



# Inactivation effect of marination liquids prepared with koruk juice and dried koruk pomace on *Salmonella* Typhimurium, *Escherichia coli* O157:H7 and *Listeria monocytogenes* inoculated on meat

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## ABSTRACT

The aim of this study was to determine the effects of marination liquids prepared with koruk juice and dried koruk pomace in terms of meat safety. In the study, marination liquids containing two different concentrations of koruk juice (25% and 50%) or dried koruk pomace (1% and 2%) were prepared separately with or without ingredients (1% salt and 0.1% thyme). Meat samples inoculated with two different levels ( $\geq 3$  log and  $\geq 6$  log) of food-borne pathogens (*S. Typhimurium*, *E. coli* O157:H7 and *L. monocytogenes*) were marinated at 4 °C for different times (2, 24 and 48 h) and the effects of the treatment on target pathogens were determined. As a result of marinating process, the counts of *S. Typhimurium*, *E. coli* O157:H7 and *L. monocytogenes* inoculated at high levels ( $\geq 6$  log) on meat samples were reduced in the range of 0.109–2.648 log CFU/g, 0.264–3.373 log CFU/g and 0.023–2.781 log CFU/g, respectively. The most effective treatment in reducing the counts of *S. Typhimurium* and *E. coli* O157:H7 was achieved by marination with ML1 (50% koruk juice + 50% water) for 48 h, while marination with ML2 (50% koruk juice + 50% water + 1% salt + 0.1% thyme) for 24 h was the most effective treatment for *L. monocytogenes*. When low inoculum levels were used ( $\geq 3$  log), the counts of pathogens on meat samples were determined under detection limits after marination even for 2 h application. The results of sensory evaluation showed that the sample marinated with ML2 for 48 h was the most favored sample in terms of appearance, color, texture, taste and overall appreciation.

## 1. Introduction

Meat and meat products have been an important part in human diet due to containing rich nutritive elements such as protein, fatty acids, vitamins, minerals and bioactive components. These products could be easily spoiled by different microorganisms and various pathogenic bacteria, which have high risk of contamination of these products such as *Salmonella* Typhimurium, *Escherichia coli* O157:H7 and *Listeria monocytogenes*, may cause food-borne diseases (CDC, 2015, 2016a, 2016b; Choi et al., 2009; Moon et al., 2017; Rhoades et al., 2013). Hence, fresh meat and meat products should be preserved by using suitable preservative methods to obtain safe and high-quality products.

In recent years, awareness of consumers for consumption of healthy foods and revealing the roles of foods containing chemical substances in diseases, has increased the tendency to consume natural anti-microbial products all over the world (Govaris et al., 2010; Hyldgaard et al., 2012; Jayasena and Jo, 2013; Mariutti et al., 2011; Solomakos et al., 2008). Natural and synthetic substances are widely used in meat

technology in order to obtain safe and high-quality products (Tajkarimi et al., 2010). Therefore, in the last years, studies on the use of herbal products, which are known to be more reliable compared to many synthetic products, were increasing in order to improve the quality and safety of foods (Bajpai et al., 2012; Fratianni et al., 2010; Jayasena and Jo, 2013).

Unripe grape (*Vitis vinifera* L.) which is known as “koruk” in Turkish, “verjons” or “koruk juice” in English, “vertjus” or “verjus” in French, “agraz” in Spanish and German, “agresto” in Italian, and “abeghureh” in Persian, is commonly used as beverage and acidifier for various dishes, salads and appetizers (Alipour et al., 2012; Aminian et al., 2003; Karapinar and Sengun, 2007; Nikfardjam, 2008). Koruk is a fruit with low sugar content and contains high amounts of tartaric and malic acids (Dupas de Matos et al., 2017). It has been reported that unripe grapes showed anti-oxidant activities due to high concentration of phenolic and polyphenolic compounds such as gallic acid, caffeic acid, catechin and quercetin glycoside (Nikfardjam, 2008; Turkmen et al., 2017). The acidic property and the phenolic components of

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grapes allow to show both anti-microbial and anti-oxidant effects.

Marination is an old method used mainly to improve the functional and sensory properties of meat (Alvarado and McKee, 2007; Ergezer and Gokce, 2004). It is recommended for the consumers to obtain more delicious products with longer shelf life (McKee and Alvarado, 2004). Various components could be used for marination such as oil, water, salt, phosphates, organic acids, herbs and spices (Parks et al., 2000; Yusop et al., 2011). This process also affects the microbiological quality and safety of meat (Vlahova-Vangelova and Dragoev, 2014).

The inactivation effect of marination liquids such as red wine, teriyaki sauce and soy sauce on various pathogens inoculated in/on red meat has been studied by some researchers. However, there is no study searching the inactivation effect of unripe grape products that could be used in marination of meat. Therefore, in this study, it is aimed to detect the effects of marination liquids (ML) prepared with koruk juice and dried koruk pomace used in marination of meat, in terms of product safety.

## 2. Materials and methods

### 2.1. Bacterial strains

Three food-borne pathogens with two different strains of each (*Salmonella* Typhimurium ATCC 13311, *S. Typhimurium* ATCC 14028, *Escherichia coli* O157:H7 ATCC 43895, *E. coli* O157:H7 ATCC 43888, *Listeria monocytogenes* ATCC 49594 and *L. monocytogenes* ATCC 13932) were used in the study. Bacterial cultures were obtained from Ege University, Food Engineering Department, Food Microbiology Research Laboratory and Izmir Food Control Laboratory. Each microorganism was used as test culture after adapting to 50 ppm of nalidixic acid (Oxoid, Basingstoke, Hampshire, England). Stock cultures were transferred into Tryptic Soy Broth (TSB, pH 7.3 ± 0.2, Oxoid, Basingstoke, Hampshire, England) supplemented with 50 ppm nalidixic acid for the activation and incubated at 37 °C for 24 h. Two strains of *S. Typhimurium*, *E. coli* O157:H7 or *L. monocytogenes* were mixed at the same ratios and centrifugated at 3000 × g for 15 min (Hettich GmbH & Co. KG, 78532, Tufflingen, Germany). Bacterial pellets were washed twice with 0.85% sterile saline solution and the final pellet was re-suspended in 10 mL of 0.85% sterile saline (Cho et al., 2016). Then the final mix including two strains of the same species, was used as test culture in the analysis.

### 2.2. Preparation of koruk products

Koruk (*V. vinifera* L.) samples belong to Yediveren variety were obtained from Yesilyurt vineyards, Izmir, Turkey. After harvesting, koruk were shorted, grained and washed with tap water. The grains which were kept in vinegar (5%, v/v) for 15 min and rinsed with tap water were chopped in blender for 1 min at high speed (Waring Commercial Blender, Waring Product Division New Hartford Conn. USA). The mixture was filtered through cheesecloth, then filtered through filter paper (Filter-Lab, 40 × 40 cm). The final liquid called as koruk juice (pH: 2.94, tartaric acid: 3.52%) was stored at (–)18 °C until analysis. The pomace obtained after removing koruk juice was dried in a tray dryer (TK Lab Model, Eksis Industrial Drying Systems, Turkey) at 60 °C, rate of 1 m/s until the moisture content reaches to 3%, pulverized (Infrared Nem Cihazı, Ohasus MB45 Nanikon, Switzerland) and stored after vacuum packing (Henkelman Boxer 42, Holland) (pH: 3.89, tartaric acid: 0.19) (Fig. 1).

### 2.3. Inoculation and marination of meat samples

Lean boneless beef rounds (disassembly) supplied by a local processor and transferred to Food Microbiology Laboratory, Food Engineering Department under cold chain. Meat samples firstly checked for the presence of *S. Typhimurium*, *E. coli* O157:H7 and *L. monocytogenes* and the samples confirmed as negative for investigated

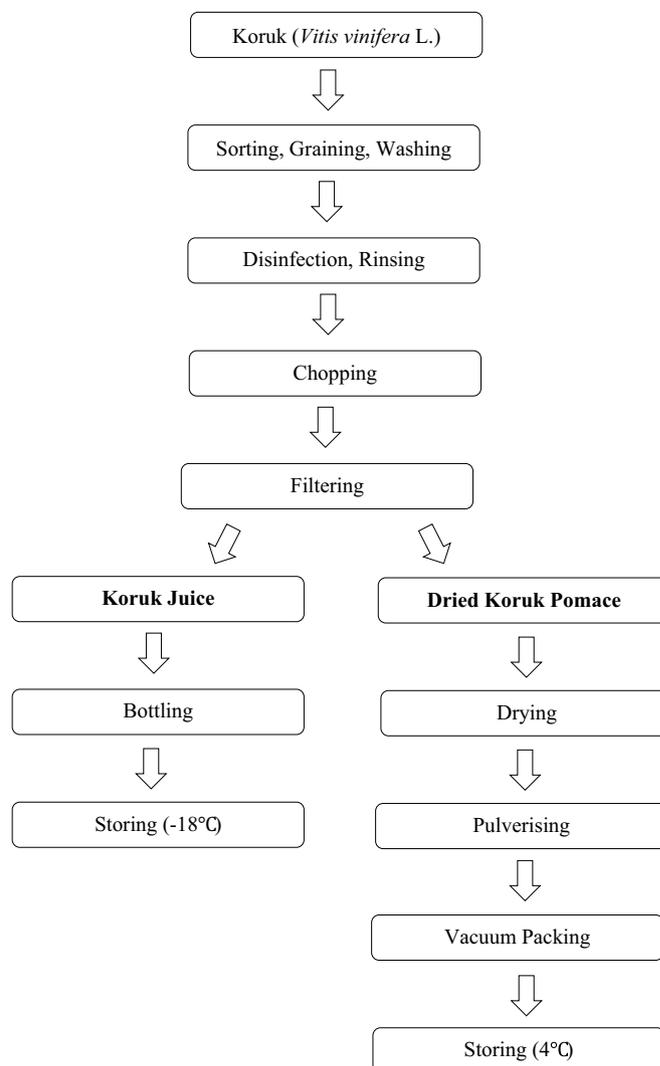


Fig. 1. Production flow diagram of koruk juice and dried koruk pomace.

pathogens were used as analyze samples. Then, fresh meat samples were aseptically cut into 25 g of fillets with approximately 1 cm thickness and transferred in to sterile glass jars. Then samples were inoculated separately with *S. Typhimurium*, *E. coli* O157:H7 and *L. monocytogenes* at low and high inoculum levels ( $\approx 3$  log and  $\approx 6$  log). Inoculated samples were stored at 20 °C for 30 min to allow cell attachment on meat surface.

Marination liquids (ML) were produced in two groups by using koruk juice and dried koruk pomace. Two concentrations of koruk juice and dried koruk pomace were prepared separately by using ingredients (salt and thyme) or not, and tap water was used for preparing dilutions (Table 1).

Meat samples were marinated with 50 mL of ML using immersion method and then samples were stored at 4 °C for 2, 24 and 48 h. Untreated meat samples or samples only treated with tap water were used as controls.

### 2.4. pH and total acidity measurement

The pH value of ML and marinated meat samples was recorded by a pH meter (Nel Mod 821) with direct immersion of the glass electrode in ML and meat sample homogenates (1:10). Total acidic values of ML and marinated meats were determined by titrimetric method and results were expressed as tartaric acid and lactic acid in g/100 mL, respectively (AOAC, 2007).

**Table 1**

Formulations of marination liquids (ML) prepared with koruk juice and dried koruk pomace.

Marination contents	ML1	ML2	ML3	ML4	ML5	ML6	ML7	ML8	C1	C2
Koruk juice (mL)	50	50	25	25	–	–	–	–	–	–
Dried koruk pomace (g)	–	–	–	–	1	1	2	2	–	–
Water (mL)	50	50	75	75	100	100	100	100	100	–
Thyme (g)	–	0.1	–	0.1	–	0.1	–	0.1	–	–
Salt (g)	–	1	–	1	–	1	–	1	–	–

ML: marination liquids, C: control.

### 2.5. Microbiological analysis

The marinated meat sample was placed in a stomacher bag containing 225 mL of 0.1% peptone water (PW, pH  $6.8 \pm 0.2$ , Oxoid Ltd. Basignstoke, Hampshire, England, L37) and homogenized in a Stomacher (Stomacher Lab-Blender 400, Seward Medical, London, UK) for 60 s. Aliquots of the homogenate were serially diluted in 9 mL of 0.1% PW and 0.1 mL inoculum was spread on the plates. Xylose Lysine Deoxycholate Agar (XLD, pH  $7.4 \pm 0.2$ , Oxoid, CM0469), Sorbitol MacConkey Agar (SMAC, pH  $7.1 \pm 0.2$ , Oxoid, CM0813), Palcam Agar (PALCAM, pH  $7.2 \pm 0.2$ , Oxoid, CM0877) containing 50 ppm nalidixic acid were used for the enumeration of *S. Typhimurium*, *E. coli* O157:H7, *L. monocytogenes*, respectively. All inoculated plates were incubated at 37 °C for 24 h except Palcam Agar (30 °C for 48 h) and typical colonies were counted.

### 2.6. Sensory evaluation

In the study, the appearance, color, texture, taste and overall appreciation characteristics of the marinated meats were evaluated. For this purpose, a panel including ten panelists was formed and thermally processed (10 min in grill pan) meat samples were presented in random order using a 9-point hedonic scale for assessment (Altug Onogur and Elmaci, 2005).

### 2.7. Statistical analysis

Experiments were conducted in three replicates and two parallels. Results of analysis were expressed as mean  $\pm$  standard error. Experimental data were evaluated by one-way ANOVA and Duncan multiple comparison methods at the significance level of  $P \leq 0.05$  using the SPSS 15.0 for Windows Software Package (SPSS, 2004).

### Key resources table

Resource	Source	Identifier
Chemical		
Nalidixic acid		
Tartaric acid		
Process		
Marination	N/A	N/A
Strain		
<i>Escherichia coli</i> O157:H7	N/A	N/A
<i>Listeria monocytogenes</i>	N/A	N/A
<i>Salmonella</i> Typhimurium	N/A	N/A

## 3. Results and discussion

### 3.1. pH and total acidity of marination liquids and marinated meats

The pH values of ML were ranged between 2.89 and 3.80 ( $P < 0.05$ ) (Table 2), where the values of ML prepared with koruk

**Table 2**

The pH and total acidic values of marination liquids.

Marination liquids	pH	Total acidity (g tartaric acid/100 mL)
ML1	$3.21 \pm 0.027^a$	$1.935 \pm 0.276^a$
ML2	$2.89 \pm 0.010^b$	$1.989 \pm 0.181^a$
ML3	$3.33 \pm 0.015^c$	$1.003 \pm 0.178^b$
ML4	$2.97 \pm 0.010^d$	$0.957 \pm 0.122^b$
ML5	$3.80 \pm 0.010^e$	$0.098 \pm 0.005^c$
ML6	$3.51 \pm 0.010^f$	$0.104 \pm 0.005^c$
ML7	$3.71 \pm 0.010^g$	$0.226 \pm 0.005^c$
ML8	$3.29 \pm 0.010^h$	$0.202 \pm 0.009^c$

Values in the same column with different lower case (a, b, c, d, e, f, g, h) are significantly different ( $P < 0.05$ ).

juice were lower than ML including dried koruk pomace ( $P < 0.05$ ). Besides, ML containing ingredients (1% salt and 0.1% thyme) have lower pH values than those of the ingredient-free formulations ( $P < 0.05$ ). The total acidity of ML was in the range of 0.098–1.989 g tartaric acid/100 mL and the highest total acidity was determined in ML2 (1.989 g/100 mL of tartaric acid), which has also the lowest pH value. Various pH values were reported for different ML prepared using kefir, mustard, honey, apple cider vinegar, white wine vinegar, dry red wine, red wine + thyme essential oil and soy sauce as 4.5, 3.9, 3.1, 3.0, 3.90, 3.90 and 4.74, respectively (Kargiotou et al., 2011; Tänavots et al., 2018).

The pH values of meat samples marinated with dried koruk pomace (in the range of 4.67–5.36) were significantly higher than meats marinated with koruk juices (in the range of 4.05–4.51) ( $P < 0.05$ ) (Table 3). Marination time significantly affected the pH values of meats, except the sample marinated with ML3 and ML5 ( $P < 0.05$ ). The total acidity of marinated meat samples varied between 0.2916 g lactic acid/100 mL and 0.0275 g lactic acid/100 mL, depending on the process applied (Table 4). The highest total acidity was determined in the sample marinated with ML1 for all marination times ( $P < 0.05$ ).

### 3.2. Effects of marination on *S. Typhimurium*, *E. coli* O157:H7 and *L. monocytogenes*

In this study, the inhibitory effect of ML prepared with koruk juice and dried koruk pomace on *S. Typhimurium*, *E. coli* O157:H7 and *L. monocytogenes* inoculated on meat at high ( $\geq 6$  log) and low ( $\geq 3$  log) levels was investigated separately for each pathogen.

The initial counts of *S. Typhimurium* were determined as  $6.047 \pm 0.141$  log CFU/g on meat samples, which were kept at 20 °C for 30 min after inoculating at high doses ( $\geq 6$  log). These samples were marinated at 4 °C for 2, 24 and 48 h, then the counts of *S. Typhimurium* were determined for each sample (Fig. 2). The counts of *S.*

**Table 3**

pH values of marinated meats.

Meat samples	Ph		
	2 h	24 h	48 h
BML1	$4.17 \pm 0.015^{a,A}$	$4.35 \pm 0.01^{a,B}$	$4.09 \pm 0.015^{a,C}$
BML2	$4.05 \pm 0.005^{b,A}$	$4.33 \pm 0.005^{b,B}$	$4.10 \pm 0.005^{a,C}$
BML3	$4.29 \pm 0.01^{c,A}$	$4.49 \pm 0.005^{c,B}$	$4.30 \pm 0.01^{b,A}$
BML4	$4.26 \pm 0.005^{d,A}$	$4.51 \pm 0.005^{c,B}$	$4.47 \pm 0.005^{c,C}$
BML5	$4.67 \pm 0.035^{e,A}$	$4.94 \pm 0.01^{d,B}$	$4.97 \pm 0.005^{d,B}$
BML6	$4.91 \pm 0.01^{f,A}$	$5.16 \pm 0.005^{e,B}$	$5.36 \pm 0.01^{e,C}$
BML7	$4.78 \pm 0.015^{g,A}$	$5.01 \pm 0.015^{f,B}$	$5.14 \pm 0.01^{f,C}$
BML8	$4.89 \pm 0.005^{f,A}$	$5.03 \pm 0.01^{g,B}$	$5.19 \pm 0.01^{g,C}$
BC1	$5.18 \pm 0.01^{h,A}$	$5.21 \pm 0.015^{h,B}$	$5.41 \pm 0.01^{h,C}$
BC2	$5.23 \pm 0.01^{i,A}$	$5.25 \pm 0.01^{i,A}$	$5.28 \pm 0.015^{h,B}$

Values in the same column with different lower case (a, b, c, d, e, f, g, h, i) and in the same row with different upper case (A, B, C) are significantly different ( $P < 0.05$ ).

**Table 4**  
Total acidity of marinated meats (g lactic acid/100 mL).

Meat samples	Total acidity (g lactic acid/100 mL)		
	2 h	24 h	48 h
BML1	0.2916 ± 0.006 <sup>a,A</sup>	0.2036 ± 0.006 <sup>a,B</sup>	0.165 ± 0.011 <sup>a,C</sup>
BML2	0.2146 ± 0.017 <sup>b,A</sup>	0.1541 ± 0.011 <sup>b,B</sup>	0.1266 ± 0.006 <sup>b,C</sup>
BML3	0.1156 ± 0.006 <sup>c,A</sup>	0.0874 ± 0.009 <sup>c,B</sup>	0.066 ± 0.011 <sup>c,C</sup>
BML4	0.099 ± 0.011 <sup>cd,A</sup>	0.0935 ± 0.006 <sup>c,A</sup>	0.0605 ± 0.006 <sup>ce,B</sup>
BML5	0.055 ± 0.011 <sup>e,A</sup>	0.0605 ± 0.006 <sup>de,A</sup>	0.0275 ± 0.006 <sup>d,B</sup>
BML6	0.0605 ± 0.006 <sup>e,A</sup>	0.0495 ± 0.006 <sup>ef,A</sup>	0.0495 ± 0.006 <sup>ef,A</sup>
BML7	0.088 ± 0.011 <sup>d,A</sup>	0.0385 ± 0.006 <sup>f,B</sup>	0.066 ± 0.011 <sup>c,C</sup>
BML8	0.1045 ± 0.006 <sup>cd,A</sup>	0.0605 ± 0.006 <sup>de,B</sup>	0.0605 ± 0.006 <sup>ce,B</sup>
BC1	0.1009 ± 0.012 <sup>cd,A</sup>	0.0495 ± 0.006 <sup>ef,B</sup>	0.0385 ± 0.006 <sup>df,B</sup>
BC2	0.1045 ± 0.006 <sup>cd,A</sup>	0.0715 ± 0.006 <sup>d,B</sup>	0.0874 ± 0.009 <sup>g,C</sup>

Values in the same column with different lower case (a, b, c, d, e, f, g) and in the same row with different upper case (A, B, C) are significantly different ( $P < 0.05$ ).

Typhimurium inoculated on meat samples were reduced by ML prepared with koruk juice in the range of 0.749–1.362, 0.860–1.828 and 1.282–2.648 log CFU/g after 2, 24 and 48 h, respectively. The highest reduction in *S. Typhimurium* (2.648 log CFU/g reduction) was achieved by marination with ML1 after 48 h treatment ( $P < 0.05$ ). The inhibition effect against *S. Typhimurium* was reduced in parallel with the decrease of koruk juice concentration in ML. Among ML prepared with dried koruk pomace, the highest reductions in the counts of *S. Typhimurium* were 1.026, 1.218 and 1.14 log CFU/g for 2, 24 and 48 h marination, respectively (Fig. 2). These results clearly showed that the anti-microbial effects of ML prepared with koruk juice (ML1, ML2, ML3, ML4) were higher than the liquids prepared with dried koruk pomace (ML5, ML6, ML7, ML8). When low inoculum levels were used, the initial counts of *S. Typhimurium* ( $2.739 \pm 0.056$  log CFU/g) on meat samples were reduced under detection limits by all ML. The numbers were only reduced to 2.117, 2.059 and 2.00 log CFU/g ( $P > 0.05$ ) by water treatment (C1) after 2, 24 and 48 h at 4 °C, respectively. However, *S. Typhimurium* counts of untreated meat samples (BC2) were retained at 2.522, 2.292 and 2.292 log CFU/g after 2, 24 and 48 h at 4 °C, respectively. Besides, only 2 h results of BC1 and BC2 samples were significantly different from each other ( $P < 0.05$ ).

In the next stage of the study, *E. coli* O157:H7 was inoculated on meat samples at high ( $\geq 6$  log) and low ( $\geq 3$  log) levels. When high level was used, the initial counts of *E. coli* O157:H7 ( $5.373 \pm 0.388$  log CFU/g) on meat samples were reduced by ML in the range of 0.264–2.144, 0.333–3.010 and 0.686–3.373 log CFU/g for 2, 24 and 48 h, respectively. There was no significant difference between the effects of ML1 and ML2 for all application times against ( $P > 0.05$ ). Among the samples prepared with dried koruk pomace, ML6 was found to be the most effective formulation by reducing the initial counts of *E. coli* O157:H7 for 1.019, 1.342 and 1.557 log CFU/g after 2, 24 and 48 h marination (Fig. 2). Then, meat samples were inoculated with low levels of *E. coli* O157:H7 and the initial counts ( $2.259 \pm 0.241$  log CFU/g) were completely inactivated by all ML for all time applications. When only water was used (C1), the numbers were reduced to 2.00 log CFU/g after 2 h and under detection limit for 24 and 48 h at 4 °C. However, *E. coli* O157:H7 counts of untreated meat samples (BC2) were found as 2.392, 2.059 and 2.00 log CFU/g after 2, 24 and 48 h at 4 °C, respectively.

When *L. monocytogenes* was inoculated on meat samples, the initial counts on meat samples ( $5.996 \pm 0.072$  log CFU/g) was most efficiently reduced by ML1 for 2 h marination, while ML2 was more effective than ML1 for 24 h and 48 h marination by showing reductions of 2.781 and 2.67 log CFU/g, respectively (Fig. 2). Among ML prepared with dried koruk pomace, the most effective ML changed depending on the marination time and the highest reduction was found as 1.272 log CFU/g, which was achieved by ML7 for 48 h application. Besides, no

significant difference was determined between the effects of ML7 and ML8 ( $P > 0.05$ ). When meat samples were inoculated with low inoculum levels, the initial counts of *L. monocytogenes* ( $2.948 \pm 0.228$  log CFU/g) on meat samples were reduced under detection limits by ML for all time applications. However, the numbers were retained at 2.292, 2.35 and 2.159 log CFU/g for water treated samples (BC1) ( $P > 0.05$ ) and 2.725, 2.563 and 2.473 for untreated samples (BC2) ( $P > 0.05$ ) after 2, 24 and 48 h at 4 °C, respectively. Besides, BC1 and BC2 samples were found significantly different for all time applications, in terms of *L. monocytogenes* counts ( $P < 0.05$ ).

The results of this study showed that the most sensitive pathogen to ML was *E. coli* O157:H7 and the most resistant one was *S. Typhimurium* ( $P < 0.05$ ). In the literature, there are some studies showing the types of microorganisms affect the inactivation effects of marination process. For example, in a study performed by Nisiotou et al. (2013), the counts of acid adapted and non-adapted *S. Typhimurium* (4.8 and 4.6 log CFU/g) on meat was reduced in the range of 1.1–2 log CFU/g and 1.4–1.9 log CFU/g, respectively, by wine marination at 4 °C for 12 h. Hence, the authors confirmed that acid adapted cells were more resistant to marination process than non-adapted cells. In another study, inactivation effects of soya sauce marination on *E. coli* O157:H7, *S. Typhimurium*, *L. monocytogenes*, *Vibrio parahaemolyticus* and *Staphylococcus aureus* inoculated on crabs (4.1–4.4 log CFU/g) were investigated at 5 °C for 28 days. At the end of 28 days, the counts of *V. parahaemolyticus* were reduced under detection limit while the counts of *E. coli* O157:H7, *S. Typhimurium*, *L. monocytogenes* and *S. aureus* were 1.4, 1.6, 3.1, 3.2 log CFU/g, respectively (Cho et al., 2016). This linear relationship between the application time and pathogen inactivation was also observed in our study, in other words, the efficiency of the process increased as the application time increased.

The formulation of ML is another factor affecting the efficiency of the marination process. In the study, it was determined that ML prepared with koruk juice were more effective against test cultures than ML prepared with dried koruk pomace. The studies on the inactivation effect of different ML such as red wine, teriyaki sauce and soy sauce on various pathogens inoculated in/on red meat were also examined by some researchers. However, there is no study in the literature for the use of koruk products for marination of meats. In a study carried by Moon et al. (2017), teriyaki sauce was used alone or in combination with natural ingredients (thyme or thymol) as ML in beef. When teriyaki sauce was used alone, it did not reduce *E. coli* O157:H7, *L. monocytogenes*, *S. Typhimurium* counts, while teriyaki sauce used with thyme (0.5%) or thymol (0.5%), all target microorganisms completely inactivated (3.1–3.5 log CFU/g reduction) within seven days. Rhoades et al. (2013) also investigated the inactivation effects of ML (soy sauce with or without lactic acid and red wine with or without 0.5% oregano) against *S. enterica* and *L. monocytogenes* on meat after marination at 5 °C for 18 h. The counts of *S. enterica* and *L. monocytogenes* were reduced by 2.1 and 3.4 log CFU/cm<sup>2</sup> with marination process, where ML includes ingredients (lactic acid or oregano). However, when marination was applied by ML prepared without ingredients, the counts of *S. enterica* and *L. monocytogenes* on meat samples were decreased in the range of 0.3–0.4 and 1.3–2 log CFU/cm<sup>2</sup>, respectively. This result is in contrast with our results, since, when salt and thyme were used in ML prepared with koruk products, the counts of target pathogens were found higher than the samples marinated with ML excluding ingredients. This difference could be related with the properties, concentration and the form (dried particles as herbs, extract or essential oil) of ingredients, marination techniques and also the interaction of ingredients with other anti-microbial agents found in ML.

In the literature, most of the studies performed on marination of meats focused on the quality and sensory properties of the marinated products. However, marination process also affects the microbiological quality and safety of meats. There are some studies interpreting the effects of marination on microbiological quality of various meats. It has been determined that counts of total aerobic bacteria, lactic acid

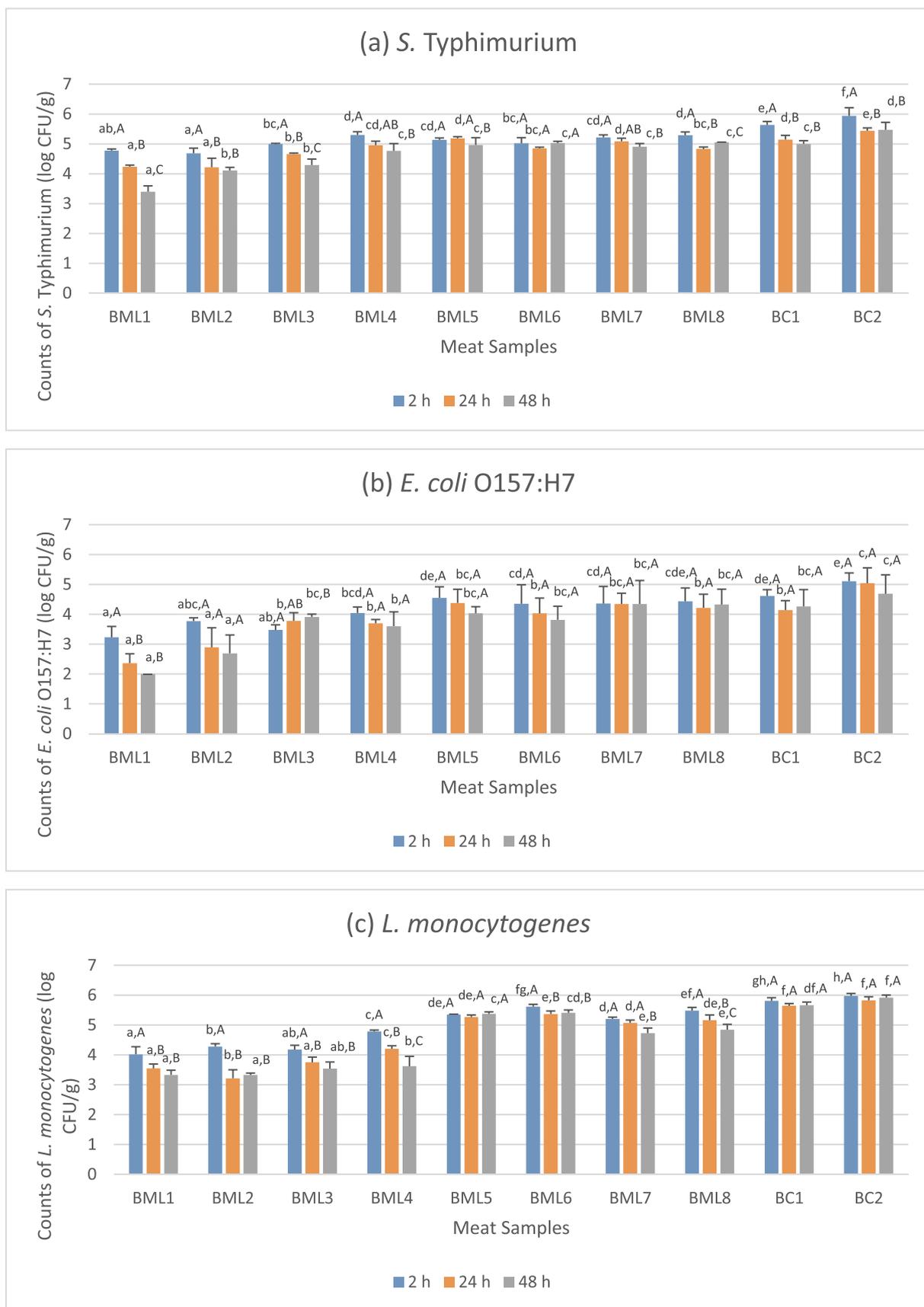


Fig. 2. The counts of *S. Typhimurium* (a), *E. coli* O157:H7 (b) and *L. monocytogenes* (c) (log CFU/g) in meat, marinated with different ML at 4 °C for 2, 24 and 48 h (Initial *S. Typhimurium* counts = 6.047 ± 0.141 log CFU/g, initial *E. coli* O157:H7 counts = 5.373 ± 0.388 log CFU/g, initial *L. monocytogenes* counts = 5.996 ± 0.072 log CFU/g before marination process).

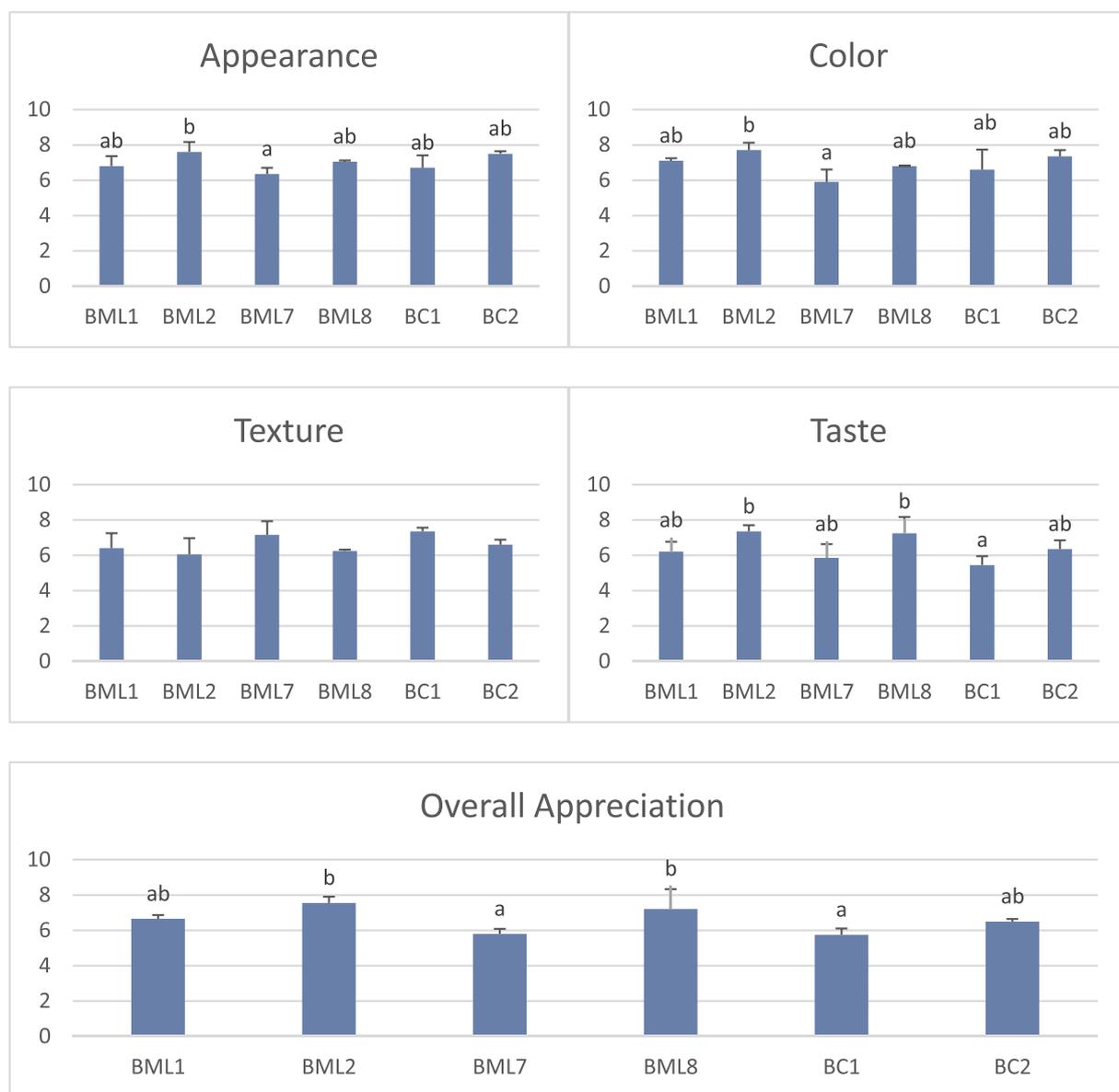


Fig. 3. Sensory evaluation results of samples marinated with koruk products for 48 h (Values with different lower case (a, b) are significantly different ( $P < 0.05$ )).

bacteria, *Pseudomonas* spp. and Enterobacteriaceae significantly reduced in meat samples marinated with acidic ML, such as pomegranate juice, lemon juice, apple vinegar and dry red wine (Kargiotou et al., 2011; Lytjou et al., 2016, 2017, 2018). However, there are limited studies investigating the effects of marination process on meat safety.

### 3.3. Sensory evaluation

Sensory evaluation was applied to meat samples which were marinated with the most effective ML including koruk juice (ML1 and ML2) and dried koruk pomace (ML7 and ML8) against test pathogens using the most effective marination time (48 h) and the results were expressed in terms of appearance, color, texture, taste and overall appreciation (Fig. 3). Although marination with koruk products affected the color of meat in negative way, no significant difference was observed between the colors of marinated and non-marinated samples after cooking process ( $P > 0.05$ ). Similarly, Istrati et al. (2015) reported that the marination of meat with dry red wine have a negative effect on meat color. When the samples were evaluated in terms of

appearance and color, meat marinated with ML2 was found as the most admired sample, while ML7 marinated meat was the least admired one ( $P < 0.05$ ) (Fig. 3). Besides, no significant difference was found between the texture characteristics of the samples ( $P > 0.05$ ). However, it was stated that the marination with wine and spices provided softening of the texture by affecting myofibrillar proteins on meat (Istrati et al., 2015). In another study, marination of trout samples with grape and apple cider vinegar lead to softening of meat texture and this affect increased as the processing time increased (Kilinc and Yavuz, 2011). The differences between the results of the studies could be related with the variation of meat type, marination liquid, marination techniques and conditions used during marination.

In terms of taste and overall appreciation, the most admired samples were identified as samples marinated with ML2 and ML8 ( $P > 0.05$ ). In overall interpretation, the sample marinated with ML2 was the most admired sample in terms of all sensory characteristics investigated. The data obtained as a result of sensory evaluation revealed that koruk juice and dried koruk pomace have the potential to contribute significantly to the sensory quality characteristics of meat.

#### 4. Conclusion

In this study, it was determined that koruk products have an important potential that can be used in meat marination by providing meat safety. Koruk juice and dried koruk pomace showed anti-microbial effect against *S. Typhimurium*, *E. coli* O157:H7 and *L. monocytogenes*, which are known as food-borne pathogens that could be contaminated on meat. Especially in the case of low levels of contamination ( $\approx 3$  log), it has been demonstrated that these meats can be made completely safe with the application of koruk marination. It has been determined that the marination process significantly contributes to the sensory properties of meat. It is thought that these results will make a significant contribution to the food industry. Further studies are needed to examine the effects of ML prepared with different koruk products on other meat types.

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