Available online at www.ijpab.com

DOI: http://dx.doi.org/10.18782/2582-2845.8970

ISSN: 2582 – 2845

Ind. J. Pure App. Biosci. (2023) *11*(1), 14-22

Indian Journal of Pure & Applied Biosciences

Peer-Reviewed, Refereed, Open Access Journal

Review Article

Causes of Meat Deterioration and Preservation Methods

Aman Ullah[1*], Riaz Ahmed Gul[2], Nimra Inaam[3], Muhammad Naeem[4], Muhammad Imran[5], Salman Aslam[6], Amir Saeed[7], Faizan Saleem[1], Abdur Rahim[8], Ahmad Raza[1]

[1]Faculty of Veterinary Sciences, Bahauddin Zikriya University, Multan, Pakistan,

[2]Department of Clinical Medicine & Surgery, Faculty of Veterinary and Animal Sciences, The İslamia University of Bahawalpur, Punjab, Pakistan

[3]University of Agriculture Faisalabad, Pakistan,

[4]Department of Pharmacology and Toxicology, University of Veterinary and Animal Sciences, Lahore, Pakistan,

[5]Institute of Microbiology, university of agriculture Faisalabad, Pakistan

[6]Epidemiology and Public Health, University of Agriculture Faisalabad, Pakistan

[7]Poultry Production from University of Veterinary and Animal Sciences Lahore, Pakistan

[8]Clinical medicine and Surgery, University of Agriculture, Faisalabad, Pakistan

*Corresponding Author E-mail: amanullahzain682@gmail.com

Received: 15.10.2022 | Revised: 17.01.2023 | Accepted: 28.01.2023

ABSTRACT

Humans have been practising the skill of meat preservation since the beginning of time, and this practice lives on in all of the foods we consume today. Primarily, meat preservation postpones the development of microorganisms like bacteria and fungi, so meat and its byproducts may sit on store shelves for longer without losing quality or flavour. Dysbiosis is the process by which any food, when exposed to organisms (bacterial and fungal), that degrade the products, changes from being edible to being inedible via denaturation of texture, color, and odor. Spoilage and a lack of storage skills during processing and analyzing generate a significant annual loss of meat and its byproducts for the economies of all countries. In general, organic material, lipid oxidation, and metabolic activity are the fundamental processes of meat deterioration. Traditional techniques for preserving food include drying, salting, pickling, and smoking, all of which aid in preservation when frozen. However, as time went on, new techniques for preserving food emerged, such as freezing, chilling, and irradiation, which significantly extended the period of preservation and made it easier to apply. Modern procedures, such as chilling and other freezing technologies, are used to preserve all manner of meat and meat products, extending their shelf life and improving their quality and texture by all but neutralizing the development of microorganisms.

Keywords: *Meat, storage, deterioration, lifespan, Flavour, Microorganism and fungi.*

Cite this article: Ullah, A., Gul, R. A., Inaam, N., Naeem, M., Imran, M., Aslam, S., Saeed, A., Saleem, F., Rahim, A., & Raza, A. (2023). Causes of Meat deterioration and Preservation Methods, *Ind. J. Pure App. Biosci. 11*(1), 14-22. doi: http://dx.doi.org/10.18782/2582-2845.8970

INTRODUCTION

Throughout history, the globe has increasingly relied on meat as a rich source of protein. According to Heinz and Hautziner (2007), animal protein (meat) consumers rank it as their top food choice globally. Chicken, turkey, beef, mutton, fish, hog, camel, etc. are all good sources of protein. We need to consider mass production and storage methods as meat consumption rises. Meat preservation is the practice of elongating the life span of meat by various techniques. Since slaughterhouses and other meat processing facilities are often located on the outskirts of town, there is a pressing need for methods of meat preservation that will allow for its safe transit over distances greater.

Several processes are involved in transforming animals, including loading slaughtering animals and taking them from the field to the butcher (Chambers & Grandin, 2001). Injuries sustained by animals as a consequence of improper animal handling lead to lower-quality meat and even spoiling. Water content in meat makes it more susceptible to assault by pathogens, which may lead to spoiling. Our environment is home to a wide variety of bacteria and diseases. Meat is preserved so that it doesn't go bad. Daily increases in animal meat consumption are accompanied by proportionate increases in the amount of meat lost to spoiling.

The rotting of meat accounts for a considerable proportion of meat waste (Heinz & Huat Zinger, 2007). Meat quality and spoiling activity will suffer as a r the animal's stress during slaughter (Chambers & Grandin, 2001). Main meat components include lipids, proteins, carbs, and water, according to (2007). We need to brainstorm some new possible preservation ways to maintain a newness that meat ingredients for the purpose of cutting down on the meat losses that are mostly caused by rotting (Barkel et al., 2004). Because people in the contemporary world want their meat to taste more like it came from the farm, there's a pressing need to develop and implement innovative strategies for keeping meat fresh for longer.

Muscle rigour mortis is a leading cause of meat deterioration. There is a correlation between the level of stress and the rate at which rigour mortis sets in after an animal's killing (Miller et al., 2002). Different forms of enzymatic activity will cause the breakdown of the numerous components of meat, including proteins, lipids, and carbs (Barket et al., 2004). Various mediaeval practises prevented food (particularly meat) from spoiling. Due to a lack of germs in the air, microbial activity was lower during that time period. More importantly, pollution levels were lower. In today's highly developed society, where air pollution is constant, food spoils more quickly than ever before due to airborne microorganisms.

A staggering amount of meat is wasted Annually, because of rotting—nearly 302.4 million tonnes.

In this review article, we will examine the primary reasons for meat spoilage and the many techniques used to prevent it, all with an eye on minimizing monetary loss and increasing profit margins in the meat processing sector.

Causes for Meat Spoilage:

A wide variety of factors may bring on meat deterioration. Here, we'll discuss how the slaughtering process influences the flavour of meat, both before and after the animal is killed. Meat spoils as a result of both of these effects when improper care and storage procedures are used. Animals under stress before slaughter have lower glycogen levels in their muscles, which influences the meat's pH. (Miller, 2002; Chambers & Grandin, 2001; & Rahman, 1999a). Animal muscle breakdown produces lactic acid through the anaerobic glycolytic pathway whenever glycogen is depleted (Rahman, 1999a).

The meat's pH will get black, hard, and dry if it is high. DFD is triggered by prolonged stress and shortens the meat's shelf life (Miller, 2002; & Chambers & Grandin, 2001). When the pressure lasts for a brief period, the flesh becomes whiter, softer, and more oozy. When protein breakdown occurs at a pH of 6.2, meat is ripe for bacterial growth and takes on a whitish hue, spongy texture, and oozing appearance (Miller, 2002; Chambers & Grandin, 2001; & Rahman, 1999a).

Here we will briefly cover three key mechanisms that lead to beef spoilage:

a) Biological process
b) oxidation of lipids
c) Activity of Autolytic Enzymes

Biological process;

Meat and meat byproducts provide fertile ground for a wide range of microorganisms, including some dangerous diseases (Jay et al., 2005). Animals' skin and digestive systems are major reservoirs of microflora and pathogens. The makeup of these pathogens is highly dependent on a large amount of circumstances, amongst others: pre-slaughter monitoring techniques; animal age; slaughter procedures; interactions; cooling systems; products; and consumer handling (Cerveny et al., 2009).

When meat has not yet begun to deteriorate, it is already home to a wide variety of bacterial, fungal, and yeast species. Cryptococcus and Candida spp. are examples of yeasts, whereas Cladosporium, Geotrichum, and Penicillin are examples of moulds (Garcia-Lopez et al., 1998). Streptococcus, Micrococcus, Xanthomonas, Bacillus, and Clostridium are just few of the many bacterial species that may be present in meat and other animal items (Lin et al., 2004; Arnaut-Rollier et al., 1999; & Nychas & Tassou, 1997).

Almost all meat samples from Lowa's diverse animal population, Enterococcus species is the most common kind of bacteria (Hayes et al., 2003). Under various conditions, several microorganisms may cause spoilage in the meat industry and related items (Carveny et al., 2009). Several varieties of microorganisms function better at lower temperatures. Refrigerated foods often have a high number of enteric bacteria. Many organisms, including Moraxella spp. and Acinetobacter spp., prefer warmer temperatures (over 20°Celsius) for optimal growth. Raw, salted cured items like hams and undercooked beef are common sources of viruses that thrive in warmer environments because salt encourages their development (curing salt).

Xanthomonas and enteric bacteria thrive at temperatures as low as 5 degrees Celsius, and are especially common in artificially created environments (Garcia-Lopez et al., 1998). Xanthomonas is a bacterial genus that can only shorten the life span of meat when the temperature is over 2 degrees Celsius, and its development rate is significantly slower when the temperature is below 0 degrees Celsius (Sentence, 1991). Just as the development rate of salmonella is too slow below 7 degrees Fahrenheit to affect meat quality or shelf life, the growth rate of many other species, such as E. coli, is too rapid above 7 degrees. Spoilage bacteria thrive in acidic environments with a pH between 5.5 and 7.0. (Russell et al., 1996). Meat quality declines within the aforementioned pH range due to microbial activity leading to the creation of slime, off-odour, and variations in texture.

Multiple ammonia derivatives, including methylamine and others, were shown to be actively involved in spoiling, as described by Garcia-Lopez et al. 1998. Ketones come in a wide variety; alcohols with a pleasant aroma are the result of microbial action.

Oxidation of lipids;

The fatty acids in meat will be impacted by free radical generation and lipid oxidation, leading to the appearance of odour, off-flavor, and a decline in the quality of the meat (Gray, 1978; Pearson et al., 1983; & Samitzis & Deligeorgis, 2010). After an animal is slaughtered, its metabolism comes to a halt as its blood supply is cut off and its fat stores begin to decompose (Gray & Pearson, 1994; & Linares et al., 2007). According to Hultin (1994), lipids' oxidation always involves forming a double bond between a oily acid and the oxygen in the air. Three fundamental stages characterize lipid oxidation: initiation, progression, and cessation. (Frankel, 1985;

Khayat & Schwall, 1983; & Fernindez et al., 1997).

Initially, free radicles are generated by natural catalysts like heat and irradiation; these radicles then combine with the oxygen in the air to generate peroxyl radicles.

Spread: newly generated free radicals and hydroperoxides are the products of the first reaction between peroxyl radicles and other lipid molecules (Fraser & Sumar, 1998; & Hultin, 1994).

Extinction: this is the result of free particles interacting with one other and generating non-radical byproducts in processes one and two.

Vitamin E, an antioxidant, and the fatty acid composition are two of the many variables influencing lipid oxidation. Hydroperoxide breakdown results in the production of many byproducts, including acids, ketones, and aldehydes (Fernindez, et al., 1997; Shahidi, 1994; Raharjo and Sofos, 1993). Extreme effects on carbohydrates, lipids, and vitamins will lead to nutrient degradation and colour loss (Simitzis and Deligeorgis, 2010), and these effects are linked to many severe pathogenic processes (Lie et al., 1995).

Lipolysis in meat may be carried out hydrolytic or non-enzymatically. Phospholipase, lipase, and other enzymes are used in hydrogenation. Phospholipase A1 and A2 are the major enzyme concerned in fat breakdown in meat (Toldra, 2006). Haemoglobin, cytochrome, and myoglobin are all proteins that are easily oxidized and, as a result, form hydroperoxides; these are the proteins essential for the non-enzymatic dissolution of red blood cells (Kanner 1994; & Love & Pearson, 1971).

Activity of Autolytic Enzymes;

Enzymes in the body are the primary culprits in the spoiling of meat. Only while an animal is alive do they function normally; after death or slaughter, they become the primary source of meat spoilage. Enzymes catalyze a chain of biochemical processes in meat it resulted in its degradation (Tauro et al., 1986). Tissue protease is an enzyme that is secreted when polypeptides are broken down; it is responsible for the alteration of taste and texture (Toldra & Flores, 2000).

Protein-digesting enzymes such as calpains and cathepsins break down flesh after death (O'Halloran et al., 1997; & Huss, 1995). Calpains facilitate the proteolytic tenderization (tenderization of meat) process. Meat quality declines mostly because the high levels of digestive enzymes and biogenic amines produced by microorganisms that thrive at low temperatures (Kuwahara & Osako, 2003).

Preservation Methods:

To keep beef fresh for longer, several alternative strategies are in use. The guy began preserving the meat for later consumption after he began making use of it. The following are examples of meat preservation techniques.

1- Drying
2- Canning
3- Smoking
4- Freezing
5- Chilling
6- Curing/Salting
7- Fermentation and Pickling
8- Irradiation

Drying:

We still rely on the oldest technique of preservation, drying, nowadays. Dehydration is another name for drying. Water is required for the development of bacteria and enzymes, but it is not enough, by removing most of the water, often to a weight of 10–20%, we kill the bacteria and render the enzymes inactive (Javeed Akhtar & Ram Krishna Pandey, 2015). People used to hang meat out in the sun to preserve it, but today we have ovens and dehydrators. With the use of a stove and oven, drying meat at home is now a simple task. To destroy any germs that could be lurking in the meat, it must first be chopped into thin, long strips before being boiled at a high temperature for 5-10 minutes and then baked. It's possible to store beef for up to two months in glass jars using this procedure (Lonergan Steven M. et al., 2018).

Canning:

Canning is another common method of preserving meat. In this case, any jar or can will do. After filling containers with meat, they spend 8 to 10 minutes in boiling water with their lids on before being cooled to 38 degrees Celsius (M.R. Berry & I.J. Pflug, 2003). The canning process requires the absence of oxygen. Additives are used in canning to increase the number of organisms that survive the process. Sodium benzoate, sodium sorbate, sodium ascorbate (ascorbic acid), and sulphur dioxide are just a few of the many additives that have been and continue to be employed (Alpana & Bhagyashree, 2017) Bacterial growth can be inhibited using acetic acid and lactic acid, while yeast growth can be stopped with sorbent and acetic (Mahendra Pal et al., 2018).

Canning meat with steam at a high enough temperature ensures that it will be safe to consume. Hot packing and raw packing are used to preserve chickens. Raw pack uses water or meat broth to preserve chicken, whereas hot pack uses roasting and stewing in fat. (Susan, 2015).

Smoking:

Smoking refers to a technique for preserving meat using the heat and smoke from burning wood or plants. In this technique, the surface moisture of the meat is eliminated using hot smoke, however, It works well when combined with salting or other seasonings. Even in case of smoke isn't too intense, the meat will stay soft (Jan Busboom, 2003) Since the outside layer of smoked meat dries up, germs have a much harder time penetrating the flesh, as they can't survive in conditions where there isn't enough moisture to sustain their growth.

There are primarily three forms of smoking: hot smoking, smoke roasting, and cold smoking (meat is not cooked in this type).In the cold smoking, the object has evaporated rapidly to inhibit the proliferation of microorganisms. Another thing to keep in mind while smoking is that smoking the meat straight from plants might lead to the formation of carcinogenic compounds. (Curing Food web).

Freezing:

All kinds of meat and vegetables may be preserved with this approach since the enzyme production of pathogens and microorganisms is slowed. The main problem with this preservation technique, however, is it possible that bacterial expansion and enzyme production are inhibited rather than permanently stopped, meaning that the animal will begin replicating again as soon as conditions are favourable for development. Bringing the temperature down to about 0 degrees or below considerably slows the growth activity of bacteria. Although they survive exposure to subzero temperatures, their activity levels drop and their spoiling effects become more gradual. The meat may be stored at -12 degrees Celsius for up to a year without losing quality or taste. But if you want to freeze anything, you'll need a reliable power supply and a nice freezer. (Muhammad Shoaib et al., 2015). It's best to use a freezer bag to prevent the meat from drying out, and to constantly make sure the bag is airtight to prevent contamination. This approach may preserve raw beef for a longer period of time beyond the typical 3-4 months. A meat freezer set to -0.6 degrees Fahrenheit is ideal for preserving the quality of various meats. Keep in mind that slow freezing results in bigger ice crystals, which might potentially break the meat cells, so try a fast freeze first. This method of preservation was found to be ineffective when applied to veggies yet successful when used to meat. (Muhammad Shafiur Rahman & Jorge F.Velez-Ruiz, 2007).

Chilling:

Chilling may slow the metabolism of harmful germs, viruses, and bacteria. Placing a container containing Taenia cysts or any other form of parasite at 18 degrees for 20 to 30 days can kill it totally. Keeping food at a temperature of 0 degrees to 5 degrees is ideal for preserving a wide range of foods. (Priyanka, 2019).

Salting/Salt cured meat:

Meat curing is another time-tested technique of storage. Even if we have made too many changes, we still cure our products to maintain flavour and texture. Its manufacture, transportation, storage, and availability are all crucial to the preservation of various food items and meat in developing nations (National centre of home Food Preservation). It's common practise to utilize sodium chloride for salting because it soaks up the flavour of the meat's moisture or slows the development of bacteria. Salting refers to either rubbing salt into meat or soaking meat in a salt solution. Utilizing a curing method enables the osmosis-based process of drying out an item. Additionally, injecting salt solution into meat is becoming increasingly common (Parthasarathy, & Bryan, (2012) Meat was dried out in the first stages of curing since this limited the amount of moisture available for microbial growth.

Fermentation and Pickling:

Fermentation refers to the process in which microorganisms undergo a controlled reaction in the absence of oxygen. Pickling uses a high concentration of salt to stop the spread of germs or bacteria. food category being pickled will largely dictate the pickling period and pickling compound. (Arghya, 2018; & Barrett, 2003).

Irradiation:

Irradiation is a preservation technique that's worth considering (cold Sterilization). Bacteria development is affected by several forms of radiation. Gamma rays have been shown to extend the meat's storage life. As a result of its bactericidal properties, ultraviolet (UV) rays are often employed to sterilize the outside of meat. (Mahendra Pal et al., 2018).

Acknowledgement:

This creative scientific literature, an acknowledgement, is an expression of gratitude for assistance in creating original work.

Funding: No Funding for this paper

Conflict of Interest

There is no conflict of interest between authors.

Author's Contribution

All authors contributed equally.

REFERENCES

Arnaut-Rollier, I., Zutter, L. D., & Hoof, J. V. (1999). Identities of the Pseudomonas spp. in flora from chilled chicken. *Int. J. Food Microbiology*, *48*, 87-96. DOI: 10.1016/S0168-1605(99)00038-0.

Arghya, M. (2018). "Food preservation by fermentation and fermented food products", *International Journal of Academic Research & Development*, (*1*), pp. 51-57.

Alpana, D., & Bhagyashree, D. (2017). "Food additives and preservation: A review", Indian J. Sci. Res, 13 (2), pp.219-225.

Barrett, D. M. (2003). "Pickling", Encyclopedia of Food Sciences and Nutrition, 2nd Ed, pp.4563-4566. https://doi.org/10.1016/B0-12-227055-X/00924-X.

Berry, M. R., & Pflug, I. J. (2003). "Canning – Principles", Encyclopedia of Food Sciences and Nutrition, 2nd Ed, pp. 816-824, https://doi.org/10.1016/B0-12-227055-X/00159-0

Berkel, B. M., Boogaard, B. V., & Heijnen, C. (2004). Preservation of fish and meat. Agromisa Foundation, Wageningen, *The Netherlands, pp: 8*, 78-80. ISBN: 90-72746-01-9.

Busboom, J. R. "Curing and smoking poultry meat", http:// cru.cahe. wsu.edu/ CE Publications/eb1660/eb1660.pdf

Cerveny, J., Meyer, J. D., & Hall, P. A. (2009). Microbiological Spoilage of Meat And Poultry Products In: Compendium Of The Microbiological Spoilage, Of Foods And Beverages. Food Microbiology and Food Safety, W.H. Sperber and M.P. Doyle (Eds.). Springer Science and Business Media, NY, pp. 69-868. DOI: 10.1007/978-1-4419-0826-1-3.

Chambers, P. G., & Grandin, T. (2001). Guidelines for humane handling, transport and slaughter of livestock. G. Heinz and T. Srisuvan (Eds.). http://www.fao.org/fileadmin/user_upload/animalwelfare/guidelines%20humane%20handling%20transport%20slaughter.pdf.

"Curing Food", http:// www. edinformatics. com/math science/ science_ of _cooking/ curing_foods.htm, Edinformatics, 2010.

Dainty, R. H. (1996). Chemical/biochemical detection of spoilage. *Int. J. Food Microbiol.*, *33*, 19-33. ISSN:0168-1605.

Frankel, E. N. (1985). Chemistry of free radical and singlet oxidation of lipids. *Progressive Lipid Research*, *23*, 197-221. Retrieved on 15th September 2010http://ddr.nal.usda.gov/bitstream/10113/23776/1/IND88046136.pdf

Fernindez, J., Perez-Alvarez, J. A., & FernindezLopez, J. A. (1997). Thiobarbituric acid test for monitoring lipid oxidation in meat. *Food Chemistry*, *59*, 345-353. DOI: 10.1016/S0308-8146(96)00114-8.

Fraser, O., & Sumar, S. (1998). Compositional changes and spoilage in fish. Nutrition *Food Sci.*, *5*, 275-279. ISSN: 0034-6659.

Garcia-Lopez, M. L., Prieto, M., & Otero, A. (1998). The physiological attributes of Gram-negative bacteria associated with spoilage of meat and meat products. In: The microbiology of meat and poultry, Davies, A., & Board, R. (Eds.), London: Blackie Academic and Professional, pp: 1-34. ISBN: 0-7514-0398-9.

Gray, J. I. (1978). Measurement of lipid oxidation: A review. *J. Am. Oil Chemists Society*, *55*, 539-546. ISSN: 1558-9331.

Gray, J. I., & Pearson, A. M. (1994). Lipid-derived offflavor in meat-formation and inhibition. In: Flavor of meat and meat products. 1st Edn., Shahidi, F.(Ed.) Chapman and Hall, London, U.K, pp: 117-139. ISBN: 0-7514-0484-5.

Hayes, J. R., English, L. L., Carter, P. J., Proescholdt, T., & Lee, K. Y. (2003). Prevalence and antimicrobial resistance of Enterococcus species isolated from retail meats. Applied EnvironmentalMicrobiology, 69: 7153-7160. DOI:10.1128/AEM.69.12.7153-7160.

Heinz, G., & Hautzinger, P. (2007). Meat Processing Technology. For Small-To Medium scale Producers. Food and Agriculture Organization of the United Nations Regional Office for Asia and the Pacific. Retrived on 1st June 2010, fromftp://ftp.fao.org/docrep/fao/010/ai407e/ai407e00.pdf.

Hultin, H. O. (1994). Oxidation of lipids in seafoods. In: Seafoods chemistry, processing technology and quality (1st Edition), Shahidi, F., & Botta, J. R. (Eds.). Blackie Academic and Professional, London, UK, pp.49-74. ISBN-10: 0751402184.

Huss, H. H. (1995). Quality and quality changes in fresh fish. *FAO Fisheries Technical Paper 348*, FAO, Rome, Italy.http://www.fao.org/DOCREP/V7180E/V7180E00.HTM.

Javeed, A., & Ram, K. P. (2015). "Meat drying technology and drying characteristics of meat and meat products", *International Journal of Applied and Pure Science and Agriculture*, *1*(8), pp.21-26.

Jay, J. M., Loessner, M. J., & Golden, D. A. (2005). Modern Food Microbiology, 7th Edn., Springer Science and Business Media. NY, pp: 63-101. ISBN: 0387231803.

Kanner, J. (1994). Oxidative processes in meat and meat products: Quality implications. *Meat Sci.*, *36*, 169-189.

DOI: 10.1016/0309-1740(94)90040-X.

Khayat, A., & Schwall, D. (1983). Lipid oxidation in sea food. *Food Technology, 37*, 130-140.

Kuwahara, K., & Osako, K. (2003). Effect of sodium Gluconate On Gel Formation Of Japanese Common Squid Muscle. *Nippon Suisan Gakkaishi, 69*, 637-42. ISSN: 0021-5392.

Linares, M. B., Berruga, M. I., Bornezv, R., & Vergara, H. (2007). Lipid oxidation in lamb meat: Effect of the weight, handling previous slaughter and modified atmospheres. *Meat Sci., 76*, 715-720. DOI: 10.1016/jmeatsci.2007.02.012.

Lin, M., Al-Holy, M., Mousavi-Hesary, M., Al-Qadiri, H., & Cavinato, A. G. (2004). Rapid and quantitative detection of the microbial spoilage in chicken meat by diffuse reflectance spectroscopy (600-1100 nm). *Letters in Applied Microbiology, 39*, 148-155. DOI:10.1111/j.1472-765X.2004.01546.x.

Love, J. D., & Pearson, A. M. (1971). Lipid oxidation in meat and meat products-A review. *J. Am. Oil Chemists' Soc., 48*, 547-549. DOI:10.1007/BF02544559.

Miller, R. K. (2002). Factors affecting the quality of raw meat, In: Meat processing Improving quality. Joseph, K., John, K., & Ledward, D. (Eds.), CRC Press, FL, USA, pp: 26-63. ISBN: 978-1-59124-484-4.

Mohammad, S. R., & Jorge, F. V. (2007). " Food Preservation by Freezing" Handbook of Food Preservation, *2nd Ed*, (*26*), pp. 635-665.

Muhammad, S., Faqir, M. A., Muhammad, S. A., & Ubaid, U. R. (2015). "Postharvest intervention technologies for safety enhancement of meat and meat based products; A critical review", *J Food Sci Technol., 53* (1), pp. 19–30.

National Center for Home Food Preservation - How Do I?, Curing and Smoking http://www.uga.edu/nchfp/how/cure_smoke.html.

Nychas, G. J. E., & Tassou, C. C. (1997). Spoilage process and proteolysis in chicken as detected by HPLC. J. Sci. Food Agriculture. 74, 199-208. DOI:10.1002/(SICI)1097-0010(199706)74:2<199:AIDJSFA790>3.0.CO;2-4.

O'Halloran, G. R., Troy, D. J., Buckley, D. J., & Reville, W. J. (1997). The role of endogenous proteases in the tenderization of fast glycolysing muscle. *Meat Sci., 47*, 187-210. ISSN: 0309-1740.

Pal, M., & Devrani, M. (2018), "Application of various techniques for meat preservation", *J Exp Food Chem, 4*(134), pp.1-6, Doi: 10.4172/2472-0542.1000134.

Parthasarathy, D. K., & Bryan, N. S. (2004). "Sodium nitrite: the "cure" for nitric oxide insufficiency" *Meat Science, 92* (3), pp. 274–279.

Doi:10.1016/j.meatsci.2012.03.001 22464105.http://www.meatprocessingforum.com

Pearson, A. M., Gray, J. I., Wolzak, A. M., & Horenstein, N. A. (1983). Safety implications of oxidized lipids in muscle foods. *Food Techn., 37*, 121-129.

Priyanka, P. (2019). "Food protection and preservation methods", *Hygiene and environmental health*, (*10*). https://www.scribd.com/document/407259856/Skip-tomain-content-docx.

Rahman, S. F. (1999a). Post harvest handling of foods of animal origin. In: Handbook of food preservation. Rahman. S.F. (ed). Marcel Dekker, NY, pp: 47-54. ISBN: 0-8247-0209-3.

Raharjo, S., & Sofos, J. N. (1993). Methodology for measuring malonaldehyde as a product of lipid peroxidation in muscle tissues: A review. *Meat Sci.*, *35*, 145-169. DOI: 10.1016/0309-1740(93)90046-K.

Russell, S. M., Fletcher, D. L., & Cox, N. A. (1996). Spoilage bacteria of fresh broiler chicken carcasses. *Poultry Sci.*, *75*, 2041-2047. PMID:8825595.

Sentence, C. B. (1991). Growth of bacteria and spoilage of meat. In: The production of chilled meat for export. Retrieved on 2nd July 2010, from http://www.meatupdate.csiro.au/data/Chilled_meat_for_export_02-91.pdf.

Susan, F. (2015). "Canning of meat and poultry", A complete course in canning and related processes, Processing procedures for canned food products, *14 Ed*, (*3*), pp.267-300, http://doi.org/10.1016/B978-0-85709-697-1.00007-6

Simitzis, P. E., & Deligeorgis, S. G. (2010). Lipid oxidation of meat and use of essential oils as antioxidants in meat products. http://www.scitopics.com/Lipid_Oxidation_of_Meat_and_Use_of_Essential_Oils_as_Antioxidants_in_Meat_Products.html.

Shahidi, F. (1994). Assessment of lipid oxidation and off-flavor development in meat and meat products. In: Flavor of meat and meat products. Chapman and Hall, London, U.K, pp: 247-266. ISBN: 0-7514-0484-5.

Steven, M. L., & Dennis, N. M. (2018). **"**Fresh and cured meat processing and preservation", The Science of Animal Growth and Meat Technology, 2nd Ed, 13**,** pp.205-228, https://doi.org/10.1016/B978-0-12-815277-5.00013-5

Toldra, F. (2006). The role of muscle enzymes in drycured meat products with different drying conditions. *Trends in Food Sci. Techn.*, *17*, 164-168. DOI: 10.1016/j.tifs.2005.08.007.

Tauro, P., Kapoor, K. K., & Yadav, K. S. (1986). An Introduction to Microbiology, 1st Edn., New Age International Publisher. New Delhi, India. pp: 364.ISBN: 085-226-878-5.

Toldra, F., & Flores, M. (2000). The use of muscle enzymes as predictors of pork meat quality. *Food Chemistry*, *69*, 387-395. DOI: 10.1016/S0308-8146(00)00052-2.