

ANTIMICROBIAL EFFICACY OF LEMONGRASS (*Cymbopogon citratus*) ESSENTIAL OIL IN SPENT BROILER BREEDER HEN MEAT PRESERVATION

Dr. Janagam Indumathi

Associate Professor, Department of Livestock Products Technology, Sri Venkateswara
Veterinary University, Tirupati, Andhra Pradesh
E-mail: indumathijanagam@gmail.com

Abstract: This study aimed to evaluate the effect of lemongrass oil extract coating on the physico-chemical, microbiological, and sensory quality of vacuum-packaged spent broiler breeder hen meat during refrigerated storage for 10 days. The meat samples were subjected to an immersion treatment in their respective concentrations of lemongrass oil (0.5% 1.0% and 1.5% v/v), while control samples were immersed in pure distilled water under identical conditions. Following immersion, all samples were vacuum-packaged in pre-labeled, pre-sterilized high-density polyethylene (HDPE) pouches and refrigerated. The results demonstrated that combining vacuum packaging with lemongrass oil treatment particularly at higher concentrations successfully reduced the maximum growth rate of the microbial population. The antioxidant activity of the lemongrass oil was significantly pronounced ($P \leq 0.05$) with increasing oil concentrations, as evidenced by a statistical variance between the control and treated spent hen meat, though no significant differences were observed among the different treatment groups. Furthermore, spent hen meat treated with lemongrass oil exhibited significantly lower values for thiobarbituric acid reactive substances (TBARS), free fatty acids (%FFA), tyrosine (% tyrosine), and all evaluated microbial parameters compared to the control. Notably, while coliforms, anaerobes, and yeast and molds were detected in the control samples, they remained undetected in the treated groups. Although sensory scores decreased across all groups as the storage period advanced, and the treated samples generally scored lower than the control, all organoleptic marks remained well within permissible limits. Ultimately, lemongrass oil immersion provided robust antioxidant and antimicrobial protection for spent broiler breeder hen meat without compromising product palatability.

Keywords: Lemon grass, essential oil, chicken meat, spent hens, quality.

1. INTRODUCTION

The food industry has advanced worldwide, resulting in an enhanced threat of food contamination by pathogenic microorganisms, chemical residues, harmful food additives, and toxins. The multiplication of spoilage and pathogenic microorganisms should be controlled to ensure food safety. Accordingly, food preservation techniques for protecting food from pathogenic bacteria and extending shelf-life include chemical methods, such as the use of preservatives; physical methods, such as heat treatment, drying, freezing, and packaging; and biological methods using microorganisms that have an antagonistic effect on the pathogenic

bacteria and produce bacteriocins [28]. Spent broiler breeder hens are parent laying hens that have reached the end of their productive cycle, typically at 60–72 weeks of age. Spent laying hen meat is a source of high animal protein but has a chewy and tough texture [43]. Meat and meat products are essential nutrient sources for humans due to their excellent protein content, essential amino acids, vitamin B groups, and minerals. However, meat and meat products also provide an appropriate environment for spoilage microorganisms or food-borne pathogens due to their high water activity and nutrient factors [14]. Lipid oxidation and microbial growth are the main factors which responsible for the deterioration in meat and It is associated with quality degradation, reducing shelf life, and decreasing consumer acceptability [3]. While synthetic additives have traditionally been used to preserve meat by inhibiting lipid oxidation [37], increasing consumer health concerns regarding artificial preservatives have shifted focus toward natural, non-meat alternatives that maintain product palatability [2]. Natural preservatives have shown potential to provide effective antimicrobial activity while reducing negative health effects. Meat and meat products containing synthetic additives are a major concern for human health [45]. Hence, meat manufacturers and researchers have begun to consider the use of natural rather than synthetic preservatives. Consequently, the integration of natural antioxidants and antimicrobials has emerged as a promising technological advancement to meet the growing consumer demand for healthier meat products [27]. Many plant species have antimicrobial and antioxidant properties, among them, the medicinal plants stand out as they can perform an inhibitory action on the growth of undesirable microorganisms and reduce the oxidative processes which makes them useful and a healthier alternative for the food industry, compared to chemical preservatives [23]. These natural preservatives consist of bioactive compounds, which are predominantly derived from plant sources. The bioactive capacity of essential oils (EOs) sourced from aromatic plants has garnered substantial interest as a sustainable alternative to chemical preservatives in food matrices [5]. While oils from rosemary, clove, and oregano exhibit varying degrees of industrial utility, lemongrass essential oil (LGEO) derived from *Cymbopogon citratus* and *C. flexuosus* stands out for its exceptional efficiency. Research indicates that lemongrass contains numerous bioactive compounds with therapeutic potential [31]. In addition to being rich in vitamin C and citric acid, the plant's phytochemical matrix comprises essential bioactive fractions such as phenolic compounds and monoterpene hydrocarbons [17]. "Specifically, LGEO offers a robust extraction yield of 1.5%–2.5% (v/w), markedly outperforming conventional sources like basil (0.3%–1.1%) and thyme (0.5%–1.3%) [11, 25].

Lemongrass exhibits robust antioxidant and antimicrobial properties, largely attributed to its potent free-radical scavenging capacity and its efficacy against pathogens such as *Salmonella typhi*, *Bacillus cereus*, and *Staphylococcus aureus* [12, 32]. Furthermore, its high concentrations of citric acid and vitamin C contribute to its significant overall antioxidant activity. This study aimed to evaluate the effect of lemongrass extract on the quality properties of fresh spent broiler breeder hen meat during refrigeration storage.

2. MATERIALS AND METHOD

2.1 Study Site and Raw Materials: The research was conducted at the Department of Livestock Products Technology, Sri Venkateswara Veterinary University, Tirupati.

2.2 Meat Procurement: Spent broiler breeder hens (72 weeks of age) were sourced from local poultry farms. The birds were slaughtered and deboned, and the meat was harvested for subsequent analysis.

2.3 Essential Oil Procurement: High-purity Lemongrass Oil was sourced from Mane Kancor (Kerala, India). The oil, derived via steam distillation of *Cymbopogon flexuosus*, presented as a free-flowing, golden-to-brownish yellow liquid with a characteristic citrus aroma.

2.4 Preparation of Experimental Treatments: Four distinct treatment groups were established to evaluate the efficacy of lemongrass oil at varying concentrations. The formulations were prepared on a volume-per-volume (v/v) basis to achieve a total volume of 30 mL per sample as follows:

- **Control (0% v/v):** 30.00 mL of pure distilled water without the addition of lemongrass oil.
- **Treatment 1 (0.5% v/v):** 0.15 mL of lemongrass oil was combined with 29.85 mL of distilled water.
- **Treatment 2 (1.0% v/v):** 0.30 mL of lemongrass oil was combined with 29.70 mL of distilled water
- **Treatment 3 (1.5% v/v):** 0.45 mL of lemongrass oil was combined with 29.55 mL of distilled water.

2.5 Samples preparation: Spent breeder hen meat samples were randomly sliced into uniform portions of approximately 100 g each. For the experimental groups, the meat samples were subjected to an immersion treatment in their respective concentrations of lemongrass oil, while the control samples were immersed in pure distilled water under identical conditions. Following immersion, the samples were transferred into pre-labeled,

pre-sterilized high-density polyethylene (HDPE) pouches according to their designated treatment formulations (Table 1). The pouches were subsequently sealed under vacuum conditions and stored at a refrigeration temperature (4 ± 1 °C) for a 10-day evaluation period.

Table 1 Formulations of experimental treatments:

Group	Lemongrass Oil (mL)	Distilled Water (mL)	Final Concentration
Control	0.00	30	0%v/v
Treatment 1	0.15	29.85	0.5% v/v
Treatment 2	0.30	29.70	1.0% v/v
Treatment 3	0.45	29.55	1.5% v/v

2.6 Analysis:

2.6.1 Physico chemical analysis: The pH of the meat samples was determined following the procedure described by [22]. Free fatty acid (FFA) values were quantified according to the method of Koniecko [24], with minor modifications. Lipid oxidation was evaluated by measuring 2-thiobarbituric acid reactive substances (TBARS) based on the extraction procedure of Witte et al [44]. The tyrosine value of the stored samples was determined using the method outlined by Strange et al [41]; concentrations were calculated using an L-tyrosine standard curve and expressed as mg tyrosine/100 g of product.

2.6.2 Microbiological Profiling: Sample Preparation and Serial Dilution Sample preparation and serial dilutions were performed under strict aseptic conditions within a horizontal laminar airflow unit pre-sterilized via ultraviolet (UV) radiation. A 10 g portion of each meat sample was aseptically weighed, transferred to a sterile mortar, and homogenized for 2 minutes with a sterile pestle while gradually introducing 90 mL of 0.1% sterile peptone water to achieve a 10^{-1} dilution. Sequential tenfold serial dilutions (10^{-2} , 10^{-3} , etc.) were subsequently prepared by transferring 1 mL of the preceding dilution into 9 mL of 0.1% sterile peptone water. Microbiological parameters including standard plate count (SPC), psychrophilic count, yeast and mold count, coliform count, Lactobacillus count, and anaerobic plate count—were determined in accordance with the Compendium of Methods for the Microbiological Examination of Foods [6, 7]. Dehydrated culture media obtained from Hi-Media Laboratories (P) Ltd. (Mumbai, India) were utilized for microbial enumeration. All plating was performed in duplicate, and microbial populations were expressed as log colony-forming units per gram log CFU/g of sample.

2.6.3 Sensory evaluation: The meat samples were oven-cooked with a uniform spice blend and evaluated by a semi-trained, six-member panel. Sensory attributes were scored using a 9-point hedonic scale (Annexure-A).

3. RESULTS AND DISCUSSION

3.1 Physico chemical Parameters:

Addition of lemongrass extract significantly affected on physico chemical parameters of vacuum spent meat. The findings revealed that lemongrass oil incorporation significantly altered meat pH ($p < 0.05$), demonstrating an inverse relationship where higher essential oil concentrations led to lower pH values (Table 2). All treatment groups exhibited statistically significant differences ($p < 0.05$), with the lowest pH recorded in treatment with highest concentration of lemon grass oil. This pattern aligns with the results reported by [33] for vacuum-packaged, refrigerated chicken breast. Furthermore, regardless of the specific treatment applied, pH values steadily declined as storage progressed. This progressive acidification is likely due to the proliferation of lactic acid bacteria over time and the subsequent accumulation of acidic metabolic products in the extracellular environment [20], which strongly corroborates the observations of [38].

Lipid oxidation is a critical phenomenon that occurs during storage, leading to rancidity and subsequent off-odors in meat products [4]. The measurement of malondialdehyde (MDA) via thiobarbituric acid reactive substances (TBARS) is a primary parameter used to monitor lipid oxidation in stored meat [29]. As detailed in Table 2, TBARS values for spent hen meat treated with lemongrass oil were monitored over a 10-day refrigeration period. While storage time significantly increased lipid oxidation across all samples, treatments containing lemongrass oil consistently maintained lower TBARS values throughout the study. Notably, the highest concentration of lemongrass oil successfully slowed the rate of oxidation, keeping TBARS levels minimal even at the end of the 10-day storage period. The antioxidant efficacy of lemongrass can be attributed to its high concentration of bioactive components including vitamin C, phenolic acids, flavonoids, and monoterpene hydrocarbons which scavenge free radicals and inhibit oxidative pathways [17, 32]. These findings align with similar antioxidant trends observed in beef burgers treated with natural extracts [1, 20]. Addition of 0.05% lemongrass essential oil gives better antioxidant properties and is organoleptically accepted [42].

FFA values in vacuum packaged spent hen meat treated with lemongrass oil showed the lowest values than control during refrigerated storage period (Table 2). The antioxidant

activity of lemongrass oil (LO) was significantly ($P \leq 0.05$) pronounced with increasing concentration of oil and also in the product as revealed by statistical difference between treatments [21]. Regards to refrigerated storage, FFA values of all treatments were significantly increased ($p < 0.05$) as the storage period increased. Meat coated with highest concentration lemon grass oil exhibited a significant decreased ($p < 0.05$) in FFA value at the end of storage period 10 days. The antioxidant activity of lemongrass oil was due to the synergistic actions of such as monoterpenoid compounds such as α -citral, β -citral, myrcene and eugenol [35, 36]. These results are in agreement with reference [26] in chicken meat silk rolls.

Data of tyrosine values of spent hen meat treated with different levels of lemongrass during refrigerated storage are showed in Table 2. Treatments treated with lemongrass extract exhibited the lowest tyrosine values than control one. Regards to refrigerated storage the tyrosine values were significantly increased ($p < 0.05$) as the time of storage increased. Spent hen meat treated with high percent of lemongrass oil showed significantly ($p < 0.05$) lower value than other treatments and control. However, no significant difference ($p > 0.05$) was found in tyrosine values of between treatments. This might be due to natural antimicrobial and antioxidant properties of lemongrass oil that restrict the growth of spoilage bacteria [39]. By limiting bacterial activity and enzymatic action, it prevents the breakdown of muscle proteins into free amino acids. Similar finding was reported by references [42, 46]

Table 2. Physico-chemical properties (Mean $\pm$ SE) of vacuum-packaged spent hen meat treated with lemongrass oil at refrigerated storage.

PARAMETER	Days of storage	pH	TBARS (% malonaldehydes)	FFA	TYROSINE
Control	0 th day	6.02 $\pm$ 0.08 ^a	0.42 $\pm$ 0.05 ^a	0.62 $\pm$ 0.01 ^a	0.32 $\pm$ 0.11 ^a
	10 th day	5.84 $\pm$ 0.04 ^b	0.72 $\pm$ 0.04 ^d	0.81 $\pm$ 0.02 ^c	0.46 $\pm$ 0.01 ^b
Treatment 1	0 th day	5.91 $\pm$ 0.02 ^a	0.41 $\pm$ 0.01 ^a	0.60 $\pm$ 0.06 ^c	0.37 $\pm$ 0.09 ^a
	10 th day	5.65 $\pm$ 0.01 ^c	0.64 $\pm$ 0.07 ^a	0.74 $\pm$ 0.07 ^d	0.45 $\pm$ 0.04 ^b
Treatment 2	0 th day	5.84 $\pm$ 0.04 ^b	0.39 $\pm$ 0.08 ^a	0.54 $\pm$ 0.08 ^b	0.36 $\pm$ 0.02 ^a
	10 th day	5.61 $\pm$ 0.01 ^c	0.62 $\pm$ 0.03 ^c	0.68 $\pm$ 0.03 ^a	0.43 $\pm$ 0.06 ^b
Treatment 3	0 th day	5.71 $\pm$ 0.08 ^b	0.38 $\pm$ 0.09 ^a	0.52 $\pm$ 0.07 ^b	0.36 $\pm$ 0.12 ^a
	10 th day	5.43 $\pm$ 0.02 ^d	0.52 $\pm$ 0.05 ^b	0.62 $\pm$ 0.01 ^c	0.39 $\pm$ 0.09 ^a

3.2 Microbiological parameters:

Table 3 illustrates the effects of a lemongrass oil coating on the microbial properties of vacuum-packaged spent hen meat. Results of antimicrobial activity of lemongrass extract showed that the antibacterial activity increased as the level of lemongrass extract was increased. Irrespective of the treatment, standard plate, psychrophilic and lactobacillus counts were decreased significantly ($p < 0.05$) as the concentration of lemongrass oil increased. The highest microbial loads were observed in the untreated control, which differed significantly ($p < 0.05$) from all lemongrass oil-treated groups. The inhibition effect of lemongrass extract may be due to its active compounds such as saponin, citral, phenolic compounds, and flavonoids [19]. Regardless of the specific treatment, microbial counts were increased significantly ($p < 0.05$) over the 10-days of storage period. However significantly ($p < 0.05$) lower scores were noticed in lemon grass treated meat than un treated meat. These findings indicate that the synergistic inhibitory effect of vacuum packaging and lemongrass oil was more pronounced against microorganisms' populations [16]. As per the reference [21] the oil extracts showed higher potential antibacterial activity and their antibacterial effect elevated with increasing the lemon grass oil concentration. This trend is consistent with results reported by [15] for chicken breast fillets, as well as [33] for vacuum-packaged and refrigerated chicken breast [1] in beef burger. Additionally, while the untreated control exhibited significantly ($p < 0.05$) elevated yeast and mould and anaerobic counts over storage period. Both yeast and mould and anaerobic counts remained completely undetectable in the lemongrass-treated meat throughout the entire 10-day refrigerated storage period. Coliforms could not be detected in any of the treatments throughout the storage period. This might be due to the potential antibacterial, antifungal activity of lemon grass oil extracts [8, 13, 18, 30, 34]. These results are close to that obtained by [17] in chicken burger.

Table 3. Microbiological profile of vacuum-packaged spent hen meat treated with lemongrass oil at refrigerated storage.

PARAMETER	Days of storage	Standard plate count	Yeast and mould count	Psychrophile count	Lactobacillus count	Anaerobic count
Control	0 th day	5.11±0.04 ^b	1.05±0.15 ^a	0.62±0.12 ^b	1.32±0.14 ^a	1.05±0.02 ^a
	10 th day	7.32±0.01 ^f	2.72±0.04 ^b	0.81±0.07 ^d	3.46±0.14 ^c	1.35±0.02 ^b
Treatment 1	0 th day	5.01±0.06 ^a	ND	0.60±0.02 ^b	1.31±0.02 ^a	ND

	10 th day	7.19±0.11 ^c	ND	0.74±0.04 ^c	1.45±0.01 ^b	ND
Treatment 2	0 th day	4.96±0.09 ^a	ND	0.54±0.01 ^a	1.31±0.05 ^a	ND
	10 th day	6.91±0.07 ^d	ND	0.68±0.06 ^c	1.43±0.08 ^b	ND
Treatment 3	0 th day	4.94±0.04 ^a	ND	0.52±0.04 ^a	1.30±0.11 ^a	ND
	10 th day	6.63±0.01 ^c	ND	0.62±0.02 ^b	1.39±0.01 ^a	ND

3.3 Sensory Parameters:

The sensory profiles of vacuum-packaged spent hen meat coated with lemongrass oil are illustrated in Table 4. Because overall consumer acceptability relies heavily on appearance, flavour, juiciness, and tenderness, these parameters were monitored over a 10-day refrigerated storage period. Vacuum-packaged spent hen meat coated with lemongrass oil significantly impacted its sensory characteristics during 10 days of chilled storage. A significant time dependent decrease ($P<0.05$) in all sensory attributes was observed from day 0 to day 10 across all groups. Furthermore, sensory acceptability was significantly ($P<0.05$) reduced as the concentration of lemongrass oil in the coating increased. While low-concentration coatings yielded scores statistical equivalent to the control, high-concentration coatings resulted in significantly lower ($P<0.05$) evaluations. However, all samples maintained acceptable sensory scores ranging from 6.2 to 7.6. These results corroborate prior research on essential oils in meat products, including studies by [10] on chicken patties, [40] on cooked sausages, and [9] on chicken meatballs.

Table 4. Sensory parameters of vacuum-packaged spent hen meat treated with lemongrass oil at refrigerated storage.

PARAMETER	Days of storage	Appearance	Flavour	Juiciness	Tenderness	Overall acceptability
Control	0 th day	7.15±0.04 ^c	7.55±0.16 ^c	7.35±0.11 ^c	7.65±0.16 ^c	7.35±0.05 ^b
	10 th day	6.32±0.01 ^a	6.72±0.01 ^a	6.62±0.03 ^b	6.22±0.01 ^a	6.51±0.07 ^a
Treatment 1	0 th day	7.11±0.06 ^c	7.42±0.16 ^b	7.29±0.10 ^c	7.59±0.16 ^c	7.32±0.05 ^b
	10 th day	6.30±0.11 ^a	6.68±0.01 ^a	6.58±0.05 ^b	6.21±0.01 ^a	6.48±0.01 ^a
Treatment 2	0 th day	7.01±0.09 ^b	7.38±0.16 ^b	7.28±0.14 ^c	7.58±0.16 ^c	7.28±0.13 ^b
	10 th day	6.28±0.07 ^a	6.65±0.01 ^a	6.49±0.06 ^a	6.22±0.01 ^a	6.48±0.07 ^a
Treatment 3	0 th day	6.98±0.04 ^b	7.31 ±0.16 ^b	7.26 ±0.11 ^c	7.49 ±0.16 ^b	7.26 ±0.02 ^b
	10 th day	6.23±0.01 ^a	6.59±0.01 ^a	6.47±0.04 ^a	6.21±0.01 ^a	6.46±0.03 ^a

4. Conclusion

Lemongrass essential oil functions as an effective natural preservative in spent hen meat by inhibiting protein degradation (hydrolysis), limiting lipid oxidation, and suppressing microbial spoilage. Furthermore, a direct concentration dependent relationship is observed, where increasing the concentration of lemongrass oil yields superior antioxidant and antimicrobial activity. However, spent hen meat coated with higher concentrations of lemongrass essential oil receives lower organoleptic scores due to the oil's strong, pungent flavor profile. Consequently, utilizing lower concentrations of lemongrass essential oil presents a more viable strategy to combat lipolysis and protein hydrolysis during storage without compromising the product's overall palatability.

BIBLIOGRAPHY

- [1] Abd El-Wahab, G.I. (2018). Utilization from lemongrass and red sorghum bran as natural antioxidant and alternative for fat to improving quality and oxidative stability of beef burger. *African Journal of Biological Sciences*. 14: 39-52. DOI: 10. 21608/ajbs.2018.65274.
- [2] Abu, A., Teye, G. A., & Adzitey, F. (2019). Effects of sweet basil (*ocimum basilicum*) leaf powder on the sensory and nutritional qualities of beef and frankfurter sausages. *UDS International Journal of Development*, 6 (1), 84-91. <http://www.udsjd.org>
- [3] Al-Dalali, S., Zheng, F., Al-Farga, A. (2019). Prolonged the shelf life of different foods using the citrus by-products as antimicrobi-als: a review article. *Annals of Agricultural and Crop Scienc-es*. 4: 1039. DOI: 10.26420/annagriccrops.2019.1039.
- [4] Al-Hijazeen, M., Lee, E. J., Mendonca, A., & Ahn, D. U. (2016). Effect of oregano essential oil (*Origanum vulgare* subsp. *hirtum*) on the storage stability and quality parameters of ground chicken breast meat. *Antioxidants*, 5(2), 18. doi: 10.3390/antiox5020018.
- [5] Al-Maqtari,, Q. A., A. Rehman, A. A. Mahdi, et al. 2021. "Application of Essential Oils as Preservatives in Food Systems: Challenges and Future Prospectives—A Review." *Phytochemistry Reviews* 21, no. 4: 1209–1246. <https://doi.org/10.1007/S11101-021-09776-Y>.
- [6] AOAC, Official Methods of Analysis. 18th ed. Assoc. Off. Anal. Chem., (Maryland, USA, 2005)
- [7] APHA. (2001). Standard methods for the examination of water and waste water. American Public Health Association, 21th ed. APHA/WWA-WEF, Washington, DC, USA.

- [8] Awad, S.M.S. (2019). Utilization of lemongrass leaves powder (*Cymbopogon citratus*) in improving beef burger. *Australian Journal of Basic and Applied Sciences*. 13: 8-17. DOI: 10.22587/ajbas.2019.13.8.2.
- [9] Awodoyin Olayemi Rashidat. (2025). The Incorporation of Lemon Grass (*Cymbopogon citratus*) Leaf Powder in Chicken Meat Ball: Influence on Nutritional Value, Sensory Attributes, Texture and Keeping Quality. *Turkish Journal of Agriculture - Food Science and Technology*, 13(5): 1207-1214.
DOI: <https://doi.org/10.24925/turjaf.v13i5.1207-1214.7459>
- [10] Babu, AJ, Sravanth, MS, Reddy DM, Karthikeyan, B, Rupasundari, A. (2012). Studies on the effect of essential oils of spices on physico-chemical, microbial and organoleptic properties of chicken meat patties during refrigerated storage. *J Adv. Vet. Res* ;2(2):127-136. https://www.advetresearch.com/index.php/AVR/article/view/166#google_vignette.
- [11] Bajrang, C. P., W. N. Sudheer, A. Banadka, V. L. Vasantha, P. Nagella, and B. T. Manjunath. 2025. Advanced Breeding Strategies of Lemon Grass (*Cymbopogon citratus*), 121–137. Springer. https://doi.org/10.1007/978-3-031-81838-7_5.
- [12] Bhoj Raj Singh, Vidya Singh, Raj Karan Singh and N. Ebibeni (2011). Antimicrobial activity of lemongrass (*Cymbopogon citratus*) oil against microbes of environmental, clinical and food origin. *International Research of Pharmacy and Pharmacology*, 1(9) 228-236. <https://www.researchgate.net/publication/260173692>.
- [13] Boeira, C P., Piovesan, N., Soquetta, M B., Flores, D C B., Lucas, B N., da Rosa, C S D., Terra, N N. (2018) Extraction of bioactive compounds of lemongrass, antioxidant activity and evaluation of antimicrobial activity in fresh chicken sausage. *FOOD TECHNOLOGY Cienc. Rural* 48 (11). <https://doi.org/10.1590/0103-8478cr2018047>.
- [14] Bohrer, B.M. 2017, Nutrient density and nutritional value of meat products and non-meat foods high in protein. *Trends Food Sci. Technol.* 65, 103–112. <https://doi.org/10.1016/j.tifs.2017.04.016>.
- [15] Dalvandi, F Almasi, H Ghanbarzadeh, B Hosseini, H and Karimian Khosroshahi, N. (2020) Effect of vacuum packaging and edible coating containing black pepper seeds and turmeric extracts on shelf life extension of chicken breast fillets,” *Journal of Food and Bioprocess Engineering*, vol. 3, no. 1, pp. 69–78.
<https://www.researchgate.net/publication/342467637>.
- [16] Dewi, G Divek V.T. Nair, Peichel, C., Timothy J. Johnson, Noll, S and Johny, A K. (2021) Effect of lemongrass essential oil against multidrug-resistant *Salmonella Heidelberg*

and its attachment to chicken skin and meat. 100:101116.
<https://doi.org/10.1016/j.psj.2021.101116>.

[17] Zaki, E.F. (2022) Effect of adding lemongrass (*Cymbopogon citratus*) extract on quality characteristics of chicken burger during frozen storage. J. Food Qual. Hazards Control. 9, 4181-189. <http://dx.doi.org/10.18502/jfqhc.9.4.11373>

[18] Eldeeb, G.S.S., Mosilhey, S.H. (2018). Antioxidant activity of lemongrass leaves in chicken burger. IOSR Journal of Environmental Science, Toxicology and Food Technology. 12: 74-81. DOI: 10.9790/2402-1209037481.

[19] Hindumathy, C.K. (2011). Invitro study of antibacterial activity of *Cymbopogon citratus*. World Academy of Science, Engineering and Technology. 5: 48-52.
<https://www.researchgate.net/publication/260321156>.

[20] Hussein, S.A., Shahin, M.F.S.A., Masoud, M.R.M. (2015). Effect of using lemongrass and thyme on some beef burger characteristics. Egyptian Journal of Agriculture Research. 93: 133-145. DOI: 10.21608/ejar.2015.153306.

[21] Ibrahim, H.M., Abu Salem, F.M. (2013). Effect of adding lemongrass and lime peel extracts on chicken patties quality. Journal of Applied Sciences Research. 9: 5035-5047

[22] Jay, J.M. (1990). Beef microbial quality determined by extract release volume (ERV). Food Technol., 18:1633. <https://doi.org/10.1111/j.1365-2621.1990.tb03966.x>Digital Object Identifier (DOI)

[23] Jayasena, D.D.; JO, C. Potential application of essential oils as natural antioxidants in meat and meat products: a review. Food Reviews International, v.30, p.71-90, 2014. Available from: <http://doi.org/10.1080/87559129.2013.853776>.

[24] Koniecko, E. K. (1979). Handbook for meat chemists (pp. 68–69). Wayne, New Jersey, USA: Avery Publishing Group Inc (Ch. 6).
<https://www.sciepub.com/reference/38151>.

[25] Kumoro, A.C., Wardhani D.H., Retnowati D.S., and Haryani K. 2021. “A Brief Review on the Characteristics, Extraction and Potential Industrial Applications of Citronella Grass (*Cymbopogon nardus*) and Lemongrass (*Cymbopogon citratus*) Essential Oils.” IOP Conference Series: Materials Science and Engineering 1053, no. 1: 012118. 10.1088/1757-899X/1053/1/012118

[26] Loi, N.V., Quy, T.V., Nam, P.H. and Hanh, D.T. (2025) Addition of lemongrass essential oil into chicken meat silk rolls. Food Research 9(3): 182–187.
[https://doi.org/10.26656/fr.2017.9\(3\).161](https://doi.org/10.26656/fr.2017.9(3).161)

- [27] Lungu, N.S., Afolayan, A.J., & Idamokoro, E.M. (2022). Warmed-over flavour profiles, microbial changes, shelf-life and check-all-that-apply sensory analysis of cooked minced pork treated with varying levels of *Moringa oleifera* leaf and root powder. *Heliyon*, 8, e10616. <https://doi.org/10.1016/j.heliyon.2022.e10616>
- [28] Matthews, K.R.; Kniel, K.E.; Montville, T.J. *Food Microbiology: An Introduction*, 4th ed.; ASM Press: Washington, DC, USA, 2017. <https://library.atu.edu.kz/flgl/41319.pdf>.
- [29] Nacak, B., Dikici, A., Yel, N., Zaimoğulları, K., İpek, G., & Özer, M. (2023). Effect of α -tocopherol, storage temperature and storage time on quality characteristics and oxidative stability of chicken Kavurma, traditional Turkish cooked meat product. *Journal of the Hellenic Veterinary Medical Society*, 74(2), 5623–5632. <https://doi.org/10.12681/jhvms.29331>
- [30] Nikos, G. Tzortzakis, Costas D. Economakis. (2007). Antifungal activity of lemongrass (*Cymbopogon citratus* L.) essential oil against key postharvest pathogens. *Innovative Food Science & Emerging Technologies*, 8(2), 253-258. <https://doi.org/10.1016/j.ifset.2007.01.002>.
- [31] Olorunnisola, S. K., Asiyanbi, H. T., Hammed, A. M., & Simsek, S. (2014): Biological properties of lemongrass: An overview. *International Food Research Journal*, 21(2), 455. <https://www.researchgate.net/publication/261220966>.
- [32] Pezeshk, S., Ojagh S.M., Alishahi A. (2015). Effect of plant antioxidant and antimicrobial compounds on the shelf-life of seafood - a review. *Czech Journal of Food Sciences*. 33: 195-203. DOI: 10.17221/593/2014-CJFS.
- [33] Piruz Sahar, and Khani Mohammadreza (2022) Comparing the Effects of Thyme (*Zataria multiflora*) and Rosemary (*Rosmarinus officinalis*) Essential Oils on Microbiological, Physicochemical, and Sensory Properties of Vacuum-Packaged and Refrigerated Chicken Breast. *Hindawi Journal of Food Quality* Volume, Article ID 6125731. <https://doi.org/10.1155/2022/6125731>
- [34] Rabbani A., Khaliq A., Sajid P., M., Akmal M. Nazir, A. (2025). Recent Advances in Lemongrass Essential Oil: Food Safety, Preservation, and Bioactivity in Food Systems. *Comprehensive Reviews in Food Science and Food Safety*, 25:e70350. <https://doi.org/10.1111/1541-4337.70350>
- [35] Rathbai,V, and Kanimozhi D. (2013) Phytochemical screening in vitro antioxidant and antimicrobial activity of ethanolic extract of *Cymbopogon citratus*. *Int. J Res. Pharm. Biomed. Sci* 4(3):s760

- [36] Ruberto, G. and Baratta, M.T. (2000). Antioxidant activity of selected essential oil components in two lipid model systems. Food Chemistry, 69(2), 167- 174. [https://doi.org/10.1016/S0308-8146\(99\)00247-2](https://doi.org/10.1016/S0308-8146(99)00247-2)
- [37] Shaltout, F. A. (2024). The effect of the natural preservatives and meat preservation against the foodborne pathogens and the spoilage microorganisms. Journal Cancer Research and Cellular Therapeutics, 8(5); DOI:10.31579/2640-1053/202
- [38] Sheykhjan, Mitra Ghodsi, Ali Fazlara, Mohammad Hojjati, Behrooz Alizadeh, Behbahani. (2025) Active food packaging strategies: Promoting mutton quality using Lepidium sativum coatings and nanoemulsions of Dracocephalum moldavica essential oil. Applied Food Research. 5(1) 101021. <https://doi.org/10.1016/j.afres.2025.101021>
- [39] Singh, Bhoj Raj Singh Vidya, Singh Raj Karan and Ebibeni,N (2011) Antimicrobial activity of lemongrass (*Cymbopogon citratus*) oil against microbes of environmental, clinical and food origin. International Research of Pharmacy and Pharmacology, 1(9). 228-236. <https://www.researchgate.net/publication/260173692>.
- [40] Sojic, R., Pavlic,B., Ikonc P. Tomovic, V Ikonc, B Zoran, Z., Kocic-Tanackov, S., Marija Jokanovic, M., Skaljic S., Ivic, M. (2019) Coriander essential oil as natural food additive improves quality and safety of cooked pork sausages with different nitrite levels, Meat Science,157, 107879. <https://doi.org/10.1016/j.meatsci.2019.107879>.
- [41] Strange, E.D., Benedict, R. C., Smith, J. L and Swift, G.E. (1977). Evaluation of rapid tests for monitoring alteration in meat quality during storage. I. Intact Meat. J Food Prot. 40: 843-847. DOI: [10.4315/0362-028X-40.12.843](https://doi.org/10.4315/0362-028X-40.12.843)
- [42] Sutha, M and Chandirasekaran, V. (2021) Effect of incorporation of lemongrass oil on the quality characteristics of chicken nuggets. The Pharma Innovation Journal 2021; SP-10(9): 159-162
- [43] Toma, S.A. Belal, S.A Baset, M.A Uddin, M.N. (2024) Meat quality of commercial spent hens and broilers. Adv. Anim. Vet. Sci. 12, 4,). <https://dx.doi.org/10.17582/journal.aavs/2024/12.4.647.656>
- [44] Witte, V. C., Krause, G. F and Bailey, M. E. (1970). A new extraction method for determining 2-thiobarbituric acid values of pork and beef during storage. <https://doi.org/10.1111/j.1365-2621.1970.tb04815.x>
- [45] Yong, H.I. Kim, T.K. Choi, H.D. Jang, H.W. Jung, S. Choi, Y.S. (2021) Clean label meat technology: Pre-converted nitrite as a natural curing. Food Sci. Anim. Resour. 41, 173–184. doi: 10.5851/kosfa.2020.e96

- [46] Yu, H.H. Chin, Y.W. Paik, H.-D. (2021) Application of Natural Preservatives for Meat and Meat Products against Food-Borne Pathogens and Spoilage Bacteria: A Review. *Foods*, 10, 2418. [https:// doi.org/10.3390/foods10102418](https://doi.org/10.3390/foods10102418).