



## Bioactive, Physicochemical and Antimicrobial Properties of Koruk (Unripe Grape, *Vitis vinifera* L.) Products

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### ABSTRACT

In the study, the bioactive, physicochemical and antimicrobial properties of koruk juice and dried koruk pomace were investigated. The total phenolic contents of koruk juice and pomace were determined as 1119.670 and 1182.170 mg GAE/L, respectively. Higher DPPH radical scavenging activity found in koruk pomace, which was consistent with total phenolic contents. Organic acid, total sugar and ascorbic acid contents of koruk juice (3.44%, 4.737 g/L and 2.559 mg/100 mL) were higher than koruk pomace (0.19%, 0.866 g/L and 0.242 mg/100 mL). The counts of Total Psychrophilic Aerobic Bacteria and mold-yeast in pomace were determined as 0.694 and 1.016 log CFU/g, respectively, while no growth was observed in koruk juice. Koruk juice and pomace indicated antimicrobial effect on all test microorganisms in the range of 31.3-500.0 µg/mL (Minimum Inhibition Concentration). The most sensitive bacteria to koruk juice were *Bacillus cereus*, while *Pediococcus acidilactici* was the most sensitive one to koruk pomace. Koruk juice also showed bactericidal effect on all test cultures at concentration ranging between 250.0 and 500.0 µg/mL (Minimum Bactericidal Concentration), koruk pomace was not showed bactericidal effect on *Escherichia coli* O157:H7, *Salmonella* Typhimurium, *E. coli* and *B. cereus*. This study demonstrated that the koruk products could be used in food applications as natural antioxidant and antimicrobial substance.

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## Introduction

Plants are natural antimicrobial and antioxidant substances and are of great importance for the food industry (Mohammed et al., 2020; Pehlivan et al., 2021). Various plants produce secondary metabolites with antimicrobial properties against many microorganisms and phenolic compounds can exhibit several biological effects associated with antioxidant activities such as anti-inflammatory, anticarcinogenic, antiallergic, hepatoprotective and antithrombotic effects (Belletti et al., 2008; Del Rio et al., 2013; Meireles et al., 2016; Sevindik et al., 2017; Vázquez-Armenta et al., 2017; Mohammed et al., 2021).

Unripe grape (*Vitis vinifera* L.), which contains high amounts of tartaric and malic acids with low sugar content, is usually utilized as acidifier and flavoring agent for several appetizers, salads and dishes (de Matos et al., 2017). It is also known as koruk, koruk juice, verjons, vertjus, verjus, agraz, abe-ghureh, agresto in different countries (Karapinar and Sengun, 2007). Koruk products have high antioxidant and antimicrobial activities due to

phenolic compounds of the grapes (Nikfardjam, 2008; Turkmen et al., 2017). The type of fruit, ripening period and environmental conditions are the factors that influence the physicochemical properties of unripe grapes. It has been reported that koruk juice has important benefits on health due to bioactive compounds such as hydroxycinnamic acid, hydroxybenzoic acid, flavonoid and phenolic (Ahmadi and Roney, 2014). It has been determined that the koruk juice has beneficial effects on glycemic control, oxidation, endothelial function, blood pressure and serum lipid profile (Aminian et al., 2003; Endemann and Schiffrin, 2004; Hadi et al., 2005; Moussa-Al-Reza et al., 2011; Setorki et al., 2011; Alipour et al., 2012; Zibaenezhah et al., 2012; Nematbakhsh et al., 2013).

Grape seeds and shells are important sources of phenolic compounds (Bail et al., 2008). There are some natural phenolic antioxidants in grape seed that prevent the oxidation of fats such as tocopherols and tocotrienols (Sabir et al., 2012). During the ripening period, significant

changes occur in grapes, especially in total acid and phenolic content. In a study conducted by Otag (2015), the titration acidity of the unripe grapes was about 10 times higher than mature grapes. Different researchers have been determined that the total amount of phenolic substances varies depending on the year of production, ripening period, grape variety and grape parts, and the total amount of phenolic substances decreases during ripening period (Doshi et al., 2006; Navarro et al., 2008; Jin et al., 2009).

There is limited knowledge on physical, chemical and microbiological properties of koruk juice and pomace. The aims of this study were to investigate 1) the physical and chemical properties of koruk juice and dried koruk pomace, 2) the potential antibacterial action of koruk products against twelve bacteria (*Bacillus cereus* No 8, *B. subtilis* ATCC 6037, *Escherichia coli* ATCC 1103, *E. coli* O157:H7 ATCC 43888, *E. coli* O157:H7 ATCC 43895, *Enterococcus faecalis* ATCC 29212, *Listeria monocytogenes* ATCC 49594, *L. monocytogenes* ATCC 13932, *Pediococcus acidilactici* ATCC 8042, *Staphylococcus aureus* 6538P, *Salmonella* Typhimurium ATCC 13311 and *S. Typhimurium* ATCC 14028).

## Material and Methods

### Preparation of Koruk Products

Unripe grapes belong to Yediveren variety were taken directly from the grower in Izmir, Turkey. Firstly, grapes were sorted, washed and followed by disinfected for 15 min by vinegar (5%, v/v). After rinsing with tap water, the grapes were cut in blender (Waring Commercial Blender, Waring Product Division New Hartford Conn., USA) at high speed for 1 min. Then the mixture was filtered from cheesecloth and filter paper (Filter-Lab, 40x40 cm), respectively. The obtained liquid (koruk juice) was stored at deep freeze (-18°C) until analysis. The pomace was dried by using tray dryer (TK Lab Model, Eksis Industrial Drying Systems, Turkey) operated at 60°C, rate of 1 m/s until the moisture content arrives at 3% (Infrared Moisture Meter, Ohasus MB45 Nanikon, Switzerland) and followed by pulverized. The final product called as dried koruk pomace was stored at 4°C after vacuum packing (Henkelman Boxer 42, Holland) (Figure 1).

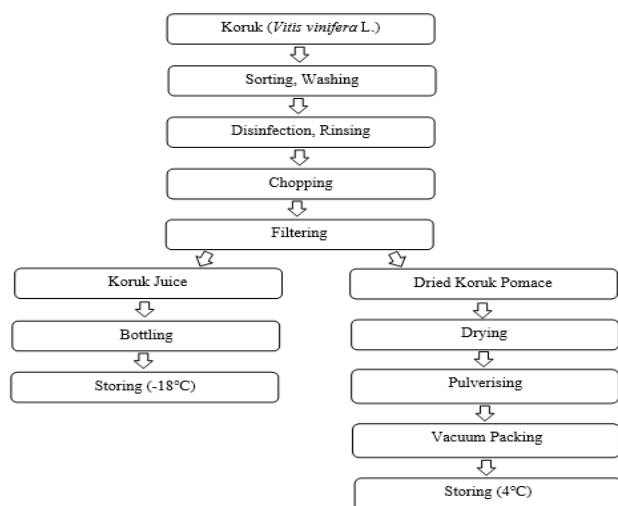


Figure 1. Production flow diagram of Koruk juice and dried Koruk pomace

### Extraction of Dried Koruk Pomace

100 g ethanol-water (40:60, v/v) was added to 2 g dried koruk pomace and incubated at 25°C for 24 h in shaking incubator. Then, sample was centrifugated at 5000 rpm for 25 min and was dried in a vacuum evaporator at 40°C to remove the ethanol (Corrêa et al., 2017).

### Microbiological Analyses

Microbiological analyses were determined using rapid microbiological methods. First dilutions of the samples were prepared using 0.1% peptone water (PW, Oxoid, pH 6.8±0.2) and followed by homogenized in a Stomacher (Stomacher Lab-Blender 400, Seward Medical, London, UK) for 60 seconds. Serial dilutions were also prepared in 9 mL of 0.1% PW. After inoculating TEMPO AC test kits (BioMerieux, Ref. 411113, BioMerieux S.A., France) for counting total mesophilic aerobic bacteria (TMAB) and total psychrophilic aerobic bacteria (TPAB), the cards were incubated at 35°C for 24-48 h and 7°C for 12 days (Gilliand et al., 1976; FDA-BAM, 2001a). TEMPO YM test kits (BioMerieux, Ref. 80001, BioMerieux S.A., France) were inoculated for detecting yeast-mold counts and the cards were incubated at 25°C for 5 days (FDA-BAM, 2001b).

### pH, Total Acidity and Brix Measurement

The pH values of the koruk products were measured using a pH meter (Nel Mod 821). The total acidic values of the products were identified using titrimetric method. Results were given as g/100 mL in tartaric acid. The Brix values of the samples were recorded by a refractometer (Hanna HI 96801) (AOAC, 2007).

### Total Sugar Content

The phenol sulfuric acid method was used for determining the total sugar contents of the samples (Taylor, 1995). 1 g/L sample was mixed with 5 mL of hydrochloric acid (2.5 N) and the mixture was kept in water bath at 95°C for 3 h. After that, the temperature of the sample was reduced to 1°C in 5 min. 750 µL sodium hydroxide (40%, w/v) was mixed with the sample and the mixture was completed with distilled water to 100 mL. Then 600 µL of the prepared solution was added to 600 µL phenol solution (5%, w/v) and 3 mL sulfuric acid was added to the mixture. The solution was held in water bath at 80°C for 30 min. The absorbance was recorded by a spectrophotometer at 490 nm. The total sugar content of the products was calculated by the equation obtained from standard solutions.

### Ascorbic Acid Content

The ascorbic acid contents of the products were determined using a spectrophotometric method at 518 nm (Hisil, 2004). 1 mL stabilizer solution was mixed with 9 mL 2,6-diklorofenolindofenol solution and the absorbance of mixture was measured (L). During the preparation of samples, 90 mL stabilizer solution was added to 10 g/mL of the sample and the mixture was filtered. Then, 9 mL 2,6-diklorofenolindofenol solution was added to 1 mL filtered sample and the absorbance of mixture was measured (Ls). The final absorbance values of the samples were determined using following equation:

The final absorbance value: L - Ls

Ascorbic acid concentrations of the products were determined by the equation obtained from the graph and expressed as mg/100mL.

### Ash Content

Ash contents of the samples were determined using muffle furnace (Carbolite Gero Ltd., Germany) at 525°C. Results were expressed as % (AOAC, 2007).

### Color Properties

The color properties of the samples were determined by HunterLab Colorflex (Management Comp., USA). The results were stated as  $L^*$  (whiteness/darkness),  $a^*$  (redness/greenness) and  $b^*$  (yellowness/blueness) (Kramer and Twigg, 1984).

### Total Phenolic Contents

The Folin-Ciocalteu colorimetric method was used to determine the total phenolic contents of koruk juice and dried koruk pomace. 1 mL of filtered sample was added to 75 mL of distilled water, and then 5 mL of Folin-Ciocalteu reagent was added to the solution. The mixture was held at room temperature in the dark for 3 min. After that, 10 mL of sodium carbonate solution (75 g/L) was added to the reaction mixture, followed by was completed to 100 mL with distilled water and the mixture was kept at room temperature in the dark for 90 min. The spectrophotometer (Agilent Technologies, Carry60 UV-Visible) was used for determining the absorbance of the solution and the absorbance was measured at 734 nm. Results were stated in mg gallic acid equivalents (GAE)/L (Cemeroğlu, 2013).

### Antioxidant Capacity

The antioxidant activities of the koruk products were analyzed according to DPPH and ABTS radical scavenging methods.

#### DPPH Radical Scavenging Activity

DPPH radical scavenging activity of the samples was examined using the modified protocol indicated by Singh et al. (2002). 5 mL of DPPH solution (0.1 mM in methanol) was added to 0.1 mL of filtered sample and the mixture was allowed in the dark at room temperature for 15 min. The absorbance was determined using a spectrophotometer at 517 nm. Methanol was used as control. DPPH radical scavenging activity was calculated using the following equation:

$$\text{DPPH radical scavenging activity (\%)} = \frac{(A_c - A_s)}{A_c} \times 100$$

$A_c$ : the absorbance of the control

$A_s$ : the absorbance of the sample.

#### ABTS+ Radical Scavenging Activity

ABTS radical scavenging capacity was also used for determining of antioxidant capacity of samples (Re et al., 1999). 7 mM ABTS+ solution and 2.45 mM ammonium persulfate were used to prepare ABTS+ stock solution. The solution was kept in the dark at room temperature for 16 h. ABTS+ solution was diluted with ethanol to obtain absorbance value of  $0.70 \pm 0.02$  at 734 nm. 3 mL of ABTS+ solution was added to 0.3 mL of samples and the mixture was kept in the dark at room temperature for 6 min. The absorbance was measured using a spectrophotometer at 734 nm. Ethanol was used as a blank. ABTS+ radical scavenging capacity was calculated using following equation:

$$\text{ABTS+ radical scavenging activity (\%)} = \frac{(A_c - A_s)}{A_c} \times 100$$

$A_c$ : the absorbance of the control

$A_s$ : the absorbance of the sample.

### Antimicrobial Activity

The antimicrobial activity of koruk juice and dried koruk pomace extract were examined against *Bacillus cereus* No 8, *B. subtilis* ATCC 6037, *Escherichia coli* ATCC 1103, *E. coli* O157:H7 ATCC 43888, *E. coli* O157:H7 ATCC 43895, *Enterococcus faecalis* ATCC 29212, *Listeria monocytogenes* ATCC 49594, *L. monocytogenes* ATCC 13932, *Pediococcus acidilactici* ATCC 8042, *Staphylococcus aureus* 6538P, *Salmonella* Typhimurium ATCC 13311 and *S. Typhimurium* ATCC 14028), which were obtained from Ege University, Food Engineering Department, Food Microbiology Research Laboratory and Izmir Food Control Laboratory. Activation of stock cultures were performed in Tryptic Soy Broth (TSB, pH  $7.3 \pm 0.2$ , Oxoid) by incubating at 37°C for 24 h. The cultures were optimized equivalent to 0.5 McFarland (DEN-1 McFarland Densitometer, Grant-bio) turbidity standard.

The minimum inhibitory concentration (MIC) of koruk products was determined using microdilution method by 96-well "U" type sterile microplates (Deng et al., 2014). 100 µL of Mueller Hinton Broth (MHB, Oxoid, pH  $7.3 \pm 0.2$ ) was transferred into every well followed by the addition of koruk juice or dried koruk pomace extract into the wells of the first row. Samples, serially two-fold diluted by MHB were transferred into wells and the final concentrations in the wells were between 1-500 µg/mL. Then, 10 µL of inoculum were added to every well and incubation was performed at 37°C for 18 h. After that, 20 µL of 0.5% 2,3,5-triphenyltetrazolium chloride (TTC, Merck) was added to each well and the plates were incubated at 37°C for 30 min for detecting MIC values of the samples. The minimum bactericidal concentration (MBC) of the samples were also detected by streaking samples taken from the first wells, where no growth was observed, on streaking on Mueller-Hilton Agar (MHA, Oxoid, pH  $7.3 \pm 0.2$ ) (Tomas-Menor et al., 2013).

### Statistical Analysis

Experiments were performed in three replicates. Results were stated as mean  $\pm$  standard error. The SPSS 20.0 for Windows Software Package was used to evaluate the experimental data and evaluation was performed (at the significance level of  $P \leq 0.05$ ) by using one-way ANOVA and Duncan multiple comparison methods (SPSS, 2011).

## Results and Discussion

### Microbiological and Physicochemical Properties

TMAB, TPAB, mold and yeast counts were performed to determine the microbiological properties of koruk products (Table 1). TMAB, TPAB and mold-yeast growth was not detected in the koruk juice. TMAB growth was not observed in the dried koruk pomace, while the counts of TPAB and mold-yeast were determined as 0.694 and 1.016 log CFU/g, respectively.

Table 1. The counts of Total Mesophilic Aerobic Bacteria (TMAB), Total Psychrophilic Aerobic Bacteria (TPAB) and yeast-mold of Koruk products

Koruk products	TMAB	TPAB	Mold-yeast
Koruk juice (log CFU/mL)	-*	-	-
Dried Koruk pomace (log CFU/g)	-	0.694±0.173 <sup>a</sup>	1.016±0.919 <sup>b</sup>

\*"-." no growth was detected. Values in the same row with different lower case (a, b) are significantly different (P<0.05).

Table 2. Some physicochemical properties of Koruk products

Analysis	Koruk juice	Dried Koruk pomace
pH	2.940±0.050 <sup>a</sup>	3.890±0.068 <sup>b</sup>
Total acidity (g tartaric acid/100 mL)	3.524±0.149 <sup>a</sup>	0.192±0.005 <sup>b</sup>
Brix	4.233±0.058 <sup>a</sup>	11.433±0.058 <sup>b</sup>
Total sugar content (mg/100 mL)	4.737±0.131 <sup>a</sup>	0.866±0.106 <sup>b</sup>
Ascorbic acid content (mg/100 mL)	2.559±0.172 <sup>a</sup>	0.242±0.04 <sup>b</sup>
Ash content (%)	0.169±0.004 <sup>a</sup>	0.169±0.005 <sup>a</sup>

Values in the same row with different lower case (a, b) are significantly different (P<0.05).

Table 3. Color properties of Koruk products

Koruk products	<i>L</i> *	<i>a</i> *	<i>b</i> *
Koruk juice	0.425±0.299 <sup>a</sup>	0.015±0.006 <sup>a</sup>	11.075±0.309 <sup>a</sup>
Dried Koruk pomace	30.635±0.286 <sup>b</sup>	36.443±0.102 <sup>b</sup>	52.655±0.328 <sup>b</sup>

Values in the same row with different lower case (a, b) are significantly different (P<0.05).

The pH, total acidity and Brix values of the koruk juice and dried koruk pomace were determined as 2.940-3.890, 3.524-0.192 g tartaric acid/100 mL and 4.233-11.433, respectively (P<0.05). Chemical properties of grape strongly change depending on growing area, variety, harvesting period and maturity. Hence, the results of the previous studies show differences. In a study, it was determined that the pH and Brix values of the koruk juice obtained from different types of grapes (Cabernet sauvignon, Chardonnay, Cabernet franc, Merlot, Glera and Sauvignon blanc) ranged between 2.56-2.91 and 3.8-9.9, respectively. The amounts of malic acid in koruk juice obtained from white and red grape varieties found between 10.90-28.62 g/L and 17.64-30.38 g/L, respectively, while the amounts of tartaric acid were determined as 5.51-11.78 g/L in the white varieties and 6.25-14.05 g/L in the red varieties (de Matos et al., 2017). In another study, pH, total acidity and Brix values of the koruk juices obtained from 8 different grape varieties (Kabarcik, Emir, Narince, Muskat, Sultana, Okuzgozu, Bogazkere, Cabernet Sauvignon) were found ranging between 2.00-2.20, 32.52-49.05 g tartaric acid/L and 4.07-5.97, respectively (Guler and Candemir, 2017). In a study performed by Karapinar and Sengun (2007), it was determined that the pH and total acidity values of the koruk juices produced by different methods were between 2.44-2.78 and 2.75-2.80 g tartaric acid/100 mL, respectively.

The total sugar contents of the koruk juice and dried koruk pomace were determined as 4.737 and 0.866 g/L, respectively (Table 2). It is determined that the total sugar content of the dried koruk pomace is lower than the koruk juice (P<0.05). In a study conducted by Nikfardjam (2008), the total sugar contents of koruk juice were ranged between 0.10 g/L and 95.10 g/L. In another study, the total sugar contents of industrially, in laboratory and traditionally produced verjuice and sour grape sauces were determined ranging between 0.85-13.56 g/L and 1.18-17.04 g/L, respectively (Oncul and Karabiyikli, 2015). Studies have shown that the total sugar contents of koruk products show

differences depending on the harvesting period, product type, genotypic properties and production methods used.

Ascorbic acid values of the koruk juice and dried koruk pomace were determined as 2.5593 mg/100 mL and 0.2419 mg/100 mL, respectively (P<0.05) (Table 2). Similarly, the ascorbic acid value of koruk juice was determined as 1.8 mg/100 mL (Setorki et al., 2011). In another study, ascorbic acid contents of koruk products were ranged between 0.00 and 5.91 mg/100 mL (Oncul, 2016).

The amount of ash shows inorganic substances that remain unburned. It was determined that the amounts of ash of koruk juice and dried koruk pomace were 0.169% and 0.169%, respectively (Table 2). In another study, the amounts of ash of koruk juices obtained from two different varieties (Yediveren and Kabarcik) were determined as 0.244% and 0.382%, respectively (Hayoglu et al., 2009).

#### Color Properties

The color characteristics of koruk products were determined by *L*\*, *a*\*, *b*\* values. *L*\*, *a*\* and *b*\* values of koruk juice were determined as 0.425, 0.015 and 11.075, while *L*\*, *a*\*, *b*\* values of dried koruk pomace were found as 30.635, 36.443 and 52.655, respectively (Table 3). In a study conducted by Oncul (2016), it was determined that, *L*\*, *a*\* and *b*\* values of koruk products were ranged between 32.97-96.57, -9.31-16.38 and -23.52-127.40, respectively. These results showed that color characteristics change depending on the raw materials and production methods used.

#### Total Phenolic Contents

The total phenolic contents of koruk juice and dried koruk pomace extract were found as 1119.670 and 1182.170 mg GAE/L (Table 4). In a study performed by Guler and Candemir (2017), it was determined that the total phenolic contents of the koruk juices obtained from eight different varieties (Kabarcik, Emir, Narince, Muskat, Sultana, Okuzgozu, Bogazkere, Cabernet Sauvignon) were between 152.11 and 317.71 mg GAE/L. In a study

conducted by Hayoglu et al. (2009), the total phenolic contents of koruk juice samples were ranged between 6262.7 and 7538.0 mg GAE/L. In a study, it was determined that the total phenolic contents of koruk juice and sour grape sauce ranged between 233.44-672.75 mg/L and 96.79-652.14 mg/L respectively (Oncul and Karabiyikli, 2015). Total phenolic contents of the koruk products (unripe grape piece, powder and juice), which were extracted separately with 10% ethanol and water, were observed in the range of 505.682-758.523 mg GAE/g and 424.432-603.409 mg GAE/g, respectively (Turkmen et al., 2017). The total phenolic contents of unripe grape marc (Yediveren and Kabarcik varieties) extracts produced using different temperatures (25-50°C), solvent ratios (ethanol/water, 0-100%) and times (1-24 h) were ranged between 85.60-405.42 mg GAE/100 g (Shojaee-Aliabadi et al., 2013). In a study performed by Golmakani et al. (2017), lower total phenolic content of koruk marc extract was reported as 49.3 mg GAE/g. It has been reported that the differences in the total phenolic content of koruk products vary according to production year, ripening period and grape variety (Doshi et al., 2006; Navarro et al., 2008; Jin et al., 2009).

#### Antioxidant Activity

Different analytical methods are used for determining the antioxidant capacity of foods (Buyuktuncel, 2013; Ray et al., 2018). In this study, two different methods (DPPH and ABTS\* radical scavenging assays) were used to determine the antioxidant activities of koruk products. Koruk juice and dried koruk pomace extract inhibited DPPH radical by 90.70% and 93.32%, respectively ( $P>0.05$ ) (Table 4). ABTS\* values of koruk juice and dried koruk pomace extract were determined as 1.202 and 0.425  $\mu\text{mol TE/mL}$ , respectively ( $P<0.05$ ). In a study conducted by Oncul and Karabiyikli (2015), the antioxidant capacities of the koruk juice and sour grape sauce were examined by TEAC and FRAP methods. The TEAC results were ranged between 0.035-0.860 and 0.070-0.885  $\mu\text{mol TE/mL}$ , while

the FRAP results were determined between 0.010-0.185 and 0.025-0.231  $\mu\text{mol TE/mL}$  respectively. In another study, antioxidant activities of koruk juices produced from eight different grape varieties (Kabarcik, Emir, Narince, Muskat, Sultana, Okuzgozu, Bogazkere, Cabernet Sauvignon) were determined between 1.36 and 4.04 mg DPPH/mL. Koruk juice produced from Okuzgozu variety has the highest antioxidant properties, while the koruk juice of Sultana variety has the lowest antioxidant activity (Guler and Candemir, 2017). In another study, it has been determined that the unripe grape marc inhibits DPPH radical in the range of 47.19% to 92.21% (Shojaee-Aliabadi et al., 2013). In another study conducted by Golmakani et al. (2017), it has been determined that the extract of unripe grape marc has an effective and rapid interaction with the DPPH radical and the IC50 value is determined as 0.3 mg/mL. The results showed that the antioxidant capacities of the samples may change according to the method used, grape variety and product.

#### Antimicrobial Activity

Koruk products show antimicrobial effects as well as antioxidant activity due to acidic characteristics and phenolic compounds in the structure (Turkmen et al., 2017; Ozturk and Sengun, 2019). Antimicrobial activities of koruk products were examined against twelve strains according to broth dilution method. The MIC values of koruk juice ranged between 31.3 and 125.0  $\mu\text{g/mL}$  depending on test cultures (Table 5). *B. cereus* No 8 was the most sensitive bacteria against koruk juice. When the MIC values determined for different microorganisms were compared, it was observed that the koruk juice was more effective than dried koruk pomace extract against tested microorganisms except *P. acidilactici* ATCC 8042. The MIC values of dried koruk pomace extract were determined in the range of 31.3 and 500.0  $\mu\text{g/mL}$ , and the most sensitive microorganism was determined as *P. acidilactici* ATCC 8042 (Table 5).

Table 4. Total phenolic content and antioxidant activity of Koruk products

Analysis		Koruk juice	Dried Koruk pomace
Total phenolic content (mg GAE/L)		1119.670±108.3 <sup>a</sup>	1182.170±56.684 <sup>a</sup>
Antioxidant activity	DPPH (%)	90.700±1.368 <sup>a</sup>	93.320±0.134 <sup>a</sup>
	ABTS ( $\mu\text{mol TE/mL}$ )	1.202±0.063 <sup>a</sup>	0.425±0.037 <sup>b</sup>

Values in the same row with different lower case (a, b) are significantly different ( $P<0.05$ ).

Table 5. MIC and MBC values of Koruk products against test microorganisms ( $\mu\text{g/mL}$ )

Microorganisms	Koruk juice		Dried Koruk pomace	
	MIC	MBC	MIC	MBC
<i>B. cereus</i> No 8	31.3	500.0	62.5	>500.0
<i>B. subtilis</i> ATCC 6037	125.0	500.0	250.0	500.0
<i>E. coli</i> ATCC 1103	62.5	500.0	500.0	>500.0
<i>E. coli</i> O157:H7 ATCC 43888	62.5	500.0	125.0	>500.0
<i>E. coli</i> O157:H7 ATCC 43895	125.0	500.0	250.0	>500.0
<i>E. faecalis</i> ATCC 29212	62.5	500.0	125.0	500.0
<i>L. monocytogenes</i> ATCC 13932	62.5	250.0	125.0	250.0
<i>L. monocytogenes</i> ATCC 49594	62.5	250.0	125.0	500.0
<i>P. acidilactici</i> ATCC 8042	62.5	250.0	31.3	500.0
<i>S. aureus</i> 6538P	125.0	250.0	250.0	500.0
<i>S. Typhimurium</i> ATCC 13311	125.0	500.0	250.0	>500.0
<i>S. Typhimurium</i> ATCC 14028	125.0	500.0	250.0	>500.0

The koruk juice showed a bactericidal effect at concentrations ranging from 250.0 to 500.0 µg/mL against all tested microorganisms (Table 5). MBC values of dried koruk pomace were determined as 500.0 µg/mL against *B. subtilis*, *E. faecalis*, *L. monocytogenes* ATCC 49594, *P. acidilactici* and *S. aureus*, while it was 250.0 µg/mL against *L. monocytogenes* ATCC 13932. The extract of dried koruk pomace did not show bactericidal effect at concentration under 500.0 µg/mL against other test cultures (*B. cereus*, *E. coli* ATCC 1103, *E. coli* O157:H7 ATCC 43888, *E. coli* O157:H7 ATCC 43895, *S. Typhimurium* ATCC 13311 and *S. Typhimurium* ATCC 14028).

The studies on the antimicrobial effect of koruk products are limited. In a study performed by Karabiyikli and Oncul (2015), koruk juice showed inhibitive effect on various microorganisms (*B. cereus*, *E. coli*, *L. monocytogenes*, *S. aureus* and *S. Typhimurium*) at concentration ranging from 6.25% to 50% and the most sensitive microorganism was found as *B. cereus*, while the most resistant bacteria was determined as *S. Typhimurium*. In another study, the antimicrobial effect of unripe grape marc extract was investigated against *Candida* spp., *Tricophyton mentagrophytes*, *T. rubrum*, *Microsporum gypseum*. The MIC values of the extracts were found between 53.58-214.31 µg/mL against *Candida* strains, while the MIC values were determined between 43.54-133.20 µg/mL against other test cultures (Simonetti et al., 2017).

## Conclusions

The results of this study demonstrated that koruk juice and dried koruk pomace have high antioxidant and antimicrobial properties. Antimicrobial activity of koruk juice was higher than the extract of dried koruk pomace. This result could be linked with the higher amount of total acidic content of koruk juice than dried koruk pomace. However, the antimicrobial effects of koruk products are not only related to the total acidity, phenolic contents of the product have also an important contribution to the antimicrobial properties. According to the results of this study, waste assessment can be provided with the use of dried koruk pomace, which could be an important contribution to the food industry. Besides, it can be used as a low-cost natural antioxidant source in foods. Further studies including food applications of koruk products that show high antimicrobial and antioxidant activities are needed.

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