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 ± 0.27 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.

**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., 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., 2010). 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 Examinations
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).

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 ºC.

| 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 ± 0.57a  | 5.85 ± 0.57b | 5.77 ± 0.57b | 5.74 ± 0.57b | 5.93 ± 0.57b | 5.86 ± 0.57b | 5.81 ± 0.57b |
| 6th day        | 6.54 ± 0.57a  | 6.01 ± 0.57a | 5.92 ± 0.57a | 5.8 ± 0.57a  | 6.13 ± 0.57b | 6.04 ± 0.57b | 5.97 ± 0.57b |
| 9th day        | 7.18 ± 0.57a  | 6.22 ± 0.57a | 6.10 ± 0.57a | 5.96 ± 0.57a | 6.37 ± 0.57a | 6.25 ± 0.57a | 6.14 ± 0.57a |
| 12th day       | 7.48 ± 0.57a  | 6.41 ± 0.57b | 6.25 ± 0.57b | 6.12 ± 0.57b | 6.58 ± 0.57b | 6.44 ± 0.57b | 6.27 ± 0.57c |

(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±1ºC.

| 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 ± 0.57a | 10.19 ± 0.57a | 8.83 ± 0.57a | 7.61 ± 0.57a | 12.48 ± 0.57a | 10.78 ± 0.57a | 10.05 ± 0.57a |
| 6th day        | 19.36 ± 0.57a | 16.30 ± 0.57a | 13.58 ± 0.57a | 11.79 ± 0.57a | 19.21 ± 0.57a | 17.4 ± 0.57a  | 16.27 ± 0.57a |
| 9th day        | 27.26 ± 0.57a | 20.11 ± 0.57a | 18.34 ± 0.57a | 17.06 ± 0.57a | 23.95 ± 0.57a | 22.1 ± 0.57a  | 18.87 ± 0.57a |
| 12th day       | 36.21 ± 0.57a | 20.11 ± 0.57a | 18.34 ± 0.57a | 17.06 ± 0.57a | 23.95 ± 0.57a | 22.1 ± 0.57a  | 18.87 ± 0.57a |

(a,b,c) different superscript letters in the same rows indicate significant differences (p < 0.05).

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

| 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 ± 0.0057a | 0.22 ± 0.0057b | 0.19 ± 0.0057b | 0.14±0.0057b | 0.17 ± 0.0057b | 0.17 ± 0.0057b | 0.17 ± 0.0057b |
| 6th day        | 1.02 ± 0.0057a | 0.46 ± 0.0057a | 0.37 ± 0.0057a | 0.29±0.0057a | 0.58 ± 0.0057a | 0.50 ± 0.0057a | 0.43 ± 0.0057a |
| 9th day        | 1.13 ± 0.0057a | 0.75 ± 0.0057b | 0.62 ± 0.0057b | 0.46±0.0057b | 0.87 ± 0.0057b | 0.81 ± 0.0057b | 0.70 ± 0.0057b |
| 12th day       | 1.34 ± 0.0057a | 0.92 ± 0.0057a | 0.83 ± 0.0057a | 0.77±0.0088b | 1.05 ± 0.0057b | 0.99 ± 0.0057b | 0.88±0.0057b |

(a,b,c) different superscript letters in the same rows indicate significant differences (p < 0.05).

LGO= Lemongrass oil
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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$^c$ | 5.32 ± 0.22$^c$ | 5.20 ± 0.23$^c$ |
| 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$^c$ | 5.48± 0.24$^c$ | 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$^c$ | 5.64 ± 0.23$^c$ | 5.41 ± 0.25$^c$ |
| 9th day        | 7.18 ± 0.33$^c$ | 6.13 ± 0.25$^b$ | 5.84 ± 0.22$^b$ | 5.53 ± 0.24$^d$ | 6.12 ± 0.21$^d$ | 5.94 ± 0.21$^bc$ | 5.65 ± 0.23$^c$ |
| 12th day       | 7.82 ± 0.34$^c$ | 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$^b$ |

(a,b,c) different superscript letters in the same rows indicate significant differences ($p<0.05$).

LGO= Lemongrass oil
BSO= Black seed oil

Table 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$^a$ | 3.99 ± 0.19$^a$ | 3.96 ± 0.16$^a$ | 3.93 ± 0.21$^a$ | 4.04± 0.20$^a$ | 4.00 ± 0.21$^a$ | 3.94 ± 0.19$^a$ |
| 3rd day        | 4.85 ± 0.21$^a$ | 4.13 ± 0.21$^a$ | 4.05± 0.19$^{ab}$ | 3.95 ± 0.20$^a$ | 4.22± 0.21$^a$ | 4.11± 0.20$^b$ | 4.09 ± 0.21$^b$ |
| 6th day        | 4.93 ± 0.19$^a$ | 4.26 ± 0.22$^{ab}$ | 4.18 ± 0.21$^b$ | 4.07 ± 0.18$^b$ | 4.31± 0.20$^b$ | 4.25 ± 0.19$^b$ | 4.11 ± 0.17$^b$ |
| 9th day        | 5.21 ± 0.21$^a$ | 4.55 ± 0.21$^a$ | 4.38 ± 0.17$^a$ | 4.31 ± 0.21$^b$ | 4.62 ± 0.19$^b$ | 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$^b$ | 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$^a$ | 3.23 ± 0.23$^a$ | 3.20 ± 0.24$^a$ | 3.04 ± 0.23$^a$ | 3.21± 0.26$^a$ | 3.14 ± 0.25$^a$ | 3.11 ± 0.23$^a$ |
| 3rd day        | 4.63 ± 0.24$^a$ | 4.56 ± 0.25$^a$ | 4.49 ± 0.22$^b$ | 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$^b$ | 3.55 ± 0.18$^b$ | 4.72± 0.23$^a$ | 4.68 ± 0.23$^a$ | 3.78 ± 0.24$^a$ |
| 9th day        | 5.32 ± 0.27$^a$ | 4.81 ± 0.27$^a$ | 4.85± 0.22$^b$ | 3.88 ± 0.21$^c$ | 4.89 ± 0.22$^b$ | 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 miniced 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 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). 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 log10 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.

REFERENCES

• Abd-Allah SMS, Abd-Elaziz DM (2018). Nutritional value and quality profile of fresh rabbit meat in Assiut city, Egypt. Int. J. Res. Agric. Food Sci. 4: 1-15.
• AOAC (1995). Method 991.42 and 993.19. Official methods of analysis (16th ed.). Washington, DC: Association of Official
Kone APN, Cinq-Mars D, Desjardins Y, Guay F, Gosselin Bakathir HA, Abbas NA (2011). Detection of the antibacterial
Burt S (2004). Essential oils: their antibacterial properties
Egyptian Standard (ES) (2005). Standards of poultry meat
Elizabeth Babatunde D, Otusemade GO, Elizabeth O, Agboola
Frangos L, Pyrgotou N, Giatrakou V, Ntzimani A, Savvaidis IN
Friedman M, Henika PR, Levin CE, Mandrell RE (2004).
Ishtiaq S, Ashraf M, Hayat MQ, Asrar M (2013). Phytochemical
ISO 21528-2 (2004). Microbiology of food and animal
O, Oyeniyi E, Deborah AK (2019). Antimicrobial activity
M, Kovàcs M, Dalle Zotte A (2014). Effect of dietary
Ozpolat E, Duman M (2017). Effect of black cumin oil (Artemisia absinthium) on the quality and shelf life of rabbit meat. Meat Sci. 117: 173-181. https://doi.org/10.1016/j.meatsci.2016.02.017
Mahmoud AF (2019). Effect of Lettuce, Marjoram and Cumin Essential Oils on the Quality and Shelf Life of Minced Meat during Refrigerated Storage. Zagazig Vet. J. 47(3): 288–297. https://doi.org/10.21608/zvjz.2019.13680.1047
Nasr MA, Abdl-Ehhamid T, Hussein MA (2017). Growth performance, carcass characteristics, meat quality and muscle amino-acid profile of different rabbits breeds and their crosses. Meat Sci. 134:150-157. https://doi.org/10.1016/j.meatsci.2017.07.027
Opzolat E, Duman M (2017). Effect of black cumin oil (Nigella sativa L.) on fresh fish (Barbus grypus) fillets during storage at 2±1 °C. Food Sci. Techno. 37(1): 148–152. https://doi.org/10.1590/1678-457x.09S16
Palazzo M, Vizzari F, Nardoia M, Ratti S, Pastorelli G, Casamassima D (2015). Dietary Lippia citriodora extract in rabbit feeding: effects on quality of carcass and meat. Arch. Anim. Breed. 58(2): 355-364. https://doi.org/10.15194/aab-58-358-2015
Pearson D (2006). Chemical Analysis of Foods. 11th Ed, Publishing Co., Churchill Livingstone, Edinburgh, London, United Kingdom.
Rodriguez-Calleja JM, Santos JA, Otero A, Garcia-Lopez ML (2004). Microbiological quality of rabbit meat. J. Food Prot. 67 (5): 966-971. https://doi.org/10.4315/0362-028X-67.5.966
Rukchon CH, Trevanich S, Jinkarn T, Suppakul P (2011). Volatile compounds as quality indicators of fresh chicken and possible application in intelligent packaging. In 12th Asian Food Science Conference, Bangkok, Thailand, pp: 287-294.
Salem-Any M, Amin-Reham A, Affif-Gehan SA (2010). Studies on Antimicrobial and Antioxidant Efficiency of Some Essential Oils in Minced Beef. J. Am. Sci. 6: 691-700.
Sharma H, Mendiratta SK, Agrawal RK, Kumar S, Soni A (2017). Evaluation of anti-oxidant and anti-microbial activity of various essential oils in fresh chicken sausages. J. Food Sci. Technol. 54(2): 279-292. https://doi.org/10.1007/s13197-016-2461-1
Simitzis PE, Babaliaris C, Charisiadou MA, Papadomichelakis G, Golomytitis M, Symeon GK, Deligeorgis SG (2014). Effect of hesperidin dietary supplementation on growth performance, carcass traits and meat quality of rabbits. World Rabbit Sci. 22(2): 113–121. https://doi.org/10.4995/wrs.2014.1760
Singh BR, Singh V, Singh RK, Eibiben N (2011). Antimicrobial activity of lemon grass (Cymbopogon citratus) oil against microbes of environmental, clinical and food origin. Int. Res. J. Pharm. Pharmacol. 1 (9):228-236.
Solomakos N, Govaris A, Koidis P, Botsoglou N (2008). The antimicrobial effect of thyme essential oil, nisin and their combination against Escherichia coli O157:H7 in minced beef during refrigerated storage. Meat Sci. 80(2):159-166. https://doi.org/10.1016/j.meatsci.2007.11.014
Valencia I, Oandapos Grady MN, Ansorena D, Astiasarain I, Kerry JP (2008). Enhancement of the nutritional status and quality of fresh pork sausages following the addition of linseed oil, fish oil and natural antioxidants. Meat Sci. 80(4):1046-1054. https://doi.org/10.1016/j.meatsci.2008.04.024

• Badr HM (2004). Use of irradiation to control foodborne pathogens and extend the refrigerated market life of rabbit meat. Meat Sci. 67(4): 541-548. https://doi.org/10.1016/j.meatsci.2003.11.018
• Bakathir HA, Abbas NA (2011). Detection of the antibacterial effect of Nigella sativa ground seeds with water. African J. Tradit. Complement. Altern. Med. 8: 159-164. https://doi.org/10.4314/ajtcam.v8i2.63203
• Burt S (2004). Essential oils: their antibacterial properties and potential applications in foods—a review. Int. J. Food Microbiol. 94(3): 223-253. https://doi.org/10.1016/j.ijfoodmicro.2004.03.022
• Dal Bosco A, Gerencsér Z, Szendrő Z, Mughni C, Cullere M, Kowács M, Dalle Zotte A (2014). Effect of dietary supplementation of Spirulina (Arthrospira platensis) and Thyme (Thymus vulgaris) on rabbit meat appearance, oxidative stability and fatty acid profile during retail display. Meat Sci. 96(1): 114–119. https://doi.org/10.1016/j.meatsci.2013.06.021.
• Egyptian Standard (ES) (2005). Standards of poultry meat products, Ministry of industry, No 1090/2005. Cairo, Egypt. For frozen poultry and rabbit.
• Elizabeth Babatunde D, Otusemade GO, Elizabeth O, Agboola O, Oyeniyi E, Deborah AK (2019). Antimicrobial activity and phytochemical screening of neem leaves and lemon grass essential oil extracts. Int. J. Mech. Eng. Technol. 10(3): 882–889.
• Frangos L, Pyrgotou N, Giatrakou V, Ntzimani A, Savvaidis IN (2010). Combined effects of salting, organo oil and vacuum packaging on the shelf-life of refrigerated trout fillets. Food Microbiol. 27(1): 115–121. https://doi.org/10.1016/j.fm.2009.09.002
• Friedman M, Henika PR, Levin CE, Mandrell RE (2004). Antibacterial activities of plant essential oils and their components against Escherichia coli O157:H7 and Salmonella enterica in apple juice. J. Agric. Food Chem. 52: 6042–6048. https://doi.org/10.1021/jf0495340
• Ishraq S, Ashraf M, Hayat MQ, Asrar M, (2013). Phytochemical analysis of Nigella sativa and its antibacterial activity against clinical isolates identified by ribotyping. Int. J. Agric. Biol. 15(6): 1151-1156.
• ISO 6888-1:1999. Microbiology of food and animal feeding stuffs - Horizontal method for the enumeration of coagulase-positive Staphylococci (Staphylococcus aureus and other species) - Part 1: Technique using Baird-Parker agar medium.
• ISO 6887-2 (2003). Microbiology of food and animal feeding stuffs - Preparation of test samples, initial suspension and decimal dilutions for microbiological examination - Part 1-3: Specific rules f or the preparation of meat and meat products.
• ISO 21528-2 (2004). Microbiology of food and animal feeding stuffs. Horizontal method for the detection and enumeration of Enterobacteriaceae, part 2: colony count method. Enumeration. EN ISO, Geneva.
• ISO 4833-1 (2013). Microbiology of the food chain - Horizontal method for the enumeration of microorganisms - Part 1: Colony count at 30C by the plate pour technique.
• Kone APN, Cinq-Mars D, Desjardins Y, Guay F, Gosselin A, Sauder L (2016). Effects of plant extracts and essential oils as feed supplements on quality and microbial traits of rabbit meat. World Rabbit Sci. 24: 107-111. https://doi.org/10.4995/wrs.2016.3665