



## Effect of basil essential oil on caprine meat's quality and shelf-life

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### Abstract

Caprine meat is regarded as a significant source of biologically valuable proteins, good fats, and minerals for human beings. While caprine meat is marketed at refrigeration temperature it is important to minimize microbial deterioration, and oxidation to ensure meat safety and quality. Thus, this research was done to assess the effect of basil essential oil (BEO) used at different three concentrations (0.5, 1, and 1.5%) on the sensory evaluation, chemical quality (pH, thiobarbituric acid "TBA", total volatile nitrogen "TVN"), and microbiological quality (total bacterial count, enterobacteriaceae, staphylococcal count, *E. coli*, total yeast & mold) of caprine meat stored for 12 days at 4°C. The obtained results demonstrated that addition of BEO at different concentrations improved the sensory properties of treated caprine meat as compared with control; Regarding chemical quality it was found that addition BEO with different concentrations decrease pH, TBA, and TVN values in treated caprine meat as compared with control samples this meaning that BEO had an antioxidant effect. In relation to microbiological quality, it was found that different concentrations of BEO decrease microbial count in treated caprine and extends shelf until day 12 of meat storage as compared with control samples. The concentration of 1.5% BEO gave the highest microbiological inhibition. Control caprine meat starts to decompose at 6<sup>th</sup> of storage while addition of BEO at concentration 0.5% extends shelf life till 9<sup>th</sup> day of storage and BEO at 1 and 1.5% extend shelf life until day 12 of storage. The obtained results revealed that BEO at 1% significantly improved sensory properties, chemical and microbiological quality of caprine meat although BEO at concentration 1.5% was more effective but gave strong odor and color changes which may be undesirable for consumers. The result of this study concludes that BEO has an antioxidant and antimicrobial effect and could be used as natural preservative for caprine meat during refrigeration temperature.

**Keywords:** Caprine meat; Basil essential oil; Microbial quality; Natural preservative

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### 1.Introduction

Caprine meat which is considered the best alternative to beef meat and is also priced relatively lower (**Abdul Aziz and Harby, 2022**). As a significant source of high biological value proteins, vitamins, and minerals, caprine meat is an essential component of the human diet (**Ivanović et al., 2016**). According to **Anaeto et al. (2010)**, caprine meat is a healthier alternative to other varieties of red meat in the human diet because of its molecular structure, which makes it easier to digest. It also contains less cholesterol and saturated fatty acids.

Many factors, such as the animal's skin and excrement, machinery including machines and cutting tools, an unclean environment, non-compliance with adequate slaughter procedures, and poor personal hygiene, may contribute as causes of contamination of carcasses along the chain of slaughter (**Khaled et al., 2012**).

Although microbial growth is the primary cause of meat deterioration, oxidation, and enzymatic activities, such as the oxidation of lipids, also have an impact, these changes to the meat's flavor and nutritional value are significant (**Vital et al., 2016**). Additionally, lipid oxidation leads to organoleptic alterations as well as the generation of hazardous compounds such aldehydes (**Banerjee et al., 2017**). The nutritional value of spoiled meat and meat products is negatively impacted by lipid oxidation and microbial growth, which also causes significant economic losses (**Shahidi and Zhong, 2010**).

Proteus, Escherichia, and Salmonella are examples of enterobacteriaceae that can enter the food chain through fecal contamination. These bacteria may be part of the natural microflora of some foods or might be introduced because of post-process contamination (**Jay, 2000**). Meat contains *E. coli* in addition to harmful *Staph. aureus*, yeast, and mould could also be pollutants (**Jay et al., 2005**). In light of the aforementioned, it is vital to control any microbial growth and keep an eye on the meat's closely related quality indicators in order to assure the absence of infections and ensure its safety (**Ayaz et al., 2018**).

Additionally, meat preservation prevents lipid oxidation, enzyme activity, and the growth of foodborne bacteria that spoils food and causes nutrient and financial losses in the meat processing business (**Falowo et al., 2016**). The use of synthetic antioxidants in meat products has been linked to adverse consumer health effects (**Kumar et al., 2015**). Basil (*Ocimum basilicum*, Lamiaceae), is one of the oldest herbs/spices that is known for its ornamental and therapeutic importance. It is originated from India, and has been reported to be antitoxic, anti-inflammatory, antibacterial, antifungal and chemopreventive agent (**Khair-ul-Bariyah et al., 2012; Miraj and Kiani, 2016**). Due to its phenolic acids and fragrant compounds, basil,

one of the most utilized culinary herbs (from the Lamiaceae family), is recognized to have potent antioxidant and antibacterial properties (Marwat et al., 2011) and antioxidizing effect (Trevisan et al., 2006). The present study was conducted to inspect the effect of basil essential oil (BEO) at different concentration (0.5, 1, and 1.5%) on caprine meat quality and shelf life during cold storage at 4°C for 12 days with sensory, chemical, and microbiological examination every 3 days.

## 2. Materials and Methods

### 2.1. Basil essential oil preparation

Briefly, basil leaves were collected from farm in Abu Homs city, El-Behera, thoroughly washed by distilled water followed by drying of the leaves using hot air oven at 50°C for 24 hours. Using a Clevenger-style apparatus, 100 g of the plant's dried leaves were hydro-distilled for 3 hours, after that the temperature was raised to 80°C for 3-4 hours, water vapor loaded with volatile oil a coolant, after that oil which leads to its condensation fall into separating funnel. The essential oil was kept in sealed vials at 4°C, this preparation of BEO was done in Faculty of Agriculture, Damanhour University, Egypt. The oil was prepared in 3 concentrations which were 0.5, 1 and 1.5% and used at it is on minced caprine meat according to meat weight (Reyes-Jurado et al., 2015).

### 2.2. Preparation of caprine meat samples

Accurately, five Kg of fresh caprine meat were purchased from butchers at Alexandria governorate, Egypt, and transferred directly to the laboratory under complete aseptic conditions. After removing any visible fat and connective parts, the fresh caprine meat was chopped into small cubes and minced in a clean meat grinder. The meat samples were divided into 4 groups (1.25 Kg for each group) and each group was represented by 5 samples (250 g for each). The first group was prepared as control (untreated group) and the other 3 groups were treated with basil essential oil at concentrations of 0.5, 1 and 1.5%. Following the addition of the essential oil as it is on minced caprine meat samples, the samples were subsequently aerobically packed in polyethylene bags, labeled, and stored at 4°C. The experiment was conducted for 12 days of chilling storage at 4°C. Each group was subjected to chemical, bacteriological and sensory assessment at zero time (within 2 hours after treatment) then regularly every 3 days until decomposition appeared in each group. The scheme was replicated 5 times (Barbosa et al., 2009).

### 2.3. Sensory evaluation of caprine meat

Twenty adults, and uneducated panelists were tasked with rating the sensory attributes of samples of caprine meat. The panelists were not made aware of the study methodology; the samples were blind coded with unique codes. While the samples were still fresh, they were asked to give a score for each of overall acceptance (uncooked). The samples were subsequently cooked without salt and presented to the panelists for sensory rating. Warm water was provided for the panelists to sip on in between tests. The descriptive scale has nine points. For the evaluation of appearance, fragrance, texture, taste, and general acceptability, a score of 7-9 signified "very high" quality, a score of 4.0-6.9 "good" quality, and a score of 1.0-3.9 "spoiled" (Lawless and Heymann, (2010).

### 2.4. Chemical evaluation of caprine meat samples

#### 2.4.1. pH measurement (EOS 63/11-2020)

A pH electrical meter was used to calculate the pH value (Bye model 6020, USA). 25 ml of neutral distilled water was used to homogenize 10 g of the meat samples under examination. After standing for 10 minutes, the mixture was filtered. The pH meter was calibrated using buffer solutions with precisely defined pH standards (pH 7.01 and 4.01).

#### 2.4.2. Determination of total volatile basic nitrogen content (TVB-N) (mg/100g) according to EOS 63/9-2006

Ten grammes of treated caprine were minced in a food processor for one to two minutes to achieve homogeneity. A distillation flask was filled with 2 g of magnesium oxide. The minced sample was mixed with 300 mL of distilled water. Following the distillation, 100

mL of distillate was received in a beaker containing 25 mL of 2% boric acid for less than 30 minutes. A light pink tint was achieved through titration against H<sub>2</sub>SO<sub>4</sub> 0.1 M.

$$\text{Calculation: TVBN mg/100 g} = R \times 14$$

Where R is the volume of H<sub>2</sub>SO<sub>4</sub> exhausted in titration.

#### 2.4.3. Determination of thiobarbituric acid (TBA) according to EOS 63/10-2006

Ten grams of treated meat sample were combined with 48 ml distilled water, added 2ml of ammonium chloride 4% to the previous contents in a warring blender for 2 minutes and left for 10 min in room temperature. Washing the mixture with 50 ml distilled water then transferred to Kjeldahl flasks, then added antifoaming agent and few glass beads. 50 ml distillates were pipette into a glass stoppard tube. The tube was stoppered, shacked, and placed in a bath of boiling water for 35 minutes after the addition of the 5 ml TBA reagent. After portion was transferred to a curette and the optical density of the sample was measured against the blank (D) by means of a spectrophotometer (Perkin Elmer, 2380, USA) at a wavelength of 538 nm.

$$\text{TBA value (mg malondialdehyde/Kg of sample)} = D \times 7.8$$

### 2.5. Microbiological examinations of treated caprine meat

25 g of the treated caprine meat samples were weighed and then put into a sterile homogenizer flask with 225 ml of sterile peptone water (0.1%) under strict aseptic conditions. The flask's contents were homogenized for 3 minutes at a speed of 14000 rpm, and then left to stand for five minutes at room temperature. One ml of the homogenate was placed into a different tube that contained 9 ml of sterile peptone water (0.1%) and was used to make tenfold serial dilutions. According to ISO 4833/1 (2013), the aerobic bacterial count (APC) was estimated using plate count medium agar and incubated for 24 hours at 37°C; According to ISO, 4832: (2006), enterobacteriaceae count was detected using violet red bile glucose agar medium (VRBG), which was incubated at 37 °C for 24 hours; FDA (2001) reported that the total staphylococcal count was performed using Baird Parker agar medium and incubated at 37° C for 48 hours; APHA (2001) mentioned that the *E. coli* count was determined using Eosin methylene blue (EMB) and incubated at 37° C for 18–24 hours; According to APHA (2001), yeast and mould count was performed using Sabouraud's dextrose agar (SDA) and incubation at 22–25 °C for 5-7 days.

### 2.6. Statistical analysis

The criteria for sensory, chemical, and microbiological evaluation were displayed as mean ± standard deviation "SD". Using the Tukey's Studentized Range (HSD) post-hoc Test ( $P < 0.05$ ), significant means were compared (SAS, 2014).

## 3. Results and Discussion

### 3.1. Overall acceptability of treated caprine meat with basil essential oil (BEO)

The obtained results revealed the overall acceptance of control caprine meat samples stored at 4°C were completely spoiled after the sixth day of storage. The general acceptability of caprine meat was considerably maintained for the 9<sup>th</sup>, 12<sup>th</sup>, and 12<sup>th</sup> days, respectively, by the addition of BEO at concentrations of 0.5, 1, and 1.5 %. The samples treated with 1.5% BEO demonstrated the highest acceptability values, when compared with 0.5 and 1% (Table 1). BEO at concentration 1% improved overall acceptability of caprine meat although BEO at 1.5% gave better results than concentration 1% but has strongest effect on sensory attributes especially odor and taste.

Our results revealed that addition of BEO preserve the overall acceptability of treated caprine meat, these findings were corroborated by Falowo et al (2019) found that color stability of minced beef improved during 7 days of refrigeration compared to the control by adding sweet BEO addition at 2% and 4%. Also, combination of clove and lemon basil essential oils improved the sensorial properties of chicken meats for 12 days during refrigerated storage (Hartanti et al., 2020). In addition, marination of meat with herbs or spices like basil

leaves paste had enhanced consumer's overall acceptance of spent layer meat (**Ibrahim et al., 2018**).

### 3.2. Effect of basil essential oil (BEO) on chemical parameter of caprine meat

#### 3.2.1. Effect of BEO on pH of caprine meat

The findings which presented in **Table 2**, revealed that treated caprine meat with different concentrations of BEO had lower pH values than the control samples for during storage periods. Additionally, the pH values showed the greatest impact in lowering the pH values through day 12 of cold storage when the BEO concentration was increased to 1.5%.

Different concentration of BEO (0.5, 1, and 1.5%) decrease pH as compared with control samples which making caprine meat undesirable for microbial growth during the refrigeration storage and thereby BEO has antimicrobial effect. Our observations were supported by the findings of **Mohammed and Alrefiee (2021)** who reported pH values of the treated camel meat burger with BEO at concentrations (10, 25 and 50  $\mu\text{l}/100\text{g}$ ) were lower than pH values of control samples (especially with increase BEO at level 50  $\mu\text{l}/100\text{g}$ ) during the period of storage (9 days).

#### 3.2.2. Effect of BEO on total volatile nitrogen (TVN) of caprine meat

Total volatile basic nitrogen is used as an index of raw meat quality. The findings found in **Table 3** revealed that the mean values of TVN were  $2.38 \pm 0.09$ ,  $12.31 \pm 0.44$ ,  $18.87 \pm 0.62$  and  $19.85 \pm 0.70$  mg/100 g in the control samples at day 0, 2, 4 and 6 of storage, respectively. The breakdown of protein due to the action of various bacteria and their proteolytic enzymes may be the source of the increase in TVN values in the meat (**Hassan and Omama, 2011**).

Caprine meat treated with BEO at concentrations of 1 and 1.5 %, TVN values increased from  $2.32 \pm 0.08$  and  $2.25 \pm 0.10$  mg/100 mg, respectively, at day 0 to  $16.98 \pm 0.63$  and  $16.33 \pm 0.11$  mg/100 mg at day 12 of storage at 4 °C, respectively while BEO at 0.5 the TVN values increased from  $2.34 \pm 0.07$  at day zero to  $17.83 \pm 0.31$  at day 9<sup>th</sup> of storage. In addition, increasing the BEO concentration to 1.5% was more effective at reducing the TVN values than the lower concentration of BEO (1%) at day 12 of storage. The control group exceeds the permissible limit by the sixth day of storage and begins to decompose in accordance with **EOS, 4334 (2008)**'s permissible limits, which stated that TVN should not exceed 20 mg/100 g. In contrast, caprine meat treated with 1 and 1.5% becomes fit until 12 days of storage at 4 °C, while caprine meat samples treated with 0.5% BEO become fit until day 9 of storage.

Total volatile nitrogen (TVN) content is an indicator for protein decomposition caused by microorganisms and/or tissue proteolytic enzymes during storage (**Gibriel et al., 2007**). Our results showed that BEO might lower TVN values at day 12 of storage and diminish protein breakdown. These findings were confirmed by **Majdinasab et al (2020)** who found that addition of basil seed essential oil lowered TVB-N content in refrigerated chicken fillets for 12 days as compared to control samples. **Falowo et al (2019)** observed preservative functions of BEO including antioxidant and antimicrobial activities.

#### 3.2.3. Effect of BEO on thiobarbituric acid (TBA) of caprine meat

One of the most used methods for determining secondary oxidation products, primarily malondialdehyde (MDA), is the thiobarbituric acid reactive substance (TBARS) assay (**Zhang et al., 2016**). Presented data in **Table 4** shows that the mean TBA values were  $0.08 \pm 0.01$ ,  $0.45 \pm 0.03$ , and  $0.86 \pm 0.04$  mg MDA/kg in control samples at 0, 2 and 4 days of storage, respectively then start to be decomposed at 6<sup>th</sup> day as exceeding permissible limits (not more 0.9 mg MDA/kg) established by **EOS, 4334 (2008)**. TBA values were 0.08, 0.24, 0.36, 0.64 and 0.75 by using 0.5% BEO; TBA values were 0.076, 0.21, 0.29, 0.61, 0.73, and 0.82 by using 1% BEO and by using 1.5% BEO values were 0.073, 0.17, 0.23, 0.48, 0.67, and 0.83, at 0-day, 2<sup>nd</sup> day, 4<sup>th</sup> day, 6<sup>th</sup> day, 9<sup>th</sup>, and 12<sup>th</sup> day, respectively. Treated meat samples with BEO at different concentrations showed lowering in TBARS values especially at 6<sup>th</sup>, 9<sup>th</sup>, and 12<sup>th</sup> day of storage period than control samples and higher concentration of BEO showed

significantly decreased the TBARS values than lower BEO concentration used. Control samples started to exhibit rancid flavor after the sixth day of storage, while the treated samples with 1 and 1.5% BEO did not exhibit rancid flavor until the end of the storage period.

Our findings agreed with **Falowo et al (2019)** who found that the addition of sweet basil essential oil exhibited higher antioxidant activity than at 2% than control samples and significantly lower TBARS in packaged minced meat. Increase of TBA values over time in all samples may be caused by the auto oxidation of meat lipids, bacteriological and oxidative rancidity (**Salem et al., 2010**). Basil essential oil's phenolic concentration, phytoconstituents, and antioxidant activity may be responsible for its inhibitory effects on TBARS production. Numerous studies have found a link between plant essential oil phytochemical content and a decrease in lipid oxidation in meat products (**Kuzelov et al., 2017**). The aromatic ring's hydroxyl group, which may donate hydrogen atoms with electrons and neutralize free radicals, has been related to the antioxidant action of phytochemical substances in essential oils (**Radha et al., 2014**).

### 3.3. Effect of basil essential oil (BEO) on microbiological quality of caprine meat

#### 3.3.1. Effect of BEO on Total aerobic bacterial count of caprine meat sample

In accordance with **EOS 4334 (2008)** which specified that the total bacterial count of fresh meat should not exceed  $10^6$  cfu/g, **Alberle et al (2001)** observed that meat is generally deemed of poor hygienic quality or unsafe for consumption when the aerobic plate count (APC) surpasses  $10^6$  cfu/g.

**Table 5** showed that the aerobic bacterial count values of control caprine meat samples were higher than treated caprine meat samples with different concentrations of BEO till sixth day of storage and control samples start to decompose. Mean values of total bacterial count of treated caprine meat with BEO at concentration 1.5% were lower than treated meat with BEO at 0.5 and 1%. Treated meat with 0.5 % BEO start to decompose at day 9 of storage while BEO 1 and 1.5% become fit till day 12 of storage. From the obtained results, samples treated by different concentrations of BEO showed decreasing count of aerobic plate microorganisms as compared to control samples especially 6<sup>th</sup> day, also high concentration of BEO (1 and 1.5%) more effective in decreasing this count than lower concentration (0.5%).

These results were confirmed with **Tankeo et al (2014)**, who reported that *O. basilicum* oil exhibits potent antibacterial properties against both Gram-positive and Gram-negative microorganisms. Additionally, according to **Al Abbasy et al (2015)**, basil chemotypes with eugenol or methyl chavicol as the primary constituent show good antibacterial activity.

#### 3.3.2. Effect of BEO on enterobacteriaceae count of caprine meat sample

**Table 6** revealed that the log means of enterobacteriaceae count in control caprine meat samples were higher than treated meat with BEO at different concentrations till sixth day of storage and control samples start to decompose. Mean values of enterobacteriaceae count of treated caprine meat with BEO at concentration 1.5% were lower than treated meat with BEO at 0.5 and 1%. Treated meat with 0.5 % BEO starts to decompose after day 9 of storage while BEO 1 and 1.5% becomes fit without deterioration till day 12 of storage. According to the results, samples treated with BEO at different concentrations (1 and 1.5%) showed a decrease in the number of enterobacteriaceae when compared to the control sample. A higher concentration of BEO (1.5%) also had a greater impact on this count reduction than a lower concentration (0.5%).

Our results demonstrated that BEO greatly reduced the number of enterobacteriaceae in the treated caprine meat. These results were consistent with **Suppakul et al (2003)** which claimed that basil extract showed antibacterial activities against Gram-negative bacteria, particularly enterobacteriaceae families.

**Table 1.** Mean values of overall acceptance of treated caprine meat with different concentrations of BEO during chilling storage period at 4°C.

Storage period	Control	Basil essential oil (BEO) concentrations		
		0.5%	1%	1.5%
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
0 day	9.00 ± 0.00 <sup>Aa</sup>	9.00 ± 0.00 <sup>Aa</sup>	8.76 ± 0.15 <sup>Ba</sup>	8.43 ± 0.30 <sup>Cb</sup>
2 <sup>nd</sup> day	6.58 ± 0.38 <sup>Cb</sup>	8.43 ± 0.31 <sup>Bb</sup>	8.68 ± 0.17 <sup>Ab</sup>	8.51 ± 0.28 <sup>Ba</sup>
4 <sup>th</sup> day	3.76 ± 0.16 <sup>Dc</sup>	6.81 ± 0.42 <sup>Cc</sup>	7.65 ± 0.25 <sup>Bc</sup>	8.03 ± 0.46 <sup>Ac</sup>
6 <sup>th</sup> day	3.60 ± 0.17 <sup>Dd</sup>	4.51 ± 0.17 <sup>Cd</sup>	6.55 ± 0.55 <sup>Bd</sup>	6.76 ± 0.37 <sup>Ad</sup>
9 <sup>th</sup> day	Decomposed	3.85 ± 0.13 <sup>Ce</sup>	4.50 ± 0.10 <sup>Be</sup>	5.03 ± 0.21 <sup>Ae</sup>
12 <sup>th</sup> day	Decomposed	Decomposed	4.40 ± 0.14 <sup>Be</sup>	4.66 ± 0.15 <sup>Af</sup>

\* Means carrying different superscript capital letter on the same row are significantly different ( $P < 0.05$ ).

\*\*Means carrying different superscript small letter on the same column are significantly different ( $P < 0.05$ ).

**Table 2.** Mean values of pH of treated caprine meat with different concentrations of BEO during chilling storage period at 4°C.

Storage period	Control	Basil essential oil (BEO) concentrations		
		0.5%	1%	1.5%
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
0 day	5.68 ± 0.04 <sup>Ad</sup>	5.68 ± 0.03 <sup>Ae</sup>	5.68 ± 0.03 <sup>Ad</sup>	5.64 ± 0.05 <sup>Be</sup>
2 <sup>nd</sup> day	6.11 ± 0.06 <sup>Ac</sup>	5.87 ± 0.07 <sup>Bd</sup>	5.81 ± 0.03 <sup>Cc</sup>	5.77 ± 0.03 <sup>Dd</sup>
4 <sup>th</sup> day	6.72 ± 0.15 <sup>Ab</sup>	6.00 ± 0.09 <sup>Bc</sup>	5.91 ± 0.06 <sup>Cb</sup>	5.85 ± 0.05 <sup>Cc</sup>
6 <sup>th</sup> day	7.11 ± 0.10 <sup>Aa</sup>	6.71 ± 0.02 <sup>Bb</sup>	6.01 ± 0.02 <sup>Cb</sup>	5.91 ± 0.06 <sup>Dc</sup>
9 <sup>th</sup> day	Decomposed	6.81 ± 0.03 <sup>Aa</sup>	6.56 ± 0.02 <sup>Ba</sup>	6.11 ± 0.08 <sup>Cb</sup>
12 <sup>th</sup> day	Decomposed	Decomposed	6.59 ± 0.02 <sup>Aa</sup>	6.39 ± 0.03 <sup>Ba</sup>

\* Means carrying different superscript capital letter on the same row are significantly different ( $P < 0.05$ ).

\*\*Means carrying different superscript small letter on the same column are significantly different ( $P < 0.05$ ).

**Table 3.** Mean values of total volatile nitrogen (TVN) (mg%) of treated caprine meat with different concentrations of BEO during chilling storage period at 4°C.

Storage period	Control	Basil essential oil (BEO) concentrations		
		0.5%	1%	1.5%
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
0 day	2.38 ± 0.09 <sup>Ac</sup>	2.34 ± 0.07 <sup>Be</sup>	2.32 ± 0.08 <sup>Ce</sup>	2.25 ± 0.10 <sup>Df</sup>
2 <sup>nd</sup> day	12.31 ± 0.44 <sup>Ab</sup>	5.02 ± 0.12 <sup>Bd</sup>	4.86 ± 0.09 <sup>Cd</sup>	4.78 ± 0.14 <sup>De</sup>
4 <sup>th</sup> day	18.87 ± 0.62 <sup>Aa</sup>	9.68 ± 0.21 <sup>Bc</sup>	8.55 ± 0.14 <sup>Cc</sup>	8.12 ± 0.37 <sup>Dd</sup>
6 <sup>th</sup> day	19.85 ± 0.70 <sup>Aa</sup>	15.77 ± 0.13 <sup>Bb</sup>	12.60 ± 0.02 <sup>Cb</sup>	11.23 ± 0.06 <sup>Dc</sup>
9 <sup>th</sup> day	Decomposed	17.83 ± 0.31 <sup>Aa</sup>	15.21 ± 0.43 <sup>Ba</sup>	14.93 ± 0.04 <sup>Cb</sup>
12 <sup>th</sup> day	Decomposed	Decomposed	16.98 ± 0.63 <sup>Aa</sup>	16.33 ± 0.11 <sup>Ba</sup>

\* Means carrying different superscript capital letter on the same row are significantly different ( $P < 0.05$ ).

\*\*Means carrying different superscript small letter on the same column are significantly different ( $P < 0.05$ ).

**Table 4.** Mean values of thiobarbituric acid (TBA) (mg/kg) of treated caprine meat with different concentrations of BEO during chilling storage period at 4°C.

Storage period	Control	Basil essential oil (BEO) concentrations		
		0.5%	1%	1.5%
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
0 day	0.08 ± 0.01 <sup>Ad</sup>	0.08 ± 0.01 <sup>Ae</sup>	0.076 ± 0.01 <sup>Af</sup>	0.073 ± 0.01 <sup>Af</sup>
2 <sup>nd</sup> day	0.45 ± 0.03 <sup>Ac</sup>	0.24 ± 0.02 <sup>Bd</sup>	0.21 ± 0.02 <sup>Ce</sup>	0.17 ± 0.02 <sup>De</sup>
4 <sup>th</sup> day	0.86 ± 0.04 <sup>Ab</sup>	0.36 ± 0.03 <sup>Bc</sup>	0.29 ± 0.02 <sup>Cd</sup>	0.23 ± 0.03 <sup>Dd</sup>
6 <sup>th</sup> day	1.01 ± 0.04 <sup>Aa</sup>	0.64 ± 0.01 <sup>Bb</sup>	0.61 ± 0.03 <sup>Bc</sup>	0.48 ± 0.02 <sup>Cc</sup>
9 <sup>th</sup> day	Decomposed	0.75 ± 0.03 <sup>Aa</sup>	0.73 ± 0.01 <sup>Ab</sup>	0.67 ± 0.02 <sup>Bb</sup>
12 <sup>th</sup> day	Decomposed	Decomposed	0.82 ± 0.02 <sup>Aa</sup>	0.83 ± 0.02 <sup>Aa</sup>

\* Means carrying different superscript capital letter on the same row are significantly different ( $P < 0.05$ ).

\*\*Means carrying different superscript small letter on the same column are significantly different ( $P < 0.05$ ).

**Table 5.** Mean values of aerobic bacterial count (log<sub>10</sub> cfu/g) of treated caprine meat with different concentrations of BEO during chilling storage period at 4°C.

Storage period	Control	Basil essential oil (BEO) concentrations		
		0.5%	1%	1.5%
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
0 day	4.86 ± 0.02 <sup>Ac</sup>	4.67 ± 0.03 <sup>Bd</sup>	4.45 ± 0.14 <sup>Cc</sup>	4.36 ± 0.06 <sup>De</sup>
2 <sup>nd</sup> day	4.87 ± 0.03 <sup>Ac</sup>	4.64 ± 0.04 <sup>Bd</sup>	4.35 ± 0.11 <sup>Cd</sup>	4.15 ± 0.07 <sup>Df</sup>
4 <sup>th</sup> day	4.95 ± 0.04 <sup>Ab</sup>	4.77 ± 0.20 <sup>Bc</sup>	4.32 ± 0.02 <sup>Cd</sup>	4.06 ± 0.11 <sup>Dd</sup>
6 <sup>th</sup> day	5.17 ± 0.06 <sup>Aa</sup>	4.94 ± 0.03 <sup>Bb</sup>	4.45 ± 0.07 <sup>Cc</sup>	4.28 ± 0.03 <sup>Dc</sup>
9 <sup>th</sup> day	Decomposed	5.03 ± 0.06 <sup>Aa</sup>	4.85 ± 0.08 <sup>Bb</sup>	4.49 ± 0.02 <sup>Cb</sup>
12 <sup>th</sup> day	Decomposed	Decomposed	5.14 ± 0.06 <sup>Aa</sup>	5.07 ± 0.07 <sup>Aa</sup>

\* Means carrying different superscript capital letter on the same row are significantly different ( $P < 0.05$ ).

\*\*Means carrying different superscript small letter on the same column are significantly different ( $P < 0.05$ ).

**Table 6.** Mean values of enterobacteriaceae count (log<sub>10</sub> cfu/g) of treated caprine meat with different concentrations of BEO during chilling storage period at 4°C.

Storage period	Control	Basil essential oil (BEO) concentrations		
		0.5%	1%	1.5%
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
0 day	3.69 ± 0.03 <sup>Ad</sup>	3.60 ± 0.04 <sup>Bc</sup>	3.37 ± 0.06 <sup>Cd</sup>	3.35 ± 0.11 <sup>Cc</sup>
2 <sup>nd</sup> day	3.87 ± 0.03 <sup>Ac</sup>	3.26 ± 0.16 <sup>Bd</sup>	3.24 ± 0.17 <sup>Cf</sup>	3.20 ± 0.14 <sup>De</sup>
4 <sup>th</sup> day	4.32 ± 0.06 <sup>Ab</sup>	3.34 ± 0.14 <sup>Bb</sup>	3.18 ± 0.12 <sup>Ce</sup>	3.17 ± 0.09 <sup>Df</sup>
6 <sup>th</sup> day	4.61 ± 0.08 <sup>Aa</sup>	4.35 ± 0.11 <sup>Cb</sup>	3.40 ± 0.08 <sup>Bc</sup>	3.28 ± 0.06 <sup>Dd</sup>
9 <sup>th</sup> day	Decomposed	4.57 ± 0.11 <sup>Aa</sup>	3.55 ± 0.03 <sup>Ab</sup>	4.35 ± 0.04 <sup>Ba</sup>
12 <sup>th</sup> day	Decomposed	Decomposed	3.67 ± 0.04 <sup>Aa</sup>	3.44 ± 0.02 <sup>Bb</sup>

\* Means carrying different superscript capital letter on the same row are significantly different ( $P < 0.05$ ).

\*\*Means carrying different superscript small letter on the same column are significantly different ( $P < 0.05$ ).

### 3.3.3. Effect of BEO on total staphylococcal count of caprine meat sample

**Table 7** shows that the staphylococcal count of control caprine meat samples was higher than treated caprine meat with different concentrations of BEO till sixth day of storage and control samples start to decompose. Mean values of staphylococcal count of treated caprine meat with BEO at concentration 1.5% were lower than treated meat with BEO at 0.5 and 1%. Treated meat with 0.5 % BEO start to decompose after day 9 of storage while BEO 1 and 1.5% become fit till day 12 of storage. According to the results, samples exposed to various concentrations of BEO had a lower staphylococcal species count than control samples, particularly on the sixth day. High concentrations of BEO (1 and 1.5%) were also more successful at lowering this count than low ones (0.5%).

Our results showed that addition of BEO was important in lowering the number of *Staphylococci*. The outcome is consistent with **Sakkas and Papadopoulou, (2017)** who mentioned that basil essential oil's antibacterial activity is attributed to its high content in linalool and estragole, whereas the antimicrobial spectrum is restricted to specific bacteria between them *Staphylococcus* species. In addition, **Stanojevic et al (2017)** reported that the basil essential oil exhibited stronger antimicrobial activity on coagulase-positive *Staphylococcus in vitro*.

### 3.3.4. Effect of BEO on *E. coli* count of caprine meat sample

**Table 8** revealed that the *E. coli* count of control caprine meat samples was higher than treated caprine meat with different concentrations of BEO till sixth day of storage and control samples start to decompose. Mean values of *E. coli* count of treated caprine meat with BEO at concentration 1.5% were lower than treated meat with BEO at 0.5 and 1%. Treated meat with 0.5 % BEO start to decompose after day 9 of storage while BEO 1 and 1.5% become fit till day 12 of storage. According to the data, samples treated with various concentrations of BEO had lower *E. coli* counts than control samples, particularly on the sixth day. High concentrations of BEO (1 and 1.5%) were also more successful at lowering this count than low ones (0.5%).

Our results showed that addition of BEO had a crucial role in decreasing *E. coli* count. These results were consistent with **Sakkas and Papadopoulou, (2017)** who mentioned that basil essential oil's antibacterial activity is attributed to its high content in linalool and estragole, whereas the antimicrobial spectrum is restricted to specific bacteria, between them *E. coli*. In addition, **Nabrdalik and Grata, (2016)** reported that *O. basilicum* essential oil at the concentration of

0.25 inhibited completely the growth of *E. coli in vitro*, and **Hernández-Hernández et al., (2019)** reported antibacterial activity of BEO against *E. coli* O157:H7. When BEO was contacted with *E. coli* the external membrane was broken leading to increased permeability (**Zengin and Baysal, 2014**). In addition, **Stanojevic et al (2017)** reported that the Basil essential oil exhibited stronger antimicrobial activity on *E. coli*.

### 3.3.5. Effect of BEO on total mold and yeast count of caprine meat sample

Presented data in **Table 9** showed that total mold and yeast count of control caprine meat samples was higher than treated caprine meat samples with different concentrations of BEO till sixth day of storage and control samples start to decompose. Mean values of total mold and yeast count of treated caprine meat with BEO at concentration 1.5% were lower than treated meat with BEO at 0.5 and 1%. Treated meat with 0.5 % BEO extent the shelf life of examined meat till day 9 and start to decompose while treatment with BEO 1 and 1.5% meat becomes fit till day 12 of storage. According to the results, samples exposed to various BEO concentrations exhibited a decline in the overall mould and yeast count when compared to control samples, particularly on the sixth day. High concentrations of BEO (1 and 1.5%) were also found to be more effective at reducing this count than low concentrations (0.5%).

These results come in agreement with those of **Joshi (2014)** and **Sakkas and Papadopoulou (2017)** who reported that basil essential oil exhibit antifungal activity. Other authors reported that lemon basil essential oil has antimicrobial activities against yeasts (**Kaya et al., 2008** and **Khalil, 2013**).

## 4. Conclusion

It has been demonstrated that basil essential oil (BEO) preserves sensory, chemical, and microbiological quality of caprine meat during cold storage, minimizing the financial losses brought on by meat decomposition. BEO's antibacterial and antioxidant capabilities help to extend the shelf life of caprine meat. The results were concentration-dependent; the highest BEO concentrations (1 and 1.5%) had a greater impact than the lowest concentration (0.5%) on extending the safety and shelf life of caprine meat. In addition, basil essential oils in our study exhibited effectiveness in inhibiting bacterial growth, making these natural products an alternative for synthetic preservatives used in food preservation.

**Table 7.** Mean values of staphylococcal count (log<sub>10</sub> cfu/g) of treated caprine meat with different concentrations of BEO during chilling storage period at 4°C.

Storage period	Control	Basil essential oil (BEO) concentrations		
		0.5%	1%	1.5%
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
0 day	4.92 ± 0.06 <sup>Ac</sup>	4.52 ± 0.58 <sup>Dc</sup>	4.81 ± 0.01 <sup>Ba</sup>	4.68 ± 0.04 <sup>Ca</sup>
2 <sup>nd</sup> day	4.94 ± 0.05 <sup>Ac</sup>	4.83 ± 0.04 <sup>Bb</sup>	4.77 ± 0.13 <sup>Cb</sup>	4.59 ± 0.03 <sup>Db</sup>
4 <sup>th</sup> day	5.05 ± 0.04 <sup>Ab</sup>	4.80 ± 0.06 <sup>Bb</sup>	4.51 ± 0.06 <sup>Ce</sup>	4.44 ± 0.09 <sup>Dc</sup>
6 <sup>th</sup> day	5.16 ± 0.51 <sup>Aa</sup>	4.84 ± 0.07 <sup>Bb</sup>	4.57 ± 0.05 <sup>Cd</sup>	4.08 ± 0.08 <sup>Df</sup>
9 <sup>th</sup> day	Decomposed	4.91 ± 0.08 <sup>Aa</sup>	4.63 ± 0.08 <sup>Bc</sup>	4.19 ± 0.10 <sup>Ce</sup>
12 <sup>th</sup> day	Decomposed	Decomposed	4.66 ± 0.05 <sup>Ac</sup>	4.37 ± 0.05 <sup>Bd</sup>

\* Means carrying different superscript capital letter on the same row are significantly different ( $P < 0.05$ ).

\*\*Means carrying different superscript small letter on the same column are significantly different ( $P < 0.05$ ).

**Table 8.** Mean values of *E. coli* count (log<sub>10</sub> cfu/g) of treated caprine meat with different concentrations of BEO during chilling storage period at 4°C.

Storage period	Control	Basil essential oil (BEO) concentrations		
		0.5%	1%	1.5%
		Mean ± SD	Mean ± SD	Mean ± SD
0 day	3.74 ± 0.04 <sup>Ac</sup>	3.69 ± 0.03 <sup>Bb</sup>	3.64 ± 0.09 <sup>Ca</sup>	3.61 ± 0.04 <sup>Ca</sup>
2 <sup>nd</sup> day	3.77 ± 0.02 <sup>Ac</sup>	3.66 ± 0.04 <sup>Bb</sup>	3.58 ± 0.03 <sup>Cb</sup>	3.47 ± 0.06 <sup>Db</sup>
4 <sup>th</sup> day	4.03 ± 0.39 <sup>Ab</sup>	3.64 ± 0.09 <sup>Bc</sup>	3.47 ± 0.02 <sup>Cc</sup>	3.29 ± 0.04 <sup>Dd</sup>
6 <sup>th</sup> day	4.71 ± 0.21 <sup>Aa</sup>	3.69 ± 0.29 <sup>Bb</sup>	3.39 ± 0.11 <sup>Cd</sup>	3.07 ± 0.21 <sup>De</sup>
9 <sup>th</sup> day	Decomposed	4.62 ± 0.13 <sup>Aa</sup>	3.58 ± 0.07 <sup>Ab</sup>	3.29 ± 0.10 <sup>Bd</sup>
12 <sup>th</sup> day	Decomposed	Decomposed	3.68 ± 0.17 <sup>Aa</sup>	3.34 ± 0.05 <sup>Bc</sup>

\* Means carrying different superscript capital letter on the same row are significantly different ( $P < 0.05$ ).

\*\*Means carrying different superscript small letter on the same column are significantly different ( $P < 0.05$ ).

**Table 9.** Mean values of yeast and mold count (log<sub>10</sub> cfu/g) of treated caprine meat with different concentrations of BEO during chilling storage period at 4°C.

Storage period	Control	Basil essential oil (BEO) concentrations		
		0.5%	1%	1.5%
		Mean ± SD	Mean ± SD	Mean ± SD
0 day	3.64 ± 0.11 <sup>Ad</sup>	3.57 ± 0.09 <sup>Ba</sup>	3.41 ± 0.35 <sup>Ca</sup>	3.44 ± 0.49 <sup>Da</sup>
2 <sup>nd</sup> day	3.71 ± 0.26 <sup>Ac</sup>	3.41 ± 0.48 <sup>Bb</sup>	3.34 ± 0.51 <sup>Cb</sup>	3.36 ± 0.21 <sup>Cb</sup>
4 <sup>th</sup> day	3.97 ± 0.33 <sup>Ab</sup>	3.01 ± 0.06 <sup>Be</sup>	2.82 ± 0.04 <sup>Cd</sup>	2.50 ± 0.17 <sup>Df</sup>
6 <sup>th</sup> day	4.10 ± 0.51 <sup>Aa</sup>	3.13 ± 0.05 <sup>Bd</sup>	2.92 ± 0.13 <sup>Cd</sup>	2.66 ± 0.06 <sup>De</sup>
9 <sup>th</sup> day	Decomposed	3.25 ± 0.04 <sup>Ac</sup>	3.06 ± 0.06 <sup>Bc</sup>	2.89 ± 0.03 <sup>Cd</sup>
12 <sup>th</sup> day	Decomposed	Decomposed	3.37 ± 0.03 <sup>Ab</sup>	3.19 ± 0.03 <sup>Bc</sup>

\* Means carrying different superscript capital letter on the same row are significantly different ( $P < 0.05$ ).

\*\*Means carrying different superscript small letter on the same column are significantly different ( $P < 0.05$ ).

## 5. References

- Abdul Aziz, H.H., & Harby, H.S. (2022). The economics of sheep and caprine meat production in Egypt "a case study in Gharbia Governorate". *IOSR Journal of Economics and Finance*, 13(2),07-17.
- Al Abbasy, D.W., Pathare, N., Al-Sabahi, J.N., & Khan, S.A. (2015). Chemical composition and antibacterial activity of essential oil isolated from Omani basil (*Ocimum basilicum* Linn.). *Asian Pacific Journal of Tropical Disease*, 5(8),645-649.
- Alberle, E.D., Forrest, J.C., Gerrard, D.E. & Mills, E.W. (2001). *Principles of meat science* (4th ed.), Kendall/Hunt Publishing Company, USA 2001.
- American Public Health Association "APHA" (2001). *Compendium of Methods for the Microbiological Examination of Foods*, 4th Edition. APHA, Washington, DC.
- Anaeto, M., Adeyeye, J.A., Chioma, G.O., Olanrinmoye, A.O., & Tayo, G.O. (2010). Caprine products: Meeting the challenges of human health and nutrition. *Agriculture and Biology Journal of North America*, 1(6), 1231-1236.
- Ayaz, N.D., Onaran, B., Cufaoglu, G., Goncuoglu, M., Ormanci, F.S., & Erol, I. (2018). Prevalence and characterization of *Listeria monocytogenes* isolated from beef and sheep carcasses in Turkey with characterization of locally isolated listeriophages as a control measure. *Journal of Food protection*, 81, 2045-2053.
- Banerjee, R., Verma, A.K., & Siddiqui, M.W. (2017). Control of lipid oxidation in muscle food by active packaging technology. *Natural Antioxidants*, 1<sup>st</sup> Edition. Apple Academic Press, 363-402.
- Barbosa, L., Rall, V., Fernandes, A., Ushimaru, P., De Silva, I. & Fernandes, T. (2009). Essential oils against food borne pathogens and spoilage bacteria in minced meat. *Foodborne Pathogens and Disease*, 6: 725-728.
- Egyptian Organization for Standardization "EOS" 4334/ (2008). Reports related to No 4334/2008 for fresh meat. Egyptian Standards, Ministry of Industry, Egypt.
- Egyptian Organization for Standardization "EOS" 63/10" (2006). Egyptian Organization for Standardization and quality control. Methods of analysis and testing for meat and meat products part: 10 determination of Thiobarbituric acid.
- Egyptian Organization for Standardization "EOS" 63/11" (2020). Egyptian Organization for Standardization and quality control.
- Methods of analysis and testing for meat and meat products Part: 11 Measurement of pH.
- Egyptian Organization for Standardization "EOS" 63/9" 2006. Egyptian Organization for Standardization and quality control. Methods of analysis and testing for meat and meat products part: 9 determination of total volatile nitrogen.
- Falowo, A.B., Muchenje, V., Hugo, C.J., & Charimba, G. (2016). *In vitro* antimicrobial activities of *Bidens pilosa* and *Moringa oleifera* leaf extracts and their effects on ground beef quality during cold storage. *CyTA - Journal of Food*, 14: 541-546.
- Falowo, A.B., Mukumbo, F.M., 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*, 2628747.
- Food and Drug Administration "FDA" (2001). *Staphylococcus aureus*. Bacteriological analytical manual .8<sup>th</sup> Ed. Chapter12. Academic Press, Gaithersburg, UK.
- Gibriel, A.Y., Ebeid, H.M., Khalil, H.I. & Abd ElFattah, A.A. (2007). Application of *Monascus purpureus* pigments produced by using some food industry wastes in beef sausage manufacture. *Egyptian Journal of Food Science*, 35, 27-45.
- Hartanti, D., Septiyaningrum, N.A., & Hamad, A. (2020). Combination of clove and lemon basil essential oils for preservation of chicken meat. *Journal of Food Quality and Hazards Control*. 7, 84-93.
- Hassan, A.A. & Omama, A. (2011). Chemical evaluation of meat and meat products. *Assuit Veterinary Medical Journal*, 57(130), 62-71.
- Hernández-Hernández, E., Castillo-Hernández, G., González-Gutiérrez, C.J., Silva-Dávila, A.J., Gracida-Rodríguez, J.N., García-Almendárez, B.E., Di Pierro, P., Vázquez-Landaverde, P., & Regalado-González, C. (2019). Microbiological and Physicochemical Properties of Meat Coated with Microencapsulated Mexican Oregano (*Lippia graveolens* Kunth) and Basil (*Ocimum basilicum* L.) Essential Oils Mixture. *Coatings*, 9(7),414.
- Ibrahim, M.S. Ibrahim, N.T., & Zaharadeen, I.M. (2018). Effects of basil leaf (*Ocimum basilicum*) marination on sensory attributes of spent layer meat. *Korean Journal of Food & Health Convergence* 4(3),12-21.
- ISO "International Standards Organization" 4832 (2006). *Microbiology of food and animal feeding stuffs*. Horizontal method

- for the enumeration of Enterobacteriaceae: Colony count technique. International Standards Organization, Geneva, Switzerland.
- ISO "International Standards Organization" 4833-1 (2013).** Microbiology of food chain- Horizontal method for the enumeration of microorganisms. Part I, Colony count at 30°C by the pour plate technique. International Standards Organization, Geneva, Switzerland.
- Ivanović, S., Pavlović, I., & Pisinov, B. (2016).** The quality of caprine meat and its impact on human health. *Biotechnology in Animal Husbandry* 32 (2),111-122.
- Jay, J.M. (2000).** Food preservation with modified atmospheres. 283:205. I.N.D.R. Hoidnian led.Modern Food Microbiology. Aspen publishers, Inc., Gaithersbura Med.
- Jay, J.M., Loessner, M.J., & Golden, D.A. (2005).** *Modern Food Microbiology*; Springer Science + Business Media: New York, NY, USA.
- Joshi, R. (2014).** Chemical composition and antimicrobial activity of the essential oil of *Ocimum basilicum* L. (sweet basil) from Western Ghats of Northwest Karnataka, India. *Ancient Science of Life*, 33(3), 151-156.
- Kaya, I., Yigit, N., & Benli, M. (2008).** Antimicrobial activity of various extracts of *Ocimum basilicum* L. and observation of the inhibition effect on bacterial cells by use of scanning electron microscopy. *African Journal of Traditional, Complementary and Alternative Medicines*, 5, 363-369.
- Khaled, H., Boukhors, K.T., Dahmani, A., Zenia, S. & Aissi, M. (2012).** Survey of hygiene in ovine slaughterhouses of Algiers region by bacteriological analysis of carcasses. *African Journal of Microbiology Research*, 6,4722-4726.
- Khair-ul-Bariyah, S., Ahmed, D., & Ikram, M. (2012).** *Ocimum Basilicum*; A Review on Phytochemical and Pharmacological Studies. *Pakistan Journal of Chemistry*, 2: 78-85.
- Khalil, A. (2013).** Antimicrobial activity of ethanolic extracts of *Ocimum basilicum* leaf from Saudi Arabia. *Biotechnology*, 12, 61-64.
- Kumar, Y., Yadav, D.N., Ahmad, T., & Narsaiah, K. (2015).** "Recent Trends in the use of natural antioxidants for meat and meat Products," *Comprehensive Reviews in Food Science and Food Safety*, 14 (6), 796-812.
- Kuzelov, A., Andronikov, D., Taskov, N., Sofjanova, E., & Saneva, D. (2017).** "Oxidative stability effect of basil, garlic and muscat blossom extracts on lipids and microbiology of minced meat," *Comptes rendus de l'Academie bulgare des Sciences*, 70 (9),1227-1236.
- Lawless, H.T. & Heymann, H. (2010).** *Sensory evaluation of food: principles and practices.* Springer Pub., New York, NY, USA.
- Majdinasab, M., Niakousari, M., Shaghaghian, S., & Dehghani, H. (2020).** Antimicrobial and antioxidant coating based on basil seed gum incorporated with Shirazi thyme and summer savory essential oils emulsions for shelf-life extension of refrigerated chicken fillets. *Food Hydrocolloids*, 108, 106011.
- Marwat, S.K., Ur-Rehman, F., Khan, M.S., Ghulam, S., Anwar, N., Mustafa, G., and Usman, K. (2011).** "Phytochemical constituents and pharmacological Activities of sweet Basil-*Ocimum basilicum* L. (Lamiaceae)," *Asian Journal of Chemistry*, 23(9), 3773-3782.
- Miraj, S., & Kiani, S. (2016).** Study of pharmacological effect of *Ocimum basilicum*: A review. *Der Pharmacia Lettre*, 8, 242-245.
- 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, 38-46.
- Nabrdalik, M. & Grata, K. (2016).** Antibacterial activity of *Ocimum basilicum* L. essential oil against Gram-negative bacteria. *Postepy Fitoterapii*, 17, 80-86.
- Radha, K.K, Babuskin, S., Azhagu, S.B.P., Sasikala, M., Sabina, K., Archana, G., Sivarajan, M., & Sukumar, M. (2014).** Antimicrobial and antioxidant effects of spice extracts on the shelf-life extension of raw chicken meat. *International Journal of Food Microbiology*, 3,171,32-40.
- Reyes-Jurado, F., Franco-Vega, A., Ramírez-Corona, N., Palou, E., and López-Malo, A. (2015).** Essential oils: Antimicrobial activities, extraction methods, and their modeling. *Food Engineering Reviews*, 7, 275-297.
- Sakkas, H. & Papadopoulou, C. (2017).** Antimicrobial activity of basil, oregano and thyme essential oils. *Journal of Microbiology and Biotechnology*, 27, 429-438.
- Salem, A.M., Amin, R.A. & Affi, G.S.A. (2010).** Studies on Antimicrobial and Antioxidant Efficiency of Some Essential Oils in Minced Beef. *Journal of American Science*, 6, 691-700.
- SAS, (2014).** *Statistical user's Guide.* Statistical analysis system. INT., Cary, NC. USA.
- Shahidi, F., and Zhong, Y. (2010).** Novel antioxidants in food quality preservation and health promotion. *European Journal of Lipid Science and Technology*, 112, 930-940.
- Stanojevic, L.P., Marjanovic-Balaban, Z.R., Kalaba, V.D., Stanojevic, J.S., Cvetkovic, D.J., & Cakic, M.D. (2017).** Chemical Composition, Antioxidant and Antimicrobial Activity of Basil (*Ocimum basilicum* L.) Essential Oil. *Journal of Essential Oil-Bearing Plants*, 20(6), 1557-1569.
- Suppakul, P., Miltz, J., Sonneveld, K., & Bigger, S.W. (2003).** Antimicrobial Properties of Basil and Its Possible Application in Food Packaging. *Journal of Agricultural and Food Chemistry*, 51, 3197-3207.
- Tankeo, S.B., Lacmata, S.T., Noumedem, J.A., Dzoyem, J.P., Kuate, J.R., & Kuete, V. (2014).** Antibacterial and antibiotic-potential activities of some Cameroonian food plants against multi-drug resistant Gram-negative bacteria. *Chinese Journal of Integrative Medicine*, 20(7), 546-54.
- Trevisan, M.T.S., Silva, M.G.V., Pfundstein, B., Spiegelhalter, B., & Owen, R.W. (2006).** Characterization of the volatile pattern and Antioxidant capacity of essential oils from different species of the genus *Ocimum*. *Journal of Agricultural and Food Chemistry*, 54, 4378-4382.
- Vital, A.C.P., Guerrero A., Monteschio J.d.O, Valero M.V., Carvalho C.B., de Abreu Filho B.A., Madrona G.S., & do Prado I.N. (2016).** Effect of edible and active coating (with rosemary and oregano essential oils) on beef characteristics and consumer acceptability. *PLoS One*, 11(8), e0160535.
- Zengin, H. & Baysal, A.H. (2014).** Antibacterial and antioxidant activity of essential oil terpenes against pathogenic and spoilage-forming bacteria and cell structure-activity relationships evaluated by SEM microscopy. *Molecules*, 19,17773-17798.
- Zhang, H., Wu, J. & Guo, X. (2016).** Effects of antimicrobial and antioxidant activities of spice extracts on raw chicken meat quality. *Food Science and Human Wellness*, 5:39-48.