Journal homepage: https://animalscience.com.ua/en
Animal Science and Food Technology, 17(1), 60-76
Received 15.09.2025 Revised 22.01.2026 Accepted 26.02.2026
Published 26.03.2026

UDC 664.91:664.292:577.115:637.5
DOI: 10.31548/animal.1.2026.60

ISSN 2706-8331
e-ISSN 2706-834X

Effect of durian rind pectin with basil and oregano essential oils on beef patty quality

Umaporn Pastsart*
PhD in Applied Biological Sciences, Associate Professor
Faculty of Innovative Agriculture, Fisheries and Food,
Prince of Songkla University Surat Thani Campus
84000, 31 Moo 6 Str., Surat Thani, Thailand
https://orcid.org/0000-0003-1844-1085

Saneeta Salam
Master
Faculty of Innovative Agriculture, Fisheries and Food,
Prince of Songkla University Surat Thani Campus
84000, 31 Moo 6 Str., Surat Thani, Thailand
https://orcid.org/0009-0008-1023-3410

Jessada Rattanawut
PhD in Animal Sciences, Associate Professor
Faculty of Innovative Agriculture, Fisheries and Food,
Prince of Songkla University Surat Thani Campus
84000, 31 Moo 6 Str., Surat Thani, Thailand
https://orcid.org/0000-0003-1967-1114

Patima Permpoonpattana
PhD in Biology, Assistant Professor
Faculty of Innovative Agriculture, Fisheries and Food,
Prince of Songkla University Surat Thani Campus
84000, 31 Moo 6 Str., Surat Thani, Thailand
https://orcid.org/0000-0002-0320-7184

Chatchawan Chotimarkorn
PhD in Food and Technology Sciences, Assistant Professor
Faculty of Innovative Agriculture, Fisheries and Food,
Prince of Songkla University Surat Thani Campus
84000, 31 Moo 6 Str., Surat Thani, Thailand
https://orcid.org/0000-0002-7522-4549

Suggested Citation:
Pastsart, U., Salam, S., Rattanawut, J., Permpoonpattana, P., & Chotimarkorn, C. (2026). Effect of durian rind pectin with basil and oregano essential oils on beef patty quality. *Animal Science and Food Technology*, 17(1), 60-76. doi: 10.31548/animal.1.2026.60.

**Corresponding author*

Abstract. This study aimed to evaluate the effects of durian rind pectin (DP) in combination with basil or oregano essential oils on the quality and shelf life of beef patties during refrigerated storage, as natural alternatives to synthetic additives. Six treatments were formulated: T1 (control), T2 (0.02% BHT), T3 (1% DP + 1% basil oil), T4 (1% DP + 1% oregano oil), T5 (1% DP + 2% basil oil), and T6 (1% DP + 2% oregano oil). Physicochemical, microbiological, and antioxidant properties were monitored over 8 days at 4°C. The incorporation of pectin and essential oils significantly ($p < 0.05$) affected pH, colour (L*, a*, b*), cooking loss, and texture. Basil oil treatments lowered pH values, while oregano oil increased them. Treated samples showed higher initial lightness, redness, and yellowness, although a* and b* values declined by day 8. Cooking loss was significantly reduced, and tenderness improved in all treated groups, as indicated by decreased hardness, gumminess, chewiness, and springiness, with no significant changes in cohesiveness or adhesiveness. Patties supplemented with pectin and essential oils exhibited higher DPPH radical scavenging activity (63-80% vs. 27% in control) and lower TBARS values (0.08-0.10 µg MDA/g vs. 0.19 µg MDA/g in control) ($p < 0.05$), indicating improved oxidative stability. Microbiological analysis showed significantly reduced total viable counts and *E. coli* levels in treated samples across all time points. No *Salmonella* spp. was detected. Overall, the combination of DP with basil or oregano essential oils enhanced the quality and extended the shelf life of beef patties ($p < 0.05$), offering a promising natural alternative to synthetic preservatives in meat products. The results of this study can be used by meat processing industries to produce safer and longer-lasting refrigerated minced meat products using natural preservatives

Keywords: minced meat products; natural preservatives; oxidative stability; shelf-life extension; agro-waste utilisation

Introduction

The stability of minced meat products during refrigerated storage represents a persistent technological and safety challenge in modern meat processing. Beef patties are widely consumed due to their convenience and sensory appeal; however, the grinding process disrupts muscle structure, increases oxygen exposure, and accelerates oxidative and microbial deterioration. These changes lead to discolouration, lipid oxidation, textural degradation, and microbial proliferation, ultimately limiting shelf life and affecting consumer acceptance. As global demand for minimally processed and clean-label foods continues to grow, developing effective natural preservation strategies for fresh meat systems has become both an industrial necessity and a scientific priority.

In recent years, researchers have increasingly explored plant-derived compounds as alternatives to synthetic antioxidants. S. Salam *et al*. (2024) demonstrated that incorporating pectin powder into beef patties improved oxidative stability and texture during retail display, although the antimicrobial effect was limited. Similarly, C. Srikamwang *et al*. (2024) reported that mango peel pectin enhanced physicochemical properties and functional performance in meat systems, emphasising the structural role of polysaccharides in water retention and matrix stabilisation. These findings suggest that plant-derived pectins can positively influence technological properties, yet their contribution to microbial control remains insufficient. Durian rind has attracted attention as a sustainable source of pectin due to its abundance as an agro-industrial by-product in Southeast Asia. M. Unhasirikul *et al*. (2021) characterised pectin extracted from durian husks and reported distinct physicochemical properties compared to commercial pectin. Their work highlighted the potential of durian rind pectin as a value-added ingredient; however, its application in meat preservation systems was not extensively evaluated. This indicates a gap between raw material characterisation and functional validation in real food matrices.

Parallel to polysaccharide research, essential oils have been widely investigated for their bioactive properties in meat systems. A. Mohammed & A. Alrefiee (2021) found that basil and oregano essential oils improved physicochemical stability and delayed spoilage in meat burgers during chilled storage. K. Zheng *et al*. (2023) further confirmed that oregano essential oil incorporated into edible coatings significantly reduced microbial growth and maintained quality in refrigerated poultry meat. More recently, M. Walasek-Janusz *et al*. (2024) analysed the chemical composition of oregano essential oil and concluded that its high carvacrol and thymol content contributes to strong antioxidant and antimicrobial activity. In addition, A. Javid *et al*. (2024) developed a basil essential oil–incorporated preservation system for ground beef and observed effective suppression of total viable counts during storage. Collectively, these studies confirm the potential of essential oils to inhibit lipid oxidation and microbial proliferation in meat products.

Despite these promising findings, most existing studies have evaluated pectin and essential oils separately. Polysaccharides primarily enhance water-holding capacity and texture, whereas essential oils contribute antimicrobial and antioxidant effects. However, limited research has investigated the combined application of waste-derived pectin and essential oils within the same meat matrix under identical storage conditions. Furthermore, direct comparison between such natural combinations and conventional synthetic antioxidants remains scarce in current literature. The absence of integrated approaches combining structural stabilisers and bioactive compounds represents a significant research gap. Addressing this gap is particularly relevant in the context of sustainable meat processing. Utilising durian rind pectin not only offers functional advantages but also contributes to waste valorisation and environmental sustainability. At the same time, optimising essential oil concentration is necessary to balance antimicrobial efficacy with product quality. An integrated preservation strategy that simultaneously improves texture, oxidative stability, and microbial safety could provide a practical solution aligned with clean-label trends and circular economy principles.

Therefore, the purpose of this study was to examine whether the integration of durian rind pectin with basil or oregano essential oils could produce complementary effects on physicochemical stability, oxidative resistance, and microbial dynamics in beef patties during refrigerated storage, and to evaluate its performance relative to a conventional synthetic antioxidant system.

Materials and Methods

In this study, durian rinds were obtained from mature ‘Mon Thong’ fruits harvested from the tree and subsequently ripened under ambient conditions for 6-9 days to achieve full ripeness, in accordance with the Thai Agricultural Standard (TAS 3-2013), issued by the National Bureau of Agricultural Commodity and Food Standards. No size grading was applied during selection. Beef Longissimus dorsi (LD) muscle and subcutaneous fat used for patty preparation were procured from a local meat vendor in Mueang Surat Thani District, Surat Thani Province, Thailand. Prior to use, visible fat and connective tissues were removed from the lean meat. Both meat and fat were stored at 4 ± 1°C under refrigeration. Commercial food-grade basil and oregano essential oils were purchased from Lapis Tropical Spa Product Co., Ltd. (Thailand) for use in treatments.

The inner white portion of 'Mon Thong' durian rinds was chopped into small fragments and weighed. These fragments were dried in a hot-air oven at approximately 55°C until a constant weight was achieved. Once dried, the material was ground into a fine powder and stored in vacuum-sealed pouches until further use. Pectin extraction was performed based on the method adapted from M. Unhasirikul *et al.* (2021), with minor modifications. Briefly, durian rind powder was mixed with 0.1 M hydrochloric acid at a 1:2 (w/v) solid-to-liquid ratio. The mixture was incubated under controlled conditions, and pectin was subsequently precipitated using 80% ethanol. The precipitate was collected by centrifugation at 8,000 rpm for 30 minutes. To purify the extract, the pectin was washed three times with ethanol and re-dried in a hot-air oven at 55°C until a constant weight was obtained. The final dried product was milled into a fine powder and stored in airtight containers for later use in the experiment.

The antibacterial activity of durian rind pectin, basil essential oil, and oregano essential oil was assessed using the agar well diffusion method, as described by M. Balouiri *et al.* (2016). Briefly, *E. coli* and *Salmonella* spp. were cultured in nutrient broth and incubated at 37°C for 24 hours until reaching the logarithmic growth phase. The bacterial suspensions were adjusted to match a 0.5 McFarland standard (approximately 1×10^8 CFU/mL). Müller-Hinton agar (MHA) plates were prepared and inoculated evenly with the bacterial suspension using sterile cotton swabs. Wells of 6 mm in diameter were created using a sterile cork borer, and 100 µL of each test solution, durian rind pectin, basil essential oil, and oregano essential oil, was introduced into the wells separately. The plates were then incubated at 37°C for 24 hours. After incubation, the diameters of the inhibition zones (in mm) surrounding the wells were measured using a digital caliper. All tests were conducted in triplicate, and results were reported as mean ± standard deviation.

The antioxidant activity of durian rind pectin, basil essential oil, and oregano essential oil was determined using the 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging assay, following the method described by O. Sharma & T. Bhat (2009), with slight modifications. Briefly, a 0.1 mM DPPH solution was prepared by dissolving 2,2-diphenyl-1-picrylhydrazyl (DPPH) in ethanol. For sample preparation, 2.5 mL of each test solution (pectin, basil essential oil, or oregano essential oil) was mixed with 7.5 mL of ethanol and vortexed to ensure homogeneity. Then, 1.5 mL of this solution was transferred into a test tube, followed by the addition of 10.5 mL of 0.1 mM DPPH solution. The mixture was vortexed and incubated in the dark at room temperature for 20 minutes. Absorbance was measured at 517 nm using a spectrophotometer, with ethanol serving as the blank. The DPPH scavenging activity (%) was calculated using the formula (1):

$$\text{DPPH Scavenging activity (\%)} = \\ = (1 - As/Ac) \times 100, \tag{1}$$

where Ac – the absorbance of the control (DPPH in ethanol without the sample); As – the absorbance of the sample.

Each sample was analysed in triplicate, and the results were expressed as mean ± standard deviation. Beef patties were prepared using lean beef (LD) and subcutaneous beef fat at a ratio of 90:10 (w/w). The meat and fat were ground and mixed thoroughly, then divided into six treatment groups, with five replicates (n = 5) per treatment. The experiment followed a completely randomised design (CRD) with the following treatments: 1) Control (ground beef), 2) BHT 0.02% (ground beef + 0.02% BHT), 3) ground beef + durian rind pectin (DP) 1% + basil essential oil 1%, 4) ground beef + DP 1% + oregano essential oil 1%, 5) ground beef + DP 1% + basil essential oil 2%, and 6) ground beef + DP 1% + oregano essential oil 2%. The concentrations of 1% and 2%

essential oils were selected based on previous studies that demonstrated their effectiveness in improving meat quality and storage stability (Falowo *et al.*, 2019; Zheng *et al.*, 2023). Essential oils were first mixed with a small amount of ground meat, followed by gradual incorporation of the remaining meat to ensure uniform distribution. The mixtures were then formed into round flat patties (approximately 100 g each) using a standard mold. Patties were wrapped in plastic film and stored at 4°C for 0, 4, and 8 days for subsequent quality analyses.

The internal pH of beef patties was measured on days 0, 4, and 8 of refrigerated storage. A portable pH meter (Mettler Toledo) equipped with a penetration-type electrode was used. The electrode was carefully inserted into the center of each patty to obtain accurate pH values. Colour attributes, including lightness (L*), redness (a*), and yellowness (b*), were evaluated according to the CIE system on days 0, 4, and 8. A HunterLab Miniscan colourimeter was used, calibrated with a white reference tile and set to a D65 illuminant, 10° standard observer, and 45°/0° geometry. Measurements were taken at three different points on each sample to ensure accuracy and account for surface variability.

Cooking loss, an indicator of water-holding capacity, was measured on days 0, 4, and 8 according to the method described by U. Pastsart *et al.* (2024). Beef patties were vacuum-sealed in plastic bags and cooked in a water bath at 90°C for 15 minutes. Each sample was weighed before and after cooking. Cooking loss (%) was calculated based on the difference between the pre- and post-cooking weights, providing an estimate of moisture retention in the patties. Texture profile analysis (TPA) was performed on days 0, 4, and 8 of storage using a Brookfield CT3 texture analyser equipped with a 10 kg load cell. Patties were cooked in a water bath at 90°C for 15 minutes and then cut into uniform cubes (1 × 1 × 1 cm). Each treatment was analysed in triplicate. Textural parameters including hardness, springiness, cohesiveness, adhesiveness, gumminess, and chewiness were measured to assess structural changes during storage.

The antioxidant capacity of beef patties was assessed on days 0, 4, and 8 of storage using the DPPH radical scavenging assay, following the method of L. Wang *et al.* (2019) as described above. Briefly, 2.5 g of each sample was homogenised in 7.5 mL of ethanol and extracted on a shaker for 10 minutes. The homogenate was then centrifuged at 1,800 rpm for 10 minutes. A 1.5 mL aliquot of the supernatant was mixed with 10.5 mL of 0.1 mM DPPH solution in ethanol. The mixture was incubated in the dark at room temperature for 20 minutes, after which the absorbance was measured at 517 nm using a UV-Vis spectrophotometer. Lipid oxidation was evaluated on days 0, 4, and 8 during the retail display period using the thiobarbituric acid reactive substances (TBARS) assay, following B. Tarladgis *et al.* (1960). The assay quantifies malondialdehyde (MDA) as a marker of oxidative degradation. Absorbance was measured at 532 nm, and results were reported as micrograms of MDA per gram of meat sample (μg MDA/g).

Beef patty samples were analysed on days 0, 4, and 8 of storage at 4°C for total plate count (TPC), *Salmonella* spp., and *E. coli*. A 5 g portion of each sample ($n = 3$) was homogenised with 45 mL of 0.85% NaCl solution, and serial dilutions (10^{-1} to 10^{-6}) were prepared. TPC was determined using Plate Count Agar (PCA), *E. coli* on Eosin Methylene Blue (EMB) agar, and *Salmonella* spp. were detected through pre-enrichment in Buffered Peptone Water (BPW), selective enrichment in Rappaport-Vassiliadis (RV) broth, and plating on Xylose Lysine Deoxycholate (XLD) agar. All plates were incubated at 37°C for 24 hours. Results were expressed as log CFU/g of sample. All collected data were subjected to analysis using the General Linear Model (GLM) procedure in SPSS. Differences between treatments were assessed using Duncan's multiple range test, and statistical significance was considered at $p < 0.05$.

Results and Discussion

The antibacterial activity of durian rind pectin, basil essential oil, and oregano essential oil against *Salmonella* spp. and *E. coli* is summarised in Table 1. Oregano essential oil showed the highest inhibition against both *Salmonella* spp. (20.00 ± 1.00 mm) and *E. coli* (14.67 ± 2.08 mm). Basil essential oil exhibited moderate activity, with inhibition zones of 7.67 ± 0.57 mm and 8.00 ± 1.00 mm, respectively. In contrast, durian rind pectin and the negative control showed no inhibition (0.00 ± 0.00 mm). *Bacillus subtilis*, used as a positive control, produced inhibition zones of 8.67 ± 0.58 mm against *Salmonella* spp. and 13.66 ± 1.53 mm against *E. coli*.

Table 1. *Zone of inhibition of durian rind pectin, basil and oregano essential oils against Salmonella spp. and E. coli. (mean ± SD)*

Test substance	Zone of inhibition (mm) against *Salmonella* spp.	Zone of inhibition (mm) against *E. coli*
Negative control	0.00 ± 0.00^{c}	0.00 ± 0.00^{c}
Pectin from durian rind	0.00 ± 0.00^{c}	0.00 ± 0.00^{c}
Basil essential oil	7.67 ± 0.57^{b}	8.00 ± 1.00^{b}
Oregano essential oil	20.00 ± 1.00^{a}	14.67 ± 2.08^{a}
Bacillus subtilis	8.67 ± 0.58^{b}	13.66 ± 1.53^{a}

Note: $^{a\text{-}c}$ different superscript letters in the same column indicate statistically significant differences among groups ($p < 0.05$)
Source: authors' own research

The results clearly demonstrate that both basil and oregano essential oils exhibit antibacterial activity against *E. coli* and *Salmonella* spp., with oregano oil showing greater efficacy. This higher inhibition may be associated with differences in chemical composition between the two essential oils. These findings align with those of M. Hossain *et al*. (2010), who reported that basil essential oil was effective against *E. coli* and *Salmonella typhi*, attributing its activity to compounds such as methyl chavicol, linalool, and eugenol. Supporting this mechanism, M. Tajkarimi *et al*. (2010) explained that phenolic components in essential oils can disrupt membrane integrity, increase membrane permeability, and impair essential metabolic processes, ultimately suppressing bacterial growth. The moderate inhibition observed for basil oil in the present study is therefore likely related to the concentration and proportion of these active compounds. The stronger antibacterial effect of oregano essential oil may be attributed to its higher content of carvacrol, a potent antimicrobial compound. According to D. Pérez-Conesa *et al*. (2011), carvacrol disrupts cytoplasmic membrane structure and interferes with energy metabolism, which may explain the larger inhibition zones recorded in the present study. This interpretation is consistent with the findings of C. Semeniuc *et al*. (2017), who demonstrated broad-spectrum antibacterial activity of oregano oil against both Gram-positive and Gram-negative bacteria, including *E. coli* and *Salmonella* spp. In contrast, durian rind pectin did not exhibit antibacterial activity against either *E. coli* or *Salmonella* spp. This lack of inhibition may be attributed to the absence of intrinsic antimicrobial compounds within purified pectin. However, although pectin alone showed no direct antibacterial effect, it may function as a film-forming or stabilising agent and potentially act synergistically with essential oils in food preservation systems. The antioxidant activity of durian rind pectin, basil essential oil, and oregano essential oil was evaluated using the DPPH assay, as shown in Table 2. Basil essential oil exhibited the highest free radical scavenging activity (91.88 ± 0.28%), followed by oregano essential oil (90.19 ± 0.28%) and durian rind pectin (81.48 ± 0.73%), with all values showing significant differences ($p < 0.05$).

Table 2. *Antioxidant activity (% free radical scavenging) by DPPH assay of durian rind pectin, basil and oregano essential oils (mean ± SD)*

Test substance	**DPPH (% free radical scavenging)**
Pectin from durian rind	81.48 ± 0.73^{c}
Basil essential oil	91.88 ± 0.28^{a}
Oregano essential oil	90.19 ± 0.28^{b}

Note: $^{a\text{-}c}$ different superscript letters in the same column indicate statistically significant differences among groups ($p < 0.05$)
Source: authors' own research

These results are consistent with previous findings demonstrating the strong radical scavenging activity of essential oils in the DPPH assay. A. Ahmed *et al.* (2019) demonstrated that basil essential oil from various sources possesses potent antioxidant activity in the DPPH assay. A. Sahu *et al.* (2023) also reported strong antioxidant capacity in basil oil, attributed to active compounds such as methyl chavicol, linalool, eugenol, and flavonoids, which function as free radical scavengers and protect against oxidative damage. The antioxidant activity observed in the present study may therefore be attributed to the concentration and composition of these phenolic constituents. Similarly, oregano essential oil has been widely recognised for its antioxidant properties. M. Walasek-Janusz *et al.* (2024) identified carvacrol and thymol as major contributors to its high radical scavenging activity. Z. Suntres *et al.* (2015) further emphasised the biological and pharmacological significance of carvacrol, particularly its role in reducing oxidative stress. The moderate antioxidant activity of durian rind pectin suggests the presence of natural antioxidants, although to a lesser extent than in essential oils. As shown in Table 3, there were no significant differences ($p > 0.05$) in the initial pH values among all treatment groups on day 0, indicating that the samples started with similar acidity. However, significant differences emerged during storage. On day 4, patties treated with durian rind pectin and essential oils particularly T4 (1% pectin + 1% oregano oil) and T6 (1% pectin + 2% oregano oil) had significantly higher pH values than other treatments ($p < 0.05$). By day 8, T1 (control) and T6 maintained the highest pH values, while T3 (1% pectin + 1% basil oil) and T5 (1% pectin + 2% basil oil) recorded the lowest.

The increase in pH during storage, particularly in the control group, is consistent with the findings of M. Triki *et al.* (2018), who observed rising pH in refrigerated meats due to the formation of nitrogenous compounds such as ammonia and amines. These are generated by proteolytic enzymes released by microorganisms during protein degradation. Interestingly, treatments containing basil essential oil (T3 and T5) consistently showed lower pH values, especially at higher concentrations. This may be attributed to a synergistic acidifying effect between durian rind pectin and basil oil. Durian pectin, rich in galacturonic acid, naturally lowers pH, while basil essential oil contains phenolic compounds such as linalool and eugenol, which possess mild acidity and antimicrobial properties. This pH-lowering effect aligns with the findings of G. Khaled *et al.* (2023), who reported similar trends in basil oil-treated goat meat stored under refrigeration.

The effect of durian rind pectin combined with basil and oregano essential oils on beef patty colour parameters (L*, a*, b*) during refrigerated storage is shown in Table 3. On day 0, treatments significantly influenced lightness (L*) and yellowness (b*), with T6 (1% pectin + 2% oregano oil) showing the highest values, while redness (a*) peaked in T4 and was lowest in T6. By day 4, L* and b* remained highest in T6 and T3, while a* was highest in T3 (1% pectin + 1% basil oil). On day 8, T6, T4, and T5 continued to show increased L*, while redness was highest in T2 (BHT), and lowest in control. Yellowness (b*) decreased across all treatments but remained significantly higher in essential oil-treated samples than the control.

Overall, the addition of durian rind pectin and essential oils significantly enhanced lightness and yellowness compared to the control across all storage days ($p < 0.05$). These results are consistent with A. Falowo *et al.* (2019), who reported increased L*, a*, and b* values in beef patties treated with basil essential oil during cold storage. I. Karabagias *et al.* (2011) also observed improved lightness and yellowness in lamb meat stored in oregano- and thyme-oil-infused packaging, attributing the effect to the antioxidant properties of the oils, which help reduce oxidative discolouration. Similarly, C. Srikamwang *et al.* (2024) found that mango peel pectin enhanced colour values in meat products due to its natural pigments and structural properties. However, a notable reduction in redness (a*) was observed by day 8 in treatments containing higher levels of essential oils, particularly T3 and T5. This may be due to the dilution or masking of meat pigments by plant-based components, as previously reported by S. Salam *et al.* (2024), who found that excessive incorporation of plant-derived ingredients can lead to undesired colour changes in meat products. The effect of durian rind pectin combined with basil and oregano essential oils on cooking loss of beef patties during refrigerated storage is shown in Table 3. All treated groups exhibited significantly lower cooking loss than the control (T1) and BHT group (T2) throughout the storage period ($p < 0.05$). On day 0, the highest cooking loss was recorded in T1 (47.10%), while the lowest was observed in T6 (42.72%). This trend persisted through days 4 and 8, with T6 consistently showing the greatest reduction, indicating enhanced water retention.

This reduction in cooking loss may result from the synergistic effects of durian rind pectin and essential oils. Pectin serves as a gelling agent that retains water within the meat matrix (Rolin, 1993), a function supported by M. Namir *et al.* (2015), who reported that tomato-derived pectin reduced cooking loss in minced meat. Additionally, basil and oregano essential oils may contribute to improved water-holding capacity by stabilising muscle protein structures and enhancing water binding, as noted by K. Zheng *et al.* (2023). A. Mohammed & A. Alrefiee (2021) similarly observed reduced cooking loss in camel meat burgers treated with these essential oils during chilled storage, attributing the effect to their antioxidant and protein-stabilising properties. In summary, the incorporation of durian rind pectin with basil or oregano essential oils effectively minimised cooking loss in beef patties, supporting better moisture retention and cooking yield during refrigerated storage.

Table 3. *Effect of durian rind pectin (DP) and basil and oregano essential oils (EOs) supplementation on quality of beef patties during refrigerated storage (mean ± SD)*

Item	T1 (Control)	T2 (BHT 0.02%)	T3 (DP 1% + Basil EO 1%)	T4 (DP1% + Oregano EO 1%)	T5 (DP 1% + Basil EO 2%)	T6 (DP 1% + Oregano EO 2%)
pH, day 0	5.48 ± 0.01	5.50 ± 0.01	5.48 ± 0.01	5.48 ± 0.02	5.49 ± 0.02	5.49 ± 0.01
pH, day 4	5.50^{b} ± 0.02	5.50^{b} ± 0.03	5.44^{c} ± 0.01	5.58^{a} ± 0.01	5.46^{c} ± 0.01	5.60^{a} ± 0.01
pH, day 8	5.66^{a} ± 0.03	5.60^{b} ± 0.02	5.21^{d} ± 0.01	5.56^{c} ± 0.03	5.19^{d} ± 0.01	5.64^{a} ± 0.01

Table 3. Continued

Item	T1 (Control)	T2 (BHT 0.02%)	T3 (DP 1% + Basil EO 1%)	T4 (DP1% + Oregano EO 1%)	T5 (DP 1% + Basil EO 2%)	T6 (DP 1% + Oregano EO 2%)
L*, day 0	$71.18^{d} \pm 0.93$	$69.60^{e} \pm 0.93$	$79.75^{c} \pm 0.93$	$82.58^{b} \pm 1.21$	$80.33^{c} \pm 0.31$	$86.40^{a} \pm 0.84$
L*, day 4	$79.85^{c} \pm 0.56$	$79.13^{c} \pm 1.23$	$90.53^{a} \pm 2.08$	$90.68^{a} \pm 0.67$	$87.60^{b} \pm 1.34$	$90.85^{a} \pm 0.91$
L*, day 8	$73.90^{c} \pm 0.94$	$72.70^{c} \pm 0.74$	$93.43^{b} \pm 1.00$	$98.20^{a} \pm 1.31$	$98.13^{a} \pm 1.45$	$99.53^{a} \pm 0.43$
a*, day 0	$13.35^{cd} \pm 0.25$	$14.85^{ab} \pm 0.57$	$14.05^{bc} \pm 0.79$	$15.05^{a} \pm 0.91$	$13.13^{cd} \pm 0.26$	$12.75^{d} \pm 0.57$
a*, day 4	$11.75^{d} \pm 0.10$	$11.93^{d} \pm 0.67$	$15.35^{a} \pm 0.35$	$12.73^{c} \pm 0.21$	$14.55^{b} \pm 0.37$	$11.85^{d} \pm 0.58$
a*, day 8	$0.15^{f} \pm 0.06$	$14.48^{a} \pm 0.42$	$1.33^{e} \pm 0.17$	$4.73^{b} \pm 0.29$	$2.88^{d} \pm 0.17$	$3.45^{c} \pm 0.21$
b*, day 0	$19.70^{d} \pm 1.45$	$20.55^{d} \pm 1.19$	$24.33^{b} \pm 0.52$	$25.93^{a} \pm 1.14$	$22.30^{c} \pm 0.53$	$26.60^{a} \pm 0.26$
b*, day 4	$24.10^{cd} \pm 0.38$	$21.33^{e} \pm 0.59$	$26.28^{a} \pm 0.39$	$23.65^{d} \pm 1.05$	$24.78^{bc} \pm 0.60$	$25.25^{b} \pm 0.37$
b*, day 8	$11.03^{f} \pm 0.22$	$18.78^{a} \pm 0.59$	$13.73^{e} \pm 0.17$	$17.23^{b} \pm 1.03$	$14.93^{d} \pm 0.39$	$15.55^{c} \pm 0.42$
% cooking loss, day 0	$47.10^{a} \pm 2.80$	$45.44^{ab} \pm 1.00$	$44.80^{abc} \pm 1.01$	$45.07^{abc} \pm 1.15$	$43.14^{bc} \pm 0.77$	$42.72^{c} \pm 1.25$
% cooking loss, day 4	$46.14^{a} \pm 0.60$	$44.16^{b} \pm 1.73$	$39.45^{c} \pm 1.92$	$40.58^{c} \pm 0.84$	$41.25^{c} \pm 0.52$	$40.20^{c} \pm 0.85$
% cooking loss, day 8	$45.80^{a} \pm 0.84$	$45.13^{a} \pm 1.63$	$40.38^{b} \pm 1.32$	$42.04^{b} \pm 1.96$	$40.72^{b} \pm 0.78$	$39.75^{b} \pm 1.62$

Note: $^{a\text{-}c}$ different superscript letters in the same row indicate statistically significant differences among groups ($p < 0.05$)

Source: authors' own research

The effect of durian rind pectin combined with basil and oregano essential oils on the texture properties of beef patties during refrigerated storage is presented in Table 4. Significant differences were observed in hardness, springiness, gumminess, and chewiness ($p < 0.05$), while cohesiveness and adhesiveness remained unaffected throughout storage ($p > 0.05$). On day 0, the control (T1) and BHT-treated patties (T2) exhibited the highest hardness, gumminess, and chewiness. In contrast, T3-T6 showed the lower values, suggesting that the addition of pectin and essential oils contributed to a softer texture, likely due to enhanced moisture retention and reduced protein cross-linking. By day 8, T6 exhibited the lowest hardness (9.86 N) and chewiness (289.25 mJ), while the control remained significantly firmer. This softening effect may be attributed to the water-binding and gelling properties of pectin, along with the interaction of essential oils with muscle proteins, which can alter structural integrity and reduce firmness (Rolin, 1993; Mohammed & Alrefiee, 2021; Zheng *et al.,* 2023). In summary, the combined use of durian rind pectin with basil or oregano essential oils significantly reduced hardness and chewiness of beef patties during storage, without compromising cohesiveness. These changes may enhance tenderness and improve consumer acceptability in cooked meat products.

Table 4. *Effect of durian rind pectin (DP) and basil and oregano essential oils (EOs) supplementation on the textural profile of beef patties during refrigerated storage (mean ± SD)*

Item	T1 (Control)	T2 (BHT 0.02%)	T3 (DP 1% + Basil EO 1%)	T4 (DP1% + Oregano EO 1%)	T5 (DP 1% + Basil EO 2%)	T6 (DP 1% + Oregano EO 2%)
Day 0						
Hardness (N)	$18.92^{a} \pm 0.95$	$18.09^{a} \pm 1.23$	$13.78^{b} \pm 0.75$	$14.05^{b} \pm 0.73$	$14.20^{b} \pm 0.68$	$14.69^{b} \pm 1.03$
Cohesiveness	0.52 ± 0.08	0.53 ± 0.02	0.53 ± 0.06	0.50 ± 0.01	0.53 ± 0.03	0.50 ± 0.04
Adhesiveness (mJ)	1.75 ± 0.50	1.75 ± 0.50	2.00 ± 0.82	1.75 ± 0.50	1.50 ± 0.58	1.75 ± 0.50

Table 4. Continued

Item	T1 (Control)	T2 (BHT 0.02%)	T3 (DP 1% + Basil EO 1%)	T4 (DP1% + Oregano EO 1%)	T5 (DP 1% + Basil EO 2%)	T6 (DP 1% + Oregano EO 2%)
Day 0						
Springiness (mm)	21.68^{a} ± 0.71	17.34^{b} ± 0.45	6.16^{c} ± 0.11	6.16^{c} ± 0.13	6.13^{c} ± 0.15	6.16^{c} ± 0.20
Gumminess (N)	15.16^{a} ± 1.02	11.98^{b} ± 0.88	8.11^{c} ± 0.62	7.96^{c} ± 0.69	8.10^{c} ± 0.48	8.27^{c} ± 0.43
Chewiness (mJ)	2,467.25^{a} ± 80.39	2,305.50^{b} ± 47.96	944.25^{c} ± 30.03	754.25^{d} ± 26.08	632.50^{e} ± 6.56	455.25^{f} ± 35.53
Day 4						
Hardness (N)	27.69^{a} ± 0.86	26.07^{a} ± 1.34	18.72^{b} ± 1.20	18.53^{b} ± 0.83	17.70^{bc} ± 1.83	15.66^{c} ± 2.36
Cohesiveness	0.41 ± 0.03	0.40 ± 0.01	0.41 ± 0.03	0.41 ± 0.03	0.41 ± 0.02	0.41 ± 0.02
Adhesiveness (mJ)	1.50 ± 0.58	1.50 ± 0.58	1.25 ± 0.50	1.50 ± 0.58	1.50 ± 0.58	1.50 ± 0.58
Springiness (mm)	6.16^{ab} ± 0.16	5.75^{c} ± 0.11	5.85^{bc} ± 0.41	6.24^{a} ± 0.17	5.97^{abc} ± 0.14	5.96^{abc} ± 0.03
Gumminess (N)	15.99^{a} ± 1.02	13.40^{b} ± 0.69	11.98^{b} ± 0.75	11.92^{b} ± 1.18	12.29^{b} ± 1.16	12.42^{b} ± 0.34
Chewiness (mJ)	1,041.75^{a} ± 72.80	819.25^{b} ± 35.91	607.50^{c} ± 52.44	562.25^{cd} ± 51.94	610.50^{c} ± 33.31	488.00^{d} ± 68.15
Day 8						
Hardness (N)	23.19^{a} ± 0.75	19.99^{b} ± 2.52	15.75^{c} ± 0.93	13.29^{d} ± 1.51	11.39^{de} ± 0.95	9.86^{e} ± 0.55
Cohesiveness	0.44 ± 0.01	0.45 ± 0.03	0.45 ± 0.02	0.45 ± 0.03	0.44 ± 0.01	0.44 ± 0.03
Adhesiveness (mJ)	1.75 ± 0.96	1.75 ± 0.96	2.00 ± 0.82	1.75 ± 0.96	1.75 ± 0.96	2.00 ± 0.82
Springiness (mm)	6.81^{a} ± 0.64	6.49^{ab} ± 0.76	5.78^{bc} ± 0.39	5.83^{bc} ± 0.25	5.80^{bc} ± 0.35	5.62^{c} ± 0.28
Gumminess (N)	11.09^{a} ± 1.29	10.64^{a} ± 0.68	5.99^{b} ± 0.47	5.94^{b} ± 0.42	5.91^{b} ± 0.30	5.92^{b} ± 0.29
Chewiness (mJ)	775.25^{a} ± 30.51	595.75^{b} ± 38.08	463.00^{c} ± 37.07	480.75^{c} ± 29.84	340.75^{d} ± 18.98	289.25^{e} ± 23.98

Note: $^{a-c}$ different superscript letters in the same row indicate statistically significant differences among groups ($p < 0.05$)

Source: authors' own research

Table 5 presents the oxidative stability of beef patties evaluated via DPPH radical scavenging activity and TBARS values during refrigerated storage. All treated samples (T2-T6) showed significantly higher DPPH activity and lower TBARS values compared to the control (T1) at every time point ($p < 0.05$). The strongest antioxidant capacity was observed in T6 (1% pectin + 2% oregano oil) and T5 (1% pectin + 2% basil oil), with DPPH scavenging activities of 67.95 ± 2.60% and 62.03 ± 3.25%, respectively, on day 0. This pattern persisted through day 8, indicating a sustained antioxidant effect.

Table 5. *Effect of durian rind pectin (DP) and basil and oregano essential oils (EOs) supplementation on the textural profile of beef patties during refrigerated storage (mean ± SD)*

Item	T1 (Control)	T2 (BHT 0.02%)	T3 (DP 1% + Basil EO 1%)	T4 (DP1% + Oregano EO 1%)	T5 (DP 1% + Basil EO 2%)	T6 (DP 1% + Oregano EO 2%)
	DPPH scavenging activity (%)					
Day 0	34.92^{e} ± 0.94	42.91^{d} ± 2.14	50.53^{c} ± 2.29	55.58^{c} ± 4.32	62.03^{b} ± 3.25	67.95^{a} ± 2.60

Table 5. Continued

Item	T1 (Control)	T2 (BHT 0.02%)	T3 (DP 1% + Basil EO 1%)	T4 (DP1% + Oregano EO 1%)	T5 (DP 1% + Basil EO 2%)	T6 (DP 1% + Oregano EO 2%)
	DPPH scavenging activity (%)					
Day 4	$31.69^{d} \pm 4.75$	$51.88^{c} \pm 5.65$	$81.69^{b} \pm 2.38$	$86.39^{ab} \pm 1.01$	$90.74^{a} \pm 0.67$	$87.60^{a} \pm 1.16$
Day 8	$27.18^{e} \pm 0.83$	$41.87^{d} \pm 2.52$	$63.93^{c} \pm 4.0$	$75.25^{b} \pm 2.88$	$80.19^{a} \pm 1.29$	$80.93^{a} \pm 1.32$
	TBARS (μg MDA/g meat)					
Day 0	$0.038^{a} \pm 0.002$	$0.033^{b} \pm 0.002$	$0.032^{b} \pm 0.001$	$0.034^{b} \pm 0.002$	$0.033^{b} \pm 0.001$	$0.033^{b} \pm 0.001$
Day 4	$0.097^{a} \pm 0.005$	$0.087^{b} \pm 0.001$	$0.066^{c} \pm 0.003$	$0.066^{d} \pm 0.004$	$0.064^{d} \pm 0.004$	$0.059^{e} \pm 0.002$
Day 8	$0.190^{a} \pm 0.003$	$0.146^{b} \pm 0.004$	$0.102^{c} \pm 0.003$	$0.097^{d} \pm 0.002$	$0.087^{e} \pm 0.002$	$0.080^{f} \pm 0.002$

Note: $^{a-f}$ different superscript letters in the same row indicate statistically significant differences among groups ($p < 0.05$)

Source: authors' own research

Lipid oxidation, indicated by increasing TBARS values over time, was significantly suppressed in all treated groups compared to the control. On day 8, T6 exhibited the lowest TBARS, followed by T5 and T4, demonstrating the effective inhibitory role of pectin-essential oil combinations on lipid peroxidation. Notably, these natural treatments outperformed BHT (T2), a common synthetic antioxidant. The improved oxidative stability likely stems from synergistic interactions between durian rind pectin and the bioactive components of essential oils. Previous studies have shown similar effects of pectin from Jerusalem artichoke, mangosteen peel, and other vegetables (Liu *et al.*, 2016; Wathoni *et al.*, 2019). The antioxidant activity of basil oil is attributed to compounds like methyl chavicol, linalool, and eugenol, while oregano oil owes its effect to carvacrol and thymol (Hossain *et al.*, 2010; Suntres *et al.*, 2015; Ahmed *et al.*, 2019). Comparable outcomes were reported in beef products by A. Falowo *et al.* (2019). Although BHT is widely used, its comparatively lower performance reinforces the growing interest in natural alternatives (Yehye *et al.*, 2015). These findings support the application of durian rind pectin combined with basil or oregano oil as promising clean-label preservatives to enhance oxidative stability in meat products.

Table 6 presents the microbial counts of beef patties supplemented with durian rind pectin and basil or oregano essential oils during refrigerated storage. Across all time points, samples treated with pectin and essential oils exhibited significantly lower ($p < 0.05$) total viable counts (TVC) and *E. coli* levels compared to the control and BHT-treated samples. On day 0, the TVC of treated samples ranged from 6.51 ± 0.02 to 6.63 ± 0.02 log CFU/g, significantly lower than the control (6.73 ± 0.03) and BHT group (6.75 ± 0.02). The lowest count was recorded in T6 (durian pectin + 2% oregano EO). *E. coli* counts followed a similar trend, with T6 exhibiting the lowest value (4.67 ± 0.02 log CFU/g). During storage, microbial growth increased in all samples; however, the rate of increase was significantly suppressed in treatments containing essential oils. On day 4, the TVC in the control reached 8.06 ± 0.02 log CFU/g, while T6 remained significantly lower at 6.66 ± 0.03 log CFU/g. By day 8, T6 again showed the lowest bacterial load (6.83 ± 0.02 log CFU/g), followed closely by T4 and T5. In contrast, the control and BHT groups exceeded 9.30 log CFU/g. *E. coli* counts also remained consistently lower in all pectin-essential oil treatments across storage. On day 8, the lowest *E. coli* level was found in T6 (5.16 ± 0.01 log CFU/g), compared to 7.15 ± 0.13 log CFU/g in the control. No *Salmonella spp.* was detected in any sample throughout the storage period.

Table 6. *Effect of durian rind pectin (DP) and basil and oregano essential oils (EOs) supplementation on bacteria counts (log10 CFU/g) of beef patties during refrigerated storage (mean ± SD)*

Item	T1 (Control)	T2 (BHT 0.02%)	T3 (DP 1% + Basil EO 1%)	T4 (DP1% + Oregano EO 1%)	T5 (DP 1% + Basil EO 2%)	T6 (DP 1% + Oregano EO 2%)
Day 0						
Total bacteria	$6.73^a \pm 0.03$	$6.75^a \pm 0.02$	$6.63^b \pm 0.02$	$6.62^b \pm 0.02$	$6.57^c \pm 0.02$	$6.51^c \pm 0.02$
E. coli	$4.86^a \pm 0.04$	$4.86^a \pm 0.02$	$4.83^{ab} \pm 0.02$	$4.74^c \pm 0.03$	$4.80^b \pm 0.03$	$4.67^d \pm 0.02$
Salmonella spp.	none	none	none	none	none	none
Day 4						
Total bacteria	$8.06^a \pm 0.02$	$8.03^a \pm 0.02$	$6.88^b \pm 0.03$	$6.71^c \pm 0.05$	$6.87^b \pm 0.05$	$6.66^c \pm 0.03$
E. coli	$6.40^a \pm 0.02$	$6.41^a \pm 0.02$	$4.98^b \pm 0.03$	$4.92^{cd} \pm 0.02$	$4.94^c \pm 0.02$	$4.88^d \pm 0.02$
Salmonella spp.	none	none	none	none	none	none
Day 8						
Total bacteria	$9.31^a \pm 0.01$	$9.30^a \pm 0.03$	$7.17^b \pm 0.04$	$6.90^d \pm 0.02$	$7.11^c \pm 0.04$	$6.83^e \pm 0.02$
E. coli	$7.15^a \pm 0.13$	$7.05^b \pm 0.02$	$5.30^b \pm 0.02$	$5.24^{bc} \pm 0.02$	$5.26^{bc} \pm 0.01$	$5.16^c \pm 0.01$
Salmonella spp.	none	none	none	none	none	none

Note: $^{a\text{-}e}$ – different superscript letters in the same row indicate statistically significant differences among groups ($p < 0.05$). None – not found in 5 g of beef patties
Source: authors' own research

These results demonstrate that the combination of durian rind pectin with basil or oregano essential oils significantly reduced total viable counts (TVC) and Escherichia coli levels in beef patties during refrigerated storage compared to both the control and BHT-treated groups ($p < 0.05$), with the strongest effect observed in the group containing 2% oregano essential oil (T6). The antimicrobial activity is largely attributed to the active compounds present in the essential oils. Basil essential oil contains methyl chavicol, linalool, and eugenol, which have been reported to disrupt bacterial membranes and inhibit microbial metabolism (Hossain *et al.*, 2010). A. Javid *et al.* (2024) developed a basil oil-infused bacterial cellulose foam for meat preservation and observed effective suppression of microbial growth. Oregano essential oil, rich in carvacrol and thymol, has been shown to damage bacterial cell membranes and induce leakage of cellular components, explaining the strong antimicrobial activity observed in the present study. No *Salmonella* spp. was detected in any of the beef patties throughout storage. This result complies with Thai food safety regulations, which require the absence of *Salmonella* spp. in 25 g of chilled meat products. Although microbial testing in this study used 5 g samples, the outcome remains within regulatory limits. The combined use of durian rind pectin and essential oils, particularly oregano oil at 2%, effectively suppressed spoilage and pathogenic bacteria during cold storage. These findings highlight the potential of these natural additives as effective antimicrobial agents for improving microbial safety and extending the shelf life of meat products.

Conclusions

This study demonstrated that durian rind pectin (DP), when combined with basil or oregano essential oils (EOs), significantly improved the quality and storage stability of beef patties during refrigerated storage. Among all treatments, the combination of 1% DP and 2% oregano oil (T6) showed the most consistent and pronounced effects. Oxidative stability was markedly enhanced in treated samples. On day 8, DPPH radical scavenging activity reached 80.93% in T6 compared to 27.18% in the control.

Lipid oxidation, measured by TBARS, was significantly reduced from 0.190 µg MDA/g in the control to 0.080 µg MDA/g in T6 ($p < 0.05$), indicating substantial inhibition of oxidative deterioration. Microbiological quality was also significantly improved. After 8 days of storage, total viable counts (TVC) increased to 9.31 log CFU/g in the control, whereas T6 maintained a significantly lower level of 6.83 log CFU/g. Similarly, *Escherichia coli* counts were reduced from 7.15 log CFU/g in the control to 5.16 log CFU/g in T6. No *Salmonella* spp. were detected in any treatment throughout storage. Technological properties were positively affected. Cooking loss decreased from 45.80% in the control to 39.75% in T6 on day 8. Texture analysis revealed substantial reductions in hardness (23.19 N vs. 9.86 N) and chewiness (775.25 mJ vs. 289.25 mJ), indicating improved tenderness. Overall, the incorporation of durian rind pectin combined with oregano essential oil at 2% effectively enhanced oxidative stability, suppressed microbial growth, and improved texture, supporting its potential as a natural alternative to synthetic preservatives such as BHT in beef patties. Future research prospects include investigating consumer sensory acceptance, optimising pectin and essential oil concentrations for industrial application, elucidating the mechanisms of antimicrobial action in meat systems, and evaluating the effectiveness of this combination in other types of meat products and under extended storage conditions.

Acknowledgements

None.

Funding

This research was financially supported by Prince of Songkla University, Surat Thani Campus, 2024 Grant No. IAF6703032S.

Conflict of Interest

The authors declare no conflict of interest.

References

[1] Ahmed, A.F., Attia, F.A.K., Liu, Z., Li, C., Wei, J., & Kang, W. (2019). Antioxidant activity and total phenolic content of essential oils and extracts of sweet basil (*Ocimum basilicum* L.) plants. *Food Science and Human Wellness*, 8(3), 299-305. doi: 10.1016/j.fshw.2019.07.004.

[2] Balouiri, M., Sadiki, M., & Ibnsouda, S.K. (2016). Methods for *in vitro* evaluating antimicrobial activity: A review. *Journal of Pharmaceutical Analysis*, 6(2), 71-79. doi: 10.1016/j.jpha.2015.11.005.

[3] Falowo, A.B., Mukumbo, F.E., Idamokoro, E.M., Afolayan, A.J., & Muchenje, V. (2019). Phytochemical constituents and antioxidant activity of sweet basil (*Ocimum basilicum* L.) essential oil on ground beef from Boran and Nguni cattle. *International Journal of Food Science*, 2019, article number 2628747. doi: 10.1155/2019/2628747.

[4] Hossain, M.A., Kabir, M.J., Salehuddin, S.M., Rahman, S.M.M., Das, A.K., Singha, S.K., Alam, K., & Rahman, A. (2010). Antibacterial properties of essential oils and methanol extracts of sweet basil (*Ocimum basilicum*) occurring in Bangladesh. *Pharmaceutical Biology*, 48(5), 504-511. doi: 10.3109/13880200903190977.

[5] Javid, A.L., Almasi, H., Molaei, R., & Moradi, M. (2024). Basil essential oil-incorporated bacterial nanocellulose foam: Fabrication, characterization, and application in extending ground beef shelf life. *Journal of Agriculture and Food Research*, 18, article number 101453. doi: 10.1016/j.jafr.2024.101453.

[6] Karabagias, I., Badeka, A., & Kontominas, M.G. (2011). Shelf life extension of lamb meat using thyme or oregano essential oils and modified atmosphere packaging. *Meat Science*, 88(1), 109-116. doi: 10.1016/j.meatsci.2010.12.010.

[7] Khaled, G., Galil, H.A., Salama, H., Bkear, N., & Ali, E. (2023). Effect of basil essential oil on caprine meat quality and shelf-life. *Damanhour Journal of Veterinary Sciences*, 9(2), 26-32. doi: 10.21608/djvs.2023.182014.1105.

[8] Liu, Y., Dong, M., Yang, Z., & Pan, S. (2016). Anti-diabetic effect of citrus pectin in diabetic rats and potential mechanism via PI3K/Akt signaling pathway. *International Journal of Biological Macromolecules*, 89, 484-488. doi: 10.1016/j.ijbiomac.2016.05.015.

[9] Mohammed, A.A.A., & Alrefiee, A.A. (2021). Effect of adding basil and oregano essential oils on the physicochemical characteristics of camel meat burger during cold storage. *American Journal of Food Technology*, 16(1), 38-46. doi: 10.3923/ajft.2021.38.46.

[10] Namir, M., Siliha, H., & Ramadan, M.F. (2015). Fiber pectin from tomato pomace: Characteristics, functional properties and application in low-fat beef burger. *Food Measure*, 9, 305-312. doi: 10.1007/s11694-015-9236-5.

[11] Pastsart, U., Sresomjit, F., Bochuai, R., & Pimpa, O. (2024). Texture profile, water holding capacity, antioxidant activity and lipid oxidation of beef during retail display from cattle fed total mixed ration supplemented with *Capsicum frutescens* L. and *Curcuma longa* L. powders. *Online Journal of Animal and Feed Research*, 14(1), 40-46. doi: 10.51227/ojafr.2024.5.

[12] Pérez-Conesa, D., Cao, J., Chen, L., McLandsborough, L., & Weiss, J. (2011). Inactivation of *Listeria monocytogenes* and *Escherichia coli* O157:H7 biofilms by micelle-encapsulated eugenol and carvacrol. *Journal of Food Protection*, 74(1), 55-62. doi: 10.4315/0362-028X.JFP-08-403.

[13] Rolin, C. (1993). Pectin. In R.L. Whistler & J.N. Bemiller (Eds.), *Industrial gums: Polysaccharides and their derivatives* (3rd ed.) (pp. 257-293). Cambridge: Academic Press. doi: 10.1016/B978-0-08-092654-4.50014-0.

[14] Sahu, A., Nayak, G., Bhuyan, S.K., Bhuyan, R., Kar, D., & Kuanar, A. (2023). Antioxidant and antimicrobial activities of *Ocimum basilicum* var. thyrsiflora against some oral microbes. *Multidisciplinary Science Journal*, 6(3), article number e2024026. doi: 10.31893/multiscience.2024026.

[15] Salam, S., Kwanonin, K., Nakawiroj, P., & Pastsart, U. (2024). Quality, textural profiles, oxidative stability and bacterial content during retail display of beef patties formulated with pectin powder. *Food Agricultural Sciences and Technology*, 10(2), 43-54. doi: 10.14456/fast.2024.11.

[16] Semeniuc, C.A., Pop, C.R., & Rotar, A.M. (2017). Antibacterial activity and interactions of plant essential oil combinations against Gram-positive and Gram-negative bacteria. *Journal of Food and Drug Analysis*, 25(2), 403-408. doi: 10.1016/j.jfda.2016.06.002.

[17] Sharma, O.P., & Bhat, T.K. (2009). DPPH antioxidant assay revisited. *Food Chemistry*, 113(4), 1202-1205. doi: 10.1016/j.foodchem.2008.08.008.

[18] Srikamwang, C., Willats, W.G.T., Bakshani, C.R., Sommano, S.R., & Wongkaew, M. (2024). Potentials of Mahachanok mango peel pectin in modulating glycaemic index in simulated *in vitro* carbohydrate digestion of meat product. *Journal of Agriculture and Food Research*, 18, article number 101304. doi: 10.1016/j.jafr.2024.101304.

[19] Suntres, Z.E., Coccimiglio, J., & Alipour, M. (2015). The bioactivity and toxicological actions of carvacrol. *Critical Reviews in Food Science and Nutrition*, 55(3), 304-318. doi: 10.1080/10408398.2011.653458.

[20] Tajkarimi, M.M., Ibrahim, S.A., & Cliver, D.O. (2010). Antimicrobial herb and spice compounds in food. *Food Control*, 21(9), 1199-1218. doi: 10.1016/j.foodcont.2010.02.003.

[21] Tarladgis, B.G., Watts, B.M., Younathan, M.T., & Dugan, L. (1960). A distillation method for the quantitative determination of malonaldehyde in rancid foods. *Journal of the American Oil Chemists' Society*, 37(1), 44-48. doi: 10.1007/BF02630824.

[22] Triki, M., Herrero, A.M., Jiménez-Colmenero, F., & Ruiz-Capillas, C. (2018). Quality assessment of fresh meat from several species based on free amino acid and biogenic amine contents during chilled storage. *Foods*, 7(9), article number 132. doi: 10.3390/foods7090132.

[23] Unhasirikul, M., Unhasirikul, K., Wisuttipat, S., Wutthanasikunchai, H., & Suwanposri, A. (2021). Extraction of pectin from durian husks for use in the production of jams from low prices of Salacca zalacca and Salacca wallichiana Mart in Chanthaburi province. *Journal of Science and Technology, Ubon Ratchathani University*, 23(1), 81-90.

[24] Walasek-Janusz, M., Grzegorczyk, A., Malm, A., Nurzyńska-Wierdak, R., & Zalewski, D. (2024). Chemical composition and antioxidant and antimicrobial activity of oregano essential oil. *Molecules*, 29(2), article number 435. doi: 10.3390/molecules29020435.

[25] Wang, L., Guo, H., Liu, X., Jiang, G., Li, C., Li, X., & Li, Y. (2019). Roles of *Lentinula edodes* as the pork lean meat replacer in production of the sausage. *Meat Science*, 156, 44-51. doi: 10.1016/j.meatsci.2019.05.016.

[26] Wathoni, N., Shan, C.Y., Shan, W.Y., Rostinawati, T., Indradi, R.B., Pratiwi, R., & Muchtaridi, M. (2019). Characterization and antioxidant activity of pectin from Indonesian mangosteen (*Garcinia mangostana* L.) rind. *Heliyon*, 5(8), article number e02299. doi: 10.1016/j.heliyon.2019.e02299.

[27] Yehye, W.A., Rahman, N.A., Ariffin, A., Hamid, S.B.A., Alhadi, A.A., Kadir, F.A., & Yaeghoobi, M. (2015). Understanding the chemistry behind the antioxidant activities of butylated hydroxytoluene (BHT): A review. *European Journal of Medicinal Chemistry*, 101, 295-312. doi: 10.1016/j.ejmech.2015.06.026.

[28] Zheng, K., Li, B., Liu, Y., Wu, D., Bai, Y., & Xiang, Q. (2023). Effect of chitosan coating incorporated with oregano essential oil on microbial inactivation and quality properties of refrigerated chicken breasts. *LWT*, 176, article number 114547. doi: 10.1016/j.lwt.2023.114547.

Вплив пектину зі шкірки дуріана у поєднанні з ефірними оліями базиліку та орегано на якість яловичих котлет

Умапон Пастсарт

Доктор філософії з прикладних біологічних наук, доцент
Факультет інноваційного сільського господарства, рибальства та харчових технологій, Університет Принца Сонгкли, кампус Сураттхані
84000, вул. 31 Му, 6, м. Сураттхані, Таїланд
https://orcid.org/0000-0003-1844-1085

Саніта Салам

Магістр
Факультет інноваційного сільського господарства, рибальства та харчових технологій, Університет Принца Сонгкли, кампус Сураттхані
84000, вул. 31 Му, 6, м. Сураттхані, Таїланд
https://orcid.org/0009-0008-1023-3410

Джессада Раттанавут

Доктор тваринницьких наук, доцент
Факультет інноваційного сільського господарства, рибальства та харчових технологій, Університет Принца Сонгкли, кампус Сураттхані
84000, вул. 31 Му, 6, м. Сураттхані, Таїланд
https://orcid.org/0000-0003-1967-1114

Патіма Пермпунпаттана

Кандидат біологічних наук, асистент професора
Факультет інноваційного сільського господарства, рибальства та харчових технологій, Університет Принца Сонгкли, кампус Сураттхані
84000, вул. 31 Му, 6, м. Сураттхані, Таїланд
https://orcid.org/0000-0002-0320-7184

Чатчаван Чотімаркорн

Доктор харчових та технологічних наук, асистент професора
Факультет інноваційного сільського господарства, рибальства та харчових технологій, Університет Принца Сонгкли, кампус Сураттхані
84000, вул. 31 Му, 6, м. Сураттхані, Таїланд
https://orcid.org/0000-0002-7522-4549

Анотація. Метою дослідження було оцінити вплив пектину з шкірки дуріану (DP) у поєднанні з ефірними оліями базиліку або орегано на якість і термін зберігання яловичих котлет під час холодильного зберігання як натуральної альтернативи синтетичним добавкам. Було сформовано шість варіантів: T1 (контроль), T2 (0,02 % BHT), T3 (1% DP + 1 % олії базиліку), T4 (1 % DP + 1 % олії орегано), T5 (1 % DP + 2 % олії базиліку) та T6 (1 % DP + 2 % олії орегано). Фізико-хімічні, мікробіологічні та антиоксидантні показники контролювали протягом 8 діб за температури 4 °C. Внесення пектину та ефірних олій достовірно ($p < 0,05$) впливало на pH, колір (L*, a*, b*), втрати під час термічної обробки та текстурні характеристики. Обробки з олією базиліку знижували значення pH, тоді як олія орегано сприяла його підвищенню. Дослідні зразки характеризувалися вищими початковими показниками світлоти, червоності та жовтизни, однак значення a* та b* зменшувалися до 8-ї доби зберігання. Втрати під час термічної обробки суттєво зменшилися, а ніжність покращилася в усіх дослідних групах, що підтверджувалося зниженням твердості, гумоподібності, жувальності та пружності, без істотних змін у показниках когезивності та адгезивності. Котлети з додаванням пектину та ефірних олій продемонстрували вищу DPPH-активність (63-80 % проти 27 % у контролі) та нижчі значення TBARS (0,08-0,10 мкг МДА/г проти 0,19 мкг МДА/г у контролі) ($p < 0,05$), що свідчить про підвищену окисну стабільність. Мікробіологічний аналіз показав достовірне зниження загальної кількості життєздатних мікроорганізмів і рівня *E. coli* у дослідних зразках протягом усього періоду зберігання. *Salmonella* spp. не виявлено. Загалом поєднання пектину з шкірки дуріану з ефірними оліями базиліку або орегано покращило якість та подовжило термін зберігання яловичих котлет ($p < 0,05$), демонструючи перспективність використання натуральних консервантів як альтернативи синтетичним у м'ясних продуктах. Результати дослідження можуть бути використані м'ясопереробними підприємствами для виробництва безпечніших і більш стабільних під час зберігання охолоджених продуктів із подрібненого м'яса з використанням натуральних консервантів

Ключові слова: продукти з подрібненого м'яса; натуральні консерванти; окисна стабільність; подовження терміну зберігання; використання агровідходів