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Effect of selected food additives on quality of meat and meat products, recent advances

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ABSTRACT

Fresh meat is perishable and has a short shelf life due to spoilage by facultative anaerobes and psychotropic aerobes which produce a foul odor. Biogenic amines are formed during the storage of meat products such as sausage and ground beef by decarboxylation of amino acids and specific enzymes produced by microorganisms. This review paper presents an overview regarding the application of several functional food materials in meat and meat products to improve their quality as well as health benefits. A comprehensive literature search was performed for studies published prior to July 2024, utilizing multiple databases and employing topic keywords in the search strategy. The use of synthetic preservatives in meat and meat products could cause adverse effects on human health. There is a pressing need to use natural preservatives for this reason. The benefits of these functional materials mostly relate to reducing lipid oxidation, microbial growth, cholesterol levels and preventing the risk of several chronic diseases such as heart disease and cancer. The benefits of selected functional food additives utilized to improve meat quality have been summarized. The functional food materials include, but are not limited to, green tea leaf extracts, grape extracts, grape seed extracts, oregano and oregano essential oil, cinnamon, rosemary, rosemary extract, and cinnamon essential oil, flaxseed, thyme, milk proteins, dietary fibers and surimi. The added substance(s) could have a variety of benefits on meat products' quality, such as

reducing lipid oxidation, spoilage, and pathogenic microorganism growth, therefore extending the meat's shelf life. Furthermore, health benefits such as lowering the risk of cardiovascular disease, obesity, and colon cancer may be dramatically diminished.

Novelty: This review summarizes recent advances in the application of natural functional food additives, including plant extracts, essential oils, and proteins, to enhance meat and meat product quality. It uniquely focuses on their potential to replace synthetic preservatives, offering health benefits like reduced risks of cardiovascular diseases and cancer, while extending shelf life and controlling spoilage.

Key words: meat products, meat quality, food additives, natural antioxidants, essential oil

Graphical abstract: Effect of selected food additives on quality of meat and meat products, recent advances

INTRODUCTION

Several food materials could be used in the field of meat processing and production to improve composition, fatty acid profile, reduce levels of fat and cholesterol and enhance the health status of the consumers. Consumers demand healthier products due to the recent rise in diseases related to the consumption of meat and meat products, such as obesity, stroke and cancer. These health benefits could be obtained by adding functional ingredients such as conjugated linoleic acid, vitamin E,

selenium, spices, herbs, n-3 fatty acids, essential oils of medicinal plants, extracts of natural antioxidants, surimi and dietary fiber to the meat to improve its functional value [1]. According to Butnariu and Sarac [2], the three basic requirements to be considered for a functional food ingredient are 1) the food should be naturally occurring, 2) it should be consumed as part of the diet, and 3) the risk of disease from such an ingredient must be prevented. Meat stored in the refrigerator could be spoiled by psychotropic aerobes, facultative anaerobes, and characterized by the development of an odor. He also claimed that psychotropic Lactobacillus causes gas-packaged and vacuum-packaged meat spoilage. Generally, sliminess, souring, and greening are the three types of spoilage in meat and meat products. Moreover, during manufacturing and storage periods of meat products such as sausage and ground beef, biogenic amines are formed by decarboxylation of amino acids through the action of a substrate of specific enzymes produced by several microorganisms such as *Streptococcus*, *Lactobacillus*, *Enterobacteriaceae*, *Bacillaceae*, and *Pediococcus*. Many functional food materials have been used to improve the quality of meat and meat products [3-5]. Table 1 presents selected ingredients used to improve the quality of meat and meat products. This article aims to highlight the functionality of food chosen ingredients to improve the quality of meat and meat products.

Methodology: A comprehensive literature search was performed for studies published before July 2024, utilizing multiple databases, including ScienceDirect, Elsevier, PubMed, ResearchGate, SCOPUS, Web of Science, Google, and Google Scholar. Keywords related to meat products, meat quality, food additives, natural antioxidants, and essential oils were employed in the search strategy.

SELECTED STUDIES ON UTILIZATION OF FUNCTIONAL FOOD INGREDIENTS AS MEAT QUALITY IMPROVERS

Green tea leaf extracts. Green tea leaf extracts are used in meat and meat products as antioxidants due to their high polyphenol content. It contains many antioxidant compounds such as *Epicatechins*, *Catechins*, *epigallocatechin*, *Epicatechin Gallate,* and *Epigallocatechin gallate* [6]. The active ingredients in green tea have high lipid antioxidant activity and prevent lipid oxidation in addition to antibacterial activity [7]. The utilization of green tea leaf extracts in meat and meat products was reported [8]. Tea contains a group of compounds, particularly catechins, known for their antioxidant-related effects [9]. The major tea catechins are (ı)-*epicatechin* (EC), (ı)-epigallocatechin, and (ı)-epigallocatechin gallate. These phenolics may represent about 30% of the dry weight of fresh tea leaves [10]. It was reported that the crude methanolic extract of black tea diluted in ethanol revealed good bactericidal activity at nearly all concentrations. However, the extract of green tea was also evaluated and resulted in antibacterial activity against microorganisms such as *P. aeruginosa, S. aureus, and S. typhus* [11]. The extract also showed potent antibacterial activity against *S. aureus* with an even minimum inhibitory concentration of 150 µL, where the zone of inhibition was only 27 mm [12]. Xingyong [13] investigated green tea powder as a functional additive in broiler chicken feed on meat quality and bacterial growth. It was found that the meat powder significantly increased both the intramuscular fat content of breast muscle and the redness (a*) value of the meat. The green tea powder also inhibited *E. coli* proliferation in the cecum and the ileum of the broiler chicken. Moreover, when the green extract was combined with polyamide

for fresh minced meat active packaging applications, it extended the shelf life of the meat for 23 days [14].

Rosemary extract. Rosemary is considered a good source of natural antioxidants; hence, it has been used in many types of food for shelf-life extension. It has been investigated as a meat quality improver [15]. Due to the presence of many phenolic compounds such as *carnosol*, *carnosic* acid, *isorosmanol*, *rosmanol*, *rosmariquinone*, *rosemary-diphenol*, and rosmaridiphenol, which can break free radical chain reactions by hydrogen donation, rosemary and rosemary extracts are excellent meat lipid oxidation inhibitors [16]. Rosemary (*Rosmarinus officinalis Linn*.) has been widely used in the food industry because of its inherent high antioxidant activity [17]. It was investigated in the concentration of (200 – 350 ppm in chicken meat) to evaluate the quality and stability of ground chicken meat stored in vacuum bags at 4 °C for up to 7 days [18]. The study revealed that the extract of rosemary in the concentration of 350 ppm was very effective as an antioxidant, comparable to other commercial antioxidants, and could be used as a good substitution for many synthetic antioxidants used in the meat industry.

Grape extracts. Grapes have high phenolic compound content and provide a good alternative to conventional antioxidants [19]. The most common phenolic acid in grapes is syringic acid, which displays various pharmacological properties, including antioxidant, anti-inflammatory, neuroprotective, and antimicrobial properties [20]. Grape extract can be found in various forms such as dietary fiber, seed extract, grape wine, and pomace. The grape seed extract is rich in oligomers and polymers of *polyhydroxy flavan*-3-oils like catechin and epicatechin [21]. The antioxidant effect of grape seed extract was evaluated in many research works. It has a practical impact on shelf life and quality of beef and beef products [22], chicken meat and chicken patties in refrigerated storage [23], raw and cooked beef and pork in refrigerated storage conditions [24], cooked pork meatballs in refrigerated storage conditions [25]. It was reported that grapes in concentrate form are rich in flavonoids, including epicatechin, catechins, epicatechin-3-O-gallate, tetrameric procyanidins, and *dimeric, trimeric* [26]. When grape antioxidant dietary fiber was used in cooked chicken patties, it showed effective results during refrigerated storage in reducing yellowness and lightness and increasing redness in raw and cooked chicken hamburgers without affecting the acceptability of the products [27]. It revealed excellent antioxidant properties, improved microbiological quality, and superior sensory evaluation scores [28].

Oregano and oregano essential oil. Due to its antioxidant activity, oregano (*Origanum vulgare*) is used in several meat products. Oregano contains more than 30 compounds, with thymol and carvacrol being the main compounds responsible for its antioxidant activity [29]. A reduction in the microbial growth in beef when active films containing oregano essential oil were used was observed [30]. On the other hand, films formulated using oregano oil and applied to beef muscle slices resulted in significant inoculation of both *Salmonella typhimurium* and *E. coli* O157: H7. Oregano essential oil was also used to evaluate its effect on the storage stability of cooked chicken meat. The addition of the oregano essential oil at 100 and 150 ppm to ground chicken breast and thigh meat resulted in a significant reduction of lipid and protein oxidation. It demonstrated effectiveness in enhancing the storage stability of chicken meat, comparable to the effect obtained with synthetic meat preservatives such as E-300, E-250, and BHA. This could make oregano essential oil an important functional ingredient for meat storage stability, and it may be used to replace synthetic antioxidants to improve the storage stability of chicken meats. The essential oregano oil was

also used as a nano emulsion with resveratrol as an edible coating to preserve fresh pork loin under high oxygen modified atmosphere packaging stored at 4 °C for 15 days. The results revealed that the oregano essential oil had significant fresh meat stability and preservation. In many recent research works, Oregano and its essential oils were reported to have significant anti-oxidative and antimicrobial activities [31].

Cinnamon and cinnamon essential oil. Cinnamon and cinnamon essential oil are used in meat treatment due to their scavenging capacity for hydroxyl radical (OH radical) and 2, 2-*Diphenyl*-1-*Picryl Hydrazyl* Radical. According to Diniz do Nascimento *et al.* [32], the scavenging property of OH and DPPH radicals is attributed to the hydrogen donated by the phenolic component. The scavenging property of OH and DPPH radicals is attributed to the hydrogen donated by the phenolic component of cinnamic oil. The antioxidant effect of cinnamon essential oils on beef meat during 10 days of refrigerated storage was investigated. It was found that cinnamon significantly reduced the thiobarbituric acid reactive substances (TBARS) in the minced beef meat. There was a proven significant reduction of ground beef's microbial and lipid oxidation kept at 4±1 °C for up to 16 days under vacuum packaging [33]. Concentrations of essential oil microcapsules from 0.5% - 1% w/w of the meat showed significant inhibition of lipid oxidation and microbial growth. Dietary supplementation of cinnamon in broiler chicken was investigated [34]. The quality of the 216-day-old chicken meat was evaluated, and a significant decrease in cholesterol level was observed.

Flaxseed and flaxseed essential oil. Flax is a functional food ingredient because it contains polysaccharides other than starch and alpha-linolenic acid lignans. The seed of flax contains approximately 20% protein, 30% dietary fiber, and 40% lipids [35]. The oil of flaxseed is considered α-linolenic richest source of α-linolenic acid. It is widely used in meat applications and is regarded as one of the best functional food ingredients for enriching the meat with total polyunsaturated fatty acids (PUFA) and omega-3 [36]. Treatments of bologna-type meat products designed for older adults improved better nutritional profiles and acceptable sensory properties [37]. Two varieties of flaxseeds were investigated to evaluate their effect on lipid oxidation in pork meatballs [38]. During the meat storage period, cholesterol degradation and stabilization of the fatty acid composition of stored meatballs were observed. A combination of flaxseed and tomato paste in a percentage of 0-20% of beef patties showed a decrease in cholesterol content and saturated fatty acids, and an increase in polyunsaturated fatty acids was observed [39].

Whey protein. Whey protein provides dietary protein and could make up to 20% of total milk protein due to consumer concerns about emerging antibiotic-resistant strains of microbiota (40). Whey protein is used in poultry diets to maintain the meat quality as an alternative functional food material to antibiotics [41]. Whey protein has prebiotics as well as non-resistant properties [42]. Whey is also used in fresh turkey in combination with chitosan as an antimicrobial incorporated in edible films [43]. It stopped the microbiological deterioration of turkey meat and the development of *S. Typhimurium*, *C. Jejuni*, and *E. coli* pathogenic microorganisms in coated fresh meat cuts for at least six days. The effect of whey protein concentrates in 1-4% concentrations on the quality and shelf life of buffalo meat was evaluated at day 25 of refrigeration storage [44]. The treatment significantly improved the quality and shelf life of the meat.

Thyme. Thyme and essential oils are natural, non-toxic, and safe plant secondary metabolites. They contain phenolic substances, namely carvacrol and thymol. They have excellent antibacterial effects on various bacteria including *Salmonella* and *Escherichia coli* (*E. coli*) O157: H7. Thyme was investigated for its antioxidant activity in fresh chicken breast meat stored at 4 °C for 3 weeks.

There are several compounds of phenolic acids in thyme, such as ferulic acid, caffeic acid, rosmarinic acid, and gallic acid [45]. It was reported that thyme reduced lipid peroxidation, deterioration of sarcoplasmic proteins, and DPPH radical formation. This helped prolong the meat's shelf life even after 2 weeks of storage. The essential oil of thyme also exhibited a strong free-radical scavenging ability and inhibited Fe^{2+}/H2O2 and Fe^{2+}/ascorbate induced lipid oxidation [46]. The effect of thyme leaves extract in concentrations of 3.7% and 7.5% was evaluated on lamb meat [47]. The quality of the meat stored in a modified atmosphere of 70% O2:30% CO2 was evaluated. The extract significantly delayed lipid oxidation, color deterioration, and bacterial counts and imparted a better appearance to the fresh lamb meat, and the treatment kept the meat quality for 21 days. The effect of thyme oil was also investigated on poultry meat quality [48]. The daily addition of the thyme oil to the chicken meat at 200 - 600 mg/kg levels significantly improved oxidative stability and meat
quality.

Dietary Fiber. Dietary fiber has been utilized as a functional ingredient in meat for its antioxidants and physiological properties. Moreover, high dietary fibre intake reduces the risk of obesity, cardiovascular diseases, colon cancer, and many other disorders [49]. Extracts and/or dried fruit powders of some plants and their by-products can be good sources of such functional materials [50]. Gum arabic, for instance, is considered a good natural functional ingredient because of its excellent dissolving property that reaches 85% of its weight [51]. Gum arabic has low viscosity, impartial taste, and high molecular weight. It contains more than 80% fiber. It is utilized in meat products with high concentrations (up to 50%) and reported as a heart disease controller by diminishing total cholesterol and lowering low-density lipoprotein cholesterol. The wheat fiber in percentages of 0-4% combined with pork back fat in percentages of 0-10% was studied on the quality of bologna sausage. The treatment improved the sausage using wheat fiber as a fat substitute.

Table 1 Selected food functional ingredients used as meat and meat products quality improvers.

S.no.	Functional food product used	Type of meat used	Function in the meat product	Reference
1	Green tea extract	Beef patties	Stabilizing color of the meat compared to untreated meat	[52]
2	Curry & mint leaves to extract	chicken meat	Lipid oxidation was reduced in chicken patties	[53]
3	Unripe papaya extract	beef kabab	Stabilize protein, fat, ash of the product	[54]
4	Oregano essential oil	Dry fermented sausage	Lower the content of aldehyde in the treated samples	[55]
5	Clove essential oil	Red meat	Improve quality stability of raw samples when incorporated with starch as an edible film	[56]
6	Orange dietary fiber	Sausages	improvement in the products Shelf-life	[57]
7	Banana peels extract	Chicken meat	Decreasing lipid oxidation	[58]
8	Grape seed flour	Frankfurter	Oxidative stability, the addition of dietary and improving water holding capacity of the product	[59]
9	Cinnamon essential oil	Red meat	Improving the shelf life of the raw red meat when incorporated as an edible film	[60]
10	papaya leaves extract	Chicken meat	Improve the tenderness of the meat	[61]
11	Whey protein concentrate	Chicken breast	Improves sensory and textural attributes	[62]
12	Gum Arabic	Beef round	Improves and increases cooking yield	[63]
13	Fish surimi	Fish nuggets	Improves sensory evaluation of the product	[64]

Scientific Innovation and Practical Implications: This review innovatively consolidates current research on using natural functional food additives in meat products, emphasizing their potential as alternatives to synthetic preservatives. By systematically analyzing the effects of green tea, grape extracts, oregano, cinnamon, rosemary, flaxseed, thyme, milk proteins, dietary fibers, and surimi, this study highlights their multifaceted benefits, including the reduction of lipid oxidation, microbial growth, and cholesterol levels. This comprehensive approach addresses the pressing need for safer meat preservation methods and underscores the potential for these additives to mitigate chronic disease risks.

The practical implications of this research are substantial. The identified natural additives offer food producers viable strategies to enhance meat quality and extend shelf life without compromising consumer health. This shift towards natural preservatives could revolutionize the meat processing industry, leading to products with improved nutritional profiles and reduced health risks. Furthermore, the review's focus on these additives' cardiovascular and anticancer benefits provides a foundation for developing functional meat products that cater to health-conscious consumers. By consolidating this information, this review is a valuable resource for researchers and industry professionals seeking to innovate meat product development and promote healthier dietary choices.

CONCLUSION

The effects of selected functional food ingredients used as meat quality improvers were summarized. The added ingredient could have many potential effects on the quality of different types of meat and meat products, such as controlling lipid oxidation, spoilage, and pathogenic microorganisms, hence extending the shelf life of the meat. Furthermore, health benefits like controlling cardiovascular diseases, obesity, and colon cancer could be significantly reduced.

Authors' Contribution: Moamed Abd Elgadir designed the analysis, collected the raw data, contributed to analysis tools, and wrote the first draft of the paper. Abdalbasit Adam Mariod conceived formatting and checked writing and grammar.

Conflict of Interest: The authors declare no conflict of interest related to this article.

REFERENCES

1. Weiss J, Gibis M, Schuh V, Salminen H. Advances in ingredient and processing systems for meat and meat products. Meat Science 2010; 86(1):196-213. DOI: https://doi.org/10.1016/j.meatsci.2010.05.008
2. Butnariu M, Sarac I. Functional Food. International Journal of Nutrition. 2019; 3 (3):7-16. DOI: https://doi.org/10.14302/issn.2379-7835.ijn-19-2615
3. Belles M, del Mar Campo M, Roncalés P, Beltran J. Supranutritional doses of vitamin E to improve lamb meat quality. Meat Science 2019; 149:14-23. DOI: https://doi.org/10.1016/j.meatsci.2018.11.002
4. Zhang H, Liao H, Zeng Q, Wang J, Ding X, Bai S, Zhang K. Effects of commercial premix vitamin level on sternum growth, calcification and carcass traits in meat duck. Journal of Animal. Physiology and Animal Nutrition. 2018; 103(1):53-63. DOI: https://doi.org/10.1111/jpn.13001
5. Jose C, Jacob R, Pethick D, Gardner G. A supply chain approach to improving the shelf life of lamb meat; vitamin E concentration, electrical stimulation, aging period and packaging system. Meat Science 2018; 139:65-73. DOI: https://doi.org/10.1016/j.meatsci.2018.01.005
6. Vuong Q, Stathopoulos C, Nguyen M, Golding J, Roach P. Isolation of green tea catechins and their utilization in the food industry. Food Review International. 2011; 27(3):227-247. DOI: https://doi.org/10.1080/87559129.2011.563397
7. Lorenzo J, Munekata P. Phenolic compounds of green tea: Health benefits and technological application in food. Asian Pacific Journal of Tropical Biomedicine. 2016; 6(8):709-719. DOI: http://dx.doi.org/10.17582/journal.aavs/2019/7.5.417.426

8. Aminzare M, Hashemi M, Ansarian E, Bimkar M, Azar H, Mehrasbi M, Daneshamooz S, Raeisi M, Jannat B, Afshari A. Using natural antioxidants in meat and meat products as preservatives: A review. Advances in Animal and Veterinary Sciences 2019; 7(5):417-426. DOI: http://dx.doi.org/10.17582/journal.aavs/2019/7.5.417.426
9. Musial C, Kuban-Jankowska A, Gorska-Ponikowska M. Beneficial properties of green tea catechins. International Journal of Molecular Sciences. 2020; 21(5):1744. DOI: https://doi.org/10.3390/ijms21051744
10. Zhao C, Tang G, Cao S, Xu X, Gan R, Liu Q, Mao Q Q, Shang A, Li H B. Phenolic profiles and antioxidant activities of 30 tea infusions from green, black, oolong, white, yellow and dark teas. Antioxidants. 2019; 8(7):215. DOI: https://doi.org/10.3390/antiox8070215
11. Rahardiyan D. Antibacterial potential of catechin of tea (Camellia sinensis) and its applications. Food Res. 2019; 3 (1): 1-6. DOI: https://doi.org/10.26656/fr.2017.3(1).097
12. Naderi N J, Niakan M, Fardv M J K H, Zardi S. Antibacterial activity of Iranian green and black tea on Streptococcus mutans: An in vitro study. Journal of Dentistry. 2011; 8: 55–59.
13. Chen X, Zhu W, Liu X, Li T, Geng Z, Wan X. The growth performance, meat quality, and gut bacteria of broilers raised with or without antibiotics and green tea powder. Journal of Applied Poultry Research. 2019; 28(3):712-721. DOI: https://doi.org/10.3382/japr/pfz023
14. Borzi F, Torrieri E, Wrona M, Nerín C. Polyamide modified with green tea extract for fresh minced meat active packaging applications. Food Chemistry 2019; 300:125242. DOI: https://doi.org/10.1016/j.foodchem.2019.125242
15. Haile D A. Comparative study on the effect of rosemary extract and sodium ascorbate on lipid and pigment oxidative stability of liver pate. Journal of Food Science and Technology 2013;52(2):992-999. DOI: https://doi.org/10.1007/s13197-013-1087-7
16. Jin S, Choi J, Lee S, Lee S, Hur S. Effect of thyme and rosemary on the quality characteristics, shelf-life, and residual nitrite content of sausages during cold storage. Korean Journal of Food Science and Animal Resources. 2016; 36 (5):656-664. DOI: https://doi.org/10.5851%2Fkosfa.2016.36.5.656
17. Senanayake S P J. Rosemary extract as a natural source of bioactive compounds. Journal of Food Bioactives. 2018; 2: 51-57. DOI: http://dx.doi.org/10.31665/JFB.2018.2140
18. AL-hijazeen M, AL-rawashdeh M. Preservative effects of rosemary extract (Rosmarinus officinalis L.) on quality and storage stability of chicken meat patties. *Food Sci. Technol.* 2019; 39(1):27-34. DOI: https://doi.org/10.1590/1678-457X.24817
19. Das A, Nanda P, Madane P, Biswas S, Das A, Zhang W, Lorenzo J M. A comprehensive review on antioxidant dietary fibre enriched meat-based functional foods. Trends in Food Science and Technology, 2020; 99:323-336. DOI: https://doi.org/10.1016/j.tifs.2020.03.010
20. Shimsa S, Mondal S, Mini S. Syringic acid: A promising phenolic phytochemical with extensive therapeutic applications. R&D of Functional Food Products. 2024 May 10;1(5):1-4.
21. Sirohi R, Tarafdar A, Singh S, Negi T, Gaur V, Gnansounou E, Bharathiraja B. Green processing and biotechnological potential of grape pomace: Current trends and opportunities for sustainable biorefinery. Bioresource Technology. 2020; 314:123771. DOI: https://doi.org/10.1016/j.biortech.2020.123771.
22. Horbańczuk O, Kurek M, Atanasov A, Brncic M, Rimac S. Brncic The Effect of natural antioxidants on quality and shelf life of beef and beef products. Food Technology and Biotechnology. 2019; 57(4):439-447. DOI: https://doi.org/10.17113%2Fftb.57.04.19.6267
23. Ruiz-Capillas C, Nardoia M, Herrero A, Jimnez-Colmenero F, Chamorro S, Brenes A. Effect of added grape seed and skin on chicken thigh patties during chilled storage. International Journal of Nutrition and Food Sciences. 2017; 4(1):67-73. DOI: https://doi.org/10.15436/2377-0619.17.1497
24. Amin R A, Edris S N. Grape seed extract as a natural antioxidant and antibacterial in minced beef. PSM Biological Research. 2017; 2 (2): 89-96. DOI: https://doi.org/10.1016/j.lwt.2005.02.003
25. Mielnik M, Olsen E, Vogt G, Adeline D, Skrede G. Grape seed extract as antioxidant in cooked, cold stored turkey meat. LWT - Food Science and Technology 2006; 39(3):191-198. DOI: https://doi.org/10.1016/j.lwt.2005.02.003
26. Ma Z, Zhang H. Phytochemical constituents, health benefits, and industrial applications of grape seeds: A mini-review. Antioxidants. 2017; 6(3):71. DOI: https://doi.org/10.3390/antiox6030071
27. Ursachi CȘ, Perța-Crișan S, Munteanu F D. Strategies to improve meat products' quality. Foods 2020; 9 (12):1883. DOI: https://doi.org/10.3390/foods9121883
28. Reddy G, Sen A, Nair P, Reddy K, Reddy K, Kondaiah N. Effects of grape seed extract on the oxidative and microbial stability of restructured mutton slices. Meat Science 2013; 95(2):288-294. DOI: https://doi.org/10.1016/j.meatsci.2013.04.016

29. Forte C, Branciari R, Pacetti D, Miraglia D, Ranucci D, Acuti G, Balzano M, Frega N G, Trabalza-Marinucci M. Dietary oregano (Origanum vulgare L.) aqueous extract improves oxidative stability and consumer acceptance of meat enriched with CLA and n-3 PUFA in broilers. Poultry Science. 2018; 97(5):1774-1785. DOI: https://doi.org/10.3382/ps/pex452
30. Gaba A B, Hassan MA, Abd EL-Tawab AA, Abdelmonem MA, Morsy M K. Protective impact of chitosan film loaded oregano and thyme essential oil on the microbial profile and quality attributes of beef meat. Antibiotics. 2022; 11(5):583. DOI: https://doi.org/10.3390/antibiotics11050583
31. Boskovic M, Djordjevic J, Glisic M, Ciric J, Janjic J, Zdravkovic N, Krnjaic D, Milan B. The effect of oregano (Origanum vulgare) essential oil on four Salmonella serovars and shelf life of refrigerated pork meat packaged under vacuum and modified atmosphere. Journal of Food Processing and Preservation. 2019; 44(1):14311. DOI: https://doi.org/10.1111/jfpp.14311
32. Diniz do Nascimento L, Moraes A A B, Costa K S D, Pereira Galúcio JM, Taube PS, Costa C M L, Neves Cruz J, de Aguiar Andrade E H, Faria L J G. Bioactive natural compounds and antioxidant activity of essential oils from spice plants: New findings and potential applications. Biomolecules. 2020;10 (7): 988. DOI: https://doi.org/10.3390/biom10070988
33. Brilliana I, Manuhara G, Utami R, Khasanah L. The effect of cinnamon bark (Cinnamomum burmanii) essential oil microcapsules on vacuumed ground beef quality. IOP Conference Series: Material Science and Engineering. 2017; 193:012057. DOI: https://doi.org/10.14202/vetworld.2018.959-964
34. Gomathi G, Senthilkumar S, Natarajan A, Amutha R, Purushothaman M. Effect of dietary supplementation of cinnamon oil and sodium butyrate on carcass characteristics and meat quality of broiler chicken. Veterinary World. 2018; 11 (7):959-964. DOI: https://doi.org/10.14202%2Fvetworld.2018.959-964
35. Rubilar M, Gutiérrez C, Verdugo M, Shene C, Sineiro J. flaxseed as a source of functional ingredients. Journal of Soil Science and Plant Nutrition. 2010; 10 (3):373-377. DOI: http://dx.doi.org/10.4067/S0718-95162010000100010
36. Raole V M, Raole V V. Flaxseed and Seed Oil: Functional Food and Dietary Support for Health. EAS Journal of Nutrition and Food Sciences. 2022, 1-4 (2): 68-77. DOI: https://doi.org//0.36349/easjnfs.2022.v04i02.007
37. Goyal A, Sharma V, Upadhyay N, Gill S, Sihag M. Flax and flaxseed oil: an ancient medicine & modern functional food. Journal of Food Science and Technology 2014; 51(9):1633-1653. DOI: https://doi.org/10.1007%2Fs13197-013-1247-9
38. Reyes-Padilla E, Valenzuela-Melendres M, Camou J, Sebranek J, Aleman-Mateo H, Davila-Ramirez J, Cumplido-Barbeitia G, González-Rios H. Quality evaluation of low-fat bologna-type meat product with a nutritional profile designed for the elderly. Meat Science 2018; 135:115-122. DOI: https://doi.org/10.1016/j.meatsci.2017.09.007
39. Valenzuela-Melendres M, Camou J, Torrentera-Olivera N, Viuda-Martos M, González-Rios H. Nutritional quality of beef patties with added flaxseed and tomato paste. *CyTA* – Journal of Food. 2018;16(1):263-270. DOI: https://doi.org/10.1080/19476337.2017.1391333
40. Kermanshahi H, Heravi R, Attar A, Pour A, Bayat E, Zadeh M, Daneshmand A, Ibrahim S. Effects of acidified yeast and whey powder on performance, organ weights, intestinal microflora, and gut Morphology of male broilers. Colégio Brasileiro de Ciências do Esporte. *Cienc*. 2017; 19 (2):309-316. DOI: https://doi.org/10.1590/1806-9061-2016-0351
41. Zarei A, Lavvaf A, Motamedi Motlagh M. Effects of probiotic and whey powder supplementation on growth performance, microflora population, and ileum morphology in broilers. Journal of Animal Research. 2017; 46(1):840-844. DOI: https://doi.org/10.1080/09712119.2017.1410482
42. Ashour E, Abd El-Hack M, Alagawany M, Swelum A, Osman A, Saadeldin I, Abdel-Hamid M, Hussein E. Use of whey protein concentrates in broiler diets. Journal of Applied Poultry Research. 2019; 28(4):1078-1088. DOI: https://doi.org/10.3382/japr/pfz070
43. Brink I, Sipailiene A, Leskauskaite D. Antimicrobial properties of chitosan and whey protein films applied on fresh-cut turkey pieces. International Journal of Biological Macromolecules. 2019; 130:810-817. DOI: https://doi.org/10.1016/j.ijbiomac.2019.03.021
44. Badpa A, Ahmad S. Effect of incorporation of whey protein concentrate on quality characteristic of buffalo meat emulsion sausage. Journal of Buffalo Science. 2014; 3(2):48-54. DOI: https://doi.org/10.6000/1927-520X.2014.03.02.3
45. Fratianni F, De Martino L, Melone A, De Feo V, Coppola R, Nazzaro F. Preservation of chicken breast meat treated with thyme and balm essential oils. Journal of Food Science. 2010; 75(8): M528-M535. DOI: https://doi.org/10.1111/j.1750-3841.2010.01791.x

46. Bozin B, Mimica-Dukic N, Simin N, Anackov G. Characterization of the volatile composition of essential oils of some lamiaceae spices and the antimicrobial and antioxidant activities of the entire oils. Journal of Agricultural and Food Chemistry. 2006;54(5):1822-1828. DOI: https://doi.org/10.1021/jf051922u
47. Nieto G, Diaz P, Banon S, Garrido M. Effect on lamb meat quality of including thyme (Thymus zygis ssp. gracilis) leaves in ewes' diet. Meat Science 2010; 85(1):82-88. DOI: https://doi.org/10.1016/j.meatsci.2009.12.009
48. Aksu T, Aksu M I, Onel S E, Baylan M, Yakan A, Kaya D, Baylan M. The effect of thyme oil (thymbra spicata l var spicata) on meat quality in Japanese quails. European Poultry Science. 2014; 78 (1):6. DOI: https://doi.org/10.1399/eps.2013.6
49. Biswas K, Kumar V, Bhosle S, Sahoo J, Chatli M K. Dietary fibers as functional ingredients in meat products and their role in human health. International Journal of. Livestock Production. 2011; 2: 45–54.
50. 50. Eskicioglu V, Kamiloglu S, Nilufer-Erdil D. Antioxidant dietary fibres: Potential functional food ingredients from plant processing by-products. Czech Journal of Food Science. 2016; 33(6):487-499. DOI: https://doi.org/10.17221/42/2015-CJFS
51. Abdalbasit A M. Gum Arabic dietary fiber, ditor(s): Abdalbasit Adam Mariod, Gum Arabic, Academic Press, 2018; Pp. 237–243. DOI: https://doi.org/10.1016/B978-0-12-812002-6.00020-8
52. Gallego M, Gordon M, Segovia F, Almajano M. *Caesalpinia decapetala* extracts as inhibitors of lipid oxidation in beef patties. Molecules. 2015; 20(8):13913-13926. DOI: https://doi.org/10.3390%2Fmolecules200813913
53. Devatkal S, Thorat P, Manjunatha M, Anurag R. Comparative antioxidant effect of aqueous extracts of curry leaves, fenugreek leaves and butylated hydroxytoluene in raw chicken patties. Journal of Food Science and Technology. 2011; 49 (6):781-785. DOI: https://doi.org/10.1007/s13197-011-0511-0
54. Saeed M. Extraction and utilization of papaya extract as meat tenderizer and antimicrobial activity against Salmonella typhimurium. Pakistan Journal of Agricultural Sciences. 2017; 54(01):153-159. DOI: https://doi.org/10.21162/PAKJAS/17.5032
55. Krkic N, sojic B, Lazic V, Petrovic L, Mandic A, Sedej I, Tomovic V. Lipid oxidative changes in chitosan-oregano coated traditional dry fermented sausage *Petrovska klobasa*. Meat Science 2013; 93(3):767-770. DOI: https://doi.org/10.1016/j.meatsci.2012.11.043
56. Radha krishnan K, Babuskin S, Rakhavan K, Tharavin R, Azhagu Saravana Babu P, Sivarajan M, Sukumar M. Potential application of corn starch edible films with spice essential oils for the shelf life extension of red meat. Journal of Applied Microbiology. 2015; 119(6):1613-1623. DOI: https://doi.org/10.1111/jam.12932
57. Viuda-Martos M, Ruiz-Navajas Y, Fernandez-López J, Perez-Alvarez J. Effect of orange dietary fibre, oregano essential oil and packaging conditions on shelf-life of bologna sausages. Food Control. 2010; 21(4):436-443. DOI: https://doi.org/10.1016/j.foodcont.2009.07.004
58. Devatkal S, Kumboj R, Paul D. Comparative antioxidant effect of BHT and water extracts of banana and sapodilla peels in raw poultry meat. Journal of Food Science and Technology 2014; 51(2):387-391. DOI: https://doi.org/10.1007/s13197-011-0508-8
59. Ozvural E, Vural H. Grape seed flour is a viable ingredient to improve the nutritional profile and reduce lipid oxidation of frankfurters. Meat Science 2011; 88(1):179-183. DOI: https://doi.org/10.1016/j.meatsci.2010.12.022
60. Yu H, Chin Y, Paik H. Application of natural preservatives for meat and meat Products against food-borne pathogens and spoilage bacteria: A review. Foods. 2021; 10 (10): 2418. DOI: https://doi.org/10.3390/foods10102418
61. Abdalla H O, Ali N N A, Siddig F S, Ali S A M. Improving tenderness of spent layer hens meat using papaya leaves (carica papaya). Pakistan Veterinary Journal. 2013; 33: 73–76.
62. Ha J H, Lee J H, Lee J J, Choi Y I, Lee H J. Effects of whey protein injection as a curing solution on chicken breast meat. Food Science of Animal Resources 2019; 39 (3), 494. DOI: https://doi.org/10.5851%2Fkosfa.2019.e44
63. Mwove J K, Gogo L A, Chikamai B N, Omwamba M N, Mahungu S M. Preparation and quality evaluation of extended beef rounds containing gum arabic from Acacia senegal var. kerensis. Food and Nutrition Sciences. 2016; 7(11):977-88. DOI: http://doi.org/10.4236/fns.2016.711096
64. Moosavi-Nasab M, Asgari F, Oliyaei N. Quality evaluation of surimi and fish nuggets from Queen fish (Scomberoides commersonnianus). Food Science and Nutrition. 2019; 16: 7(10), 3206-3215. DOI: https://doi.org/10.1002%2Ffsn3.1172