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Determination of phenolic acid profiles by HPLC in lacto-fermented fruits and vegetables (pickle): Effect of pulp and juice portions

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Abstract

Antioxidant activity, total polyphenol content (TPC) and phenolic acid profile of 30 kinds of lacto-fermented fruits and vegetables (pickle) were investigated in the present study. Pulp and juice portions of samples were separately examined and compared for all analysis. Phenolic acid profile of pickle samples was investigated using 9 phenolic acid standards by high-performance liquid chromatography. Results showed that sinapic, syringic, gallic, and chlorogenic acids were the most abundant phenolic acids, while caffeic, vanillic and *trans*-ferulic acids were found in a low concentration and *p*-coumaric and 4-hydroxybenzoic acids were not found. Total antioxidant activity of lacto-fermented fruits and vegetables was measured by both the β-carotene bleaching assay and by the 2,2-diphenyl-1-picrylhydrazyl radical scavenging assay. TPC were determined according to the Folin–Ciocalteu method. Our findings show that bioactive compounds depending on juice and pulp portions of pickle samples had significant statistical differences ($p < .05$).

Practical applications

Fermented foods have been consumed for centuries in various parts of the world and are known as rich resources of functionally important microorganisms and bioactive compounds. The present study reports the phenolic acid profile (sinapic, syringic, gallic, chlorogenic, caffeic, vanillic, *trans*-ferulic, *p*-coumaric, 4-hydroxybenzoic acids), antioxidant activity, and total phenolic content of pulp and juice portions of the 30 kinds of lacto-fermented fruits and vegetables (pickle). The phenolic acids of pickles were higher in the juice portions than in the pulp portions and so, the juice portions of pickles have a good potential for commercial exploitation and positive effects on health.

1 | INTRODUCTION

Fermentation is a natural food preservative method using raw material-specific microorganisms and usually carried out to introduce a variety of diets into food preparations. Most food materials are perishable in their raw states (e.g., fruits and vegetables, milk), which make them prone to spoilage attack. Hence, they are fermented by natural inoculation and biochemical activities of microorganisms. Thereby, different types of fruits and vegetables preserve by organic acid and alcohols formed as a result of fermentation. The fermentation process improves stability of storage and extends shelf life. Additionally, this biotechnological process affects the nutritional value and biological activity of food and contributes to the organoleptic properties. Fermented foods may prevent pathogenic infections through various mechanisms and improve intestinal health, thus have great potential in preventing diseases and maintaining health (Çetin, 2011; Patra, Das, Paramithiotis, & Shin, 2016; Yildiz, 2011).

Fruits and vegetables are important for human health due to their rich nutritional ingredients. They are rich sources of polyphenols, antioxidants, pigments, vitamins, and minerals (Blasa, Gennari, Angelino, & Ninfali, 2010). These plant foods commonly used in the production of various products have also an important place in pickle production. Pickle is a product of lactic acid fermentation and the lactic acid bacteria (LAB) playing a critical role in fermentation are the most important organisms for phenolic compounds found in plant material. Some strains belonging to species of LAB (especially *Lactobacillus plantarum*) may degrade various phenolic compounds (particularly hydroxycinnamic acids) in food and affect aroma of foods (Rodríguez et al., 2009).

Phenolic acids are one of the most important groups of phytochemicals that can be usually found in plant-derived foods, constituting a significant part of our daily diet. The two primary classes of phenolic acids found in plants are C6–C1 and C6–C3. C6–C1 phenolic acids are hydroxybenzoic acids and include gallic, *p*-hydroxybenzoic, protocatechuic, vanillic, salicylic, and syringic acids. C6–C3 phenolic acids are hydroxycinnamic acids and include caffeic, ferulic, sinapic, *p*-coumaric, and chlorogenic acids. Contrary to other phenolic compounds, hydroxybenzoic and hydroxycinnamic acids have acidic qualities due to the presence of a carboxylic group on the molecule (Balasundram, Sundram, & Samman, 2006; Haminiuk, Maciel, Plata-Oviedo, & Peralta, 2012). Phenolic acids exhibit anti-allergic, anti-atherogenic, anti-inflammatory, antimicrobial, antioxidant, anticarcinogenic, and vasodilatory activities. These positive impacts of phenolic acids are attributed to their antioxidant properties (Deng et al., 2013; Haminiuk et al., 2012; Khanam, Oba, Yanase, & Murakami, 2012).

In this study, we examined the total polyphenol content, phenolic acid profile by high-performance liquid chromatography (HPLC), and antioxidant activity of both pulp and juice portion of 30 kinds of samples by considering the insufficiency in the literature on the bioactive compounds of lacto-fermented fruits and vegetables. A previous work reported the effect of pickling on antioxidant activities and total phenolic contents of 10 vegetables (Sayın & Alkan, 2015). However, limited information is available about phenolic acids in different pickle samples.

The present research aimed to (a) determine the quantitative and qualitative properties of 9 main phenolic acids in lacto-fermented fruits and vegetables through HPLC. We also aimed to (b) determine total polyphenols and antioxidant activity in 30 pickles and to (c) exhibit the difference between pulp and juice portions of pickles in terms of bioactive compounds.

2 | MATERIALS AND METHODS

2.1 | Materials

The 30 kinds of lacto-fermented fruits and vegetables were obtained from local producers in Cubuk county (Ankara, Turkey) which hosts the International Pickle and Culture Festival and were brought to the laboratory in their original packaging. Samples were stored at +4°C until analysis.

2.2 | Chemicals

Standards of 9 phenolic acids were obtained from various manufacturers (Sigma, St. Louis, USA and Merck Gernsheim, Germany). Ethanol, chloroform, Tween 40, β-carotene, DPPH• and linoleic acid were supplied by Sigma (Sigma, St. Louis, CO, USA). Folin–Ciocalteu phenol reactant, sodium carbonate, BHA, and BHT were purchased from Merck (Gernsheim, Germany). All chemicals and solvents used were analytical or HPLC grade.

2.3 | Extraction

Total polyphenol, antioxidant, and phenolic compounds were extracted from the pulp portion of pickle according to Meng et al. (2011). A total of 25 g from pulp portion of each pickle sample was weighed and disintegrated in a laboratory-type blender. Then, 3 g of this mixture was extracted from 20 ml of 80% methanol aqueous solution containing 1M HCl. Samples were sonicated in an ultrasonic bath (SK06GT Kudos ultrasonic water bath, Korea) for 30 min at room temperature. Then the extract was centrifuged at 8,000× *g* for 15 min in a high-speed refrigerated centrifuge (Hanil Science Industrial Combi 514R, Korea). The supernatant obtained was transferred to a 50-ml volumetric flask. After repeating extractions, three supernatants were combined. On the other hand, the juice portions of pickles were extracted according to Xu, Yue, Bian, Zhai, and Yao (2018) with some modifications. Three milliliters of the sample was mixed with 20 ml of acidified methanol and sonicated in an ultrasonic bath for 30 min. The supernatant was centrifuged at 8,000× *g* for 15 min. This extraction process was repeated 3 times. All the combined supernatants were filtered through a 0.45-μm PTFE syringe filter and stored at −80°C (Operon deep freeze −86°C, Korea), until analysis.

2.4 | Determination of antioxidant activity of extracts

2.4.1 | β-carotene Bleaching

Assay was assessed according to Şengül, Erkaya, Şengül, and Yıldız (2012). First, 0.1 mg of β-carotene was dissolved in 1 ml of chloroform, then 40 mg of linoleic acid and 200 mg of Tween 40 were added. The mixture was evaporated at 50°C by means of a rotary evaporator to remove chloroform. Then 100 ml of distilled water saturated with oxygen was added slowly to the residue and shaken to give a stable emulsion. Then, 800 μl of the extract was added to 3-ml aliquots of β-carotene/linoleic acid emulsion. As soon as the emulsion was added to test tubes, the zero-time absorbance was measured at 470 nm against a blank sample using a visible spectrophotometer (Shimadzu UV-1208, Japan). The mixtures were incubated at 50°C for 100 min, and the measurement was carried out at 10-min intervals for 100 min. The blank sample was prepared by lacking β-carotene, and butylated hydroxyanisole (BHA, a synthetic antioxidant) and butylated hydroxytoluene (BHT, a synthetic antioxidant) were used as standard. All samples were assayed in triplicate. The degradation rate (DR) was calculated according to first-order kinetics using the following equation:

$$\mathrm{DR}_{\mathrm{sample,\,control,\,standard}} = \ln\,(a/b) \times 1/t$$

where ln is natural log, *a* is the initial absorbance (470 nm) at time 0, *b* is the absorbance (470 nm) at 100 min, and *t* is time.

Antioxidant activity (AA) was expressed as a percentage of inhibition relative to the control, using the following formula:

$$\mathrm{AA} = \left(\mathrm{DR}_{\mathrm{control}} - \mathrm{DR}_{\mathrm{sample\ or\ standard}}\right) / \mathrm{DR}_{\mathrm{control}} \times 100$$

2.4.2 | DPPH• (2,2-diphenyl-1-picrylhydrazyl)

Assay was performed according to the method of Şengül et al. (2012). To evaluate the free radical scavenging activity, the extracts were allowed to react with a stable free radical (DPPH•). The absorbance was measured at 517 nm against blank samples lacking scavenger.

2.5 | Determination of total phenolic content

TPC was evaluated by the Folin–Ciocalteu method, using gallic acid as reference compound. Briefly, 1 ml of the solution (contains 1 mg sample) extract in water was pipetted into a glass amber reagent bottle. Then, 46 ml of distilled water and 1 ml of Folin–Ciocalteu reagent were added and mixed thoroughly. The mixture was left to stand for 3 min, and 3.0 ml of 2% sodium carbonate was added. After 120 min of incubation at ambient temperature with shaking, the resulting absorbance was measured against a blank sample at 760 nm. All measurements were performed in triplicate. Results are expressed by reference to the calibration curve as micrograms of Gallic Acid Equivalents per milligram sample (Şengül et al., 2012).

2.6 | Determination of phenolic acid profile

Phenolic acid profile of pickle samples was determined according to Gundogdu (2013) and Dragovic-Uzelac, Delonga, Levaj, Djakovic, and Pospisil (2005) with some modifications. Each extract was analyzed in an HPLC system (Shimadzu SPD-M20A PDA). Separation was achieved on a reversed-phase ODS column (5 μm, 4.6 × 250 mm) maintained at 30°C by a thermostat. The binary mobile phase contained both methanol (solvent A) and 2% acetic acid–H_2O (solvent B), which was pumped at a flow rate of 0.8 ml/min and 20 μl of the injection volume was used for spectral measurements at 245 and 340 nm.

2.7 | Statistical analysis

All measurements and analyses were carried out in triplicate. Results were analyzed statistically using SPSS 22.0 program. Variance analysis was performed to determine the differences in the phenolic content, phenolic acid profile, and antioxidant activity of samples, as well as to establish in terms of these parameters the differences between both pulp and juice portions of samples.

3 | RESULTS AND DISCUSSION

3.1 | Antioxidant activities of lacto-fermented fruits and vegetable samples

Determination of antioxidant activity was conducted by means of two different spectrophotometric methods (β-carotene bleaching assay and DPPH•) (Tables 1 and 2). There were significant statistical differences ($p < .05$) in antioxidant activity depending on pulp and juice portions of pickle samples. The β-carotene bleaching assay is the oldest and commonly applied method of estimating the antioxidant activity of food and beverages. According to the results of this assay, the highest antioxidant activity in the pulp portions was found in purple cabbage (86.01 ± 4.52%), followed by pine cone pickle (82.83 ± 3.25%), okra pickle (82.42 ± 4.46%), and wild pear pickle (81.91 ± 0.21%) (Table 1). Purple cabbage which has a high antioxidant activity is amo ng the most consumed vegetables worldwide (Mizgier et al., 2016). On the other hand, the lowest antioxidant activity in the pulp portions was found in greengage plum pickle (45.08 ± 5.47%) (Table 1). In the juice portions of samples, pine cone pickle (96.95 ± 0.00%) exhibited the highest antioxidant activity, while rock samphire pickle possessed the lowest antioxidant activity (54.29 ± 3.70%) (Table 1). Among the pickle samples, the most noteworthy was pine cone pickle. In the literature it was reported that polyphenols in pine cone have a therapeutic effect in the treatment of degenerative diseases like cancer (Yi, Qu, Wu, Wang, & Wang, 2017; Yi et al., 2018). Though this material is not used for consumption under normal conditions, the usage of pine cone in pickle production is quite remarkable when considering that its polyphenols pass into the pickle juice.

This study showed that antioxidant activities of the juice extracts of sweet long green pepper, jalapeno, and white cabbage pickles were similar to BHA. Furthermore, the antioxidant activities of the juice extracts of okra, ornamental pepper, and green bean pickles were similar to another synthetic antioxidant BHT. In addition, pine cone, sour grapes, purple cabbage, and bitter greengage pickles had higher antioxidant activities than the BHA and BHT (Table 1).

DPPH• is a stable nitrogen-centered and lipophilic-free radical that has been widely accepted for estimating the free radical

TABLE 1 Antioxidant activity values for juice and pulp extracts of lacto-fermented fruits and vegetables according to the β-carotene bleaching assay

Lacto-fermented fruits and vegetables	β-carotene bleaching assay (%)	
	Pulp	Juice
Chard pickle	62.67 ± 4.92^{ijklB}	70.34 ± 5.66^{mA}
Purple cabbage pickle	86.01 ± 4.52^{abB}	95.29 ± 0.64^{abcA}
Beetroot pickle	76.33 ± 7.13^{cdefgA}	72.82 ± 0.58^{lmB}
Carrots pickle	72.61 ± 3.92^{efghB}	91.65 ± 0.17^{defgA}
Eggplant pickle	75.78 ± 2.09^{cdefgB}	92.66 ± 1.16^{bcdefA}
Gherkins pickle	70.94 ± 2.02^{fghiB}	93.80 ± 0.98^{bcdA}
White cabbage pickle	64.21 ± 0.16^{hijklB}	93.04 ± 0.01^{bcdeA}
Pine cone pickle	82.83 ± 3.25^{bcB}	96.95 ± 0.00^{aA}
Tomato dip pickle	72.85 ± 0.66^{efghB}	77.19 ± 1.94^{jkA}
Hot pepper pickle	75.69 ± 0.34^{cdefgB}	92.84 ± 0.04^{bcdefA}
Tomatoes pickle	69.57 ± 1.75^{fghijB}	86.98 ± 0.17^{hA}
Okra pickle	82.42 ± 4.46^{bcB}	92.20 ± 0.02^{cdefA}
Green almonds pickle	61.65 ± 6.91^{jklB}	74.85 ± 0.01^{klA}
Ornamental pepper pickle	61.42 ± 4.28^{jklB}	92.35 ± 0.01^{cdefA}
Green beans pickle	68.45 ± 0.87^{fghijkB}	92.24 ± 0.03^{cdefA}
Capia pepper pickle	50.50 ± 4.85^{mnB}	66.77 ± 5.53^{nA}
Greengage plums pickle	45.08 ± 5.47^{nB}	86.73 ± 1.38^{hA}
Wild pears pickle	81.91 ± 0.31^{bcdA}	81.68 ± 0.57^{iA}
White cucumber pickle	59.40 ± 12.40^{klB}	81.11 ± 0.68^{iA}
Mixed vegetables[1] pickle	73.27 ± 13.27^{defgB}	89.65 ± 0.22^{fghA}
Mixed vegetables[2] pickle	76.76 ± 0.75^{cdefB}	90.24 ± 0.20^{efgA}
Bitter greengage pickle	63.25 ± 4.29^{ijklB}	94.80 ± 0.22^{abcdA}
Jalapeno peppers pickle	70.08 ± 4.19^{fghijB}	93.00 ± 0.54^{bcdeA}
Sour grapes pickle	75.24 ± 2.76^{cdefgB}	95.97 ± 0.41^{abA}
Unripe melon pickle	50.59 ± 1.48^{mnB}	78.09 ± 0.34^{jA}
Cauliflower pickle	67.39 ± 4.84^{ghijkB}	88.68 ± 0.60^{ghA}
Rock samphire pickle	67.39 ± 4.84^{ghijkA}	54.29 ± 3.70^{oB}
Sweet long green pepper pickle	57.33 ± 2.52^{lmB}	93.32 ± 0.53^{bcdeA}
Bitter long green pepper pickle	81.00 ± 0.00^{bcdeB}	92.65 ± 0.34^{bcdefA}
Sloes pickle	59.50 ± 0.50^{klB}	88.63 ± 0.96^{ghA}
BHA	93.49 ± 0.97^{aA}	93.49 ± 0.97^{bcdeA}
BHT	92.00 ± 2.19^{aA}	92.00 ± 2.20^{cdefA}

$^{a-n}$Within each column, values with different superscript (lowercase) are significantly different ($p < .001$).

Aa^{A,B}Within each line, values with different superscript (uppercase) are significantly different ($p < .05$).

scavenging activities of antioxidants. According to the results of this assay, the highest antioxidant activity in the pulp portions was found in bitter long green pepper pickle (2.94 ± 0.03 μg/ml), followed by

TABLE 2 Antioxidant activity values for juice and pulp extracts of lacto-fermented fruits and vegetables according to the DPPH method

Lacto-fermented fruits and vegetables	DPPH (IC_{50} μg/ml)	
	Pulp	Juice
Chard pickle	23.74 ± 0.46^{lmA}	82.30 ± 1.66^{eB}
Purple cabbage pickle	22.98 ± 0.57^{klmA}	58.07 ± 0.17^{bcdB}
Beetroot pickle	19.71 ± 0.81^{ijklA}	88.72 ± 6.82^{eB}
Carrots pickle	19.11 ± 0.07^{hijkA}	nd
Eggplant pickle	15.95 ± 2.81^{fghiA}	nd
Gherkins pickle	10.91 ± 0.39^{cdeA}	461.54 ± 74.32^{kB}
White cabbage pickle	nd	nd
Pine cone pickle	nd	28.00 ± 0.62^{a}
Tomato dip pickle	17.88 ± 0.01^{ghijA}	86.57 ± 0.90^{eB}
Hot pepper pickle	15.34 ± 0.32^{fghA}	78.43 ± 0.12^{deB}
Tomatoes pickle	20.42 ± 0.49^{jklmA}	nd
Okra pickle	8.89 ± 1.22^{bcdA}	105.82 ± 19.95^{fB}
Green almonds pickle	11.59 ± 0.02^{deA}	40.15 ± 1.63^{bB}
Ornamental pepper pickle	17.51 ± 0.08^{ghijA}	57.37 ± 6.31^{bcdB}
Green beans pickle	19.70 ± 4.26^{ijkl}	nd
Capia pepper pickle	11.38 ± 0.03^{deA}	66.31 ± 0.68^{cdB}
Greengage plums pickle	16.87 ± 0.32^{ghijA}	74.66 ± 3.81^{cdeB}
Wild pears pickle	20.77 ± 1.92^{jklmA}	74.06 ± 1.50^{cdeB}
White cucumber pickle	23.31 ± 0.71^{lmA}	286.06 ± 51.34^{hB}
Mixed vegetables1 pickle	22.01 ± 0.58^{klmA}	323.54 ± 13.87^{iB}
Mixed vegetables2 pickle	22.21 ± 0.21^{klmA}	504.86 ± 29.22^{lB}
Bitter greengage pickle	19.97 ± 1.59^{jklA}	90.74 ± 7.16^{eB}
Jalapeno peppers pickle	9.11 ± 0.02^{bcdA}	411.94 ± 19.12^{jB}
Sour grapes pickle	7.44 ± 3.85^{bcA}	104.87 ± 1.75^{fB}
Unripe melon pickle	13.01 ± 0.31^{efA}	219.26 ± 44.49^{gB}
Cauliflower pickle	23.33 ± 0.05^{lmA}	287.50 ± 6.71^{hB}
Rock samphire pickle	24.37 ± 8.54^{mA}	42.15 ± 1.50^{bcB}
Sweet long green pepper pickle	6.84 ± 2.80^{bA}	38.31 ± 4.64^{bB}
Bitter long green pepper pickle	2.94 ± 0.03^{aA}	110.79 ± 8.23^{fB}
Sloes pickle	14.62 ± 3.00^{efgA}	56.28 ± 0.62^{bcdB}

$^{a-m}$Within each column, values with different superscript (lowercase) are significantly different ($p < .001$).

^{A,B}Within each line, values with different superscript (uppercase) are significantly different ($p < .05$).

sweet long green pepper pickle (6.84 ± 2.80 μg/ml) and sour grape pickle (7.44 ± 3.85 μg/ml). Zhuang, Chen, Sun, and Cao (2012) investigated antioxidant activity and bioactive properties of 9 pepper varieties. They reported that IC_{50} values of fresh pepper varieties found ranging from 135.13 to 366.67 μg/ml. In our study, IC_{50} values in pulp portions of 6 pepper pickles varied between 2.94 and 17.51 μg/ml. These values are higher than reported by Zhuang et al. (2012). The difference may be due to growing conditions of plant and fermentation process. The lowest antioxidant activity of pulp portions was detected in rock samphire pickle, showing 24.37 ± 8.54 µg/ml (Table 2). Rock samphire, which is also known as sea fennel or sea peppergrass, is a salt-resistant Mediterranean plant. It grows commonly on rocks and its leaves are also used as a component in salads (Mekinić et al., 2018; Meot-Duros & Magné, 2009). The highest (28.00 ± 0.62 µg/ml) and lowest (504.86 ± 29.22 µg/ml) antioxidant activities in juice portions of pickle samples were observed in pine cone pickle and mixed vegetable pickle[2], respectively.

Unlike the β-carotene bleaching assay, the results of the DPPH assay indicated that the antioxidant activity of the pulp extracts of pickle samples was higher according to the juice extracts. This difference may be due to the detection method used. This result points out the importance of using various methods to determine the antioxidant activity of any sample.

3.2 | Total phenolic contents of lacto-fermented fruits and vegetable samples

TPC of 30 kinds of pickle samples were determined spectrophotometrically, and a large variability among them was observed. TPC showed a significant difference ($p < .001$) in all kinds of pickles (Table 3). The highest TPC in the juice portions of samples was detected in pine cone pickle (235.19 ± 1.06 µg GAE/mg), while the lowest TPC was found in tomato pickle (16.94 ± 0.81 µg GAE/mg). The highest (135.39 ± 1.26 µg/ml) and lowest (4.82 ± 0.02 µg/ml) TPC in pulp portions of pickle samples were observed in pine cone pickle and green bean pickle, respectively. When the juice and pulp extracts of samples except the wild pear and sour grape pickles are compared, the pickle juice extracts showed significantly higher total polyphenol content than the pulp extracts ($p < .05$) (Table 3). These variations in concentrations can be explained by the hydrophilicity and polarity differences among the phenolic compounds.

Our results showed that TPC was not detected in the pulp portions of carrot and white cabbage pickles. Tinrat (2016) reported that TPC in white cabbage leaves were 0.0084 µg GAE/g. Results of our study were in agreement with previously reported by Tinrat (2016). TPC values in the juice portions of carrot and white cabbage pickles were found as 19.68 ± 0.88 and 27.81 ± 1.01 µg GAE/mg, respectively.

TPC was found as 11.26 ± 0.46 µg GAE/mg in the pulp portion of okra pickle. Jiang et al. (2017) reported that TPC in fresh okra was 12.73 mg GAE/g. This result was similar to our findings. TPC in the juice portion of okra pickle was higher than in the pulp portion, showing 144.66 ± 18.00 µg GAE/mg (Table 3).

In this study, TPC in the pulp portion of tomato pickle was identified as 4.90 ± 0.10 µg GAE/mg, while this value was 16.94 ± 0.81 µg GAE/mg in the juice portion. For gherkin and white cucumber pickles, the TPC in pulp portion were 6.60 ± 0.20 and 6.84 ± 0.71 µg GAE/mg, respectively, while these values in the juice portion were 26.51 ± 1.04 and 31.79 ± 2.32 µg GAE/mg, respectively. In the pulp and juice portions of sour grape pickle, the TPC were determined as 93.95 ± 1.82 and 86.80 ± 0.00 µg GAE/mg, respectively. A study conducted on TPC of several fruits and vegetables reported that TPC was found to be 0.42 mg/g in tomatoes,

TABLE 3 Total phenolic content (TPC) of juice and pulp extracts of lacto-fermented fruits and vegetables

Lacto-fermented fruits and vegetables	TPC (µg GAE/mg)	
	Pulp	Juice
Chard pickle	6.63 ± 0.15^{lB}	63.46 ± 0.66^{lA}
Purple cabbage pickle	12.95 ± 0.52^{fB}	181.80 ± 3.00^{cA}
Beetroot pickle	7.14 ± 0.99^{klB}	230.18 ± 1.38^{aA}
Carrots pickle	nd	19.68 ± 0.88st
Eggplant pickle	8.01 ± 0.12^{jkB}	103.69 ± 1.56^{hA}
Gherkins pickle	6.60 ± 0.20^{lB}	26.51 ± 1.04^{prA}
White cabbage pickle	nd	27.81 ± 1.01^{pr}
Pine cone pickle	135.39 ± 1.26^{aB}	235.19 ± 1.06^{aA}
Tomato dip pickle	5.42 ± 0.04^{mB}	87.18 ± 1.05^{kA}
Hot pepper pickle	11.75 ± 0.28^{gB}	89.33 ± 1.20^{jkA}
Tomatoes pickle	4.90 ± 0.10^{mB}	16.94 ± 0.81^{tA}
Okra pickle	11.26 ± 0.46^{ghB}	144.66 ± 18.00^{eA}
Green almonds pickle	16.00 ± 0.53^{eB}	158.01 ± 2.54^{dA}
Ornamental pepper pickle	8.41 ± 0.28^{jB}	129.61 ± 2.14^{fA}
Green beans pickle	4.82 ± 0.02^{mB}	18.46 ± 0.99^{stA}
Capia pepper pickle	10.44 ± 0.97^{hıB}	130.31 ± 1.51^{fA}
Greengage plums pickle	10.67 ± 0.13^{ghı0042}	95.76 ± 0.96^{lA}
Wild pears pickle	100.21 ± 1.41^{bA}	94.13 ± 1.33^{ijB}
White cucumber pickle	6.84 ± 0.71^{klB}	31.79 ± 2.32^{opA}
Mixed vegetables[1] pickle	7.79 ± 0.33^{jklB}	35.86 ± 1.06^{noA}
Mixed vegetables[2] pickle	9.98 ± 0.51^{ıB}	23.62 ± 0.82^{rsA}
Bitter greengage pickle	13.47 ± 0.00^{fB}	87.87 ± 1.07^{kA}
Jalapeno peppers pickle	11.03 ± 0.90^{ghıB}	38.51 ± 1.04^{nA}
Sour grapes pickle	93.95 ± 1.82^{cA}	86.80 ± 0.00^{kB}
Unripe melon pickle	5.09 ± 0.29^{mB}	47.79 ± 0.99^{mA}
Cauliflower pickle	8.64 ± 0.51^{jB}	64.40 ± 0.93^{lA}
Rock samphire pickle	11.19 ± 0.39^{ghıB}	128.13 ± 1.33^{fA}
Sweet long green pepper pickle	17.53 ± 1.40^{dB}	193.73 ± 3.60^{bA}
Bitter long green pepper pickle	16.16 ± 0.69^{eB}	95.29 ± 1.16^{ijA}
Sloes pickle	15.16 ± 0.31^{eB}	112.44 ± 2.31^{gA}

$^{a\text{-}t}$Within each column, values with different superscript (lowercase) are significantly different ($p < .001$).

^{A,B}Within each line, values with different superscript (uppercase) are significantly different ($p < .05$).

0.11 mg/g in gherkins, and 1.53 mg/g in ripe grapes (Ellong, Billard, Adenet, & Rochefort, 2015). Lutz, Hernández, and Henríquez (2015) reported as 2.3 mg GAE/g of TPC in fresh tomatoes. This difference may be due to the ripening period of plant and fermentation process.

TPC in the pulp and juice portions of eggplant pickle were detected as 8.01 ± 0.12 and 103.69 ± 1.56 μg GAE/mg, respectively (Table 3). A study performed on the phenolic content and antioxidant capacity of fresh and dried fruits and vegetables reported that TPC of fresh carrots, eggplant, and fresh green pepper were determined as 3.7, 9.3, and 6.9 mg GAE/g, respectively. On the other hand, they reported that TPC of dried carrots, eggplant, and green pepper were 19.90, 80.10, and 58.30 mg GAE/g, respectively (Lutz et al., 2015). The TPC in the pulp portion of jalapeno pickle in our research was determined to be 11.03 ± 0.90 μg GAE/mg, while the juice portion contained 38.51 ± 1.04 μg GAE/mg. Blanco-Rios et al. (2017) reported that the fermentation process could cause a reduction in TPC and antioxidant capacity of jalapeno peppers. Sayın and Alkan (2015) reported that the fermentation process caused an increase in bioactive compounds of vegetables. Among the possible causes of this situation was the structural disintegration of plant cell walls and so the synthesis of various antioxidant compounds. Additionally, many factors such as microorganism, temperature, pH, and fermentation duration may cause a significant change in the antioxidant properties of fruits and vegetables (Sayın & Alkan, 2015). Considering that some of the phenolic compounds pass into the juice portion during the fermentation process, a research which only includes the pulp portion cannot mention loss of bioactive compounds. In this context, our findings showed that the TPC was higher in juice portions for all samples apart from wild pear and sour grape pickles (Table 3).

3.3 | Phenolic acid profile of lacto-fermented fruits and vegetable samples

The concentrations and composition of 9 phenolic acids in 30 kinds of pickles were determined using the HPLC system. In the previous researches, antioxidant activity and total polyphenol content of few pickles were studied, and the research on the comparison of phenolic acid content in different pickles was not found. The distribution of phenolic acids in different pickles is shown in Table 4.

Gallic acid (detected in 22 pickles), chlorogenic acid (detected in 30 pickles), vanillic acid (detected in 30 pickles), caffeic acid (detected in 30 pickles), sinapic acid (detected in 30 pickles), *trans*-ferulic acid (detected in 3 pickles), and syringic acid (detected in 21 pickles) were found in the juice portion of pickles. On the other hand, gallic acid (detected in 15 pickles), chlorogenic acid (detected in 17 pickles), vanillic acid (detected in 12 pickles), caffeic acid (detected in 22 pickles), sinapic acid (detected in 30 pickles), *trans*-ferulic acid (detected in 16 pickles), and syringic acid (detected in 1 pickle) were found in the pulp portion of pickles. *p*-Coumaric acid and 4-hydroxybenzoic acid were not detected in both pulp and juice portions of pickles. The phenolic acids of pickles were different in pulps and juices (Table 4).

Sinapic acid is a phytochemical commonly found in foods such as fruits, vegetables, oily seeds, cereal grains, and medical aromatic plants (Martinović, Abramovič, & Ulrih, 2019). Positive effects on health such as UV protection, anticarcinogenic and anti-inflammatory properties, and cardiovascular protection have been reported (Aguilar-Hernández et al., 2017). Sinapic acid (104.25 mg/kg-236.32 mg/L) was found in both pulp and juice portions of all lacto-fermented vegetables and fruits.

Ferulic acid, a hydroxycinnamic acid, is a natural antioxidant found in plant cell walls. It has a high antioxidant activity and low toxicity (Flores et al., 2016). In recent years, intensive studies have been performed about the effects of ferulic acid and its derivatives on cancer, cardiovascular diseases, diabetes, and skin diseases (Zhang et al., 2018). Among pickle samples, the most noteworthy pickle sample in terms of *trans*-ferulic acid content was the purple cabbage pickle (68.03 ± 3.48 mg/L in the juice portion). Lee et al. (2018) reported that ferulic acid in purple cabbage was 1,660 μg/g and that the seasons affected the concentration of this compound. However, *trans*-ferulic acid was also detected in the juice portions of okra and capia pepper pickles. Results showed that the pulp portions of samples except mixed vegetable pickle[2], sour grape, cauliflower, and sweet long green pepper pickles contain *trans*-ferulic acid.

Syringic acid is a phenolic compound synthesized in plants with the shikimic acid pathway and is commonly found in fruits and vegetables. The syringic acid has therapeutic effects for many degenerative diseases due to antioxidant, antimicrobial, anti-inflammatory, antiendotoxic, neuro and hepato-protective activities (Cheemanapalli, Mopuri, Golla, Anuradha, & Chitt, 2018). Of all samples, cauliflower pickle has higher syringic acid content in comparison with other phenolic acids (1,066.85 ± 4.29 mg/L in juice portion). This sample was followed by white cucumber and white cabbage. In the juice portion of white cabbage were detected chlorogenic, vanillic, caffeic, syringic, and sinapic acids while in the pulp portion of white cabbage were found sinapic and *trans*-ferulic acids (Table 4). Hounsome, Hounsome, Tomos, and Edwards-Jones (2009) reported that caffeic, coumaric, gallic, syringic, and vanillic acids were among the phenolic acids of white cabbage. Syringic acid (45.93 ± 4.65 mg/kg) was found in only wild pear pickle within the pulp portions of samples (Table 4).

We determined gallic, chlorogenic, vanillic, caffeic, syringic, and sinapic acids in juice portions of the white cucumber and gherkin pickles (Table 4). The white cucumber and/or gherkin are commonly used in pickle production and contain many important components such as flavonoid, tannin, alkaloid, saponin, and steroids. They can be used fresh in salads and hamburgers. Due to the presence of anthraquinone and saponin it was reported that white cucumber and/or gherkin display antibacterial and antifungal properties against clinical pathogens (Thiruvengadam & Chung, 2015; Yoon, Chung, & Thiruvengadam, 2015).

Chlorogenic acid has anticarcinogenic, anti-inflammatory, antimicrobial, antioxidant, antiobesity, cardioprotective, hypotensive, and neuroprotective effects. Additionally, chlorogenic acid plays

TABLE 4 Composition and concentrations of 9 phenolic acids in juice and pulp extracts of 30 lacto-fermented fruits and vegetables

Lacto-fermented fruits and vegetables	Juice (mg/L)	Pulp (mg/kg)	Juice (mg/L)	Pulp (mg/kg)	Juice (mg/L)	Pulp (mg/kg)
	Gallic acid		4- hydroxybenzoic acid		Syringic acid	
Chard pickle	34.57 ± 1.97^{sA}	nd	nd	nd	nd	nd
Purple cabbage pickle	73.28 ± 6.13^{hA}	nd	nd	nd	114.50 ± 1.61^{rA}	nd
Beetroot pickle	nd	117.94 ± 4.79^{hA}	nd	nd	430.20 ± 2.39^{eA}	nd
Carrots pickle	nd	nd	nd	nd	nd	nd
Eggplant pickle	104.80 ± 3.68^{bB}	179.92 ± 0.94^{dA}	nd	nd	296.64 ± 2.59^{jA}	nd
Gherkins pickle	30.37 ± 1.67^{t}	nd	nd	nd	57.79 ± 1.51^{uA}	nd
White cabbage pickle	nd	nd	nd	nd	798.48 ± 3.71^{cA}	nd
Pine cones pickle	nd	nd	nd	nd	237.65 ± 3.48^{nA}	nd
Tomato dip pickle	nd	13.37 ± 1.12^{oA}	nd	nd	nd	nd
Hot pepper pickle	65.94 ± 4.79^{kB}	248.81 ± 0.01^{aA}	nd	nd	271.74 ± 2.59^{lA}	nd
Tomatoes pickle	nd	nd	nd	nd	nd	nd
Okra pickle	67.80 ± 4.68^{iB}	204.99 ± 0.01^{bA}	nd	nd	16.64 ± 1.85^{vA}	nd
Green almonds pickle	80.18 ± 5.72^{dB}	165.77 ± 2,41^{fA}	nd	nd	109.17 ± 0.72^{sA}	nd
Ornamental pepper pickle	66.50 ± 0.91^{jA}	nd	nd	nd	228.77 ± 3.58^{oA}	nd
Green beans pickle	25.44 ± 5.23^{vA}	nd	nd	nd	101.51 ± 1.45^{tA}	nd
Capia pepper pickle	75.55 ± 3.59^{fA}	nd	nd	nd	347.10 ± 1.26^{hA}	nd
Greengage plums pickle	78.03 ± 1.81^{eA}	nd	nd	nd	nd	nd
Wild pears pickle	146.81 ± 1.69^{aA}	nd	nd	nd	517.03 ± 1.69^{dA}	45.93 ± 4.65^{aB}
White cucumber pickle	46.23 ± 1.76^{oA}	nd	nd	nd	964.93 ± 2.83^{bA}	nd
Mixed vegetables[1] pickle	58.13 ± 1.03^{lA}	41.05 ± 0.02^{nB}	nd	nd	249.01 ± 4.61^{mA}	nd
Mixed vegetables[2] pickle	35.40 ± 4.87^{rB}	175.61 ± 3.89^{eA}	nd	nd	nd	nd
Bitter greengage pickle	nd	45.28 ± 0.70^{mA}	nd	nd	412.94 ± 1.63^{fA}	nd
Jalapeno peppers pickle	nd	nd	nd	nd	272.78 ± 2.67^{kA}	nd
Sour grapes pickle	48.69 ± 3.60^{nA}	nd	nd	nd	nd	nd
Unripe melon pickle	45.32 ± 5.23^{pB}	90.44 ± 5.08^{kA}	nd	nd	nd	nd
Cauliflower pickle	90.45 ± 1.63^{cB}	187.91 ± 0.45^{cA}	nd	nd	1,066.85 ± 4.29^{aA}	nd
Rock samphire pickle	28.21 ± 1.98^{uB}	91.82 ± 1.67^{jA}	nd	nd	nd	nd
Sweet long green pepper pickle	73.63 ± 2.48^{gA}	62.76 ± 0.16^{lB}	nd	nd	303.74 ± 2.36^{iA}	nd
Bitter long green pepper pickle	67.65 ± 2.84^{iB}	164.09 ± 0.03^{gA}	nd	nd	357.25 ± 4.51^{gA}	nd
Sloes pickle	51.84 ± 1.71^{mB}	92.21 ± 0.16^{iA}	nd	nd	200.13 ± 1.58^{pA}	nd
	Vanillic Acid		Caffeic acid		Chlorogenic acid	
Chard pickle	3.33 ± 5.23^{nA}	nd	30.06 ± 0.37^{sB}	31.94 ± 2.74^{aA}	76.19 ± 3.27^{jA}	66.34 ± 0.73^{bB}
Purple cabbage pickle	6.03 ± 1.59^{jA}	nd	36.82 ± 3.27^{gA}	31.20 ± 1.78^{cdB}	63.73 ± 1.58^{rB}	66.34 ± 3.48^{bA}
Beetroot pickle	17.15 ± 3.76^{bA}	nd	31.97 ± 2.59^{nA}	31.11 ± 5.82^{deB}	63.31 ± 3.41^{sB}	66.36 ± 2.87^{bA}
Carrots pickle	31.81 ± 2.67^{aA}	nd	33.61 ± 3.87^{jA}	nd	63.92 ± 2.63^{pA}	nd
Eggplant pickle	5.57 ± 2.59^{kA}	nd	34.61 ± 4.21^{iA}	30.91 ± 9.54^{fB}	135.47 ± 2.56^{fA}	66.36 ± 2.58^{bB}
Gherkins pickle	3.13 ± 4.06^{oA}	nd	32.81 ± 2.53^{kA}	nd	62.88 ± 1.47^{tA}	nd
White cabbage pickle	0.08 ± 1.69^{yA}	nd	30.08 ± 4.69^{sA}	nd	62.42 ± 2.65^{uvA}	nd
Pine cones pickle	6.57 ± 2.49^{hA}	1.12 ± 0.92^{cB}	32.05 ± 2.49^{mnA}	31.37 ± 2.93^{bcB}	62.28 ± 4.10^{vyA}	nd
Tomato dip pickle	3.17 ± 4.31^{oA}	nd	32.14 ± 3.21^{mnA}	30.92 ± 5.69^{fB}	62.46 ± 3.47^{uvB}	66.33 ± 4.76^{bA}
Hot pepper pickle	8.88 ± 1.23^{fA}	1.02 ± 0.91^{eB}	74.61 ± 3.28^{aA}	30.92 ± 3.51^{fB}	96.54 ± 2.84^{hA}	66.47 ± 0.27^{bB}
Tomatoes pickle	2.97 ± 3.51^{pA}	nd	32.43 ± 1.52^{lA}	nd	62.94 ± 4.51^{tA}	nd
Okra pickle	16.19 ± 1.06^{cA}	1.03 ± 3.13^{eB}	68.52 ± 3.29^{bA}	31.50 ± 0.59^{bB}	73.67 ± 1.68^{kA}	66.44 ± 1.65^{bB}

TABLE 4 Continued

	Vanillic Acid		Caffeic acid		Chlorogenic acid	
Green almonds pickle	6.03 ± 3.56^{jA}	1.10 ± 0.10^{cdB}	32.07 ± 0.48^{mnA}	31.21 ± 4.67^{cdB}	67.82 ± 3.56^{mA}	66.34 ± 3.57^{bB}
Ornamental pepper pickle	5.28 ± 3.31^{lA}	0.95 ± 0.73^{fB}	35.81 ± 2.45^{hA}	30.98 ± 1.79^{efB}	95.10 ± 1.97^{iA}	66.41 ± 0.59^{bB}
Green beans pickle	2.83 ± 0.79^{rsA}	nd	31.16 ± 3.93^{pA}	nd	62.82 ± 0.59^{tA}	nd
Capia pepper pickle	12.65 ± 0.16^{dA}	1.04 ± 0.68^{eB}	50.70 ± 2.61^{cA}	31.05 ± 1.73^{defB}	137.03 ± 2.90^{eA}	66.36 ± 2.91^{bB}
Greengage plums pickle	0.17 ± 2.69^{xA}	nd	32.45 ± 0.58^{lA}	31.04 ± 0.97^{defB}	233.15 ± 2.56^{aA}	66.35 ± 1.75^{bB}
Wild pears pickle	2.89 ± 3.41^{prA}	1.28 ± 2.73^{bB}	37.84 ± 1.49^{fA}	31.55 ± 6.12^{bB}	167.71 ± 4.12^{dA}	66.50 ± 0.73^{abB}
White cucumber pickle	3.97 ± 1.09^{mA}	nd	31.60 ± 2.59^{oA}	31.50 ± 4.49^{bA}	62.34 ± 6.23^{uvyA}	nd
Mixed vegetables[1]pickle	2.45 ± 3.24^{tA}	nd	32.91 ± 3.41^{kA}	31.36 ± 2.84^{bcB}	67.93 ± 2.48^{mA}	nd
Mixed vegetables[2] pickle	2.94 ± 1.63^{pA}	nd	32.84 ± 7.12^{kA}	31.12 ± 4.67^{deB}	67.49 ± 1.65^{nA}	nd
Bitter greengage pickle	6.08 ± 2.42^{jA}	nd	32.80 ± 4.21^{kA}	30.96 ± 6.82^{efB}	73.23 ± 0.58^{lA}	nd
Jalapeno peppers pickle	4.78 ± 3.28^{lA}	0.96 ± 0.46^{fB}	34.56 ± 1.38^{iA}	nd	64.91 ± 1.58^{oB}	66.35 ± 0.26^{bA}
Sour grapes pickle	0.84 ± 3.41^{vB}	2.35 ± 3.47^{aA}	30.36 ± 1.42^{rB}	31.18 ± 3.72^{dA}	62.33 ± 4.21^{uvyA}	nd
Unripe melon pickle	0.98 ± 1.12^{uA}	nd	30.06 ± 0.62^{sA}	nd	62.48 ± 1.59^{uA}	nd
Cauliflower pickle	2.78 ± 0.27^{sA}	nd	30.45 ± 1.19^{rA}	nd	62.21 ± 3.63^{yA}	nd
Rock samphire pickle	6.21 ± 3.29^{iA}	0.92 ± 1.75^{fB}	32.22 ± 2.33^{mA}	30.96 ± 4.92^{ef}	200.30 ± 1.52^{bA}	66.68 ± 5.75^{aB}
Sweet long green pepper pickle	0.35 ± 2.74^{wB}	0.96 ± 0.11^{fA}	44.68 ± 2.75^{dA}	30.92 ± 6.83^{f}	179.46 ± 1.77^{cA}	66.51 ± 0.49^{abB}
Bitter long green pepper pickle	7.75 ± 4.32^{gA}	1.06 ± 0.52^{deB}	41.33 ± 1.37^{eA}	30.73 ± 0.67^{g}	76.34 ± 1.67^{jA}	66.45 ± 0.03^{bB}
Sloes pickle	9.72 ± 1.74^{eA}	nd	32.41 ± 0.43^{lA}	30.91 ± 4.85^{f}	132.62 ± 2.56^{gA}	66.37 ± 2.96^{bB}
	***p*-coumaric acid**		***trans*-ferulic acid**		**Sinapic acid**	
Chard pickle	nd	nd	nd	0.17 ± 3.79^{dA}	136.03 ± 2.63^{nA}	107.71 ± 2.26^{aB}
Purple cabbage pickle	nd	nd	68.03 ± 3.48^{aA}	0.35 ± 6.47^{cB}	136.75 ± 5.81^{jA}	107.70 ± 1.69^{aB}
Beetroot pickle	nd	nd	nd	0.43 ± 5.67^{bA}	136.28 ± 2.49^{klA}	107.21 ± 1.98^{cB}
Carrots pickle	nd	nd	nd	0.02 ± 3.71^{ghiA}	136.12 ± 3.14^{lmnA}	104.46 ± 5.87^{hijB}
Eggplant pickle	nd	nd	nd	0.01 ± 5.71^{hiA}	137.80 ± 3.41^{gA}	104.32 ± 3.42^{hijkB}
Gherkins pickle	nd	nd	nd	0.03 ± 2.74^{ghiA}	139.28 ± 4.18^{dA}	104.28 ± 4.27^{ijkB}
White cabbage pickle	nd	nd	nd	0.02 ± 1.75^{ghiA}	136.38 ± 1.37^{kA}	104.30 ± 6.95^{hijkB}
Pine cones pickle	nd	nd	nd	0.53 ± 1.79^{aA}	137.64 ± 2.59^{ghA}	104.43 ± 1.73^{hijkB}
Tomato dip pickle	nd	nd	nd	0.04 ± 1.89^{ghiA}	138.55 ± 4.27^{fA}	104.49 ± 8.86^{ghB}
Hot pepper pickle	nd	nd	nd	0.10 ± 1.84^{fA}	136.29 ± 2.59^{klA}	104.29 ± 4.62^{hijkB}
Tomatoes pickle	nd	nd	nd	0.02 ± 4.67^{ghiA}	140.29 ± 0.41^{cA}	104.33 ± 5.87^{hijkB}
Okra pickle	nd	nd	5.06 ± 2.09^{bA}	0.16 ± 3.13^{deB}	138.97 ± 6.24^{eA}	104.28 ± 2.79^{ijkB}
Green almonds pickle	nd	nd	nd	0.16 ± 3.36^{deA}	135.97 ± 0.66^{nA}	104.66 ± 4.73^{gB}
Ornamental pepper pickle	nd	nd	nd	0.04 ± 5.53^{ghiA}	136.022 ± 4.31^{nA}	104.26 ± 4.73^{jkB}
Green beans pickle	nd	nd	nd	0.02 ± 2.74^{ghiA}	136.24 ± 2.30^{klmA}	104.31 ± 2.96^{hijkB}
Capia pepper pickle	nd	nd	1.34 ± 2.83^{cA}	0.18 ± 2.95^{dB}	158.39 ± 2.53^{bA}	104.42 ± 2.74^{hijkB}
Greengage plums pickle	nd	nd	nd	0.03 ± 1.49^{ghiA}	136.05 ± 2.69^{mnA}	104.66 ± 2.41^{gB}
Wild pears pickle	nd	nd	nd	0.15 ± 4.52^{deA}	137.77 ± 3.61^{gA}	105.78 ± 4.69^{eB}

TABLE 4 Continued

	p-coumaric acid		*trans*-ferulic acid		Sinapic acid	
White cucumber pickle	nd	nd	nd	0.06 ± 1.63^{gA}	137.24 ± 1.12^{iA}	104.25 ± 1.76^{kB}
Mixed vegetables[1] pickle	nd	nd	nd	0.01 ± 3.79^{hiA}	136.37 ± 1.97^{kA}	104.28 ± 4.72^{ijkB}
Mixed vegetables[2] pickle	nd	nd	nd	nd	136.63 ± 1.17^{jA}	105.84 ± 2.86^{eB}
Bitter greengage pickle	nd	nd	nd	0.04 ± 0.83^{ghiA}	137.21 ± 1.73^{iA}	106.30 ± 3.28^{dB}
Jalapeno peppers pickle	nd	nd	nd	0.03 ± 3.49^{ghiA}	137.13 ± 2.59^{iA}	105.13 ± 4.71^{fB}
Sour grapes pickle	nd	nd	nd	nd	135.91 ± 0.89^{nA}	104.30 ± 1.29^{hijkB}
Unripe melon pickle	nd	nd	nd	0.13 ± 4.74^{efA}	135.96 ± 1.79^{nA}	107.43 ± 2.64^{bB}
Cauliflower pickle	nd	nd	nd	nd	137.52 ± 3.72^{hA}	104.66 ± 1.21^{gB}
Rock samphire pickle	nd	nd	nd	0.03 ± 1.63^{ghiA}	136.28 ± 1.47^{klA}	107.40 ± 5.41^{bB}
Sweet long green pepper pickle	nd	nd	nd	nd	236.32 ± 1.79^{aA}	106.18 ± 1.16^{dB}
Bitter long green pepper pickle	nd	nd	nd	0.05 ± 0.01^{ghA}	136.10 ± 0.59^{lmnA}	104.37 ± 2.34^{hijkB}
Sloes pickle	nd	nd	nd	0.16 ± 2.52^{deA}	135.95 ± 1.76^{nA}	104.47 ± 4.35^{hiB}

$^{a-y}$Within each column, values with different superscript (lower case letter) are significantly different ($p < .001$).

^{A,B}Within each line, values with different superscript (capital letter) are significantly different ($p < .05$).

Abbreviation: nd, not detected.

an effective role in the treatment of diabetes-sourced wounds because it has the ability to modify glucose metabolism. Chlorogenic acid protects endothelial cells against oxidative stress and neurons from the toxic effects of glutamate (Kaushik et al., 2017; Meinhart, Caldeirão, Damin, Filho, & Godoy, 2018). According to our results, the juice portion of greengage plum pickle was rich in chlorogenic acid (233.15 ± 2.56 mg/L). The highest concentration of chlorogenic acid in the pulp portion of samples was also found in rock samphire pickle (66.68 ± 5.75 mg/kg) (Table 4). Mekinić et al. (2018) reported that rock samphire contains vanillic acid, caffeic acid, cinnamic acid, and chlorogenic acid.

Caffeic acid was detected in all juice portions of lacto-fermented fruits and vegetables. In the pulp portions of other samples except eight (carrot, gherkins, white cabbage, tomato, green bean, jalapeno pepper, unripe melon, and cauliflower) caffeic acid was also found. The highest concentration of caffeic acid in the juice portions of samples was determined in hot pepper pickle (74.61 ± 2.28 mg/L), followed by okra pickle (68.52 ± 3.29 mg/L), and capia pepper pickle (50.70 ± 2.61 mg/L) (Table 4).

The richest pickle sample in terms of vanillic acid was carrot pickle (31.81 ± 2.67 mg/L in juice portion). The carrot pickle was followed by beetroot pickle (17.15 ± 3.76 mg/L in juice portion) and okra pickle (16.19 ± 1.06 mg/L in juice portion). The highest concentration of gallic acid in pulp portions was found in hot pepper pickle (248.81 ± 0.01 mg/kg), followed by okra pickle (204.99 ± 0.01 mg/kg) (Table 4). Okra is a vegetable unique to tropical and subtropical regions of the world. It may be consumed as either fresh or dried and its leaves and seeds are also edible. As it contains vitamin C, carotenoids, and flavonoids in significant amounts, the okra also exhibits antioxidant property (Petropoulos, Fernandes, Barros, & Ferreira, 2018).

Gallic acid is derived from shikimic acid and is a component of tannins that can be hydrolyzed in plants. Gallic acid and its derivatives are found in many fruits such as hazelnut, grape, and strawberry and in drinks like tea and wine (Dávalos, Lima, Santos, Romero, & Liebman, 2019; Lima et al., 2016). While the highest concentration of gallic acid in pickle samples was found in the juice portion of wild pear pickle (146.81 ± 1.69 mg/L), the highest value in the pulp portion was determined in hot pepper pickle (248.81 ± 0.01 mg/kg). The concenrations of gallic acid in both juice and pulp portions of green almond pickle were determined as 80.18 ± 5.72 mg/L and 165.77 ± 2.41 mg/kg, respectively (Table 4). Kaneria, Rakholiya, Marsonia, Dave, and Golakiya (2018) reported that gallic acid was among the phenolic acids found in green almonds. Singh et al. (2016) identified gallic, vanillic, and sinapic acids in green almonds and reported that the amounts of these phenolic acids were 135.5, 22.15, and 8.8 µg/g, respectively.

Of pickle samples analyzed, there were 6 kinds of pepper pickles. Gallic acid was identified in pepper pickles except jalapeno. Zhuang et al. (2012) detected 0.48–16.12 µg/g FW gallic acid in eight of nine fresh pepper. In addition, we determined that all pepper varieties contained syringic acid (Table 4).

Of the 9 phenolic acids, five were hydroxycinnamic acids and four were hydroxybenzoic acids. The concentrations of hydroxycinnamic acids were higher than those of hydroxybenzoic acids in most of the investigated pickles. In the juice portions of 16 kinds of pickles, the total concentrations of hydroxycinnamic acids were higher than the total concentrations of hydroxybenzoic acids. On the other hand, the total concentrations of hydroxycinnamic acids in the pulp portions of 27 kinds of pickles were higher than those of hydroxybenzoic acids. Hydroxycinnamic acids exhibit higher antioxidant activity compared to hydroxybenzoic acids. The higher antioxidant activity of the hydroxycinnamic acid could be due to the CH=CH–COOH group, which ensures greater H-donating ability and radical stabilization than the –COOH group in the hydroxybenzoic acids (Balasundram et al., 2006).

4 | CONCLUSIONS

In this paper, the qualitative and quantitative analyses of 9 phenolic acids in 30 kinds of lacto-fermented fruits and vegetables were performed considering pulp and juice portions. Phenolic acid profiles and total phenolic content were clearly higher in the juice portion than in the pulp portion. Gallic acid (detected in 22 pickles), chlorogenic, vanillic, caffeic, sinapic acids (detected in 30 pickles), *trans*-ferulic acid (detected in 3 pickles), and syringic acid (detected in 21 pickles) were found in the juice portion of pickles. On the other hand, gallic acid (detected in 15 pickles), chlorogenic acid (detected in 17 pickles), vanillic acid (detected in 12 pickles), caffeic acid (detected in 22 pickles), sinapic acid (detected in 30 pickles), *trans*-ferulic acid (detected in 16 pickles), and syringic acid (detected in 1 pickle) were found in the pulp portion of pickles. *p*-Coumaric acid and 4-hydroxybenzoic acid were not detected in both the pulp and juice portions of pickles. The juice and pulp portions created statistically significant differences ($p < .05$) in the phenolic composition and antioxidant activities of pickles. It was concluded that the lacto-fermented fruits and vegetables are a good source of dietary phenolic compounds and have strong antioxidant activity.

Considering the variety of plant materials, various materials from wild fruits to aromatic plants may be used in order to increase the product range in the production of traditional products like pickles. Generally, pickle consumption habit is intrinsic to the pulp portions. If salt in pickle production is carefully used, it may be recommended that the production of pickle juice as a functional food is popularized and that consumers may change the propensity to consume pulp only.

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CONFLICT OF INTEREST

The authors have declared no conflicts of interest for this article.

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