OPEN ACCESS
Journal of Animal Health and Production
Research Article

Improving the Quality and Shelf Life of Rabbit Meat During Chilled Storage using Lemongrass and Black Seed Oils

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Abstract | Rabbit meat is considered to be a significant source of high biological value protein, and has become more popular among consumers in recent years. In this study, antimicrobial and antioxidant effects of lemongrass oil (LGO) at concentrations (0.5, 0.75 and 1%) and black seed oil (BSO) at concentrations (0.1, 0.25 and 0.5%) on the physico-chemical parameters and bacteriological status of rabbit meat was investigated for 12 days of chilling at 3±1°C. The obtained results showed that oil-treated samples indicated significantly lower values (p<0.05) for chemical and bacterial assessment as compared to untreated (control) ones. The mean values of pH (6.21), total volatile basic nitrogen (11.38 mg/100g) and thiobarbituric acid content (0.47 mg MDA/kg) in control group was respectively reduced to (5.74, 4.28 and 0.14 in 1% LGO-treated group) and (5.81, 4.76 and 0.17 in 0.5% BSO-treated group) on 3rd day of chilling. In addition, the enumeration of aerobic plate count (7.82 ± 0.34 log10 CFU/g), *Staphylococcus* (5.32 ± 0.24 log10 CFU/g) and *Enterobacteriaceae* (5.72 ± 0.26 log10 CFU/g) in control group was respectively reduced to (5.92 ± 0.21, 4.46 ± 0.19 and 4.11 ± 0.19 log10 CFU/g in 1% LGO-treated group) and (6.04 ± 0.22, 4.55 ± 0.18 and 4.18 ± 0.27 log10 CFU/g in 0.5% BSO-treated group) on 12th day of chilled storage. Consequently, LGO and BSO could be used as an alternative option to preserve and extend the shelf life of rabbit meat during chilled storage.

Keywords | Rabbit meat, Lemongrass oil (LGO), Black seed oil (BSO), Chemical indices, Bacterial quality, Chilling.

Received | July 21, 2021; **Accepted** | August 08, 2021; **Published** | August 25, 2021
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Citation | Morshdy AM, Al Ashkar AT, Mahmoud AFA (2021). Improving the quality and shelf life of rabbit meat during chilled storage using lemongrass and black seed oils. J. Anim. Health Prod. 9(s1): 56-61.
DOI | http://dx.doi.org/10.17582/journal.jahp/2021/9.s1.56.61
ISSN | 2308-2801

INTRODUCTION

In Egypt, rabbits are traditionally raised in small colonies in backyards by the housewives to improve family income, but in the last few decades, rabbit breeding has become a special source of meat production. Rabbit is considered as ideal meat producing animal for short pregnancy periods, short life cycles and is very productive with a high feed conversion rate. It is characterized by low production costs and less space for breeding. Likewise, the economic benefits for fur production from rabbit skin and the ideal experimental laboratory animals. The integration of rabbit meat into human diet would promote human health as it contains lean meat of high biological value in addition to high levels of unsaturated fat, and low content of cholesterol (Abd-Allah and Abd-Elaziz, 2018).

Rabbit meat may be contaminated with various types of food spoilage and food poisoning bacteria that gain access to carcass from living animals during slaughtering, evisceration and further processing. Rabbit carcasses sold under chilling condition in Egypt with a short shelf life due to bacterial spoilage so that it is economically important for extending their shelf life. Today, the growth of spoilage and pathogenic microorganisms in meat and meat products has many ways to be managed. Essential oils (EOs) are known as aromatic oily extracts derived from special plant parts, such as leaves, wood, flowers, bark, roots, peel or seeds that

exhibit bactericidal or bacteriostatic activities (Burt, 2004). They are regarded as natural preservatives for meat and meat products because of their antimicrobial and antioxidant activities (Mahmoud, 2019).

As an antimicrobial agent, EOs interrupt the bi-layers lipid of cell membranes and inactivate the genetic material of bacteria as well as depress the bacterial enzyme mechanism (Solomakos et al., 2008). EOs demonstrate their effects on pathogenic and spoilage microorganisms, including both gram-negative and gram-positive (Frangos et al., 2010). In addition, EOs contain a high proportion of phenolic compounds that serves as natural antioxidant that can effectively delay oxidative reactions (Sharma et al., 2017). Therefore, the aim of this study was to assess the impact of lemongrass oil (LGO) and black seed oil (BSO) in preserving the physicochemical and bacteriological status of rabbit meat chilled at 3±1˚C for 12 days.

MATERIALS AND METHODS

Sample Collection and Preparation

Six hours after slaughtering 17.5 kg of healthy domestic rabbits' meat (175 loin pieces 100g, for each) were collected. The samples immediately transported in an ice box to the laboratory of the Meat Hygiene, Faculty of Veterinary Medicine, Zagazig University, Egypt. Samples were divided into 7 categories, the first control group (dipped in sterilized distilled water), lemongrass oil (LGO) at three concentrations (0.5, 0.75 and 1%; as groups II, III and IV, respectively) and black seed oil (BSO) at three concentrations (0.1, 0.25 and 0.5%; as groups V, VI and VII, respectively). The pure essential oil obtained by squeezing and extraction of natural oils in the National Research Center, Dokki, Giza, Egypt. The essential oil dissolved in sterile distilled water with the required concentration using tween 80 (emulsifying agent). Immediately after dipping for 15 minutes, the excess solution was drained off and all groups were sampled (zero time). Rabbit meat samples were then individually packed aerobically and refrigerated at 3±1˚C to be periodically examined for physicochemical and bacteriological changes at zero, 3rd, 6th, 9th and 12th days of storage.

Chemical Exminations

The pH was determined according to method described by Pearson (2006). Briefly, 10 g of sample were blended in 10 mL of neutralized distilled water. The homogenate was left at room temperature for 10 min with continuous shaking. The pH value was determined by using an electrical pH meter (Bye model 6020, USA). Total volatile basic nitrogen (TVB-N) content was estimated according to AOAC (1995). The thiobarbituric acid (TBA) content was calculated by the method of Nasr et al. (2017).

Bacteriological Examinations

The preparation of the rabbit meat samples and serial dilutions were performed according to ISO 6887-2 (2003). Briefly 25 g of each rabbit meat sample were homogenized aseptically with mixing in 225 ml of 0.1 % buffered peptone water (BPW, HIMEDIA, M614-500G) in a stomacher (Colworth, 400) for 2.5 min at room temperature (25˚C and then allowed to stand for 5 min to provide a homogenate which represents the dilution of 10^{-1}). Quantity of 1 ml of the homogenate was transferred into a sterile test tube containing 9 ml of 0.1% BPW, then ten folds serial dilutions were prepared up to the required dilution (10^{-9}). Enumeration of aerobic plate count (APC) was done according to ISO 4833-1: (2013) using pour plate method of 1ml onto plate count agar (Oxoid CM325) then incubated at 30^{O} C. However, *Staphylococcus* count was carried out using Baired-Parker agar plates (Oxoid, CM 275) according to ISO, 6888-1: (1999) and enumeration of *Enterobacteriaceae* according to ISO 21528-2 (2004) was conducted on violet red bile glucose ager (VRBG, Himedia). Both medium inoculated by spreading 0.1 ml of the ready prepared serial dilutions onto the agar surface then plates were incubated for 48 h at 37±0.5˚C.

Statistical Analysis

All values of analysis are presented as mean ± standard error (Mean ±SE). All microbial counts were converted to $\log_{10}$ CFU/g values. Statistical differences in chemical and bacteriological data in the control and treated samples and their relation to the storage time were evaluated by analysis of variance (One-way ANOVA) accompanied with Duncan's significant difference test. P-values less than 0.05 were considered statistically significant.

RESULTS

Chemical Examinations

The mean values of pH were slightly decreased in the treated groups than the control group at zero time. On the 12th day of storage, the pH values increased in control group and in all the treated groups but the treated groups had lower pH values than the control group (Table 1). Regarding to TVB-N, there were no significant effects of essential oil at zero time within different concentration. Significant variations (p<0.05) appeared from the 3rd day between all treated group and the control group. The TVB-N values gradually increased with increasing chilling period from the 3rd day. Finally, the TVB-N values were increased in all groups but the control group had the highest values on the 12th day of storage (Table 2). Additionally, thiobarbituric acid at zero time had no significant differences (p>0.05), but significant differences (p<0.05) were found on 6th day of chilling in all treated groups. The higher reduction of TBA values was observed by 1% LGO-treated groups at

Table 1: Changes of pH values of control, LGO and BSO- treated rabbit meat samples during chilling at 3±1°C.

Storage period	Control group	LGO-treated groups			BSO- treated groups		
		0.5% LGO	0.75% LGO	1% LGO	0.1% BSO	0.25% BSO	0.5% BSO
Zero time	5.72 ± 0.57	5.66 ± 0.57	5.63 ± 0.57	5.62 ± 0.57	5.69 ± 0.57	5.67 ± 0.57	5.64 ± 0.57
3rd day	6.21 ± 0.57^{a}	5.85 ± 0.57^{ab}	5.77 ± 0.57^{b}	5.74 ± 0.57^{b}	5.93 ± 0.57^{ab}	5.86 ± 0.57^{ab}	5.81 ± 0.57^{b}
6th day	6.54 ± 0.57^{a}	6.01 ± 0.57^{b}	5.92 ± 0.57^{b}	5.8 ± 0.57^{c}	6.13 ± 0.57^{b}	6.04 ± 0.57^{b}	5.97 ± 0.57^{b}
9th day	7.18 ± 0.57^{a}	6.22 ± 0.57^{b}	6.10 ± 0.57^{b}	5.96 ± 0.57^{c}	6.37 ± 0.57^{b}	6.25 ± 0.57^{b}	6.14 ± 0.57^{bc}
12th day	7.48 ± 0.57^{a}	6.41 ± 0.57^{b}	6.25 ± 0.57^{b}	6.12 ± 0.57^{c}	6.58 ± 0.57^{b}	6.44 ± 0.57^{b}	6.27 ± 0.57^{c}

$^{(a,b,c)}$ different superscript letters in the same rows indicate significant differences ($p < 0.05$).
LGO= Lemongrass oil
BSO= Black seed oil

Table 2: Changes of total volatile nitrogen (TVB-N mg/100g) content of control, LGO and BSO- treated samples during chilling at 3±1°C.

Storage period	Control group	LGO-treated groups			BSO- treated groups		
		0.5% LGO	0.75% LGO	1% LGO	0.1% BSO	0.25% BSO	0.5% BSO
Zero time	2.84 ± 0.57	2.69 ± 0.57	2.63 ± 0.57	2.55 ± 0.57	2.73 ± 0.57	2.68 ± 0.57	2.60 ± 0.57
3rd day	11.38 ± 0.57^{a}	5.04 ± 0.57^{ab}	4.49 ± 0.57^{b}	4.28 ± 0.57^{b}	6.13 ± 0.57^{ab}	5.45 ± 0.57^{ab}	4.76 ± 0.57^{b}
6th day	19.36 ± 0.57^{a}	10.19 ± 0.57^{b}	8.83 ± 0.57^{b}	7.61 ± 0.57^{c}	12.48 ± 0.57^{b}	10.78 ± 0.57^{b}	10.05 ± 0.57^{b}
9th day	27.26 ± 0.57^{a}	16.30 ± 0.57^{b}	13.58 ± 0.57^{b}	11.79 ± 0.57^{c}	19.21 ± 0.57^{b}	17.4 ± 0.57^{b}	16.27 ± 0.57^{bc}
12th day	36.21 ± 0.57^{a}	20.11 ± 0.57^{b}	18.34 ± 0.57$^{=b}$	17.06 ± 0.57^{b}	23.95 ± 0.57^{b}	22.1 ± 0.57^{b}	18.87 ± 0.57^{b}

$^{(a,b,c)}$ different superscript letters in the same rows indicate significant differences ($p < 0.05$).
LGO= Lemongrass oil
BSO= Black seed oil

Table 3: Changes of thiobarbituric acid (TBA mg MDA/Kg) content of control, LGO and BSO- treated samples during chilling at 3±1°C.

Storage period	Control group	LGO-treated groups			BSO- treated groups		
		0.5% LGO	0.75% LGO	1% LGO	0.1% BSO	0.25% BSO	0.5% BSO
Zero time	0.05 ± 0.0057	0.05 ± 0.0057	0.04 ± 0.0057	0.04±0.0057	0.05 ± 0.0057	0.05 ± 0.0057	0.04 ± 0.0057
3rd day	0.47 ± 0.0057^{a}	0.22 ± 0.0057^{ab}	0.19 ± 0.0057^{b}	0.14±0.0057^{b}	0.30 ± 0.057^{ab}	0.23± 0.0057^{ab}	0.17 ± 0.0057^{b}
6th day	1.02 ± 0.0057^{a}	0.46 ± 0.0057^{b}	0.37 ± 0.0057^{b}	0.29±0.0057^{c}	0.58 ± 0.0057^{b}	0.50 ± 0.0057^{b}	0.43 ± 0.0057^{b}
9th day	1.13 ± 0.0057^{a}	0.75 ± 0.0057^{b}	0.62± 0.0057^{b}	0.46±0.0057^{c}	0.87 ± 0.0057^{b}	0.81 ± 0.0057^{b}	0.70 ± 0.0057^{b}
12th day	1.34 ± 0.0057^{a}	0.92 ± 0.0057^{b}	0.83± 0.0057^{b}	0.77±0.0088^{b}	1.05 ± 0.0057^{b}	0.99 ± 0.0057^{b}	0.88± 0.0057^{b}

$^{(a,b,c)}$ different superscript letters in the same rows indicate significant differences ($p < 0.05$).
LGO= Lemongrass oil
BSO= Black seed oil

zero-time, 3rd ,6th, 9th and 12th day of chilling (Table 3).

Bacteriological Investigations

The APC was progressively increased by increasing the storage period. As shown in Table 4, significant differences ($p< 0.05$) in treated groups with higher concentration of added essential oils. The APC counts reached 7.82 ± 0.34, 6.48 ± 0.21, 6.24 ± 0.23, 5.92 ± 0.21, 6.38 ± 0.25, 6.34 ± 0.25 and 6.04 ± 0.22 $\log_{10}$CFU/g in control, 0.5% LGO, 0.75% LGO, 1% LGO, 0.1%BSO, 0.25% BSO and 0.5% BSO, respectively on the 12th day of chilling. Concerning the *Staphylococcus* count, there were no significant differences among oil-treated groups at various concentrations and control one at zero time. *Staphylococcus* count in all groups was gradually increased to 4.72 ± 0.19, 5.32 ± 0.24, 4.95 ± 0.16, 4.67 ± 0.22, 4.46 ± 0.19, 4.97 ± 0.21 and 4.55 ± 0.18 $\log_{10}$ CFU/g in control, LGO 0.5%, LGO 0.75, LGO 1%, BSO 0.1, BSO 0.25% and BSO 0.5%, respectively on the 12th day of storage (Table 5). However, *Enterobacteriaceae* counts were slightly decreased from 3.25 ± 0.22 in control group to 3.23 ± 0.23, 3.20 ± 0.24, 3.04 ± 0.23, 3.21 ± 0.26, 3.14 ± 0.25 and 3.11 ± 0.23 $\log_{10}$ CFU/g at zero time in 0.5% LGO, 0.75% LGO, 1% LGO, 0.1%BSO, 0.25% BSO and 0.5% BSO, respectively. The counts were increased in all treated groups but the counts still below the control group on 12th day. The best reduction counts achieved for *Enterobacteriaceae* count was at concentration of 1% LGO and 0.5% BSO (Table 6).

Table 4: Changes of aerobic plate counts (log_{10}CFU/g) of control, LGO and BSO- treated samples during chilling at 3±1°C.

Storage period	Control group	LGO-treated groups			BSO- treated groups		
		0.5% LGO	0.75% LGO	1% LGO	0.1% BSO	0.25% BSO	0.5% BSO
Zero time	6.07 ± 0.25^{a}	5.58 ± 0.22^{ab}	5.25 ± 0.23^{b}	5.09 ± 0.24^{b}	5.44± 0.23^{a}	5.32 ± 0.22^{b}	5.20 ± 0.23^{b}
3rd day	6.57 ± 0.27^{a}	5.63 ± 0.21^{b}	5.39 ± 0.21^{b}	5.13 ± 0.21^{c}	5.59 ± 0.24^{b}	5.48± 0.24^{b}	5.21 ± 0.24^{c}
6th day	6.94 ± 0.31^{a}	6.02 ± 0.23^{b}	5.52 ± 0.24^{b}	5.33 ± 0.23^{c}	5.92± 0.23^{b}	5.64 ± 0.23^{b}	5.41 ± 0.25^{c}
9th day	7.18 ± 0.33^{a}	6.13 ± 0.25^{b}	5.84 ± 0.22^{c}	5.53 ± 0.24^{d}	6.12 ± 0.21^{b}	5.94 ± 0.21^{bc}	5.65 ± 0.23^{c}
12th day	7.82 ± 0.34^{a}	6.48 ± 0.21^{b}	6.24 ± 0.23^{b}	5.92 ± 0.21^{c}	6.38 ± 0.25^{b}	6.34 ± 0.25^{b}	6.04 ± 0.22^{bc}

$^{(a,b,c)}$ different superscript letters in the same rows indicate significant differences ($p < 0.05$).
LGO= Lemongrass oil
BSO= Black seed oil

Table 5: Changes of *Staphylococcus* count (log_{10}CFU/g) of control, LGO and BSO- treated samples during chilling at 3±1°C.

Storage period	Control group	LGO-treated groups			BSO- treated groups		
		0.5% LGO	0.75% LGO	1% LGO	0.1% BSO	0.25% BSO	0.5% BSO
Zero time	4.13 ± 0.18	3.99 ± 0.19	3.96 ± 0.16	3.93 ± 0.21	4.04± 0.20	4.00 ± 0.21	3.94 ± 0.19
3rd day	4.85 ± 0.21^{a}	4.13 ± 0.21^{a}	4.05± 0.19^{ab}	3.95 ± 0.20^{b}	4.22 ± 0.21^{a}	4.11± 0.20^{ab}	4.09 ± 0.21^{ab}
6th day	4.93 ± 0.19^{a}	4.26 ± 0.22^{ab}	4.18 ± 0.21^{ab}	4.07 ± 0.18^{b}	4.31± 0.20^{ab}	4.25 ± 0.19^{ab}	4.11 ± 0.17^{b}
9th day	5.21 ± 0.21^{a}	4.55 ± 0.21^{b}	4.38 ± 0.17^{b}	4.31 ± 0.21^{b}	4.62 ± 0.19^{ab}	4.53 ± 0.21^{b}	4.35 ± 0.19^{b}
12th day	5.32 ± 0.24^{a}	4.95 ± 0.16^{ab}	4.67 ± 0.22^{b}	4.46 ± 0.19^{b}	4.97 ± 0.21^{ab}	4.72 ± 0.19^{b}	4.55 ± 0.18^{b}

$^{(a,b,c)}$ different superscript letters in the same rows indicate significant differences ($p < 0.05$).
LGO= Lemongrass oil
BSO= Black seed oil

Table 6: Changes of total *Enterobacteriaceae* count (log_{10}CFU/g) of control, LGO and BSO- treated samples during chilling at 3±1°C.

Storage period	Control group	LGO-treated groups			BSO- treated groups		
		0.5% LGO	0.75% LGO	1% LGO	0.1% BSO	0.25% BSO	0.5% BSO
Zero time	3.25 ± 0.22	3.23 ± 0.23	3.20 ± 0.24	3.04 ± 0.23	3.21± 0.26	3.14 ± 0.25	3.11 ± 0.23
3rd day	4.63 ± 0.24^{a}	4.56 ± 0.25^{a}	4.49 ± 0.22^{ab}	3.41 ± 0.20^{b}	4.51 ± 0.24^{a}	4.53± 0.23^{a}	3.64 ± 0.22^{b}
6th day	4.96 ± 0.22^{a}	4.67 ± 0.24^{a}	4.64 ± 0.23^{ab}	3.55 ± 0.18^{b}	4.72± 0.23^{a}	4.68 ± 0.23^{a}	3.78 ± 0.24^{b}
9th day	5.32 ± 0.27^{a}	4.81 ± 0.27^{ab}	4.85± 0.22^{b}	3.88 ± 0.21^{c}	4.89 ± 0.22^{ab}	4.75 ± 0.24^{b}	3.96 ± 0.22^{c}
12th day	5.72 ± 0.26^{a}	4.92 ± 0.23^{b}	4.89 ± 0.22^{b}	4.11 ± 0.19^{c}	4.97 ± 0.21^{b}	4.91 ± 0.22^{b}	4.18 ± 0.27^{bc}

$^{(a,b,c)}$ different superscript letters in the same rows indicate significant differences ($p < 0.05$).
LGO= Lemongrass oil
BSO= Black seed oil

DISSCUSSION

Physicochemical Changes During Chilled Storage

Acidic pH possesses a bacteriostatic power while alkaline pH promotes microbial growth. The results in table (1) declared that mean value of pH at zero day ranged from 5.72 ± 0.57 in control to 5.62 ± 0.57 in LGO 1%. Similarly, pH values of (5.81 and 5.98) were obtained respectively by Dal Bosco et al. (2014) in Hungary, and by Rodriguez-Calleja et al. (2004) in Spain. Lower pH value (5.53) was reported in Greece (Simitzis et al., 2014). Meanwhile, higher values of 6.34 were obtained in Italy by Palazzo et al. (2015). Significant differences between control group and treated groups were observed by increasing the storage period. The control group had the highest pH value which may be due to increase of Gram negative bacteria populations such as *Enterobacteriaceae*, which cause protein and amino acid degradation resulting in formation of ammonia as the end product of amino acid decomposition and consequent pH increase (Valencia et al., 2008).

TVB-N is commonly used as an index for estimating the spoilage rate and shelf life of different kinds of meat. The results in table (2) revealed that the control group signif-

icantly had a higher level of TVB-N on 9th and 12th day (p< 0.05) than LGO and BSO-treated groups assuming that the LGO and BSO inhibited the microbial activity in chilled rabbit meat. Similar TVBN value of chilled rabbit meat of 23.4 mg/100 g was recorded over 10 days of storage (Lan et al., 2016). All treated groups were in the range of permissible level mentioned by Egyptian standards (ES, 2005) which not exceed 20 mg /100g. Meanwhile, the control group exceeded the permissible limit due to rapid growth rate of spoilage bacteria which led to degradation of protein with formation of free amines, trimethylamine, dimethylamine and ammonia (Rukchon et al., 2011). Our results were in accordance with Salem et al. (2010) who found that 1.5% LGO distinctly lowered TVB-N values in minced meat, in addition to Ozpolat and Duman (2017) who recorded that treatment of fish fillet with 0.6% BSO could retard TVB-N formation.

Thiobarbituric acid (TBA) is generally used in assessment of lipid oxidation. Our data showed that the mean value of TBA ranged from 0.04 ± 0.0057 in 1% LGO-treated group to 0.05 ± 0.0057 mg MDA/kg in control group. Nearly similar findings of 0.09 mg MDA/kg were obtained in Italy by Dal Bosco et al. (2014). Higher values of 2.16 mg MDA/kg were reported in Canada by Koné et al. (2016). On the 3rd day of chilling TBA values among treatments followed similar increasing trends with storage period, but values were all less than 0.9 mg MDA/kg. On the 9th and 12th day of storage the TBA sharply increased in control group exceeding the Egyptian standards (ES, 2005) which established that 0.9 mg MDA/kg considered as the maximum permissible limit. The obtained results were coincided with Salem et al. (2010) who proved the effectiveness of essential oils in retarding lipid oxidation in minced beef. These findings suggest that LGO and BSO could be used as natural preservatives with remarkable antioxidant activities that delayed lipid oxidation during storage.

Bacteriological Assessment of Control and Treated Samples

The results of current study revealed that APC was dramatically increased under chilling condition, but the higher rate belonged to the control group on the 12th day of chilling. The comparatively higher APC of control samples can be due to inadequate hygienic measures adopted in slaughtering and evisceration. However, the higher concentration of LGO (1%) or BSO (0.5%) significantly reduced APC count. The effect of LGO on APC count is nearly similar to that of Salem et al. (2010) who found LGO reduce APC in minced meat, as well as Ozpolat and Duman (2017) who observed a substantial reduction in APC after addition of BSO to fish fillet.

Our current investigation revealed that *Staphylococcus* count increased by time elapsing and higher counts belonged to control group. There were significant variances in oil treated groups especially at concentration 1% LGO and 0.5% BSO. The effectiveness of BSO against Gram-positive *Staphylococcus* previously described by Bakathir and Abbas (2011). Furthermore, the activity of LGO against Staphylococci was reported by Elizabeth et al. (2019).

The counts of *Enterobacteriaceae* recorded in table 6 increased over the storage period and higher counts belonged to control group. Similar *Enterobacteriaceae* count (4.886 $\log_{10}$CFU/g) was obtained in Egypt by Badr (2004). All treated groups were significantly lower than control group due to the influence of essential oils. The LGO proved a good activity against *Enterobacteriaceae* isolated from environmental, and food samples (Singh et al., 2011). Also, Ishtiaq et al. (2013) have reported the significant impact of BSO on in vitro-derived *Enterobacteriaceae* members.

The antibacterial activity of LGO due to presence of geraniol and citral known to be main active components (Friedman et al., 2004). The antibacterial activity of BSO could also be attributed to active ingredients, particularly thymoquinone and melanin (Bakathir and Abbas, 2011). Theses active ingredients tend to involve cell membrane destruction accompanied by bacterial cell death.

CONCLUSION

The findings of this study indicated that Lemongrass and black seed oils could maintain the quality of rabbit meat under refrigerated storage for 12 days. The physicochemical parameters, in particular TVB-N and TBA, and the results of the bacteriological assessment collectively demonstrate the significant potential of BSO and LGO to extend the shelf life of refrigerated meat. Therefore, 1% LGO and 0.5% BSO may be used commercially in order to enhance preservation of rabbit meat and to prolong its' shelf life without using of harmful synthetic chemical additives.

CONFLICT OF INTEREST

None of the authors has any conflict of interest to declare.

AUTHOR CONTRIBUTION

All authors contributed equally.

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