage microflora at chilling temperatures consists predominantly of the pseudomonads, while the LAB is the primary organism of concern under anaerobic conditions or MAP. The nutrient content at certain storage temperatures in meat is another factor that influences microbial growth. An inverse relation has been observed with temperature and amino acid utilization by Lactobacillus arabinosus, wherein the bacterium requires phenylalanine, tyrosine, and aspartate for growth at 39C, phenylalanine and tyrosine at 37C, and none of these amino acids at 26C. Also, a high microbial load before freezing can contribute to the persistence of microbial enzymes such as lipases even at freezing temperatures. Although the microbial growth process is arrested by freezing, microbial enzymes may continue to produce deleterious changes in meat quality even at temperatures as low as 30C. The Packaging and the gaseous atmosphere, The gaseous atmosphere within a packed meat product has a significant impact on the spoilage microbiome. The Pseudomonas spp., Acinetobacter spp., and Moraxella spp. are predominant bacterial genera involved in aerobically stored meat products within a temperature range of 1C to 25C. Specifically, P. fluorescens, P. fragi, P. ludensis, and P. putida are the significant species commonly isolated from aerobically packaged meat. In the vacuum-packed and MAP meat, there is a shift from aerobic bacteria to the overgrowth and prevalence of facultative and strict anaerobic spoilage microbes. Shewanella spp., Brochothrix spp. (B. thermosphacta and B. campestris), Serratia spp. and LAB are the major groups involved in the spoilage of vacuum and/or MAP meat products. S. putrefaciens is a predominant spoilage bacterium found in chilled and vacuum-packaged meat. Reduced water activity along with microaerophilic conditions inhibits gram-negative spoilage microbes and favors the growth and establishment of the LAB. The Implicit factors, The Implicit factors influencing spoilage develop as a result of microbial succession that occurs in meat through the production continuum. The factors previously described can either have a synergistic or antagonistic effect on strain selection and eventual composition of the spoilage microflora. Synergistic effects include the breakdown of macromolecules in meat by the initial microflora, thereby providing easily accessible nutrients for a subsequent group of microorganisms that would otherwise be unable to sustain themselves in the food environment. Similarly, changes in acidity or buffering capacity of meat and water activity help select for strains that are tolerant to the altered conditions thereby establishing the secondary spoilage microflora on meat. While these conditions may serve to support a certain group of organisms, they are antagonistic to other species that are sensitive to this food environment **[12,13,14,15,16,17,18,19]**.

Conclusion

Microorganisms play in the spoilage of meat and meat products, it is critical to develop productive and feasible approaches to prevent and curtail the growth of spoilage microorganisms. However, in order to develop practical antimicrobial hurdles, it is important to identify, characterize, and understand the predisposing factors in a food system that promote bacterial growth and spoilage. Furthermore, developing product-specific intervention strategies that can be implemented at any point in the food production continuum will be made easier with the clarification of the microbial signature linked to diverse foods as well as different handling and food production continuum.

Conflicts of Interest

The author declare no conflicts of interest.

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