e-ISSN: 2757-8836
ORIGINAL ARTICLE
J. Raw Mater. Process. Foods vol.3(1), (2022) 26-34

Recieved: 11/06/2022 Revised: 09/08/2022 Accepted article published: 18/08/2022 Published online: 22/08/2022

Changes in Some Biochemical Properties of Brassica Vegetables (Cabbage, Cauliflower and Broccoli) Pickles and Brines

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DOI:
https://doi.org/10.57252/jrpfoods.2022.4

Abstract

Lactic acid fermentation is an important process in terms of storing fruits and vegetables for a longer time and preserving their nutritional content. It is also important in terms of improving the taste and aroma of fruits and vegetables for consumer preference. In this study, the physicochemical, bioactive, and sensorial properties of pickles and brines, which are formed as a result of 18 days of lactic acid fermentation of cabbage, cauliflower, and broccoli vegetables, were investigated. The highest total phenolic content (TPC) and antioxidant activity (AA) were found in fresh (7198.27 ppm Gallic Acid Equivalent (GAE), 7179.33 ppm $FeSO_4 \cdot 7H_2O$) and pickled broccoli (3600.10ppm GAE and 3253.03 ppm $FeSO_4 \cdot 7H_2O$), respectively. The highest AA of brines was accounted from pickled broccoli as 303.44 ppm $FeSO_4 \cdot 7H_2O$ while cauliflower brine had the highest TPC (246.87 ppm GAE). Fresh broccoli its pickle and brine have exhibited the highest content of vitamin C (4878.4, 1739.4, and 247.3 ppm ascorbic acid, respectively). The results show that pickling has a protective effect on the bioactive contents of vegetables. Moreover, the study demonstrated that fermentation impacted the color of samples. According to the results of sensorial analysis, cabbage and cauliflower samples got the highest score among the pickles evaluated in terms of overall acceptability. In brines, the overall acceptability score did not change significantly ($p>0.05$). Overall, the relationship between vegetables and fermentation can be said to be important for maintaining or enhancing the sensorial, nutritive properties of foods and also for the production of new products such as brine that may be beneficial for health.

Keywords: *Brassica vegetables, pickling, total phenolic content, antioxidant activity, sensorial properties*

1. INTRODUCTION

Pickle making is one of the oldest methods developed by people in order to store foodstuffs for a long time and to benefit from these products in places and periods when they are not available or when they are scarce. Pickle is a fermented product and is formed as a result of the lactic acid fermentation of fruits and vegetables. After the fermentation is completed, fruits and vegetables gain a desired feature in terms of flavor and structure. Thanks to the lactic acid formed, the spoilage of the product is prevented and it can be stored for a long time without significant loss in nutritional value. By preserving the vitamins and minerals it contains, substances that are difficult to digest become easily digestible and the development of disease-causing microorganisms are suppressed. In addition to the pleasure taste of fermented foods, purchasingand processing the product during periods when the product is abundant and cheap also provides an economic advantage. Compared to other methods, lactic fermentation method needs considerably fewer requirements in terms of both mechanical and thermal energy. It is possible to produce pickles from all vegetables and fruits, but vegetables are more suitable for pickle production due to their structure (Özler & Kılıç, 1996; Tangüler, 2010).

Since fruits and vegetables contain significant amounts of bioactive compounds, they have protective effects as well as preventing the occurrence of diseases (Ahmed & Ali, 2013; Soengas et al., 2011). Numerous epidemiological studies reveal that some diseases such as hypertension and stroke risk are prevented (Di Cagno et al., 2011), cancer, cardiovascular diseases (Björkman et al., 2011), inflammation, aging-related disorders (Soengas et al., 2011), atherosclerosis (Podsędek, 2007) by the consumption of fruits and vegetables are prevented. The vegetables aremajor sources of water-soluble vitamins, provitamin A, phytosterols, dietary fibers, minerals (Di Cagno et al., 2011) and phytochemicals including phenolic acids, flavonoids, flavones, iso-flavones, anthocyanins, catechins, and iso-catechinsfor human nutrition. Consumption of brassica vegetables (Liu, 2003), which are a rich source of phytochemicals, can reduce some types of cancer (Björkman et al., 2011), age-related chronic diseases and other degenerative diseases (Kris-Etherton et al., 2002). Brassica species include different genus of cabbage, cauliflower, broccoli, Brussels sprouts and kale (Podsędek, 2007). Due to the nutritional value of brassica vegetables, their consumption is increasing day by day (Ahmed & Ali, 2013).

Brassica-type vegetables such as cabbage, broccoli, and cauliflower are considered some of the most popular winter vegetables. Many of these vegetables are consumed in different ways, both raw and processed. Furthermore, cabbage, cauliflower, and broccoli can also be subjected to alternative methods such as fermentation or pickling depending on the season and region (Qing et al., 2015; Sayın & Alkan, 2015). Lactic acid fermentation (LAF) is a technological process used to preserve and improve the safety, shelf life, sensorial and nutritional properties of fruits and vegetables. Products such as pickles obtained by fermentation have a unique taste and great health promoting effects (Karovičová & Kohajdová, 2005; Sayın & Alkan, 2015).

Brassica vegetables are generally consumed fresh and raw. Enabling these vegetables to be consumed in every season not just as raw but also as the final product, pickling them is a good way to present them to the consumer. Although there are some reports on the bioactive compounds and antioxidant activities of brassica vegetables, there is little information regarding the pickling of cabbage, broccoli, and cauliflower for their health-related properties. For this reason, it is aimed to determine the physicochemical, bioactive, and sensory properties of pickles and brines formed as a result of 18-day lactic acid fermentation of brassica vegetables, cabbage, cauliflower, and broccoli.

2. MATERIALS AND METHODS

2.1. Materials

The main ingredients used in producing pickles in the study were cabbage, broccoli, cauliflower, salt and citric acid. After the vegetables purchased from a local market (Mersin, Türkiye) were brought to the laboratory, the stem, peel and leaves were manually separated and cleaned by washing under tap water. Vegetables were cut into equal-sized pieces and placed in plastic jars, and then the brine prepared for pickle making was added to it.

2.2. Preparation of pickle formulation

The brine used for making pickles was prepared to contain 6% (w/v) salt and 1.5% (w/v) citric acid suggested by Aktan et al. (2003). The formulation of pickles was set as vegetable:brine ratio of 600 grams:1300 mL. Chopped and washed vegetables were filled into 2000 mL plastic jars and the brine was added to them without leaving any gaps. The plastic jars were then capped and left to fermentation in a dark place at ambient temperature (20±2°C) (Figure 1). Fermentation was finished when no more pH changes were observed (fermentation for 18 days). Titratable acidity (as lactic acid %), pH and salt content (as % by Mohr method) were measured according to the methods described by Cemeroglu (2010).

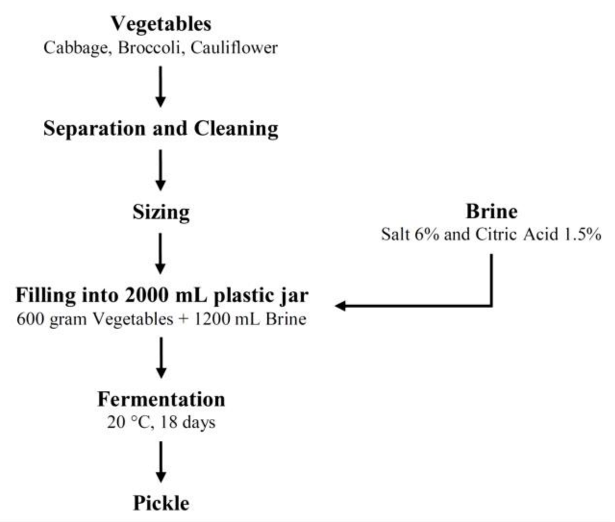

Figure 1. Scheme of pickling process

2.3. Color analysis

Color values (L*, a* and b*) of fresh vegetables and pickles were determined using a colorimeter (Konica-Minolta CR400, Japan). Measurements were made from three different points in each sample. Based on L*(lightness or white-black), a* (redness/greenness) and b* (yellowness/blueness) total color difference (ΔE*), hue angle (ho) and color intensity (Chroma, C*) were calculated using following equations (Dadali et al., 2007).

$$\Delta E^* = \sqrt{(L^* - L^*{}_0)^2 + (a^* - a^*{}_0)^2 + (b^* - b^*{}_0)^2} \quad (1)$$

$$h^\circ = tan^{-1}\left(\frac{b^*}{a^*}\right), \quad (2)$$

$$C^* = \sqrt{(a^{*2} + b^{*2})} \quad (3)$$

2. 4. Total antioxidant analysis

Antioxidant activity was determined as Ferric Reducing Ability of Power (FRAP) according to Benzie and Strain(1996) method. After drying the fresh vegetables and pickle samples in a freeze-dryer (Telstar Cryodos Model: 230, -50°C, Spain) for 48 hours, the dried samples obtained were extracted with 80% aqueous methanol.1 gram of dried sample in 40 mL of 80% aqueous methanol was extracted at room temperature for 2 hours. After extraction, the mixture was centrifuged (J.P. Selecta Medifriger BL-S, Spain) at 4000 rpm at 4°C for 5 min and the supernatant obtained was used for total phenolic content and antioxidant analyses. The brine obtained at the end of fermentation was analyzed after appropriate dilution with 80% aqueous methanol.0.3 M acetate buffer, 10mM 2,4,6-tripyridyl-s-triazine (TPTZ), and 20 mM ferric solution were mixed in a 10:1:1 ratio to prepare the FRAP solution. FRAP reagent was prepared freshly and warmed to 37°C in a water bath. 1.8 mL of FRAP reagent were mixed with 200 µL extract/diluted brine and incubation at 37°C for 10 minutes. At the end of the incubation period, the absorbance values of the mixtures at a wavelength of 593 nm were measured by a spectrophotometer (Perkin Elmer Lambda 25 UV-VIS, USA).The results were given in terms of ppm $FeSO_4{\cdot}7H_2O$ in brine and dry matter of fresh or pickled vegetables.

2.5. Total phenolic content analysis

Total phenolic content (TPC) was determined according to the method of Velioglu et al. (1998), which was based on a colorimetric oxidation/reduction reaction. Folin-Ciocalteu reagent (diluted 10 times with water) was used as the oxidizing agent. To 0.2 mL of extract, 1.5 mL of Folin-Ciocalteu reagent was added. After 5 minutes, 1.5 mL of Na2CO3 (60 g/L) was added to the mixture and incubated for 90 minutes in the dark. After incubation, the absorbance of the mixtures at 725 nm was measured by a spectrophotometer. The results were given in terms of ppm Gallic acid equivalents in brine and in dry matter of pickle samples.

2.6. Ascorbic acid content

The ascorbic acid content in fresh vegetables, pickles, and brine was determined according to the method suggested by Nisperos-Carriedo et al.(1992).One gram of dried sample was mixed with 20 mL of meta-phosphoric acid solution (2.5 g of m-phosphoric acid in 100 mL of water) and extracted for 2 hours at 200 rpm using an orbital shaker (Rotabit - J.P. Selecta, Spain). After extraction, the mixture was centrifuged at 4000rpm at 4°C for 10 min. Then the supernatant was filtered through a 0.45 µm teflon filter. The brine obtained at the end of the fermentation was analyzed after appropriate dilution with meta-phosphoric acid solution. The amount of ascorbic acid in the samples was measured using HPLC-UV/VIS (Shimadzu-20AD, Japan). An INTERSIL ODS-3 (GL Science, Japan) column (4.6×250 mm, 5 µm) was used for the analysis of the samples, and the ascorbic acid value at 244 nm was determined in the UV/VIS detector. Flow rate was performed isocratically at 0.7 mL/min at 25°C using 2% KH_2PO_4 (pH 2.4) mobile phase. The results were given in terms of ppm ascorbic acid in brine, fresh vegetables and pickles on dry basis.

2.7. Sensorial analysis

Sensorial analysis in pickles and brines was performed by 11 panelists (about 20-30 years old of 4 male and 7 female graduate students and academic personnels). Sensorial analysis was evaluated in terms of appearance, saltiness, sourness, brittleness, and overall acceptability parameters. The panelists were asked to use a 9-point scale to determine the intensity of each parameter tested: 1: undesirable, 5: moderate and 9: extremely intensive.

2.8. Statistical analysis

Statistical analysis of all results was done by one-way analysis of variance (ANOVA) using SPSS. Mean values were analyzed by Tukey's test ($p < 0.05$).

3. RESULTS AND DISCUSSION

3.1. Salt and titratable acidity content of fresh vegetables, pickles and brines

At the end of fermentation, the pH values were 2.76, 2.75 and 3.20 for cabbage, cauliflower and broccoli pickles, respectively. Salt and titratable acidity content of fresh vegetables, pickles and brines are shown in Table 1. According to the results, the salt content of fresh vegetables was found to be 0.09% on average (p>0.05). Since salt is transferred to the vegetables during fermentation, the salt content of the brine, which was 6% at the beginning, decreased at the end of the fermentation. There was no significant difference between the salt content of the brines at the end of fermentation and the salt content decreased to an average of 3.36% (p> 0.05). While there was no significant difference between the salt contents of cabbage and broccoli pickles, pickled cauliflower was found to be the pickle with the highest salt content (3.01%). The mean lactic acid content of fresh vegetables and brine at the end of fermentation was found to be 0.30% and 1.56%, respectively (p> 0.05). While there was no significant difference between the lactic acid contents of cabbage and cauliflower pickles (p> 0.05), the broccoli pickle was found to be the pickle with the lowest lactic acid content with 0.85%.

3.2. Total antioxidant activity, total phenolic content, and total ascorbic acid content of fresh vegetables, pickles and brines

Total antioxidant activity, total phenolic content and total ascorbic acid content of fresh vegetables, pickles and brines are shown in Table 1.According to the results, the highest antioxidant activity, total phenolic content and total ascorbic acid content among fresh vegetables were found in broccoli. While the antioxidant activity value in broccoli was 7179.33 ppm $FeSO_4 \cdot 7H_2O$, it was 3618.38 and 3182.37 ppm $FeSO_4 \cdot 7H_2O$ in cabbage and cauliflower, respectively. The total phenolic content of fresh vegetables was found to be 3403.82, 4260.95 and 7198.27 ppm GAE in cabbage, cauliflower and broccoli, respectively. In addition, the ascorbic acid content in cabbage, cauliflower and broccoli is 2138.81, 2789.66 and 4878.36 ppm, respectively. The antioxidant activity, total phenolic content and total ascorbic acid content of fresh vegetables showed a significant difference when compared ($p < 0.05$). The results obtained are consistent with those reported by Soengas et al.(2011), who reviewed a study for Brassica vegetables. Upadhyay et al. (2016) reported that the TPC in green cabbage is slightly higher than in cauliflower. Podsędek (2007) reported that cabbage has a very low AA value, while broccoli has a high AA value. In another study, the antioxidant capacity of vegetables in terms of inhibition of lipid peroxidation was broccoli > cauliflower > cabbage (Azuma et al., 1999).

The ascorbic acid values obtained in this study are consistent with the studies of Kurilich et al. (1999) and Septembre-Malaterre et al.(2018). The variation in the content of antioxidants, phenolic, and ascorbic acid of the broccoli, cabbage, and cauliflower species may be due to cultivars, environmental conditions, growing seasons, agricultural practices, and analytical methods.

Table 1. Salt, titratable acidity, total antioxidant activity, total phenolic content, and total ascorbic acid content of fresh vegetables, pickles and brines

Sample		Salt (%)	Titratable acidity (%)	Total Antioxidant (ppm $FeSO_4 \cdot 7H_2O$)	Total phenolic (ppm GAE)	Ascorbic acid (ppm)
	Cabbage	0.09 ± 0.01^a	0.24 ± 0.01^b	3618.38 ± 59.76^b	3403.82 ± 105.74^c	2138.81 ± 83.17^c
Fresh	Cauliflower	0.10 ± 0.01^a	0.32 ± 0.01^a	3182.37 ± 37.58^c	4260.95 ± 95.33^b	2789.66 ± 63.29^b
	Broccoli	0.08 ± 0.01^a	0.34 ± 0.01^a	7179.33 ± 151.80^a	7198.27 ± 107.15^a	4878.36 ± 102.45^a
	Cabbage	2.75 ± 0.03^b	1.24 ± 0.01^a	1473.09 ± 52.68^b	1804.94 ± 33.52^b	485.63 ± 27.16^c
Pickle	Cauliflower	3.01 ± 0.01^a	1.26 ± 0.02^a	954.96 ± 40.07^c	1573.85 ± 49.68^c	769.35 ± 13.32^b
	Broccoli	2.68 ± 0.04^b	0.85 ± 0.01^b	3253.03 ± 66.93^a	3600.10 ± 49.08^a	1739.42 ± 88.50^a
	Cabbage	3.32 ± 0.03^a	1.54 ± 0.03^a	238.89 ± 1.34^c	160.03 ± 0.38^c	96.02 ± 5.31^b
Brine	Cauliflower	3.35 ± 0.05^a	1.57 ± 0.01^a	258.22 ± 1.10^b	246.87 ± 3.03^a	106.64 ± 2.08^b
	Broccoli	3.41 ± 0.05^a	1.56 ± 0.04^a	303.44 ± 0.96^a	228.33 ± 1.22^b	247.25 ± 17.71^a

Mean values ± SD and different letters in the same column indicate significant difference for fresh vegetables, pickles and brines, individually ($p < 0.05$).

The TPC of pickled vegetables in the range of 1573.85 and 3600.1 ppm GAE. Among the pickles broccoli demonstrated the highest TPC of 3600.1 ppm Gallic acid, followed by cabbage (1804.94 ppm GAE) and cauliflower (1573.85 ppm GAE) ($p < 0.05$).The TPC concentration of all pickled samples changed during fermentation and decreased at the end of fermentation. Among the pickles, the highest decrease in TPC concentration compared to fresh vegetables was cauliflower with 63%. A similar tendency has been observed for the effect of fermentation time on the AA of samples (Table 1). Pickled broccoli showed the highest AA with 3253.03 ppm $FeSO_4 \cdot 7H_2O$, while pickled cauliflower showed the lowest AA with 954.96 ppm $FeSO_4 \cdot 7H_2O$. The antioxidant activity of pickles showed a significant difference when compared ($p < 0.05$). AA gradually decreased over time and showed the largest decrease (69.7%) in AA on day 18th of pickled cauliflower, followed by cabbage (59.3%) and broccoli (54.7%). Similarly, some studies have found that fermentation reduces the effect of AA. For instance, at the end of fermentation AA of olive (Othman et al., 2009), potherb mustard (Fang et al., 2008), and tea (Kim et al., 2011) decreased. On the contrary, many studies carried out on pickled foods revealed that fermentation enhanced the antioxidant activity. This effect of pickling on AA may be explained by the release of the simple phenolic compounds by acid and enzymatic hydrolysis of polymerized phenolic compounds. The second possible explanation is the enzymatic and non-enzymatic antioxidant mechanisms of lactic acid bacteria.

So, these results showed that the effect of fermentation on the AA of food is variable depending on the factors during fermentation such as microorganisms, cultivation medium, times, temperature, pH, and atmosphere (Sayın & Alkan, 2015). Fermentation caused about 77.3% decrease in the content of ascorbic acid for pickled cabbage, 72.4% for pickled cauliflower, and 64.3% for pickled broccoli compared with fresh vegetables. The ascorbic acid content in cabbage, cauliflower, and broccoli pickles was found to be 485.63, 769.35, and 1739.42 ppm, respectively.

In a study, lactic acid-fermented vegetables were reported to contain 20% to 70% of the initial ascorbic acid content, depending on production (Kohajdová et al., 2006). In another study, it was stated that 84.7-87.8% of the ascorbic acid content in fresh vegetables was retained in the brine at the end of fermentation (Karovičová & Kohajdová, 2005). Similarly, in this study, it was observed that the ascorbic acid content in the pickle samples was lower than that of fresh vegetables with about 36 % of ascorbic acid compare to beginning. This situation can be explained because of degredation of ascorbic acid and also diffusion into the brine during fermentation.

The antioxidant activity, the phenolic and the ascorbic acid contents of brine samples were found in variable amounts (Table 1). Brine of pickled broccoli has the highest antioxidant activity (303.44 ppm $FeSO_4{\cdot}7H_2O$) compared to other samples ($p < 0.05$). The AA content in the brine of cabbage and cauliflower pickles was found to be 238.9 and 258.22 ppm $FeSO_4{\cdot}7H_2O$, respectively. TPC of brines was found to be 160.03, 246.87 and 228.33 ppm GAE in cabbage, cauliflower and broccoli pickles, respectively. Although the highest ascorbic acid content was found in a brine of broccoli pickled as 247.25 ppm, no statistically significant difference was found between the ascorbic acid content of the brine of cabbage and cauliflower pickles.

3.3. Color values of fresh vegetables and pickles

Color values (L*, a* and b*) of fresh vegetables and pickles were given in Table 2.The color values of fresh vegetables showed a significant difference ($p < 0.05$). Among fresh vegetables, cauliflower has the highest L* and a* values and the lowest b*values, while broccoli has the highest b* value and the lowest L* and a* values. The L*, a* and b*values of fresh cabbage were measured as 89.20, -2.49 and 14.81, respectively. The highest color angle and chroma values in fresh vegetables were obtained with cauliflower (1.55) and broccoli (13.27), respectively

Table 2. Color values of fresh vegetables and pickles

Sample		L^*	a^*	b^*	ΔE^*	$h°$	C^*
Fresh	Cabbage	89.20 ± 0.34^b	-2.49 ± 0.12^b	14.81 ± 0.18^b	-	-1.40 ± 0.01^c	5.98 ± 0.06^b
	Cauliflower	93.00 ± 0.42^a	0.12 ± 0.06^a	6.78 ± 0.32^c	-	1.55 ± 0.01^a	3.69 ± 0.09^c
	Broccoli	71.39 ± 0.25^c	-11.53 ± 0.16^c	21.55 ± 0.39^a	-	-1.08 ± 0.01^b	13.27 ± 0.11^a
Pickle	Cabbage	91.98 ± 0.10^b	-1.09 ± 0.17^b	8.49 ± 0.21^b	7.05 ± 0.26^b	-1.44 ± 0.01^b	4.26 ± 0.09^b
	Cauliflower	93.54 ± 0.43^a	-0.27 ± 0.023^a	5.02 ± 0.22^c	1.91 ± 0.39^c	-1.52 ± 0.01^c	3.18 ± 0.07^c
	Broccoli	76.15 ± 0.72^c	-3.77 ± 0.132^c	22.69 ± 0.49^a	9.19 ± 0.37^a	-1.41 ± 0.01^a	7.72 ± 0.12^a

L [lightness or white (0)-black (100)]; a* [greenness (-60)/redness (+60)]; b* [blueness (-60)/yellowness (+60)], ΔE*: Total color difference; C*: Chroma; h°: hue angle. Mean values ± SD and different letters in the same column indicate significant difference for fresh vegetables and pickles, individually (p < 0.05).*

There were differences in the L*, a*, b* values of the pickle samples, which were formed after 18 days of fermentation, according to the fresh vegetables. Differences in color values of fresh vegetables were similar in pickles (Table 2). Cauliflower pickled have the highest L* (93.54) and a* (-0.27) values and the lowest b* (5.02) values compared to other pickles. Broccoli pickles also have the highest b* (22.69) value and the lowest L* (76.15) and a* (-3.77) values compared to other pickles. It was observed that the L* value of pickles increased compared to fresh vegetables (Table 2). The greatest increase in L* value was in broccoli (from 71.39 to 76.15). Negative a*value means that the sample color is greenness. The highest green color value was -11.53 in fresh broccoli, but this value decreased to -3.77 in broccoli pickles formed after fermentation. This situation was also between fresh cabbage (-2.49) and cabbage pickles (-1.09), but it did not between fresh cauliflower (0.12) and cauliflower pickles (-

0.27). The decrease in the green color value in vegetables is thought to be due to the breakdown of the chlorophyll pigment in their structures during fermentation. In order to know the color change between fresh vegetables and pickles, the total color difference (ΔE*) should be calculated. Therefore, L*, a*, b* values of fresh vegetables were used as controls to calculate ΔE* values of pickles. The ΔE* values of the pickles showed a significant difference ($p < 0.05$). The ΔE* values of cabbage, cauliflower and broccoli pickles were calculated as 7.05, 1.91 and 9.19, respectively. Color angle (h°) values of both fresh vegetables and pickles showed a significant difference ($p < 0.05$). While the highest h° value was found in cauliflower (1.55) among fresh vegetables, it was found in broccoli (-1.41) among pickles. The highest chroma (C*) values were found in broccoli with 13.27 and pickled broccoli with 7.72 ($p < 0.05$).

3.4.Sensorial analysis of pickles and brines

Sensorial analysis was performed in pickle and brine samples by 11 panelists. Panelists evaluated the pickle and brine samples in terms of appearance, salinity, sourness, brittleness, and overall acceptability parameters. The mean scores of pickle and brine samples at the end of the sensorial analysis were given in Table 3.

Table 3. Sensorial properties of pickles and brines

Sample		Appearance	Saltiness	Sourness	Brittleness	Overall acceptability
Pickle	Cabbage	8.22 ± 1.09^a	7.44 ± 1.51^a	7.90 ± 0.99^a	8.10 ± 1.20^a	8.13 ± 0.99^a
	Cauliflower	8.40 ± 0.70^a	7.60 ± 1.07^a	7.78 ± 1.09^a	8.27 ± 0.79^a	8.20 ± 0.42^a
	Broccoli	7.22 ± 0.67^b	6.78 ± 1.30^a	7.80 ± 1.03^a	6.70 ± 1.70^b	6.86 ± 1.35^b
Brine	Cabbage	7.90 ± 0.99^a	5.55 ± 1.69^a	6.90 ± 1.37^a	-	6.75 ± 0.89^a
	Cauliflower	6.14 ± 1.46^b	5.44 ± 1.13^a	6.11 ± 1.05^{ab}	-	6.33 ± 0.87^a
	Broccoli	7.71 ± 0.95^a	4.91 ± 1.58^a	5.36 ± 1.20^b	-	6.44 ± 1.13^a

Mean values ± SD and different letters in the same column indicate significant difference for pickles and brines, individually ($p < 0.05$). A 9-point scale was used to determine the intensity of each parameter: 1: undesirable, 5: moderate and 9: extremely intensive.

According to the results obtained, broccoli pickles had the lowest appearance (7.22), brittleness (6.70), and overall acceptability (6.86) scores compared to other pickles ($p < 0.05$). There was no significant difference between the appearance, brittleness, and overall acceptability scores of cabbage and cauliflower pickles ($p > 0.05$). The average saltiness and sourness scores of the pickles were 7.27 and 7.83, respectively, and there was no statistically significant difference between both the saltiness and sourness scores of the pickles ($p > 0.05$).

While there was no significant difference between the appearance scores of cabbage and broccoli brine ($p > 0.05$), cauliflower brine has the lowest score of 6.14. There was no statistically significant difference between both salinity and overall acceptability scores of the brines ($p > 0.05$). The average salinity and overall acceptability scores of the brines are 5.30 and 6.50, respectively. When the sourness scores of the brine were compared, cabbage got the highest score (6.90) and broccoli got the lowest score (5.36).

4. CONCLUSIONS

The pickle is a widely consumed fermented product that contributes to the preservation of bioactive compounds. In this study, the physicochemical, bioactive, and sensorial properties of pickles and brines, which are formed as a result of 18 days of lactic acid fermentation of cabbage, cauliflower, and broccoli vegetables, were investigated. According to the results obtained, while most of the bioactive compounds in the structure of vegetables were preserved in the pickles, some of them were transferred to the brine. Since fresh broccoli has the highest bioactive compound content, higher total antioxidant, total phenolic, and ascorbic acid content among pickles were found in broccoli pickles. In brines, the highest total antioxidant and ascorbic acid content were obtained in broccoli brine, while the highest total phenolic content was obtained in cauliflower brine. According to the results of sensorial analysis, cabbage and cauliflower samples got the highest score among the pickles evaluated in terms of overall acceptability. In brines, the overall acceptability score did not differ significantly ($p > 0.05$). Pickled fruit and brine can be used not only as functional food or beverage but also as a potential source of natural antioxidants. So, in daily food consumption, and intake of both pickles and brines of broccoli, cabbage, and cauliflower may provide a substantial amount of antioxidant efficiency.

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