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RESEARCH ARTICLE

QUALITY INDICES OF CHICKEN PATTIES PREPARED WITH BLENDS OF OREGANO (*Origanum vulgare*) AND LEMON (*Citrus limon*) ESSENTIAL OILS AS ADDITIVES

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ABSTRACT

The use of synthetic preservatives and additives in food processing is becoming less popular due to adverse health effects linked to them. Consequently, there is a rising demand by consumers for clean-label food products. This study was therefore designed to evaluate how blends of Oregano Essential Oil (OEO) and Lemon Essential Oil (LEO) as natural preservative additives at 0.05% inclusion impacted the shelf life and quality characteristics of chicken patties. Breast muscles of healthy 8-week-old broiler chickens were harvested, manually deboned and ground. One kilogram each of chicken patty emulsion was prepared in six treatment combinations as follows: (T1) No essential oil, (T2) 100% OEO, (T3) 100% LEO, (T4) 50% OEO:50% LEO, (T5) 75% OEO:25% LEO and (T6) 25% OEO:75% LEO. Each treatment was done in triplicate and arranged using a completely randomised pattern. Each emulsion was then portioned into individual patties (100 g) and cooked at 180 °C in an oven until they reached an internal temperature of 72 °C. Product yield, Thiobarbituric Acid Reactive Substances (TBARS), microbial load, and physicochemical properties were measured using standard methods at days 0, 7, 14, and 21 of storage. Sensory properties of patties were also evaluated by ten trained panellists, using a 9-point hedonic scale. Data collected were analysed with ANOVA at α-0.05. Significant differences were observed in product yield, with T4 having a significantly higher (P <0.05) product yield (0.91±0.01), comparable to Control. Treatment 4 also had significantly lower (P <0.05) TBARS on Day 14 (0.69±0.00) and Day 21 (0.69±0.00). Treatment 2 had significantly lower (P <0.05) bacteria (6.55±0.07) and fungal (1.15±0.07) count at day 21. Sensory analysis showed no significant differences at day 21. Based on its positive effects of increasing product yield and reducing lipid oxidation, 50% OEO:50% LEO (T4) is rated as the best blend of Oregano and Lemon oil in chicken patty preparation and recommended for further study.

Keywords: Essential oils, Chicken patties, Lemon oil, Oregano oil, Lipid oxidation, Sensory properties

INTRODUCTION

The relatively reduced fat and higher polyunsaturated fat content in chicken meat have made chicken products a significant part of daily human diets. Their global popularity has been steadily increasing due to their exceptional nutritional value and quality characteristics. (Chinprahast *et al.*, 2020), Thus, chicken meat is a popular and widely consumed animal protein source. Chicken patties are widely consumed due to their convenience, taste, and nutritional profile. However, during frozen storage, they are vulnerable to oxidative alterations and microbiological changes. Aerobic conditions can produce fat autoxidation, and microbial growth can impact several parameters, including moisture, protein, polyunsaturated fatty acids and pH (Santana Neto *et al.,* 2021; Adediran and Abdul, 2022).

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Primary concerns in the preservation of chicken patties are microbial growth and lipid oxidation. Both factors can significantly affect the sensory characteristics, safety, and overall acceptability of these products. Microbial contamination can lead to spoilage and foodborne illnesses, while lipid oxidation results in rancidity, off-flavours, and potential loss of nutritional value (Zhou *et al*., 2010; Awojimi *et al.,* 2023). Therefore, finding effective natural preservatives that can enhance the qualitative indices of chicken patties is crucial. Recently, the use of antioxidants and antimicrobials of natural sources in the chicken meat industry has dramatically increased (Sharma, 2020).

Oregano (Origanum vulgare), of the Lamiaceae family and native to Western Eurasia and the Mediterranean area, is an aromatic plant species. It is widely utilized globally as a spice and medicinal plant. Its carvacrol and thymol contents are responsible for its antibacterial, antifungal and antioxidant functions. Antioxidant constituents in oregano include carvacrol, thymol, tocopherols, and phenolic compounds (Silva *et al*., 2013).

Lemon (Citrus limon) is an essential member of the Citrus family. Citrus species are one of the major sources of essential oils, which are valuable natural bioactive compounds like hydrocarbons, polyphenols, sesquiterpenes, esters, sterols and aldehydes (Darjazi, 2013).

Applying essential oils in chicken patties production can also align with consumer trends toward clean labels and natural ingredients. Consumers have a growing interest in food products with fewer artificial additives and preservatives, driven by concerns about health and wellness. Essential oils, being derived from plants, can meet this demand while providing effective preservation. Additionally, essential oils can play a role in extending the shelf life of chicken patties, reducing food waste, and promoting sustainability by minimizing the need for synthetic chemicals and resource-intensive preservation methods (Dorman and Deans, 2000). This study aimed to investigate the quality indices such as product yield, sensory properties, lipid oxidation and microbial load of chicken patties prepared with blends of oregano and lemon essential oils. By exploring the quality indices of chicken patties prepared with blends of oregano and lemon essential oils, this research will contribute to the advancement of food science and technology, ultimately benefiting the poultry industry, consumers, and public health.

MATERIALS AND METHODS

Procurement of study materials

Chicken source

Live, disease-free and healthy, eight-week meat-type chickens were procured from a local farm in Ibadan. The chickens were slaughtered on the farm and refrigerated immediately after evisceration. The breast muscles were then carved out the next day.

Essential oil source

Oregano and Lemon Essential oils used for the experiment were obtained from Blomera oils, Lagos State, Nigeria. The oils were extracted via a mechanical method.

Soybean flour preparation

The soybean was obtained from a local market in Ibadan. The beans were picked to separate sand, dust and other foreign bodies from the soybean. The soybean was then soaked in water for 48 hours. The soybean was washed thoroughly to separate the soybean from the shaft. The soybean was then spread in a clean room and air-dried for 3 days before being ground into powder.

Non-meat Ingredients

Other ingredients such as margarine, spices, salt and sugar were purchased from a reputable supermarket in Ibadan.

Spice proportion used in the chicken patty production

A combination of three (3) spices was used in the production of the chicken patties: white pepper at 40%, hot pepper at 40% and nutmeg at 20% (w/w).

Meat patties preparation/ experimental design

The formulation procedure for the experimental product is detailed in Table 1. Breast muscle obtained from 8-week-old Arbour Acre broiler chickens was minced and deboned manually. Subsequently, the deboned chicken breast was cut into smaller pieces with an average thickness of 2 mm and ground with an electric meat grinder (Philips, 500W, Netherlands). Six kilograms of emulsion were put together for the production of experimental chicken patties, with 1000 g designated for each treatment group. Each treatment was repeated thrice using a completely randomised design. The thoroughly mixed emulsion was portioned into 80 g servings, shaped into patties with a patty cutter, and cooked in a preheated electric oven (Kenwood, 3600W, Germany) at 180 °C. Cooking continued until the patties reached an internal temperature of at least 72 °C. After cooking, the patties were removed from the oven and left to cool to room temperature (27 °C). The patties allocated for Day 0 analysis were then evaluated. The remaining patties were weighed, tightly packed, and individually placed in labelled Ziploc bags before being stored at -4 °C for shelf-life analysis. To facilitate identification, the chilled samples were tagged as T1, T2, T3, T4, T5 and T6 (Table 1). Further evaluation was done on days 7, 14, and 21 post-production.

PHYSICOCHEMICAL PROPERTIES OF CHICKEN PATTIES

Proximate composition of chicken patties

Using the method described by AOAC (1990), the proximate composition of patties was examined for moisture, protein, fat, and ash levels. For every treatment, every analysis was carried out in triplicate and double-checked twice. Assessments were conducted on the day of patty production and repeated on day 21 post-production.

pH determination of chicken patties

Once the patties cooled to an ambient temperature of 27 °C, their pH was measured using a pH meter with a glass electrode (FC200, H19024C, Hanna Instruments, Singapore). The volume of 1 mL of ground patty was mixed with 10 mL of distilled water in a beaker, the electrode of the pH meter was inserted into the mixture for 30 seconds, and the pH value was recorded. This analysis was done in triplicate for each treatment. Assessments were conducted on the day of patty production and repeated on days 7, 14, and 21 post-production.

Water holding capacity

This was estimated as described by Suzuki *et al.* (1991). Five grams of cooked patties per treatment were placed between two filter papers, pressed for one minute between two plexiglass sheets, and then compressed with a table vice. Compressed samples were then dried

Table 1: Ingredients used in the chicken patty production

Ingredients	T1	T2 (100%OEO)	T3 (100%LEO)	T4 (50%OEO:50%LEO)	T5 (75%OEO: 25%LEO)	T6 (25%OEO: 75%LEO)
Chicken	75.00	75.00	75.00	75.00	75.00	75.00
Margarine	7.00	6.95	6.95	6.95	6.95	6.95
Soybean flour	12.00	12.00	12.00	12.00	12.00	12.00
Salt	1.00	1.00	1.00	1.00	1.00	1.00
Sugar	1.00	1.00	1.00	1.00	1.00	1.00
Spices	1.50	1.50	1.50	1.50	1.50	1.50
Seasoning	0.30	0.30	0.30	0.30	0.30	0.30
Eggs	2.20	2.20	2.20	2.20	2.20	2.20
OEO only	-	0.05	-	-	-	-
LEO only	-	-	0.05	-	-	-
OEO+LEO	-	-	-	0.05	0.05	0.05
Total	100.00	100.00	100.00	100.00	100.00	100.00

OEO: Oregano essential oil, LEO: Lemon essential oil, Treatment 1 (T1): Chicken patties made with no essential oil, Treatment 2 (T2): Chicken patties made with 100% oregano essential oil only, Treatment 3 (T3): Chicken patties made with 100% lemon essential oil only, Treatment 4 (T4): Chicken patties made with 50% oregano essential oil and 50% lemon essential oil, Treatment 5 (T5): Chicken patties made with 75% oregano essential oil and 25% lemon essential oil, Treatment 6 (T6): Chicken patties made with 25% oregano essential oils and 75% lemon essential oil in an oven (65 ºC) till constant weight to deduce their moisture levels. The amount of moisture expressed was indirectly measured by comparing the wetted area of filter paper to the area of the compressed sample.

The WHC was worked out thus:

$$WHC = \frac{100 - [(Ar - Am) \times 9.47)]}{Wm \times Mo} \times 100 \quad \text{(Eq. 1)}$$

Where; A_r: Area of water leaked from meat (cm^2), A_m: Area of meat sample (cm^2), W_m: meat weight in milligrammes, and M_o: Moisture content of meat (%). 9.47 is a constant factor.

This analysis was replicated twice for each treatment. Assessments were conducted on the day of patty production and repeated on days 7, 14, and 21 post-production.

Product yield determination

This was determined by weighing the patties in each treatment before cooking in the oven. After cooking till being properly done, patties were cooled to ambient temperature, then weighed again to determine product yield. The yield of the product was worked out thus:

$$\text{Product yield} = \frac{\text{Weight}_f}{\text{Weight}_i} x\, 100 \quad \text{(Eq. 2)}$$

Where; Weight_f: Weight of final product, and Weight_i: Initial weight of the sample

Determination of lipid oxidation

The TBARS assay was estimated as described by Schmedes and Holmer (1989). A 10 g patty sample was macerated in 25 mL of trichloroacetic acid solution (200 g/L TCA in 135 mL/L phosphoric acid solution) and blended for 30 seconds. The mixture was then filtered, and 2 mL of the filtrate was combined with 2 mL of TBA solution (3 g/L) in a test tube. This was followed by incubation of test tubes in the dark, at ambient conditions for twenty hours. Thereafter, absorbance was read at 532 nm with a UV–VIS spectrophotometer. The TBA value was expressed as mg malonaldehyde/kg of patty. All analyses were performed twice per treatment, with assessments conducted on the day of patty production and repeated on days 7, 14, and 21 post-production.

Microbial load evaluation

Following the method of Babatunde and Adewunmi (2014), a 10 g patty sample was homogenized with 90 mL of sterile peptone water (1 g/L) using an AM-5 Ace homogenizer (Nihonseiki, Japan), and serial dilutions were made. Afterwards, 0.1 mL of each serial dilution was evenly spread onto plates of pre-prepared, dried standard plate count agar, using a bent sterile glass rod. After incubating at 25 ° C for 48 hours, colonies were outlined and enumerated. The results were rendered as $\log_{10}$ CFU/g of sample. Assessments were conducted on the day of patty production and repeated on days 7, 14, and 21 post-production.

Sensory evaluation of patties

Sensory evaluation of the chicken meat patties, including texture, flavour, juiciness, colour, and overall acceptability, was conducted using a hedonic scale from 9 (extremely liked) to 1 (extremely disagreeable) by 10 trained taste panellists, made up of the department's staff and students. The patties to be evaluated were diced into small bite-sized portions, then placed in clean, well-labelled plates and served to panellists in a clean, spacious, and well-lit room. The procedure was done on the day of Patty production and repeated on day 7, day 14 and day 21 of storage.

Statistical analysis

Data are presented as mean ± standard deviation of triplicate. A One-way analysis of variance (ANOVA) was conducted to examine data generated from the study, and the Scheffé multiple comparison test was used to identify significant differences ($P < 0.05$) between means. Statistical software, SPSS (2006), version 16.0.1 for Windows, was used.

RESULTS AND DISCUSSION

Effect of blends of oregano and lemon essential oils on the product yield of chicken patties

The effect of blends of oregano and lemon essential oils on the Product yield of chicken patties is shown in Table 2. The inclusion of different blends of essential oils resulted in a significant (p <0.05) difference in yield, with values ranging from 0.94 (T1) to 0.83 in T5 and T6.

Table 2: Product yield of chicken patties processed with blends of oregano and lemon essential oil

Parameters	Product yield
T1	0.94±0.01[a]
T2	0.86±0.03[cd]
T3	0.89±0.01[bc]
T4	0.91±0.01[ab]
T5	0.83±0.01[d]
T6	0.83±0.02[d]

[a, b, c, d] means that with different superscripts on the same column are significantly different (P< 0.05), Treatment 1 (T1): Chicken patties made with no essential oil, Treatment 2 (T2): Chicken patties made with 100% oregano essential oil only, Treatment 3 (T3): Chicken patties made with 100% lemon essential oil only, Treatment 4 (T4): Chicken patties made with 50% oregano essential oil and 50% lemon essential oil, Treatment 5 (T5): Chicken patties made with 75% oregano essential oil and 25% lemon essential oil, Treatment 6 (T6): Chicken patties made with 25% oregano essential oils and 75% lemon essential oil

Significant difference exists in the yield of chicken patties when the formulation was supplemented with essential oil blends (P <0.05). T1, containing no essential oils, had the best yield of 0.94±0.01, implying that there was less moisture and fat loss during processing than with the other treatments. This result is consistent with studies indicating that a lack of essential oils decreases oxidative reactions and increases water-holding capacity (Ruiz-Hernández *et al.,* 2023). Amongst the treatments consisting of essential oils, only T4 (50%OEO:50% LEO) recorded yield (0.91±0.01), similar to the control treatment, thus indicating that the two oils have a harmonious effect in improving the yield of the product. This might be due to the antimicrobial and antioxidant effects of oregano and lemon oils stabilizing and increasing the moisture of the product and suppressing lipid oxidation (Ruiz-Hernández *et al.,* 2023). T3 (100% LEO) had a moderate yield, T2 (100% OEO), and T5 (75% OEO:25% LEO) gave slightly poorer yields (0.86±0.03 and 0.83±0.01, respectively). Lower yields in these groups may be attributed to variations in the concentration of bioactive compounds, such as carvacrol and citral. When present in high concentrations, these compounds have the potential to unmask protein matrices if not optimised (Mahato *et al*., 2019). The significant difference in yield of the various treatments under study underscores the need to standardize the blend ratio of the essential oils. These high concentrations may lead to protein denaturation or excessive moisture loss due to the lipophilic character, thus compromising the meat proteins' binding capacity (Ojeda-Piedra *et al.,* 2022). From the results of this research, the blend of oregano and lemon essential oils in a 50:50 ratio appears to yield a relatively optimal condition for producing more of the product while maintaining the quality of the meat.

Interaction effects of storage intervals and blends of essential oils on physicochemical properties of chicken patties

The interaction effect of storage intervals and essential oils on the physicochemical properties of chicken patties is shown in Table 3. There exists a significant (P <0.05) effect of storage days and essential oils on the physicochemical properties of chicken patty. The pH value of the chicken patty was significantly (p <0.05) the highest (6.27±0.01) on day 7 for the 75% OEO:25% LEO processed chicken patty and lowest on day 7 for the 100% OEO processed chicken patty. No Significant difference (p <0.05) in the WHC but highest (1.16±0.02) on day 21 for the 100% LEO processed chicken patty and lowest on day 21 for (T1) chicken patties with no essential oil (0.92±0.01) for WHC. The TBARS significantly (p <0.05) were highest (3.28±0.01) at day 0 of chicken patties made with 75%OEO:25% LEO (T5) and lowest (0.69) at day 14 and day 21 of chicken patties made with 50% OEO:50% LEO.

Table 3: Interaction effect of blends of oregano and lemon essential oils and storage intervals on physicochemical properties of chicken patties

Days	Treatment	pH	WHC (g/g)	TBARS (mg MDA/100 g)
0	1	6.10±0.01^{def}	0.98±0.01	1.31±0.02^{hi}
	2	6.15±0.01^{cde}	1.02±0.01	1.50±0.01^{f}
	3	6.04±0.01^{f}	0.97±0.01	2.60±0.01^{b}
	4	6.11±0.01^{cdef}	1.06±0.01	1.46±0.00^{g}
	5	6.18±0.01^{bcd}	1.05±0.01	3.28±0.02^{a}
	6	6.11±0.01^{cdef}	0.93±0.01	2.06±0.01^{c}
7	1	6.08±0.04^{ef}	0.94±0.01	1.14±0.00^{k}
	2	5.89±0.01^{g}	0.99±0.01	1.28±0.01^{hi}
	3	6.16±0.01^{cde}	0.95±0.01	1.89±0.01^{e}
	4	6.19±0.01^{abc}	1.02±0.01	1.22±0.00^{j}
	5	6.27±0.01^{a}	1.00±0.02	2.01±0.00^{d}
	6	6.25±0.01^{ab}	0.97±0.01	1.05±0.01^{f}
14	1	6.13±0.01^{cdef}	1.00±0.01	0.78±0.00^{n}
	2	5.91±0.01^{g}	1.04±0.01	0.99±0.00^{l}
	3	6.08±0.01^{ef}	1.02±0.01	1.21±0.00^{j}
	4	6.12±0.01^{cdef}	0.95±0.01	0.69±0.00^{o}
	5	6.18±0.01^{bcd}	1.02±0.01	1.33±0.00^{h}
	6	6.13±0.01^{cdef}	1.02±0.01	0.89±0.00^{m}
21	1	6.08±0.01^{ef}	0.92±0.01	0.78±0.00^{n}
	2	6.11±0.01^{cdef}	1.13±0.01	0.99±0.00^{l}
	3	6.08±0.01^{ef}	1.16±0.02	1.21±0.00^{j}
	4	6.13±0.01^{cde}	1.05±0.01	0.69±0.00^{o}
	5	5.95±0.08^{g}	1.00±0.01	1.33±0.00^{h}
	6	6.04±0.01^{f}	1.06±0.02	0.89±0.00^{m}

$^{a, b, c, d, e, f, g, h, i, j, k, l, m, n, o}$ means with different superscripts on the same column are significantly different (p<0.05), WHC**:** Water Holding Capacity, TBARS**:** Thiobarbituric Acid Reactive Substances, T1: Chicken patties made with no essential oil (Control), T2: Chicken patties made with 100% oregano essential oil only, T3: Chicken patties made with 100% lemon essential oil only, T4: Chicken patties made with 50% oregano essential oil and 50% lemon essential oil, T5: Chicken patties made with 75% oregano essential oil and 25% lemon essential oil, T6: Chicken patties made with 25% oregano essential oils and 75% lemon essential oil

The combination effects of storage intervals and blends of essential oils on the physicochemical characteristics of chicken patties showed changes in pH, water holding capacity (WHC) and thiobarbituric acid reactive substances (TBARS). These results suggest that T2–T6 essential oils affect the stability and shelf lifespan of chicken patties. The result showed that the pH of chicken patties changed differently according to the treatment type and storage periods. At day 0, the effect on the pH was highest with T5 containing 75% oregano and 25% lemon essential oils, having the highest pH of 6.18±0.01, with T3 containing 100% lemon essential oil having the lowest at 6.04±0.01. A striking similarity in trends was observed during storage, where T6 (25% OEO: 75% LEO) exhibited higher pH values on both day 7 (6.25±0.01) and day 21 (6.04±0.01). The fact that essential oils do not cause a pH shift is probably because they have antimicrobial effects that inhibit microbial activity and may delay the process of protein degradation (Šojić *et al*., 2017). WHC varied across the treatments, suggesting that these oils impact the ability to maintain moisture. On day 0, T4 with an equal proportion of oregano and Lemon oil had the maximum WHC of 1.06± 0.01 g/g, indicating an enhancement effect of the oil blend. And on day 21, T3 had the highest WHC at 1.16±0.02 g/g, which could be explained by the antioxidant effect of lemon essential oil in maintaining muscle fibres (Li *et al.,* 2021). TBARS values, which are an indicator of lipid oxidation, were also affected by the essential oils and storage intervals. T5 (75% OEO:25% LEO) had the highest TBARS value on the day of preparation, 3.28±0.02 mg MDA/100 g, which may be attributed to the higher oregano concentration. This concentration arrested the oxidation at the initial stage but allowed accumulation at later stages. On the other hand, T4 and T6 gave the lowest TBARS scores on day 14, 0.69±0.00 mg MDA/100 g and day 21, 0.69±0.00 mg MDA/100 g, proving that the essential oil combination exerted vigorous antioxidant activity. These results support the previous work of Jung *et al*. (2021), which explored the mechanisms of lipid stabilisation using essential oils.

Interaction effect of blends of oregano and lemon essential oil and storage intervals on proximate composition of chicken patties

The proximate composition of chicken patties as affected by the interaction between storage intervals and blends of essential oils is displayed in Table 4. There exists a significant (P <0.05) difference in all the proximate composition parameters across all interactions. The highest (31.09±0.02) crude protein value was observed in the chicken patties processed with 75% OEO:25% LEO (T5) in the final phase (Day 21), while the lowest (24.57±0.08) was in 100% LEO at the initial phase (Day 0). The Ash content was significantly (p <0.05) the highest (3.92±0.01) at the initial phase in the chicken patties processed with 25%OEO:75% LEO (T6) and the lowest (2.86) in the final phase for chicken patties processed with 100% OEO (T2). Ether extract had significantly the highest value (10.89±0.06) at the initial phase with chicken patties processed with 25%OEO:75%LEO (T6) and the lowest (6.87±0.05) in the final phase processed with 50%OEO:50% LEO (T4). The Crude fibre was significantly (p <0.05) the highest (4.04±0.01) in the initial phase for the control chicken patties and lowest (1.57±0.05) in chicken patties made with 100% OEO. The dry matter contents were significantly highest (53.92±0.04) in 100% LEO chicken patties at the final phase and the lowest (47.93±0.01) in control chicken patties at the final phase.

Table 4: Interaction effect of blends of oregano and lemon essential oils and storage intervals on proximate composition of chicken patties

Days	Treatment	%CP	%ASH	%EE	%CF	%MC
0	1	28.42±0.04^{c}	3.68±0.03^{b}	8.90±0.01^{d}	4.04±0.01^{a}	49.47±0.05^{h}
	2	24.57±0.08^{f}	3.33±0.03^{d}	8.94±0.04^{d}	1.57±0.05^{g}	50.37±0.06^{f}
	3	26.73±0.05^{de}	3.49±0.02^{c}	10.31±0.04^{b}	2.67±0.02^{c}	49.25±0.07^{i}
	4	27.06±0.11^{cd}	3.37±0.03^{cd}	8.75±0.07^{d}	3.01±0.01^{b}	51.18±0.01^{cd}
	5	28.43±0.06^{c}	3.37±0.03^{cd}	9.90±0.11^{c}	2.51±0.03^{cd}	51.29±0.06^{c}
	6	26.51±0.05^{e}	3.92±0.01^{a}	10.89±0.06^{a}	3.19±0.01^{b}	48.59±0.04^{j}
21	1	30.98±0.15^{a}	3.28±0.04^{d}	7.19±0.04^{f}	2.60±0.14^{cd}	47.93±0.01^{k}
	2	27.25±0.16^{d}	2.86±0.06^{f}	7.28±0.04^{f}	2.08±0.04^{f}	53.30±0.02^{b}
	3	24.19±0.16^{f}	3.08±0.04^{e}	8.75±0.21^{d}	2.28±0.04^{ef}	53.92±0.04^{a}
	4	29.66±0.16^{b}	2.99±0.05^{ef}	6.87±0.05^{g}	2.42±0.05^{de}	50.92±0.05^{e}
	5	31.09±0.02^{a}	2.91±0.02^{f}	8.32±0.04^{e}	2.17±0.02^{f}	50.17±0.04^{g}
	6	26.38±0.16^{c}	3.38±0.04^{cd}	8.97±0.03^{d}	2.25±0.07^{ef}	51.01±0.05^{de}

a,b,c,d,e,f,g,h,I,j,k: means with different superscripts on the same column are significantly different (p<0.05), CP: Crude Protein, EE: Ether Extract, CF: Crude Fibre, MC: Moisture Content, T1: Chicken patties made with no essential oil (Control), T2: Chicken patties made with 100% oregano essential oil only, T3: Chicken patties made with 100% lemon essential oil only, T4: Chicken patties made with 50% oregano essential oil and 50% lemon essential oil, T5: Chicken patties made with 75% oregano essential oil and 25% lemon essential oil, T6: Chicken patties made with 25% oregano essential oils and 75% lemon essential oil

Blends of essential oils and storage intervals affected the proximate composition of chicken patties in this study. This was expressed in changes in crude protein (CP), ash, ether extract (EE), crude fiber (CF), and moisture content (MC). The CP content was generally increased with storage time (p <0.05). On day 0, T1 (control) had the CP of 28.42±0.04, and T5 (75% oregano:25%lemon essential oil) had the highest CP of 31.09±0.02 on the 21st day. The general increase in CP with storage time could be due to several factors such as change in moisture content, structural changes and microbial activity (Wu *et al.,* 2014). In this case, it could be due to significant moisture reduction observed for T1 (Control), and degradation of structural proteins like myosin for the other treatments with similar changes (Zou *et al.,* 2020). Some essential oils can also have antimicrobial effects which minimize protein breakdown when stored for some time (Shange *et al.,* 2019). The ash content, related to mineral ingredients, varied from 2.86±0.06 in T2 (100% OEO) on day 21 to 3.92±0.01 in T6 (25%OEO:75% LEO) at day 0. These declines in ash content may be attributed to oxidative reactions, which lower the stability of ash, as Ruiz-Hernández *et al.* (2023) have noted. Ether Extract (EE) content differed (p <0.05), and T6 showed the highest EE (10.89±0.06) with reference to day 0, which used a higher concentration of Lemon essential oil, which enhances fat accrual. However, the oregano and lemon blend in a 50%OEO:50%LEO (T4) had the lowest EE of only 6.87±0.05 at day 21, possibly because of the occurrence of lipid oxidation according to Ruiz-Hernández *et al.*, 2023. There were also marked differences in CF content; the level of CF content that was detected was also relatively low. The maximum percentage (T1-4.04%) and the minimum percentage (T2-1.57%) were both obtained on day 0. This reduction could be due to the hydrolytic enzymes that break down fiber components during storage as opposed to their bonding together as observed by Wilding *et al.*, (1986). The moisture loss of MC decreased over the experimental period, with T1 at 47.93±0.01 on day 21 and T3 at 100% lemon at 53.92±0.01. This outcome could be attributed to the water-retention properties of essential oils, which help maintain moisture (Unal *et al.,* 2022).

Interaction effects of storage intervals and blends of oregano and lemon essential oils on microbial load of chicken patties

The interaction effect of storage intervals and essential oils on microbial load of chicken patties is expressed in Table 5. There exists a significant (p <0.05) effect of storage days and essential oils on microbial composition of chicken patty. The Total Bacterial Count (TBC) was highest (10.00±0.28) at day 21 of chicken patties processed with 25%OEO:75% LEO (T6) and was lowest (0.55±0.07) at day 0 of patties made with 100% OEO (T2). Also, the Total Fungal Count (TFC) was highest (2.94) at day 21 of chicken patties prepared with 25%OEO:75% LEO (T6) and were lowest (0.00) at all treatments of day 0 and day 7 of chicken patties made with 100% OEO.

Table 5: Interaction effect of blends of oregano and lemon essential oils and storage intervals on microbial load of chicken patties

Days	Treatment	TBC (cfu/g) x10^{-4}	TFC (cfu/g) x10^{-2}
0	1	$0.75±0.07^{lm}$	$0.00±0.00^{j}$
	2	$0.55±0.07^{m}$	$0.00±0.00^{j}$
	3	$1.16±0.01^{lm}$	$0.00±0.00^{j}$
	4	$1.02±0.01^{lm}$	$0.00±0.00^{j}$
	5	$0.85±0.07^{lm}$	$0.00±0.00^{j}$
	6	$1.25±0.07^{lm}$	$0.00±0.00^{j}$
7	1	$2.25±0.21^{jk}$	$0.57±0.03^{hi}$
	2	$1.65±0.07^{kl}$	$0.00±0.00^{j}$
	3	$2.65±0.21^{j}$	$2.25±0.07^{gh}$
	4	$2.75±0.07^{j}$	$1.65±0.04^{fg}$
	5	$2.45±0.07^{jk}$	$0.25±0.07^{ij}$
	6	$3.00±0.14^{j}$	$1.40±0.14^{ef}$
14	1	$4.85±0.64^{hi}$	$1.70±0.14^{e}$
	2	$4.00±0.14^{i}$	$0.60±0.14^{hi}$
	3	$5.95±0.21^{fg}$	$1.65±0.21^{e}$
	4	$5.30±0.14^{gh}$	$2.20±0.28^{cd}$
	5	$4.70±0.14^{hi}$	$1.05±0.07^{fg}$
	6	$7.00±0.14^{de}$	$1.80±0.14^{de}$
21	1	$7.55±0.21^{cd}$	$2.50±0.14^{abc}$
	2	$6.55±0.07^{ef}$	$1.15±0.07^{fg}$
	3	$8.80±0.42^{b}$	$2.60±0.14^{abc}$
	4	$8.00±0.14^{bc}$	$2.45±0.07^{bc}$
	5	$7.80±0.42^{cd}$	$2.85±0.07^{ab}$
	6	$10.00±0.28^{a}$	$2.94±0.08^{a}$

a, b, c, d, e, f, g, h, i, j, k, l, m: means with different superscripts on the same column are significantly different (p<0.05), T1: Chicken patties made with no essential oil (Control), T2: Chicken patties made with 100% oregano essential oil only, T3: Chicken patties made with 100% lemon essential oil only, T4: Chicken patties made with 50% oregano essential oil and 50% lemon essential oil, T5: Chicken patties made with 75% oregano essential oil and 25% lemon essential oil, T6: Chicken patties made with 25% oregano essential oils and 75% lemon essential oil, TBC: Total Bacterial Count, TFC: Total Fungal Count

This study also investigated the storage intervals and blends of essential oils in influencing the microbial load on chicken patties, and the results revealed significant differences in the TBC and TFC (p <0.05). It has been reported that the microbial load rises gradually with storage time, following the literature on the preservation of meats (Dave and Ghaly, 2011). Nevertheless, the observed microbial load did not exceed acceptable limits set by the Nigerian food safety regulation (Adesetan *et al.,* 2017). All the treatments registered low microbial status at day 0, suggesting effective microbial status at processing/packaging conditions. Indeed, the microbial counts of treatments with essential oils (T2-T6) were significantly lower than those of the control (T1). This enforces earlier literature indicating that essential oils have an antimicrobial effect that inhibits microbial activity and may delay the process of protein degradation (Šojić *et al.*, 2017). Again, significant differences were observed by day 7 between the different treatments. Compared to the control treatment, T2 (100% oregano oil) and T5 (75% OEO: 25% LEO) exhibited low reductions in microbial count. This indicates that there is a kind of compounded antimicrobial effect when using the combination of oregano and lemon purified oils (Jung *et al*., 2021). The microbial counts of the samples treated with T6 (25% OEO:75%LEO) were highest on the fourteenth day. This could be due to differences in the percentage level of oregano oil, which has a higher antibacterial undertaking compared with lemon oil (Kouidhi *et al*., 2011). The antifungal activity trends were nearly identical, and lower TFC values were noted in blends with increasing levels of oregano oil. At day 21, the microbial growth was richest in the control T1, but poor at T6, and all samples recorded exponential growth. This enhances the action with essential oil concentration, and the ratios of the blends are all the more significant. T6 exhibited higher microbial counts than T2 and T5. Chouhan *et al.,* (2017) postulated that a particular proportion may exist where the microbial killing effect of lemon oil becomes ineffective due to its diluted concentration.

Effect of storage intervals and blends of Oregano and Lemon essential oils on sensory quality of chicken patties

The sensory qualities of chicken patties processed with and without blends of essential oils and stored over days are as shown in Table 6.

Table 6: Effect of storage intervals and blends of essential oils on sensory quality of chicken patties

Day	Treatment	Colour	Flavour	Texture	Juiciness	Overall Acceptability
0	1	6.60±1.35^{abc}	5.10±1.66	5.60±1.90	5.90±2.20	7.40±0.70^{ab}
	2	6.90±1.10^{ab}	4.60±2.01	6.60±1.35	6.10±1.85	6.80±1.03^{ab}
	3	6.00±1.15^{abcde}	4.20±2.04	5.70±1.70	5.50±2.01	6.80±0.79^{ab}
	4	5.60±1.35^{abcde}	4.50±1.58	5.00±1.56	5.00±1.83	6.70±1.25^{ab}
	5	5.90±1.60^{abcde}	4.30±1.64	6.10±1.37	5.50±1.78	7.00±1.33^{ab}
	6	4.90±1.29^{bcdef}	6.10±2.02	6.40±1.90	6.40±1.78	7.50±1.18^{a}
7	1	6.60±0.70^{abc}	6.00±1.83	5.90±1.52	4.70±2.06	6.60±1.17^{ab}
	2	6.70±0.48^{ab}	5.60±2.01	5.20±1.87	4.70±1.25	5.20±1.14^{c}
	3	5.60±1.35^{abcde}	5.80±1.99	6.60±1.71	6.00±1.76	6.50±1.58^{ab}
	4	6.10±0.88^{abcd}	5.20±2.25	6.40±1.90	6.30±1.83	6.80±0.92^{ab}
	5	4.00±1.41^{efg}	6.10±2.23	4.80±2.04	5.20±1.32	5.90±1.10^{ab}
	6	4.00±1.33^{efg}	5.00±2.58	4.90±1.85	5.80±1.25	7.20±1.23^{ab}
14	1	6.60±1.07^{abc}	5.20±1.87	5.60±1.78	5.70±2.50	6.50±1.35^{ab}
	2	7.20±0.79^{a}	5.40±2.32	4.90±1.37	3.70±1.70	3.60±1.58^{c}
	3	4.60±1.17^{cdefg}	4.70±1.34	4.80±1.87	4.80±1.14	6.60±1.17^{ab}
	4	4.20±0.85^{defg}	4.50±1.35	4.60±1.43	4.80±1.48	5.90±1.52^{ab}
	5	3.50±1.58^{fg}	3.70±1.06	4.40±0.97	4.30±1.77	5.60±1.65^{abc}
	6	2.70±1.49^{g}	4.70±1.83	4.70±1.49	4.30±1.70	5.40±1.35^{bc}
21	1	6.50±1.35^{abc}	4.60±2.50	4.80±1.62	5.00±1.41	7.00±1.25^{ab}
	2	7.40±0.97^{a}	5.20±2.49	5.60±1.65	5.60±1.35	6.40±1.35^{ab}
	3	6.90±1.10^{ab}	4.70±1.95	5.30±1.83	5.80±1.32	6.10±1.45^{ab}
	4	6.50±0.85^{abc}	4.10±2.13	4.90±1.52	5.70±1.49	6.00±1.25^{ab}
	5	6.10±1.85^{abcd}	5.50±1.96	5.50±1.84	5.60±2.01	7.60±1.26^{a}
	6	5.70±1.42^{abcde}	5.60±2.07	4.80±1.23	6.00±1.56	7.10±1.20^{ab}

$^{a, b, c, d, e, f, g, h:}$ means that with different superscripts on the same column are significantly different ($p<0.05$), T1: Chicken patties made with no essential oil (Control), T2: Chicken patties made with 100% oregano essential oil only, T3: Chicken patties made with 100% lemon essential oil only T4: Chicken patties made with 50% oregano essential oil and 50% lemon essential oil, T5: Chicken patties made with 75% oregano essential oil and 25% lemon essential oil, T6: Chicken patties made with 25% oregano essential oils and 75% lemon essential oil

The interactive effect of storage intervals and essential oils had a significant (p <0.05) effect on the colour and overall acceptability of chicken patties. Statistical analysis showed that the chicken patties processed with 100% Oregano essential oil (T2) at day 21 had the highest colour (7.40±0.97) while the chicken patties made with 25% OEO: 75% LEO (T6) at day 14 had the lowest (2.70±1.49) colour value. The result revealed that the flavour was not significantly different, with the highest value (6.10±2.02) in chicken patties processed with 75%OEO: 25% LEO (T5) on day 7. In contrast, the same 75%OEO: 25% LEO (T5) chicken patties had the lowest (3.70±1.06) flavour value on day 14. For the texture, chicken patties processed with 100% LEO (T3) on day 7 had the highest (6.60±1.35) textural value, while 75%OEO: 25% LEO (T5) processed chicken patties at day 14 had the lowest (4.40±0.97) value. The juiciness was significantly (p <0.05) the highest (6.40±1.78) in 25% OEO: 75% LEO (T6) processed chicken patties at day 0 and lowest (3.70±1.70) in 100% Oregano oil chicken patties at day 14. The overall acceptability had the highest (7.60±1.26) value for chicken patties processed with 75% OEO: 25% LEO (T5) at day 21. In comparison, the lowest (3.60±1.58) value was observed in chicken patties processed with 100% Oregano oil (T2) on day 14.

The sensory attributes of chicken patties, including colour, flavour, texture, juiciness, and overall acceptability, were influenced by the interaction between storage intervals and blends of essential oils. The findings demonstrate that essential oil treatments maintained sensory quality better than the control (T1). Colour scores decreased with more extended storage periods, with T2 (100% oregano essential oil) maintaining the highest colour stability on day 21 (7.40±0.97), likely due to its antioxidant properties that delay pigment oxidation (Rodriguez-Garcia *et al.,* 2019). The lowest color scores were observed in T6 (25% oregano and 75% lemon essential oil) on day 14 (2.70±1.49), suggesting that higher lemon oil concentration may enhance oxidative degradation due to its high citral content (Wilson *et al*., 2002). Flavour scores varied across treatments, with T6 showing the highest flavor score on day 0 (6.10±2.02) and T5 (75% oregano and 25% lemon essential oil) on day 7 (6.10±2.23). This aligns with reports that essential oils enhance meat flavour by inhibiting microbial growth and oxidative reactions (Ruiz-Hernández *et al*., 2023). However, flavour scores generally declined with storage time, indicating gradual spoilage. Texture stability was notable in T3 (100% lemon essential oil), maintaining a high score of 6.60±1.71 on day 7, likely due to its ability to maintain meat protein integrity through antioxidant activity (Jacinto-Valderrama, 2023). However, treatments with lower essential oil concentrations exhibited decreased texture quality over time. Juiciness scores fluctuated across treatments. T6 maintained a high score (6.40±1.78) on day 0, possibly due to its ability to retain moisture by reducing oxidative damage. The control group consistently recorded lower juiciness scores after day 7, indicating the essential oils' role in moisture retention. Overall acceptability was highest in T6 (7.50±1.18) on day 0 and in T5 (7.60±1.26) on day 21. These findings suggest a synergistic effect of mixed essential oils in enhancing sensory attributes, consistent with previous studies highlighting essential oil blends' preservative potential (Khodaei *et al*., 2023).

CONCLUSION

The study demonstrated that blends of oregano and lemon essential oils possess significant bioactive properties, with potential applications in preserving the quality of meat and meat products. Evaluating chicken patties treated with these essential oil blends revealed improved yield, enhanced antioxidant stability, and reduced microbial growth, particularly in blends with higher OEO content. The 50% OEO and 50% LEO blend emerged as the most effective formulation, balancing yield, preservation, nutritional retention, and microbial safety. These findings suggest that blending essential oils can optimize their functional properties through synergistic interactions, offering a natural, and sustainable alternative to synthetic preservatives in meat products.

AUTHOR CONTRIBUTION

AOA conceptualised the study. ABD and AOA carried out the experiments. AOA, ABD, and AOO wrote the paper with input from all authors. All authors discussed the results and commented on the manuscript.

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