

In vitro study of Antioxidant and Antimicrobial Potential of *Moringa oleifera* Leaves as a Green Food Preservative in Chicken Burger

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Abstract

Moringa oleifera L. (from the *Moringaceae* family) is highly valued for its rich nutritional profile, phytochemical composition, and abundant crucial vitamins and minerals. Due to its enormous medicinal and non-medicinal benefits, the *Moringa oleifera* L. is famous as a miracle tree or tree of life. This study aimed to investigate the effects of bioactive compounds from *Moringa oleifera* leaves on the antimicrobial properties and shelf life of chicken burgers. Five variants of chicken burgers were prepared, including a control group with no antioxidants and groups with 1% or 2% concentrations of *Moringa oleifera* polyphenol extract (MOPE) and whole *Moringa oleifera* powder (WMOP). Results showed that burgers treated with 1% and 2% concentrations of WMOP and MOPE had significantly lower total plate counts (TPCs) after a 7-day storage period than the control group. Additionally, burgers supplemented with WMOP and MOPE exhibited higher levels of total flavonoid, phenolic content, and antioxidants compared to the control, without affecting acceptability. These findings suggest that incorporating WMOP and MOPE at 1% and 2% concentrations could serve as effective natural preservatives in chicken burgers, potentially extending their shelf life while maintaining consumer satisfaction.

Keywords: *Moringa oleifera*, Antioxidants, Antimicrobial agent, preservation

Highlight:

- *Moringa oleifera* L has a vibrant nutritional and phytochemical composition
- Antioxidant potential and antimicrobial activities of ethanolic leaf extract
- WMOP and MOPE act as an effective natural preservative in chicken burgers

1. Introduction

Moringa oleifera L (MO) is a plant from the Moringaceae family and has scientific significance due to its abundant phytochemical composition, considerable vitamins, mineral content, and significant nutritional value (Islam et al., 2021; Meireles et al., 2020). It is often referred to as the "wonder tree" or "miracle tree" primarily due to its significant socioeconomic importance resulting from its diverse applications in pharmacology and industry (Abdel-Latif et al., 2022). All parts of the MO tree, including the bark, roots, sap, flowers, leaves, and seeds, are extensively utilized for culinary and medicinal purposes (Padayachee & Baijnath, 2020). The MO tree possesses characteristics such as lack of resistance, making it a valuable crop with substantial nutrient and medicinal attributes, particularly in dry and semiarid regions (Arora & Arora, 2021). Research has extensively explored the bioactive compounds present in MO, which include carotenoids, alkaloids, glycosides, glucosinolates, terpenoids, and flavonoids, known for their role in preventing various chronic disorders (Chhikara et al., 2021; Liu et al., 2022; Milla et al., 2021; Mutar et al., 2021). Additionally, MO leaves are recognized as a valuable source of protein with therapeutic properties, contributing to its significance in traditional medicine and modern healthcare practices (Abdel-Latif et al., 2022; Alqurashi & Aldossary, 2021; Ahmad et al., 2022).

In the food industry, there is a growing interest in consumers for natural products due to their superficial health benefits (Ahmad et al., 2022). Polyphenols derived from plants have gained attention as potential natural food preservatives to extend the shelf life of meat products (Alqurashi & Aldossary, 2021; Manassis et al., 2020). Research has demonstrated that ingredients rich in antioxidants can mitigate microbial spoilage while storing meat products, including chicken burgers. Chicken burgers, a widely popular processed meat product worldwide, are favoured for their convenience and affordability, appealing to a large population segment (Gómez et al., 2020; Martillanes et al., 2020; Rudy et al., 2020). Numerous reports have highlighted the ability of ingredients rich in antioxidants to effectively minimize microbial decomposition in preserving meat products (Tayengwa et al., 2020). Chicken burgers are among the most widely consumed meat products worldwide (Assanti et al., 2021). These products have gained immense popularity and are widely encompassed by an extensive portion of the population, primarily because of their accessibility and affordability (Lorenzo et al., 2021). Over the last five years, Pakistan has shown rapid growth in the number of local restaurants; therefore, chicken & other meats have less stability, probably as a result of microbial activity and lipid content peroxidation, which can have adverse impacts on safety and human (Ahmad et al., 2023; Alqurashi & Aldossary, 2021). *Moringa oleifera* is a plant that may offer health assistance, such as reducing your risk of high blood pressure. Conventionally, the *Moringa oleifera* powder is used to cure wounds,

ulcers, liver pain and other diseases (Abd El-Hack et al,2018). The bioactive ingredients of MO leaves developed at Al-Rahman farm, Pakistan, have not been thoroughly examined. Hence, this analysis aimed to investigate the influence of *Moringa oleifera* leaves and their bioactive components, antioxidant properties, and antimicrobial characteristics on chicken burgers. These components were explored as natural food preservatives that could potentially extend the product's shelf-life for the first time.

Material and Methods.

2.1. Chemicals and Reagents

Each chemical used in this study such as aluminum chloride, methanol, ethanol, sodium carbonate (Anhydrous), Folin-Ciocalteu reagent, ammonium thiocyanate, gallic acid, ascorbic acid, catechin, ferric chloride, ferrous chloride, BHT (butylated hydroxyl toluene), sodium nitrite and DPPH (2,2-diphenyl-1-picrylhydrazyl) were bought from Nadeem Scientific store Faisalabad, Pakistan.

2.2. Plant collection and pretreatment

Fresh *Moringa oleifera* (MO) leaves were manually harvested from fully grown trees selected in 2023 from the Al-Rahman farm located in Kabirwala, Punjab, Pakistan (Fig. 1). After thoroughly cleaning these MO leaves to remove any unwanted debris, they were washed with hot water and then with distilled water. They were then chopped into a fine powder (whole *Moringa oleifera* powder (WMOP) and set aside for air drying at room temperature (25°C) for 96 hours to prepare them for use in chicken burgers. After that, the WMOP was mixed with chicken burger samples and centrifuged at 4000 rpm for 10 minutes. Then, the supernatants were collected after each centrifugation. The mixed supernatants were concentrated using a rotary evaporator (Ecohim Ltd., Ekros Group of 20 enterprises, Saint-Petersburg) at 40°C and vacuum conditions provided by a vacuum pump. After that, the extracted materials were freeze-dried.



Figure 1: MO leaves growth in Al-Rahman farm, Kabir Wala, Pakistan

2.3. Preparation of chicken burger

Fresh chicken from a local poultry market in Al-Syed, Pakistan, was used to prepare chicken burgers. The ingredients used for making the chicken burgers are listed in Table (1), which consists of 86% minced chicken breast, 6% whole egg, 1% salt, and 7% breadcrumbs. The chicken burgers were treated with *Moringa oleifera* polyphenol extract (MOPE) and whole *Moringa oleifera* powder (WMOP) at varying concentrations (1% and 2%). Antioxidants were not used in the control group. The samples were individually made into chicken burgers using a bowl chopper. The burgers were then aerobically packed in plastic bags and kept at 4°C. Raw chicken burger samples were analyzed at intervals of 0, 3, 5, and 7 days of storage under refrigerated conditions (4°C) to determine total phenolic, flavonoid, and antioxidant potential. Furthermore, the control, WMOP and MOPE samples of cooked chicken burgers were evaluated for their sensory qualities. Each experiment was carried out three times to ensure the reliability and strength of the results.

Table 1: Ingredients used for the preparation of chicken burgers

| Ingredients | Control | 1 % WMOP | 2% WMOP | 1% MOPE | 2% MOPE |
|-----------------|---------|----------|---------|---------|---------|
| Whole MO powder | 0.0 | 1.0 | 2.0 | 0.0 | 0.0 |

| | | | | | |
|-------------------------------|-----|-----|-----|-----|-----|
| MO polyphenols extract | 0.0 | 0.0 | 0.0 | 1.0 | 2.0 |
| Brest chicken | 86 | 86 | 86 | 86 | 86 |
| Salt | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| Whole egg | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 |
| Breadcrumbs | 7.0 | 6.0 | 5.0 | 6.0 | 5.0 |

Control (without antioxidant), 1%, 2% WMOP (burgers with 1% & 2% whole MO powder), 1%, 2% MOPE (burgers with 1% & 2% MO polyphenol extract)

2.4. Estimation of total phenolic contents (TPCs)

The Folin-Ciocalteu method, followed by a slight modification reported by Ahmad et al. (2022), was used to determine the TPCs. To put it briefly, 15 g of chicken burger samples containing WMOP and MOPE at two concentrations of 1% and 2%, and 75 ml of aqueous ethanol (80% v/v) was used to homogenize the control group, which did not use antioxidants. After being remixed and centrifuged for ten minutes at 4000 rpm, the mixture was incubated for 5 minutes. After taking 1.5 ml aliquot of the supernatant, it was transferred to tubes holding 0.5 ml of Folin-Ciocalteu reagent. The tubes were incubated at 25°C for 5 minutes before being filled with 4 ml of sodium carbonate solution and shaken it for about half an hour. The absorbance of the resultant solution was measured at 755nm with a UV/Vis Spectrophotometer (Model: STA-8200, STALWART). The TPC was determined using a calibration curve built with gallic acid as a reference. The results were represented as gallic acid equivalents (GAE) mg/g of dried *Moringa oleifera* leaves.

2.5. Estimation of total flavonoid contents (TFCs)

Total flavonoid contents (TFCs) were determined using the method with slight modification reported by Boeira et al. (2021). To put it briefly, 15 g of chicken burger samples containing WMOP and MOPE at two concentrations of 1% and 2%, 75 ml of aqueous ethanol (80% v/v) was used to homogenize the control group, which did not use antioxidants. After being mixed again and centrifuged for 10 minutes at 4000 rpm, the mixture was let to stand for 5 minutes. The supernatants were mixed with 0.2 ml of a 5% NaNO₂ solution. After incubating for 10 minutes at 25°C, 0.2 ml of 10% AlCl₃ solution was added. After a further incubation of 10 minutes, 2 ml of (1.0 M) NaOH solution was mixed, and the volume was finally adjusted to 10 mL using distilled water. Using a UV/Vis Spectrophotometer (Model: STA-8200, STALWART), the absorbance of the reaction mixture was determined at 510 nm. The catechin equivalents (mg CE)/g were used to determine the overall TFCs.

2.6. DPPH radical scavenging assay

The antioxidant activity of chicken burgers was assessed using the 2,2-diphenyl-1-picrylhydrazyl (DPPH) assay by following the methodology given by Ramli et al. (2020). The basis of this assay is the DPPH free radical's capacity to take up an electron and change into a stable diamagnetic molecule. In this experiment, 4 ml of 0.1 mM DPPH in methanol was combined with 4 ml of chicken burger samples that contained WMOP and MOPE at concentrations of 1% and 2%, as well as the control group without antioxidants. After that, the mixture was incubated for 20 minutes at 25°C in a dark environment. After incubation, a UV-1800 spectrophotometer (Shimadzu, China) was used to measure the absorbance at 517 nm. The following equation was used to express the antioxidant activity as a percentage:

$$I (\%) = 100 \times (A_{\text{blank}} - A_{\text{sample}} / A_{\text{blank}})$$

Where, I is inhibition, A_s and A_b represent sample and blank absorbance values, respectively.

2.7. Antimicrobial analysis

The samples of chicken burgers were divided into portions of 10 g each. The control group (without antioxidants) was compared to each treatment that included *Moringa oleifera* polyphenol extract (MOPE) and whole *Moringa oleifera* powder (WMOP) at different concentrations (1% and 2%). After standardizing each sample in 90 ml of sterile peptone water (0.1%), the samples were diluted to different quantities. The total plate count (TPC) was then calculated by inoculating a 1 ml dilution onto Petrifilm (3M, Pakistan). According to Alqurashi & Aldossary (2021), the Petrifilm plates were stored in a refrigerator at 4°C after being heated at 37°C for 0, 3, 5, and 7 days. Additionally, to evaluate the impact of chicken burger samples on *Escherichia coli* and *Staphylococcus*, 1 ml dilutions were put onto certain agar media. Macconkey agar and Baird-Parker medium were the agar media utilized, and the plates were cultured for 24 hours at 37°C. Microbial analysis was conducted after 0, 3, 5, and 7 days of storage at 4°C in a refrigerator. The number of microbial colonies on the plates was calculated and is shown as (log¹⁰ cfu/g).

2.8. Estimation of pH change

The pH values were calculated by following the method reported by Sarker et al. (2021). In brief, 1 g of samples containing WMOP and MOPE at two concentrations of 1% and 2%, as well as the antioxidant-free control group, were mixed entirely and standardized in 10 ml of distilled water. The samples were filtered through filter paper No. 1 before measuring the pH.

The pH of each sample was determined using a pH meter before analysis, and buffer solutions with pH values of 5.0, 7.0, and 9.0 were used to calibrate the instrument.

2.9. Sensory evaluation

A panel of fifteen judges conducted a sensory evaluation at the University of Education, Lahore. These judges possessed expertise in assessing the characteristics of chicken products. Flavor, taste, texture, color, and general acceptability were among the sensory aspects that were evaluated as described by Shen et al. (2022) 6-point descriptive scale, where 6 meant "Like extremely," and 1 meant "Dislike extremely." On a grill, the chicken burgers were grilled for 10 minutes. The chicken burgers were broiled in a microwave for fifty seconds before dishing. The panellists assessed each sample after washing their palates with water in between samples. The evaluation included the control group (antioxidant-free chicken burgers) in addition to the MOPE and WMOP items.

2.10. Statistical analysis

Every experimental result was displayed as the standard error (SE) and the average of 3 replicate experiments. The SPSS software was used to conduct the statistical analysis. ANOVA was used to compare all samples, consisting of both control and MO treatment samples (WMOP and MOPE). A significant level of 5% ($p < 0.05$) was used to evaluate the impact of various treatments on chicken burgers.

3. Results and Discussion

3.1. Determination of TPC and TFC

The total phenolic (TPC) and flavonoid content (TFC) of the control chicken burger treated with WMOP and MOPE at various concentrations (1% and 2%) are summarized in Table (2). Chicken burgers treated with MOPE or WMOP (1% and 2%) exhibited substantially greater TPC and TFC values compared to control samples. Chicken burgers treated with MOPE exhibited prominently greater TPC and TFC than those treated with WMOP ($p < 0.05$). This difference could be attributed to the polarity of the solvent employed for extracting polyphenols from MO leaves, leading to enhanced incorporation of antioxidants into chicken burgers. This increase in antioxidant content likely contributed to the observed improvements in antimicrobial activity (Alqurashi & Aldossary, 2021; Hadadi et al., 2020).

Table 2: Antioxidant activity, total flavonoid content (CE mg/g), and total phenolic content (GAE mg/g) of *Moringa oleifera* leaves in chicken burgers

| Sample | Antioxidant activity | TFC | TPC |
|---------|----------------------|-------------|-------------|
| Control | 0.02 ± 0.05 | 0.02 ± 0.69 | 0.01 ± 0.02 |
| 1% WMOP | 49 ± 1.16 | 16.3 ± 0.87 | 36.7 ± 1.12 |
| 2% WMOP | 71 ± 1.25 | 33.7 ± 1.29 | 65.5 ± 1.37 |
| 1% MOPE | 55 ± 1.71 | 14.6 ± 1.57 | 39.7 ± 1.04 |
| 2% MOPE | 71.2 ± 1.54 | 19.8 ± 1.4 | 83 ± 1.01 |

Control (without antioxidant), 1%, 2% WMOP (burgers with 1% & 2% whole MO powder), 1%, 2% MOPE (burgers with 1% & 2% MO polyphenol extract)

3.2. Antioxidant activity of MO leaves

DPPH serves as a free radical employed to assess plant extracts' capacity to scavenge free radicals (Hussen & Endalew, 2023). This research evaluated the antioxidant potential of chicken burgers treated with WMPO and MOPE. The treated sample exhibited more antioxidant potential than the control. The antioxidant activity of the 1% and 2% WMOP and MOPE samples differed considerably ($p < 0.05$) from that of the control (Table 2). The analysis of antioxidant activity showed that MOPE had a strong ability to scavenge radicals in chicken burgers. This effect became stronger when the concentration was raised: 2% MOPE addition ($83\% \pm 1.01$) and 1% MOPE addition ($55\% \pm 1.71$). This activity may be attributed to elevating the levels of TPC and TFC in MOPE, which are known to contribute to enhanced antioxidant capacity. Recent studies have highlighted the potential of antioxidants as natural additives in various meat products to extend shelf life, improve safety, and enhance product quality (Badawy et al., 2020; Hajji et al., 2021; Ramli et al., 2021). Additionally, foods enriched with these natural bioactive ingredients offer various health benefits and are explored as natural efficient nutrients, attracting growing attention from the food industry. (Gutiérrez-Del-río et al., 2021).

3.3. Changes in pH during storage.

After being refrigerated at 4 °C for 0, 3, 5, and 7 days, the pH values of the control and MO-treated chicken burgers were determined, as depicted in Table (3). Our findings reveal a prominent increase in pH levels across all samples with preservation duration (0, 3, 5, and 7 days). Specifically, pH values rose from 6.19 ± 0.02 to 7.24 ± 0.02 in the control group, from 6.13 ± 0.02 to 6.98 ± 0.02 with 1% MOPE treatment, from 6.27 ± 0.01 to 6.74 ± 0.02 with 2% MOPE treatment, from 5.89 ± 0.01 to 6.85 ± 0.01 with 1% WMOP treatment, and from 5.71 ± 0.02 to 6.85 ± 0.02 with 2% WMOP treatment. This rise in pH may be attributed to microbial metabolism and enzymatic reactions within the samples with time (Duan et al., 2020; Wang et al., 2020). Moreover, our results demonstrated A substantial decrease in pH levels in MO-treated chicken burgers (both WMOP and MOPE) compared to control samples during different storage periods (0, 3, 5, and 7 days) ($p < 0.05$). This

observation could be related to the elevated levels of antioxidants and bioactive ingredients present in MO leaves, which were incorporated into the chicken burger. Similar trends have been observed in previous studies, where using MO flowers and leaves resulted in increased pH levels in chicken meat nuggets and sausages over various storage periods (Gomes et al., 2023; Verma et al., 2020).

Table 3: Change of pH with different preservation time

| Treatment | Preservation Time (Days) | | | |
|-----------|--------------------------|-------------|-------------|-------------|
| | 0 | 3 | 5 | 7 |
| Control | 6.19 ± 0.02 | 6.37 ± 0.01 | 6.91 ± 0.02 | 7.24 ± 0.02 |
| 1% WMOP | 5.89 ± 0.01 | 6.16 ± 0.01 | 6.37 ± 0.02 | 6.85 ± 0.01 |
| 2% WMOP | 5.71 ± 0.02 | 6.12 ± 0.02 | 6.24 ± 0.01 | 6.49 ± 0.02 |
| 1% MOPE | 6.13 ± 0.02 | 6.36 ± 0.03 | 6.67 ± 0.01 | 6.98 ± 0.02 |
| 2% MOPE | 6.27 ± 0.01 | 6.40 ± 0.02 | 6.49 ± 0.01 | 6.74 ± 0.02 |

Control (without antioxidant), 1%, 2% WMOP (burgers with 1% & 2% whole MO powder), 1%, 2% MOPE (burgers with 1% & 2% MO polyphenol extract)

3.4. Antimicrobial activity of MO leaves

The total plate count (TPC) values of control and MO-treated (WMOP and MOPE) chicken burger at varying concentrations (1% and 2%) following 0, 3, 5, and 7 days of storage at 4 °C are shown in Table (4). As the storage duration increased, there was a substantial rise in the bacterial action count in the control, WMOP, and MOPE groups. Specifically, TPC in control burgers without antioxidants exhibited an increase from $4.59 \pm 0.02 \log^{10}$ cfu/g (0 days) to $126.83 \pm 0.17 \log^{10}$ cfu/g (7 days). When comparing WMOP and MOPE samples at concentrations of 1% and 2% to control samples (MOPE and WMOP) after 3, 5, and 7 days of storage, a prominent reduction in total phenolic content ($p < 0.05$) was noted. This study has shown that higher amounts of bioactive chemicals and antioxidant capacity can help reduce bacterial action in meat products, extending their shelf-life (Rebezov et al., 2022; Wu et al., 2023). As a result, these factors may be responsible for this reduction. Moreover, after 7 days of storage, chicken burgers treated with MO (1% and 2% concentrations of MOPE and WMOP) showed considerably fewer TPCs than the control. This observation aligns with previous reports indicating that polyphenols and bioactive ingredients in MO leaves possess antimicrobial properties against various pathogenic bacteria (Abdallah et al., 2023). Several bioactive ingredients, like pterygospermin found in MO leaves, exhibit antimicrobial capacities that can mitigate the levels of harmful bacteria in meat products, thus contributing to their prolonged shelf life and serving as natural food preservatives. Previous studies have highlighted that high levels of phenolic components from various plant sources can effectively reduce microorganism levels in poultry and meat products (Fraqueza et al., 2021). Phenolic chemicals may interfere with protein translocation, affect DNA and RNA synthesis, and damage cell walls, among other potential mechanisms (Alqurashi & Aldossary, 2021). In addition, our research concluded that *Staphylococcus* or *E. coli* was not found in any of the samples (data not shown), which is probably because Pakistan applies strict food safety and hygiene regulations to chicken and meat products.

Table 4: Total plate count (TPC; \log^{10} cfu/g) of chicken burgers

| Treatment | Preservation Time (Days) | | | |
|-----------|--------------------------|--------------|--------------|---------------|
| | 0 | 3 | 5 | 7 |
| Control | 4.59 ± 0.02 | 36.15 ± 0.21 | 89.37 ± 0.52 | 126.83 ± 0.17 |
| 1% WMOP | 3.19 ± 0.07 | 9.76 ± 0.05 | 42.27 ± 0.02 | 89.47 ± 0.02 |
| 2% WMOP | 4.75 ± 0.03 | 6.95 ± 0.07 | 17.65 ± 0.02 | 35.48 ± 0.02 |
| 1% MOPE | 3.09 ± 0.12 | 18.74 ± 0.03 | 24.67 ± 0.1 | 71.38 ± 0.02 |
| 2% MOPE | 2.06 ± 0.05 | 12.67 ± 0.03 | 58.19 ± 0.08 | 81.57 ± 0.06 |

Control (without antioxidant), 1%, 2% WMOP (burgers with 1% & 2% whole MO powder), 1%, 2% MOPE (burgers with 1% & 2% MO polyphenol extract)

3.5. Sensory analysis

To determine the optimum quantity of MO leaf (WMOP and MOPE) added to chicken burgers, a sensory evaluation was conducted using different concentrations (1% & 2%) in addition to the control. The sensory attributes of all chicken burgers were assessed, and no significant differences were observed (Table 5). Across all concentrations, including the control, MOPE, and WMOP chicken burger, there were no notable changes in flavour, colour, texture, taste, or overall acceptability ($p > 0.05$). This suggests that the incorporation of MO leaf extracts (WMOP and MOPE) at both 1% and 2% concentrations did not adversely affect the sensory characteristics of the chicken burgers. These findings imply that MO leaf extracts can be effectively added to chicken burgers as natural additives without compromising their sensory qualities, thereby enhancing their nutritional value and potential health benefits.

Table 5: Effect on sensory attributes burgers

| Treatment | Overall acceptance | Flavor | Color | Texture | Taste |
|-----------|--------------------|-------------|-------------|-------------|-------------|
| Control | 8.21 ± 1.12 | 8.29 ± 1.43 | 8.29 ± 1.27 | 7.87 ± 1.09 | 7.49 ± 1.45 |
| 1% WMOP | 7.61 ± 1.06 | 7.31 ± 1.25 | 7.88 ± 1.48 | 8.18 ± 1.37 | 7.62 ± 1.98 |
| 2% WMOP | 6.29 ± 1.37 | 6.38 ± 1.17 | 7.58 ± 1.35 | 7.81 ± 1.63 | 7.29 ± 1.31 |
| 1% MOPE | 7.81 ± 1.16 | 7.89 ± 1.53 | 7.98 ± 1.73 | 7.21 ± 1.06 | 7.78 ± 1.19 |
| 2% MOPE | 6.70 ± 1.49 | 7.61 ± 1.12 | 7.52 ± 1.22 | 7.01 ± 1.68 | 6.53 ± 1.34 |

Control (without antioxidant), 1%, 2% WMOP (burgers with 1% & 2% whole MO powder), 1%, 2% MOPE (burgers with 1% & 2% MO polyphenol extract)

4. Conclusion:

This study is the first to examine the antimicrobial and antioxidant properties of *Moringa oleifera* (MO) leaves collected from Al-Rahman farm in Kabir Wala, Punjab, Pakistan, and demonstrates how they might be used in chicken burgers. Our findings indicate that MO leaves are a rich source of polyphenols, serve as an important reservoir and show excellent antioxidant activity. These antimicrobial properties successfully extend the shelf-life of chicken burgers, with refrigerated storage at 4°C showing potential for up to 7 days. The utilization of MOPE and WMOP as natural food preservatives in chicken burgers presents a promising avenue for the food industry. Beyond enhancing shelf-life, these natural additives offer valuable antioxidant activities, providing potential health benefits to consumers. Our results further highlight the importance and applicability of MOPE and WMOP in food preservation by indicating that they may be essential in increasing the shelf-life of different meat products.

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Conflict of Interest: It is declared that there is no conflict of interest among authors

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