

Why we Extend 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 physico-chemical activities may interact and make the product unacceptable for the human consumption.

A 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. Meat and fish, due to their physico-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 large variety of microbial species originate from the physiological status of the animal during the farming, the slaughtering, the harvesting, the fishing, the processing, the transportation, the preservation, and the storage conditions. The contamination also 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 microorganisms 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 and 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 for certain bacteria. The initial mesophilic bacterial count on the meat and the cooked meat products is about 10⁶-10⁷ cfu, /cm² 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 lower. Since the meat products are heated to a temperature of 65-75°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, the environmental factors such as the temperature, the gaseous atmosphere, the pH and the NaCl will select for certain bacteria, and affect their growth rate and activity. The shelf-life of the refrigerated meat and the meat products may vary from days up to several months. The bacteria able to grow and cause the spoilage during the storage of the meat, the cooked and the cured meat products (8,9,10,11,12,13 and 14).

Causes of the meat spoilage

can be caused by physical, chemical and biological agents, including the microorganisms-bacteria, yeast and mold, the action of enzymes in meat

such as lipases and proteases, the chemical reactions in the foods such as the browning and the oxidation, the physical changes introduced by the freezing, the drying, and the application of the pressure. Although several agents are implicated in the 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, carbohydrate, 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 and 21).

The Meat

The Environmental influence on the bacterial growth and the 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, The 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*, *Rhodotulola*, *Cryptococcus*, *Pichia*, and *Saccharomyces* in the fresh and the refrigerated meat and the 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 and 28).

The Micro flora of the 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 as the slaughterhouse microbiome, which is a combination of the microbial population in the facility and the animal's gut. Toward this, Mills and coworkers demonstrated that *Carnobacterium* spp. identified on lamb carcasses were traced back 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 and 35).

The Packaging

Three different packaging types are in use: air, vacuum and modified atmospheres (MA). MA contains different levels of oxygen and carbon dioxide, balanced with inert nitrogen. The Packages containing up to 80% oxygen and 20% carbon dioxide (High oxygen-MA) 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 MA, and beef in a vacuum or MA due to the need for tenderization during an extended storage. Transitions between the different packaging-types may be performed for retail cuts. The shelf-life of meat increases in the order: air, high oxygen-MA, vacuum, no oxygen-MA and 100% CO₂. *Pseudomonas* spp. dominate on aerobically stored meat, and due to a high growth rate the shelf-life is a matter of days. A long the shelf-life may be attained in pure CO₂, the time needed to reach 10⁷ bacteria/cm² 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 and 42).

The temperature

The lowest cold-storage temperature for the meat is - 1.5°C, while the minimum growth temperature of psychrotrophic bacteria is - 3°C. Decreasing refrigeration temperatures decrease the bacterial growth, and affect the composition of the bacterial flora. For 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 - 1.5°C, but a transition on to 4°C initiated the growth (43,44,45,46,47,48 and 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; DFD-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 adipose tissue spoil more rapidly than the normal pH meat since the amino acids are rapidly attacked. The Vacuum-packed pork have a shorter shelf-life than the beef, even though the lactic acid bacteria dominate on both

types of the 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 Enterobacteriaceae~ are developed better on the pork than on the beef. The pink colour of the cooked, the 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 micro-organisms, such as the Enterobacteriaceae and the *B. thermosphacta*, but not on the lactic acid bacteria (50,51,52,53,54,55 and 56).

The Bacteria associated with the spoilage of the meat products.

The Lactic acid bacteria are the major bacterial group associated with the spoilage of the refrigerated vacuum- or MA-packaged cooked, cured meat products. At the time of the spoilage some products contain 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 the product composition (product-related flora) as well as the manufacturing site. The Lactic acid bacteria spoil the refrigerated meat products by causing the defects such as the sour off-flavors, the discoloration, the gas production, the slime production and the decrease in PH (57,58,59,60,61,62 and 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 acid. 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 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. thermofacta* *Lactobacillus* spp. and *Corynebacterium* spp. (64,65,66,67,68,69 and 70).

The Discoloration

The Bacteria producing H₂O₂ may cause a green discoloration through the oxidation of nitrosohaemochrome to choleomyoglobin, frequently seen as green spots. Exposure to air is necessary for the formation of H₂O₂. The bacterial greening in the Centre of the meat products is caused by bacteria surviving the cooking process which after exposure to air start to produce H₂O₂. Due to a 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. Homofermentative *Lactobacillus* spp., heterofermentative *La-tobacillus* spp., *Leuconostoc* spp. and *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 and 77).

The Gas production

The *Clostridium* spp. have 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 the vacuum-packaged beef and pork (78,79,80,81,82,83 and 84).

The Heat processed meat products

The Environmental influences on the bacterial growth and shelf-life

The microbiological stability of the cooked, the cured meat products depend 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 and 90).

The Packaging

The Cooked meat products are chill-stored. Usually in vacuum-pack or in MA-packs, but are also distributed unpacked, i.e., stored in an aerobic atmosphere. Furthermore, in 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 flora composed of *Bacillus* spp., *Micrococcus* spp and *Lactobacillus* spp. is reported to dominate. In addition, *Pseudomonas* spp. may increase up to 105 CFU/g. In the cured, the raw meat products, *B. thermosphacta*, *Moraxella* spp\ *Psychrobacter* spp. and the *Pseudomonas* spp. were retrieved. In addition, good growth of yeast occurred. The Vacuum-packaging is frequently used for the 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 and 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 lactic acid bacteria on 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 two-fold; from 7°C to 0°C about four-fold. Thus, for meat products the storage temperature is an important factor influencing the shelf-life (98,99,100,101,102,103 and 104).

The Analysis of the spoilage

The Bacterial indicators

The maximum level of bacteria reached during refrigerated storage of meat is 10⁷- 10⁹ cfu/cm², and of meat products about 10⁷- 10⁹ 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 10⁷ *Lactobacillus* spp/g meat product would cause overt spoilage is about 10%. The times between reaching bacterial counts of 10⁷ cfu/g, and that of evident spoilage, were 19 and 30 days at 4°C and 2°C respectively. A similar situation is also valid for vacuum-packaged beef. At 4°C off odours occurred one week after achieving a count of 10⁷ cfu/cm³. However, at -1.5°C off-odors were pronounced as early as four weeks before a count of 10⁷ cfu/cm² (105,106,107,108,109,110 and 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 product composition. The occurrence of slime and the decrease in pH in meat products will depend on the presence of fermentable carbohydrates. For example, a drop in pH from 6.3 to 5.6 was observed in Bologna-type sausage, while in liver Sausage, the pH dropped to 5.0. The type and number of bacterial end-products formed were dependent on the type of bacteria growing on the meat. o-lactate and acetate indicated high numbers of *Lactobacillus* sp. while D-lactate and ethanol indicated high numbers of a *Leuconostoc* sp. (112,113,114, 115, 116,117 and 118).

The Microbiological spoilage of the meat

The Meat and the meat products are ideal growth media for animalborne as well as environmental sources of microbes. In general, the skin and intestinal contents are the primary sources of animal borne microbes in meat. Muscle glycogen-derived lactic acid from 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 *B. thermosphacta* and oxidative strains of *Shewanella putrefaciens*. The Pseudomonads are predominantly seen during spoilage as a result of their faster growth rate along with a higher affinity for the oxygen. Once glucose reserves are depleted, lactate is the next energy source utilized both under aerobic and anaerobic conditions, followed by the amino acids. In general, the sensorial

meat spoilage development is due to the metabolic activity of the meat surface micro biota 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 pseudomonads oxidize glucose and glucose-6-phosphate to form D-gluconate, pyruvate and 6-phosphogluconate. The Odoriferous metabolites derived from the amino acids such as the sulfides, the methyl esters, and the ammonia are usually the first manifestation of the spoilage of the chilled meat and the poultry. Some of the microorganisms commonly involved in putrefaction include *P. fragi*, *S. putrefaciens*, *Proteus*, *Citrobacter*, *Hafnia*, and *Serratia* (119,120,121,122,123 and 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 the alcohols. 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. Among the different spoilage organisms, *Pseudomonas* spp. and *Carnobacterium* spp. are predominantly involved in the production of the alcohols, and some of the compounds generated are indicative of possible off-odor in meat (125,126,127,128,129 and 130).

The Aldehydes

The production of aldehydes by the spoilage organisms is known to impart sharp acidic to the fatty flavor in the meat. The Acidic flavors are commonly attributed to the short-chain aldehydes, whereas an increase in the aldehyde chain length with the varying degrees of the unsaturation contributes to the fattiness. These compounds are derived from the triglyceride hydrolysis, the oxidation of the unsaturated fatty acids, or the lipid auto oxidation. Moreover, the aldehydes can also 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..For example, the hexanal, the nonanal, the benzaldehyde, and the 3-methylbutanal are aldehydes seen in the naturally spoiled meat, which at detectable threshold levels are known to generate fresh green fatty aldehydic grass leafy, fruity sweaty odor, fatty and green herbal odor, volatile almond oil and burning aromatic taste, and cheese and 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. Although aldehydes are known to produce off-flavors in fresh as well as the spoiled meat, correlating their presence with spoilage bacteria is difficult due to their low concentration and oxidation to acids during the early storage phase. Spoilage bacteria and the meat quality (131,132,133,134 and 135).

The Ketones

The Ketones are generated either via chemical or by 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 is some of the putative routes for ketone production in fresh meat. As with aldehydes, *Pseudomonas* spp., *Carnobacterium* spp., and *Enterobacteriaceae* are also known to be primarily associated with volatile ketones from the spoiled meat. Acetoin and diacetyl are major ketones that contribute to cheesy odor and butter, sweet, creamy, and 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 and 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 and 11).

The Volatile fatty acids

The 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 breakdown of amino acids through Stickland reaction, or by Clostridia through butyric fermentative metabolism in vacuum-packaged meats. The Butanoic acid is known to produce a rancid, sharp, acid, cheesy, butter, and fruity odor in spoiled meat (31,32,33,34,35 and 36).

The Sulfur compounds

The Volatile sulfur compounds are produced by spoilage microbes as a result of 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 a 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 and 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 micro flora is dependent on the product itself and the processing and storage conditions. In general, the factors that influence microbial proliferation on meat are grouped into three categories. The Intrinsic parameters, these 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, The storage and handling environment specifically temperature, humidity, and atmosphere condition (aerobic, anaerobic, and MAP). The Implicit parameters, these 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 the others. Further, the initial break down of these macromolecules to simpler molecules paves the way for microbial succession by organisms that in turn feed on these metabolites. Beyond nutrient availability, 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 in food to improve shelf life and promote food safety (134,135,136,137,138 and 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 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 a 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 concentration generally used in ham-curing brine. They are capable of growing on cured unprocessed hams and produce polysaccharides with associated deterioration in flavor and appearance. The Extrinsic factors, 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 ranges: 2C 7C, 10C 40C, and 43C, v66C, respectively. The Aerobic spoilage microflora at chilling temperatures consists predominantly of the pseudomonads, while the LAB are the primary organisms 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 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 gramnegative 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 and 19).

Conclusion

The microorganisms play in the spoilage of meat and meat products, it is critical to develop effective 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, the elucidation of the microbial signature associated with different foods, and various handling and storage conditions will help to develop intervention strategies that are product specific and can be applied along the food production continuum.

Conflicts of Interest

The author declares no conflicts of interest

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