EFFECTS OF LYOPHILIZED WATER EXTRACT OF *SATUREJA HORTENSIS* ON THE SHELF LIFE AND QUALITY PROPERTIES OF GROUND BEEF

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ABSTRACT

Summer savory (*Satureja hortensis* L.) can be used for the preservation and/or extension of the shelf life of raw and processed foods owing to its antioxidant and antimicrobial activities. In this study, the effects of different concentrations of lyophilized water extract of *S. hortensis* (LSHWE) on the shelf life of ground beef were investigated. Ground beef was treated with various concentrations of LSHWE (i.e., 0, 100, 250 and 500 ppm) and stored at 4 ± 0.5C for 72 h. LSHWE concentrations had statistically significant effects on the microbial counts. In ground beef samples treated with LSHWE, mesophilic, psychrotrophic, *Pseudomonas* and Enterobacteriaceae decreased. Different LSHWE concentrations had also significant effects on pH. Lipid oxidation decreased, depending on LSHWE concentrations, and 500 ppm of LSHWE gave the lowest thiobarbituric acid reactive substance values, with 11.57 ± 4.07 μmol malonaldehyde/kg at the end of storage. LSHWE levels had also significant effects on color values (L^*, a^* and b^*) of the ground beef.

PRACTICAL APPLICATIONS

The consumption of ground beef is popular worldwide, but ground beef is more susceptible to lipolytic reactions and to microbial spoilage because of its larger surface area compared with other fresh meat products. These can lead to a shorter shelf life with potential risks for human health during storage at low temperature. The counts of spoilage bacteria such as *Pseudomonas* and psychrotrophic in the ground beef can be suppressed, and lipid oxidation can be decreased using natural antimicrobial and antioxidant agents. Our study has clearly shown that preservation of ground beef using lyophilized *Satureja hortensis* L. water extract leads to shelf life longer than that of normal ground beef during storage at 4 ± 0.5C for 72 h.

INTRODUCTION

Summer savory (*Satureja hortensis* L.) is a herbaceous plant belonging to the family Lamiaceae, which is used as a condiment and is utilized to treat infectious diseases in traditional folk medicine (Dorman and Hiltunen 2004). It is distributed in the warmer regions of both hemispheres and cultivated in France, Germany, Spain, Yugoslavia, Albania, Great Britain, Canada, North Africa and the U.S.A. (Ravindran and Pillai 2004; Raghavan 2007).

The herb has a thyme-like flavor (Ravindran and Pillai 2004). Its leaves, flowers and stems are used as tea or food additive because of its aroma and flavor. *S. hortensis* possesses a broad spectrum of biological activities, including antispasmodic, antidiarrheal, antinociceptive, anti-inflammatory, antioxidant, and antimicrobial properties (Hajhashemi *et al.* 2000, 2002; Gulluce *et al.* 2003; Dorman and Hiltunen 2004). There are many reports on the composition of essential oil of *S. hortensis* L. from different parts of the world (Ghannadi *et al.* 2000; Hajhashemi

et al. 2000). Summer savory oil is described as light yellow to dark brown liquid and comprises carvacrol, *p*-cymene, pinene, dipentane, thymol, terpinene, ursolic acid, etheral oil, phenolic substances, resins, tannins and mucilage (Prakash 1990; Karnick 1994; Gulluce *et al*. 2003; Adiguzel *et al*. 2007).

Ground beef is an easily spoiled meat product and thus leads to a shorter shelf life with potential risks for human health. Therefore, by adding antimicrobial and antioxidant agent into ground beef, it is possible to extend its shelf life (Morrissey *et al*. 1998; McMillin 2008; Alp and Aksu 2010).

Spices and herbs are used in foods to impart flavor, pungency and color, and also have antioxidant, antimicrobial, pharmaceutical and nutritional properties (Gulluce *et al*. 2003; Ozer *et al*. 2006; Adiguzel *et al*. 2007). Indeed, some plant extracts have been shown to prolong the shelf life of meat and meat products (Aksu 2003; Aksu and Kaya 2004; Alp and Aksu 2010). In this context, *S. hortensis* can serve as a good source of natural antioxidants and antimicrobials (Madsen *et al*. 1998; Kosar *et al*. 2003; Dorman and Hiltunen 2004; Dorman *et al*. 2004). Madsen *et al*. (1996) also pointed out that *S. hortensis* improved the oxidative stability of meat balls. Similarly, Gulluce *et al*. (2003) determined that *S. hortensis* extracts have a protective effect against lipid oxidation and undesirable microorganisms and can therefore be used as antimicrobial and antioxidant agents in food industry and to extend of the shelf life of raw and processed foods. To date, no research regarding the effect of lyophilized *S. hortensis* water extract (LSHWE) on the lipid oxidation, color properties and microbiological quality of ground beef during storage has been published. Therefore, the present study was conducted to determine the effect of the concentrations of 0, 100, 250 and 500 ppm of LSHWE during different storage periods (0, 24, 48 and 72 h) on the total aerobic mesophilic, psychrotrophic, *Pseudomonas* and Enterobacteriaceae counts, thiobarbituric acid reactive substance (TBARS), and L^*, a^* and b^* values of ground beef at 4 ± 0.5C.

MATERIALS AND METHODS

Materials

Beef from carcasses (EBK Slaughterhouse, Erzurum, Turkey) was ground through a 3-mm-diameter mincer under hygienic conditions and then transported, under refrigeration, to the laboratory, where it was kept at 4C for 1 h until use.

Preparation of the LSHWE

S. hortensis leaves were dried for 3 days at 30–35C until the maximum moisture level was 1–2%, then ground and sifted through a 14-in. sieve. A 20 g of the material was added to 400 mL of boiling water and mixed by a magnetic stirrer. After filtering over (Whatman No. 1, Cat. No. 100 1125, Whatman International, Ltd., Maidstone, U.K.), it was frozen at −38C and lyophilized at −50C (Aksu 2003; Alp and Aksu 2010).

Preparation the Ground Beef Samples, Addition of the LSHWE and Storage

For each experiment, 6.4 kg of ground beef was used, which was divided into four groups for each treatment. The first group of samples (8 lots of 200 g) were placed into the packaging material and then stored as aerobic control. For the second group of samples, 100 ppm LSHWE (8 lots of 200 g) was added and then was aerobically packaged. For the third group of samples, 250 ppm LSHWE (8 lots of 200 g) was added and then was aerobically packaged. The fourth group (8 lots of 200 g) was prepared with 500 ppm LSHWE and then was aerobically packaged. Aerobic packaging for all groups was carried out by wrapping with single stretched film material put in polystyrene trays. All samples were stored in the dark at 4 ± 0.5C for 72 h.

Analysis

Total aerobic mesophilic bacteria (TAMB), psychrotrophic bacteria, *Pseudomonas* and Enterobacteriacea counts, TBARS, pH and color values (L^*, a^* and b^*) were determined after 0, 24, 48 and 72 h of storage.

Microbiological Analysis

Ground beef (25 g) was aseptically taken from the samples and placed in stomacher bags, with 225 mL of solution of NaCl (0.85%) and homogenized for 1 min. Serial dilutions of the homogenates were prepared and the surface plate method was used for enumeration. TAMB was enumerated on plate count agar (PCA; Oxoid, CM 0325, Basingstoke, U.K.) after incubation at 30C for 48 h. Psychrotrophic bacteria were plated on PCA after aerobic incubation at 10C for 7 days. *Pseudomonas* was enumerated on Cetrimide-Fucidin-Cephaloridine (CFC) selective agar supplement (Oxoid SR 0103), supplemented CFC agar (*Pseudomonas* agar base , Oxoid CM 0559) and aerobically incubated at 25C for 48 h. Violet red bile dextrose agar (Oxoid) was used for Enterobacteriacea, and plates were anaerobically incubated at 30C for 48 h (Baumgart *et al*. 1993).

Determination of TBARS, pH and Color Values

TBARS values of samples were determined according to the methods of Tarladgis *et al*. (1962) and Lemon (1975).

TABLE 1. MEANS FOR THE MAIN EFFECTS OF LSHWE AND STORAGE TIME ON TOTAL AEROBIC MESOPHILIC, PSYCHROTROPHIC, *PSEUDOMONAS* AND ENTEROBACTERIACEAE COUNTS (log cfu/g) IN GROUND BEEF

	Total aerobic mesophilic bacteria	Psychrotrophic bacteria	*Pseudomonas*	Enterobacteriaceae
LSHWE levels				
Control	5.65 ± 1.18[a]	5.55 ± 1.28[a]	5.06 ± 1.04[a]	4.73 ± 0.69[a]
100 ppm LSHWE	5.28 ± 1.13[b]	5.20 ± 1.20[b]	4.79 ± 0.96[b]	4.13 ± 0.59[c]
250 ppm LSHWE	5.34 ± 1.00[b]	5.27 ± 1.25[b]	4.74 ± 1.02[b]	4.34 ± 0.61[b]
500 ppm LSHWE	5.19 ± 0.86[b]	5.27 ± 1.20[b]	4.76 ± 0.93[b]	4.37 ± 0.62[b]
Significance	**	**	**	**
Storage time (ST, h)				
1	4.33 ± 0.81[c]	4.74 ± 0.91[c]	4.39 ± 0.47[c]	3.85 ± 0.34[d]
24	5.34 ± 0.69[b]	5.26 ± 0.93[b]	4.50 ± 0.76[c]	4.20 ± 0.54[c]
48	5.52 ± 0.66[b]	5.43 ± 1.08[b]	4.82 ± 0.73[b]	4.51 ± 0.43[b]
72	6.27 ± 0.97[a]	5.87 ± 1.61[a]	5.64 ± 1.27[a]	5.00 ± 0.66[a]
Significance	**	**	**	**
LSHWE × ST	NS	*	*	**

* $P < 0.05$.

** $P < 0.01$.

a–d Means in the same column and in the same section having the same letters are not significantly different at $P > 0.05$.

LSHWE, lyophilized *Satureja hortensis* water extract; NS, not significant.

According to their method, 1 g of sample was taken from each treatment and 6 mL of trichloroacetic acid (TCA) solution was added (7.5% TCA, 0.1% ethylenediaminetetraacetic acid and 0.1% propyl gallate, 1-propyl gallate was dissolved in 3 mL of ethanol). The mixture was filtered (Whatman No. 1) after homogenization for 15–30 s. Then, 1 mL of the filtrate was added to 1 mL of 0.02 M thiobarbituric acid solution. This mixture was kept in a boiling water bath for 40 min, then cooled and centrifuged at 2,000 × g for 5 min, and the absorbance was measured at 532 nm (Shimadzu, UV 160 A; Serial No. 28 K 01636, Kyoto, Japan), and TBARS values were determined as μmol malonaldehyde/kg of meat (Aksu 2009).

The pH value was recorded using a pH meter (Orion 3 Star, Thermo Scientific, Singapore, pH Benchtop). Ground beef meat samples (10 g) were homogenized (Nach Prof. P. Willem, Janke and Kunkel KG, IKA 25 Werk, Staufen I. Breisgau) with 100 mL of distilled water and the homogenate was used for pH determination.

A Minolta model colorimeter (CR-400, Minolta Co., Osaka, Japan) was used for the color measurement on external surfaces of the samples. The instrument was calibrated to standard plate before analysis. ($L^* = 0$, darkness; $L^* = 100$, lightness [darkness/lightness]; a^*; $+a^*$ = red, $-a^*$ = green and b^*; $+b^*$ = yellow, $-b^*$ = blue.)

Data Analysis

Statistical evaluations were performed using the SPSS package (SPSS 1996), using a completely randomized block design procedure. The differences among means were tested by Duncan's multiple range test (significance $P < 0.05$). The model included LSHWE levels (0, 100, 250 and 500 ppm) and storage period (0, 24, 48 and 72 h) as the main factors and all of their interactions. The results of the statistical analyses are shown as mean ± standard deviations in the tables.

RESULTS AND DISCUSSION

The counts of total aerobic mesophilic, psychrotrophic, *Pseudomonas* and Enterobacteriaceae of ground beef are given in Table 1. Levels of LSHWE had significant effects on the total aerobic mesophilic counts ($P < 0.01$). The addition of LSHWE into ground beef increased the inhibition of total aerobic mesophilic ($P < 0.05$). Also, the time of storage was found to have important effects on the total aerobic mesophilic counts ($P < 0.01$). As seen in Table 1 and Fig. 1a, an increase in total aerobic mesophilic counts of the LSHWE group samples was lower than that in the control group during storage. However, the lowest aerobic mesophilic bacteria counts were found in the 500 ppm LSHWE samples. The maximum acceptable TAMB count in ground beef is 10^6 cfu/g (6.0 log cfu/g) (Anon 2003). In the current study, the TAMB counts of the 0 (control), 100, 250 and 500 ppm LSHWE samples at the start of storage were 4.45, 4.35, 4.42 and 4.09 log cfu/g, but increased to 6.84, 6.15, 6.17 and 5.90 log cfu/g at the end of the storage, respectively.

The differences between control and other LSHWE groups in psychrotrophic counts were significant ($P < 0.01$, Table 1), and the highest counts occurred in the control group with a mean value of 5.55 cfu/g. However, there were

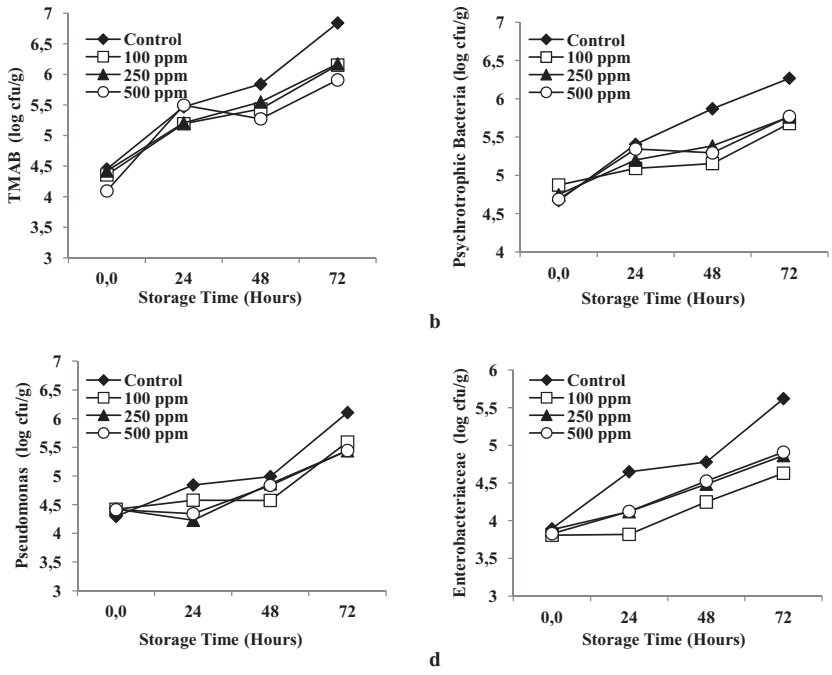

FIG. 1. INTERACTION EFFECTS OF LYOPHILIZED *SATUREJA HORTENSIS* WATER EXTRACT × STORAGE TIME ON TOTAL AEROBIC MESOPHILIC BACTERIA (TAMB) (A), PSYCHROTROPHIC (B), *PSEUDOMONAS* (C) AND ENTEROBACTERIACEAE (D) COUNTS IN GROUND BEEF

no significant differences in psychrotrophic counts among the LSHWE groups ($P > 0.05$). The storage time ($P < 0.01$) and LSHWE levels × storage interactions ($P < 0.05$) also significantly affected the psychrotrophic counts (Table 1, Fig. 1b). There was a significant change in the psychrotrophic counts in all LSHWE levels during storage. The lowest psychrotrophic counts were found at the start of storage with a mean value of 4.74 log cfu/g. The psychrotrophic counts of the 3-day-stored samples increased from 4.74 to 5.87 log cfu/g during storage ($P < 0.05$). However, there were no significant differences in the psychrotrophic counts between 1 and 2 days of storage ($P > 0.05$). As seen in Fig. 1b, an increase in psychrotrophic counts of the LSHWE group samples was lower than that of the control group samples during storage.

The psychrotrophic bacteria commonly cause a variety off-flavor and physical defects in many foods. In foods stored at 0–7C, the psychrotrophic bacteria counts affect the quality of foods in the case of extended storage. Generally, psychrotrophic bacteria such as *Pseudomonas*, *Flavobacterium*, etc., cause spoilage in meats stored at low temperature (Temiz 1999; Ünlütürk and Turantas 1999). There was significantly ($P < 0.01$) an effect on *Pseudomonas* counts of the LSHWE levels and the highest *Pseudomonas* counts were determined in control group compared with the 100 ppm LSHWE, 250 ppm LSHWE and 500 ppm LSHWE groups. Although LSHWE levels had a significant effect ($P < 0.01$) on *Pseudomonas* counts, there was no difference among the 100 ppm LSHWE, 250 ppm LSHWE and 500 ppm LSHWE groups (Table 1). The storage time ($P < 0.01$) and LSHWE levels × storage interactions ($P < 0.05$) have significantly affected *Pseudomonas* counts (Table 1, Fig. 1c). The lowest *Pseudomonas* counts were found at the start and 1 day of storage with mean values of 4.39 and 4.50 log cfu/g, respectively. The increase in *Pseudomonas* counts of the LSHWE group samples was lower than the control group samples during storage. While this count did not significantly change with LSHWE samples until 2 days of storage, it differed with 2 and 3 days of storage (Fig. 1c). Highly significant LSHWE ($P < 0.01$), storage ($P < 0.01$) and LSHWE × storage interaction effects ($P < 0.01$) were observed on Enterobacteriaceae counts (Table 1). This count was higher in LSHWE samples compared with those of the control samples (Table 1). Enterobacteriaceae counts increased during storage. A significant change was observed in Enterobacteriaceae counts in all LSHWE levels during storage (Table 1), and the lowest counts among LSHWE groups were found in the 100 ppm LSHWE group during storage (Fig. 1d). The highest Enterobacteriaceae counts were observed in the control group during storage (Fig. 1d). Gulluce *et al.* (2003) revealed that the essential oil of *S. hortensis* showed a significant antimicrobial activity against 23 bacterial species such as *Bacillus subtilis*, *Enterococcus faecalis*, *Pseudomonas aeruginosa*, *Salmonella enteritidis* and *Streptococcus pyogenes*. Similarly, Adiguzel *et al.* (2007) studied the antimicrobial and antioxidant activities of the essential oil and methanol extract of *S. hortensis* and found that the essential oil of *S. hortensis* exhibited activity against 25 bacteria, 8 fungi and a yeast, and that the methanol extract of the plant also had an antimicrobial activity. On

TABLE 2. MEAN VALUES FOR THE MAIN EFFECTS OF LSHWE AND STORAGE TIME ON THIOBARBITURIC ACID REACTIVE SUBSTANCE AND pH VALUES IN GROUND BEEF

	TBARS†	pH
LSHWE levels		
Control	20.04 ± 13.29[a]	5.86 ± 0.16[a]
100 ppm LSHWE	17.10 ± 13.32[b]	5.79 ± 0.17[b]
250 ppm LSHWE	14.94 ± 9.39[c]	5.81 ± 0.16[b]
500 ppm LSHWE	11.57 ± 4.07[d]	5.82 ± 0.17[b]
Significance	**	**
Storage time (ST, h)		
1	6.80 ± 0.86[d]	5.78 ± 0.16[c]
24	11.37 ± 1.48[c]	5.80 ± 0.16[c]
48	19.43 ± 11.48[b]	5.84 ± 0.16[b]
72	26.07 ± 11.46[a]	5.87 ± 0.17[a]
Significance	**	**
LSHWE × ST	**	**

** $P < 0.01$.

† μmol malonaldehyde/kg.

a–d Means in the same column and in the same section having the same letters are not significantly different at $P > 0.05$.

LSHWE, lyophilized *Satureja hortensis* water extract.

the other hand, a recent study showed that the essential oil of *Satureja wiedemanniana* had inhibitory effects against *Bacillus* species isolated from raw meat samples and thus it can be used as a natural preservative in meat against spoilage bacteria (Yucel *et al.* 2009). Yucel and Aslim (2011) also found that several *Bacillus* strains identified from chicken meat were strongly inhibited, *in vitro,* by the essential oil from *S. wiedemanniana*, and its main component, *p*-cymene, exhibited strong antimicrobial activity against some *Bacillus* strains. As a result, the authors recommended the use of *S. wiedemanniana* essential oil as a protective agent to chicken meat.

In the present study, TBARS values were affected by the LSHWE levels ($P < 0.01$). Among the LSHWE groups, the highest TBARS value was observed in the control group with the values of 20.04 ± 13.29 μmol malonaldehyde/kg ($P < 0.05$), while the lowest TBARS value was found in the 500 ppm LSHWE group (11.57 ± 4.07 μmol malonaldehyde/kg of meat) (Table 2). There was a significant ($P < 0.01$) difference in the TBARS content among the LSHWE groups stored for 3 days, and this value increased during storage, and the highest values was obtained at the end of the storage ($P > 0.05$) (Table 2). LSHWE levels × storage time interaction resulted in a significant effect on the TBARS values of ground beefs ($P < 0.01$). As can be seen Fig. 2a, the greatest changes in the TBARS values of ground beef occurred in the control (0 ppm) group. However, at the 500 ppm LSHWE group, changes in the TBARS values were lower than the other LSHWE groups during storage (Fig. 2a). The TBARS values of the control group for 1, 24, 48 and 72 h of storage were 6.80, 12.65, 27.81 and 32.91 μmol malonaldehyde/kg, respectively. The TBARS values for the 100 ppm LSHWE group increased up to 29.11 μmol malonaldehyde/kg at the end of the storage. The TBARS values of the LSHWE group samples of 250 and 500 of ppm for 1 and 72 h of storage were in the ranges of 6.80–26.59 and 6.80–15.62 mg malonaldehyde/kg, respectively. Results of the present study show that LSHWE has an antioxidant effect, and in ground beef, lipid oxidation can be prevented by using LSHWE; the use of higher levels of LSHWE decreases the TBARS values. It is clear from the results that lipid oxidation of ground beef can be protected better using the LSHWE of 500 ppm than that of 250 and 100 ppm levels. Dorman *et al.* (2004) reported that the water-soluble extract from savory (*S. hortensis*) plant possesses exploitable antioxidant properties, and that the extracts were capable of inhibiting the formation of TBARS. On the other hand, Gumus *et al.* (2011) also determined that irradiated or nonirradiated *S. hortensis* possessed excellent antioxidant activity and 2,2-diphenyl-1-picrylhydrazyl radical-scavenging activity. This activity observed in this study and previous studies may be related to the antioxidant properties of its secondary metabolites (Kosar *et al.* 2003; Dorman and Hiltunen 2004). Madsen *et al.* (1996) found that *S. hortensis* (0.05%, pulverized) significantly improved the oxidative stability of meat balls, and that a significant reduction in warmed-over flavor caused by the addition of *S. hortensis* was measured by a reduction in 2-

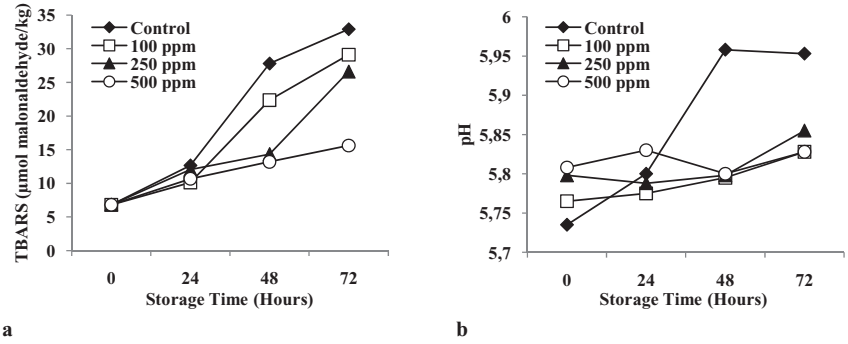

FIG. 2. INTERACTION EFFECTS OF LYOPHILIZED *SATUREJA HORTENSIS* WATER EXTRACT × STORAGE TIME ON THIOBARBITURIC ACID REACTIVE SUBSTANCE (TBARS) (A) AND pH (B) VALUES IN GROUND BEEF

TABLE 3. POOLED MEANS FOR THE MAIN EFFECTS OF LSHWE AND STORAGE TIME ON EXTERNAL SURFACE *L**, *a** AND *b** VALUES IN GROUND BEEF

	*L**	*a**	*b**
LSHWE levels			
Control	44.34 ± 1.53[b]	24.21 ± 3.62[a]	12.96 ± 1.49[b]
100 ppm LSHWE	46.26 ± 3.13[a]	21.77 ± 2.97[b]	14.25 ± 1.91[a]
250 ppm LSHWE	46.28 ± 2.65[a]	22.69 ± 3.21[ab]	14.65 ± 1.87[a]
500 ppm LSHWE	43.83 ± 3.17[b]	21.27 ± 3.00[b]	13.63 ± 1.68[ab]
Significance	*	*	*
Storage time (ST, days)			
1	44.61 ± 1.55	23.47 ± 3.23	13.19 ± 1.86[b]
24	45.25 ± 4.21	22.20 ± 4.13	13.55 ± 1.43[b]
48	45.32 ± 2.82	21.23 ± 2.44	13.92 ± 1.76[ab]
72	45.53 ± 2.42	23.04 ± 3.17	14.84 ± 1.92[a]
Significance	NS	NS	*
LSHWE × ST	NS	NS	NS

* $P < 0.05$.

a–b Means in the same column and in the same section having the same letters are not significantly different at $P > 0.05$.

LSHWE, lyophilized *Satureja hortensis* water extract; NS, not significant.

thiobarbituricacid reactive substances (TBARS) and hexanal. Madsen *et al.* (1998) determined that for an oil-in-water emulsion dressing, the addition of 0.15% of dried leaves of *S. hortensis* had a significantly greater antioxidative protection than that of 80 ppm of propyl gallate during dark storage at 19C for up to 24 weeks, as determined by the development of conjugated dienes, peroxide value, head space hexanal and TBARS.

The pH values partially increased at the start of the storage with the increasing LSHWE levels as *S. hortensis* had basic properties, and LSHWE levels significantly affected the pH values ($P < 0.01$) during storage. The highest pH value was found in the control group ($P < 0.01$). On the other hand, the pH values of the 100, 250 and 500 ppm LSHWE levels did not show a significant difference (Table 2). Storage time significantly altered the pH values ($P < 0.01$), and the mean pH values of the 3-day-stored samples increased from 5.78 to 5.87 during storage ($P < 0.05$). However, there were no significant differences in pH between 1 and 24 h of storage ($P > 0.05$). LSHWE levels × storage time interaction had also very significant effect ($P < 0.01$) on the pH value. The pH values did not differ significantly among the 100, 250 and 500 ppm LSHWE groups between 0 and 3 days of the storage. However, the pH values increased rapidly in the control samples along with the storage period, as can be seen from Fig. 2b.

Color values were significantly affected ($P < 0.05$) by the LSHWE levels (Table 3). The *a** value was the highest in the control group, while *L** and *b** values increased with the LSHWE applications of 100, 250 and 500 ppm. There was no difference between the 100 and 200 ppm LSHWE groups for *L** and *b** values (Table 3). Only the *b** value was significantly affected ($P < 0.05$) by the storage time. There was a significant ($P < 0.05$) difference in ground beef among storage times, and the highest values were detected at the end of storage time. Storage time (for *L** and *a** values) and LSHWE levels × storage time interactions (for *L**, *a** and *b** values) had no any effect ($P > 0.05$) on the values of color in ground beef without and with LSHWE. Storage time had also a very significant effect on *b** values of the external surface, and values of *b** were not stable during storage (Table 3).

CONCLUSION

The results of the current study show that lipid oxidation and bacterial growth (total aerobic mesophilic, psychrotrophic, *Pseudomonas* and Enterobacteriaceae) can be suppressed (<0.3–<0.6 log cfu/g for microbiological results) by LSHWE in ground beef, and that the lipid oxidation of ground beef stored at 4 ± 0.5C can be protected best using 500 ppm of LSHWE compared with 0, 100 and 250 ppm of the LSHWE groups. The results also showed that LSHWE has antioxidant properties and therefore it can be used as a natural antioxidative for fresh meat and fresh meat products.

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