Turkish Journal of Agriculture - Food Science and Technology, 7(3): 490-497, 2019
DOI: https://doi.org/10.24925/turjaf.v7i3.490-497.2350

Turkish Journal of Agriculture - Food Science and Technology

Available online, ISSN: 2148-127X | www.agrifoodscience.com | Turkish Science and Technology

Some Special Properties of Fermented Products with Cabbage Origin: Pickled Cabbage, Sauerkraut and Kimchi

Ceren Özer[1a], Hatice Kalkan Yıldırım[2b*]

[1]*Food Engineering Department, Institute of Natural and Applied Sciences, Ege University, 35100 Bornova/İzmir, Turkey*
[2]*Food Engineering Department, Faculty of Engineering, Ege University, 35100 Bornova/İzmir, Turkey*
[*]*Corresponding author*

A R T I C L E I N F O

Research Article

Received : 16/11/2018
Accepted : 00/00/0000

Keywords:
Fermented-cabbage products
Kimchi
Sauerkraut
Pickled cabbage
Medical properties

A B S T R A C T

Consumption of fermented products rich in antioxidants, anti-inflammatory, anti-diabetes, anti-obesity and anti-carcinogenic compounds is growing into a key strategy to fortify antioxidant defense system. Cabbage products produced by lactic-acid fermentation are chosen via their special microbiota. Considering these special medical properties of fermented-cabbage products as pickled cabbage, sauerkraut and kimchi were produced and evaluated. The data demonstrated that pickled cabbage (109.89±4.74 mg ascorbic acid/100 g d.w.) and its brine (208.14±17.29 mg ascorbic acid/100 g d.w.) exhibited the highest vitamin C content, followed by kimchi (77.42±2.87 mg ascorbic acid/100 g d.w.). The highest total phenolic content was detected in kimchi and sauerkraut with 869.64±70.16 and 438.257±25.05 mg gallic acid equivalents/100 g fresh weight (f.w.), respectively. 50% of the scavenging effect (EC50) values of free radical scavenging activity (DPPH) in kimchi 14.6 mg/ml, followed by sauerkraut (15.52 mg/ml) and pickled cabbage (18.88 mg/ml). Results demonstrated that fermented cabbage products have a great potential with content of bioactive compounds, high antioxidant features promising high beneficial impacts.

[a] *cerenozer.ege@gmail.com* *https://orcid.org/0000-0001-8898-1058* | [b] *hatice.kalkan.y@gmail.com* *https://orcid.org/0000-0001-9698-9682*

Introduction

Recently, consumers have showed increasing interest to traditional fermented foods due to their health-promoting properties (Park et al., 2016; Kim et al., 2018). Many researches have been focused on traditional fermented products worldwide (Park et al., 2016; Soltan Dallal et al., 2017). Lactic acid (LA) fermentation of traditional fermented-cabbage products including kimchi, sauerkraut, Chinese sauerkraut, Pao Cai and pickled cabbage spontaneously developed by lactic acid bacteria (LAB) present in the raw materials under anaerobic conditions (Aktan et al., 1998; Lu et al., 2011; Jagannath et al., 2012; Liang et al., 2016; Xiong et al., 2016; Liu et al., 2017).

White cabbage (*Brassica oleracea* L. var. *capitata* L.) is widely used for sauerkraut and pickled cabbage production in Europe, USA and Asian countries (Holzapfel, 2014). Chinese cabbage (*Brassica rapa* var. *pekinensis*) is the main ingredient of kimchi and Chinese sauerkraut (Park et al., 2016; Kim et al., 2018). Seong et al. (Seong et al., 2016) demonstrated that leaves of Chinese cabbage have higher levels of antioxidant activity and polyphenolic compounds. Fresh white cabbages and Chinese cabbage are rich in antioxidants such as glucosinolates, vitamins, folic acid, α-tocopherol, carotenoids, flavonoids and phenolic compounds (Peñas et al., 2015; Patra et al., 2016; Seong et al., 2016; Hallmann et al., 2017; Kapusta-Duch et al., 2017). Furthermore, antioxidant activity of raw and processed cabbages are highly associated with their polyphenolics contents (Chun et al., 2004).

Natural LA fermentation of vegetables have been used as preservation method over the years as simple and valuable biotechnological process (Jagannath et al., 2012; Frias et al., 2017; Kapusta-Duch et al., 2017). Various vegetables mainly cabbage, cucumber, olives and pepper were usually fermented for long-term to improve palatability and nutritional features of vegetables and fruits (Frias et al., 2017). Spontaneous fermentation depends on several factors including vegetable freshness, quality and natural microflora; fermentation time and temperature; salt concentration and salt-type (rock, sea, pickling, kosher, solar and bamboo salt). It is worth-noting that salt concentration and fermentation temperature influence on growth of the natural microbial population and the sensory properties of fermented-cabbage (Beganović et al., 2011; Xiong et al., 2016).

So far, the types of fermented foods produced with specific fermentation practices have varied according to region, culture, availability of food sources, environmental conditions, taste preferences and variety of raw materials (Frias et al., 2017). Pickled cabbage (PC), sauerkraut (SK) and kimchi (KM) are fermented by different methods: Brining technique (PC) and dry salting (SK and KM).

Cabbages are generally immersed in 6-8% brine and allowed to undergo LA fermentation by traditional ways for 30-40 days in PC production (Aktan et al., 1998; Yücel and Üren, 2008). Meanwhile, PC are traditionally prepared by brine and vinegar solution with carrot, garlic and chickpea (Aktan et al., 1998; Lu et al., 2011, 2013). Brine concentration is chosen as suitable for growth of LAB thereby many natural LAB present in raw materials performed LA fermentation. In addition, new compounds are obtained by the metabolism of the LAB during natural fermentation (Aktan et al., 1998). Moreover, PC has a good taste and aroma as well as richness of nutrients.

Sauerkraut is one of the most common fermented product produced by fermentation technique which is widely consumed in many European countries (Central and Eastern Europe), and the USA (Holzapfel, 2014; Mozzi et al., 2016). Sauerkraut could be stored for long periods even though its low salt content. Spices, herbs, carrot and wine are also used in the manufacture of sauerkraut. Growth of spoilage microorganisms is inhibited since LAB produce acids during fermentation in a short time. Fermentation commences with activity of *Leuconostoc mesenteroides* which converts sugar to LA, acetic acid, alcohol, CO_2 and other compounds. Hence, it is contributed to the flavor of sauerkraut due to activity of *L. mesenteroides* at the beginning of fermentation. When *L. mesenteroides* inhibited due to accumulation of acids, fermentation is carried on mainly with *Lactobacillus brevis, Pediococcus* cerevisiae and *Lactobacillus plantarum*.

Kimchi is the most popular traditional Korean fermented food made from many vegetables such as cabbage, radish, green onion, ginger, various spices, seasonings and fermented fish products (Kim et al., 2018). Fresh vegetables are prepared traditionally to preserve and enhance the organoleptic and nutritional qualities. Fermentation of kimchi is performed slowly with low salt content (2-3%) at low temperatures (4-10°C). Health-promoting effects of kimchi such as antioxidative, lipid-lowering, anti-inflammatory and anti-atherogenic effects may be attributed to bioactive substances (ascorbic acid, quercetin, carotenoids, capsaicin, gingerol, allylsulfide, β-sitosterol, phenolic compounds and LAB present in kimchi (Patra et al., 2016; Woo et al., 2017a, 2017b). Moreover, amounts of ascorbic acid, capcaicin, quercitrin and quercetin in kimchi were found as 280, 270, 30 and 20 μg/g.

PC, SK and KM are important sources of minerals such as calcium, phosphorus, iron, sodium and potassium. These fermented products have also high contents of vitamin B and C than unfermented-cabbage (Xiong et al., 2014). Moreover, biochemical changes resulted from chemical reactions, enzymes and natural microorganisms during fermentation may effect on the changes of antioxidant capacity (Cheigh et al., 1994). Some phytochemicals also have antioxidant activity and protect cells versus oxidative damage induced by free radicals (Chun et al., 2004; Peñas et al., 2015). Furthermore, antioxidant activity of cabbage during the fermentation increases 3-4 times (Peñas et al., 2015).

Even the large number of studies related to fermented products, there is lack of knowledge related to special properties and differences among products with the same raw material origin. So, the purpose of this study was to evaluate the effects of different production techniques used during processing on special properties as antioxidant activities, phenols.

Materials and Methods

Preparation of Pickled Cabbage, Sauerkraut and Kimchi

White cabbage (*Brassica oleracea* L. var. *capitata* L.) used for SK and PC, Chinese cabbage (*Brassica rapa* L. var. *pekinensis*) used for KM were the main vegetables and purchased from a local market. Outer leaves and cores (inedible parts) of these vegetables were discarded. In all products, different concentrations of rock salt were used during fermentation. Sugar was used as a promotor of fermentation process. Each production for pickled cabbage, sauerkraut and kimchi was performed in triplicate.

Concerning production of the PC, cabbages (2 kg) were divided into four parts and placed in 3 L plastic bottles. After addition of sterile 8% brine solution, grape vinegar (%2) and sugar (%2) were added. Fermentations were carried out at 25-28°C for 30-40 days.

Regarding production of SK, the fresh cabbages (3 kg) were shredded into approximately 2mm thick strips. The spontaneous fermentation of SK was carried out with 3% salt concentration and %2 sugar at 21°C for 30 days.

During the preparation of KM, Chinese cabbages were cut into pieces (5x5 cm) and soaked in a brine solution containing 10% NaCI (w/v) for 7-8 h. The soaked Chinese cabbages were washed three times for removal of residual salt and drained (1 hour) at room temperature. After draining the sliced Chinese cabbages (75%) were mixed with various seasonings including red pepper powder (2.2%), minced garlic (0.85%), sliced Daikon radish (7.5%), ginger (0.85%), green onion (2.0%), onion (1.1%), fermented fish sauce (anchovy) (0.5%), apple (2.00%), wheat flour-tap water (porridge) (8%). The resulting mixture was then tightly packed into 3 L plastic bottles and allowed to fermentation at 4-7°C for 33 days.

Sampling of Materials for Analyses

During the fermentation, cabbage samples were aseptically collected at intervals of three days from the day zero to observe development of acidity and pH. In addition, samples (10 g) were taken to determine salt content (NaCI) once a week throughout fermentation. The plastic bottles were shaken and mixed prior to sampling. After fermentation was terminated, fermented products were immediately stored at -20°C for further analyses. Samples were taken from both brine and cabbage. Number of sampling for analysis is in quadruplet.

Determination of Total Acidity and pH

Total acidity of the fermented products was determined by titration method with standard solution of 0.1N NaOH

(Cemeroglu, 2007). 5-8 g samples were used for sampling. 1 g samples juice were taken and made up to 10 ml using distilled water in volumetric flasks. The pH of the samples was determined using a calibrated pH meter (WTW, Inolab pH 7110) before titration with sodium hydroxide. 10 ml each of the juices were titrated with 0.1N NaOH using phenolphthalein (0.1% w/v in 95% ethanol) as an indicator. The end point was stated as 8.3 pH. Titratable acidity was expressed as % LA. Total acidity was calculated in terms of LA,

$$\text{Acidity}\ \left(\frac{g}{100}\ \text{mL}\right)=\frac{V.f.E.100}{M}$$

Where V is the amount of 0.1N NaOH solution used (ml), *f* is the factor of 0,1N NaOH solution, E is the constant of LA equivalent to 1 ml of 0,1N NaOH solution (0,009008) and M is the amount of sample used. Dilution factor was also considered in calculations.

Determination of Salt (NaCI) Content

The concentration of the sodium chloride was determined as follow with some modifications (Cemeroglu, 2007; Aktan and Kalkan Yıldırım, 2012). 10 g of the sample was homogenized with 100 ml of distilled water. Boiling process was applied to mixture of sample-distilled water for 30-40 min. The mixture was kept at room temperature for 5-6 h before the mixture was filtered with filter paper. Then, 2 ml of the filtrate was collected from the filtrated sample.

1 ml of potassium chromate was added and resulting mixture was titrated with standard 0.1N silver nitrate solution until a tile red developed. The concentration of sodium chloride was calculated as:

$$X=V\times f\times 0.005844\times Df\times 100$$

$$Df=\frac{V1}{M}\times\frac{1}{V2}$$

Where X is the concentration of sodium chloride (%), V is the volume (ml) of the silver nitrate consumed in titration, *f* is the factor of standardized solution of 0.1N $AgNO_3$, 0.005844 represents the weight of sodium chloride that is equal to 1 ml of standardized silver nitrate solution and *Df* is the dilution factor of initial sample. In addition, M is the weight (g) of the sample, V_1 is the initial total volume of the filtrate, V_2 is the volume of the filtrate used for titration.

Dry-matter Determination

Dry-matter content was determined by drying at 105°C to constant weight (Memmert Universal Oven UN55, Germany). Dry matter of fermented-cabbage products (CP, SK and KM) was determined according to Cemeroğlu (Cemeroglu, 2007). Different cabbage samples were cut into small pieces. Then, cabbage tissues were subjected to drying process (105°C, 24 h and atmospheric pressure). Relatively dried cabbage samples were cooled in desiccator and weighed after 24 h. This procedure was repeated three times to reach a constant weight. Then dry-matter content was calculated as g/100 g of material.

Determination of Ascorbic Acid (Vitamin C) Content

Ascorbic acid was determined by spectrophotometric method (Genesys 10S UV-Vis Spectrophotometer, Thermo Scientific) taking absorbance at 518 nm according to method described by Hışıl (Hışıl, 2007). 2,6-dichlorophenol indophenol dye was reduced by ascorbic acid, which was reduced to the colorless. At the end of the reaction, the excess of unreduced dye showed a rose-purple color in the acidic solution (Hışıl, 2007). Oxalic acid solution was used for extraction of the ascorbic acid. The weighed of SK, KM and PC samples were extracted with certain amount of 0.4% oxalic acid by homogenizer (IKA-WERKE, T25 Ultra-Turrax Basic Homogenizer) for 2 min. The collected filtrates were used for the ascorbic acid assay. The results were calculated from the equation of standard curve.

Determination of Total Phenol Content (TPC)

Total phenol content of the fermented products was determined by spectrophotometric method according to Folin-Ciocalteu procedure. 1 g of samples were weighed into falcon tubes prior to addition of 10 ml 80% methanol solution (methanol: deionized water; v/v). Samples were extracted with 80% methanol by homogenizer (IKA-WERKE, T25 Ultra-Turrax Basic Homogenizer) for 2 min. The sample extracts were then carrying out by shaking incubator at room temperature for 16-18 h and filtered with filter paper. Then 300 µL of sample extracts were transferred into test tube and 1,5 ml of Folin-Ciocalteu reagent previously diluted 10-fold with deionized water were added. 10 ml of 7.5% sodium carbonate (w/v) was added to the mixture. The mixture was allowed to stand at room temperature in the dark for 90 min before measuring the absorbance at 765 nm using a UV-Vis Spectrophotometer (Genesys 10S UV-Vis Spectrophotometer, Thermo Scientific). TPC of samples was reported as gallic acid equivalents (GAE) (mg/L) using a calibration curve constructed using gallic acid.

Determination of Antioxidant Activity by DPPH Free Radical Scavenging Assay

DPPH radical scavenging activity was performed with some modifications according to the method described by (Cemeroglu, 2007). The DPPH assay is based on electron transfer from the sample to the reagent radical (2,2-diphenyl-1-picrylhydrazyl) and is measured spectrophotometrically through evaluating color changes. 2 g of samples were homogenized with 10 ml of 80% ethanol solution by homogenizer for 2 min. Various amount of extracts (0, 20, 40, 60, 80 and 100 µL) of sample were mixed with 600 µL of 1 mM DPPH methanol radical solution. The mixture was then shaken vigorously and allowed to stand for 15 min in dark. The absorbance was immediately measured at 517 nm. The DPPH radical scavenging capacities of different cabbage extracts were expressed as mg/ml. The percent of DPPH was calculated according to the following equation which was inhibited in the sample:

$$\text{DPPH}\ (\%)= A_0\text{-}A_1/A_0\ \times 100$$

Where A_0 and A_1 were the absorbance values of the blank and samples extract (test samples), respectively. The IC_{50} value was calculated to express the concentration of antioxidants in the sample extracts, which inhibited 50% of the radicals in the reaction mixture. Calculation was done using standard curve equation by considering dilution factor.

Statistical Analysis

Statistical analysis was evaluated with the SPSS (IBM, USA) software program version 23 for Windows. The one-way analysis of variance (ANOVA) was used to determine the significance among parameters. Duncan's multiple range test was used as post-hoc test. Confidence interval was chosen as 95%.

Result and Discussion

Total Acidity, pH and NaCI changes

The pH, acidity and salt content are the primary quality attributes and fermentation indicators of fermented products. Changes in the titratable acidities, pH values and salt concentrations of PC, SK and KM during their incubation at 25-28°C (PC), 21°C (SK) and 4-7°C (KM) between 30-40 days are shown in Figure 1. On the onset of fermentation, the total acidities were 0.24% (pH 4.76), 1.05% (pH 4.48) and 0.3% (pH 5.85) for PC, SK and KM, respectively. Acidity of SK initiated faster manner than PC and KM. At the end of fermentation, the highest titratable acidities were determined for SK (1.09%; pH 4.15) and KM (0.99%; pH 4.29). However, acidity increment of the PC were very slowly until 24 d (0.43%, pH 4.05), after which acidity remained stable. These results demonstrated that LA fermentation of SK occurs faster than KM and PC. The fermentation process of products were followed by parameters (pH, acidity and salt content) as stated in other studies (Jeong et al., 2011).

NaCI concentration is the important factor for fermentation kinetics and fermented product microflora. KM and SK are generally fermented at low salt content, approximately 2-3% whereas PC is fermented at condition with 5-8% of salt concentration (Aktan et al., 1998; Jung et al., 2014). Additionally, Zhang et al. (Zhang et al., 2015) reported that pH and total acidity of the low salt products decreased or increased faster than high salt product. NaCI content have an impact on growth of LAB (Zhang et al., 2016).

Ascorbic Acid (Vitamin C) Content

White cabbage (36.6 mg/100 g) and Chinese cabbage (27.0 mg/100 g) contained high amount of vitamin C according to USDA (United States Department of Agriculture) Food Composition Database.

Levels of vitamin C ranged from 77.43±3.32 (KM) to 208.14±21.18 (PC brine) mg ascorbic acid/100 g d.w. PC brine contained most vitamin C (P<0.05), followed by its cabbage. Although it is known that fermented-cabbages have high content vitamins, there are limited studies regarding vitamin C production by KM, SK and PC. Vitamin C content of KM, SK and PC are shown in Figure 2. Peñas et al. (Peñas et al., 2015) reported Vitamin C content of 20.1 mg/100 g in sauerkraut. In present study, the vitamin C content was found 15.5 mg/100 g in sauerkraut. Martinez et al. (Martinez-Villaluenga et al., 2009) found that Vitamin C content of sauerkraut was ranged from 156.72 mg/ 100 g d.w. to 256.31 mg/ 100 g d.w. for natural fermentation. It was reported that Vitamin C content is affected by chemical and enzymatic oxidations (Martinez-Villaluenga et al., 2009). Cutting or shredding could affect vitamin C contents. Excessive trimming of leafy-vegetables leads to loss of outer leaves containing more vitamins than inner leaves. Trimming of outer leaves, the core and inner leaves of Chinese cabbage had a major effect on reduction of vitamin C content. In study done by Zhao et al. (Zhao et al., 2016), vitamin C content of fermented Chinese cabbage was found 43.2 mg/kg. Woo et al. (Woo et al., 2017a) identified 280 μg/g ascorbic acid in kimchi obtained by methanol extraction.

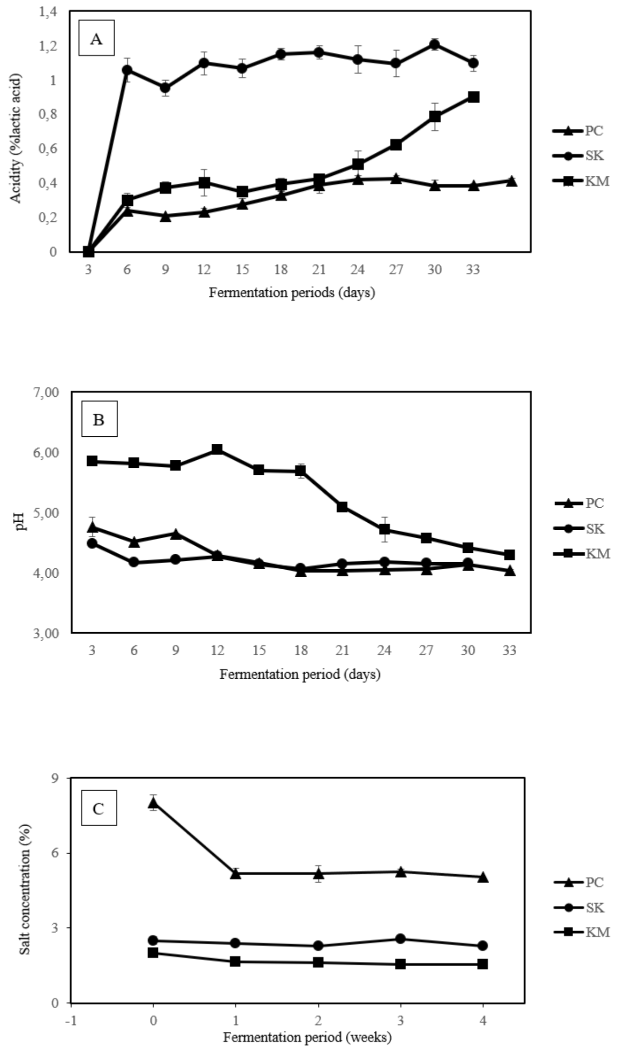

Figure 1 Changes in titratable acidity (A), pH (B) and salt concentrations (C) of cabbage-derived products during the fermentation period. ▲ pickled cabbage; ● sauerkraut; ■ kimchi. Data were presented as means ± SD (n=3).

The ascorbic acid content of raw white cabbage (329.5 mg/100 g d.w.) and Napa cabbage (27.7 mg/100 g d.w.) were reported by Villaluenga et al. (Martinez-Villaluenga et al., 2009) and Chun et al. (Chun et al., 2004). According to literature data, ascorbic acid content of white cabbage varied from 19 to 47 mg/100 g fresh product (Podsedek et al., 2006). It was claimed that during cabbage fermentation, vitamin C content decreased for some reasons and fresh cabbages contain more vitamin C than fermented-cabbage products (Martinez-Villaluenga et al., 2009, 2012; Hallmann et al., 2017; Kapusta-Duch et al., 2017). Ascorbic acid content of fermented food is quite easily to be damaged by oxidation (Zhao et al., 2016). Besides that, ascorbic acid is an unstable component and could be decomposed rapidly under storage conditions (Hashemi et al., 2017). However, sample cultivars, preparation methods, fermentation conditions, product acidity, preservation conditions and analytical method showed considerable variation on ascorbic acid content (Cheigh et al., 1994; Chun et al., 2004; Martinez-Villaluenga et al., 2009; Kapusta-Duch et al., 2017). Moreover, it was reported that stability of ascorbic acid is impacted by pH, dissolved-oxygen, garlic and preservatives (Cheigh et al., 1994). However, the salt concentration was reported that don't contribute to ascorbic acid changes in for sauerkraut (Martinez-Villaluenga et al., 2009). Nonetheless, minimal decrement of vitamin C content was observed in PC brine whereas KM showed the highest losses of vitamin C compared to raw cabbages within the scope of our study.

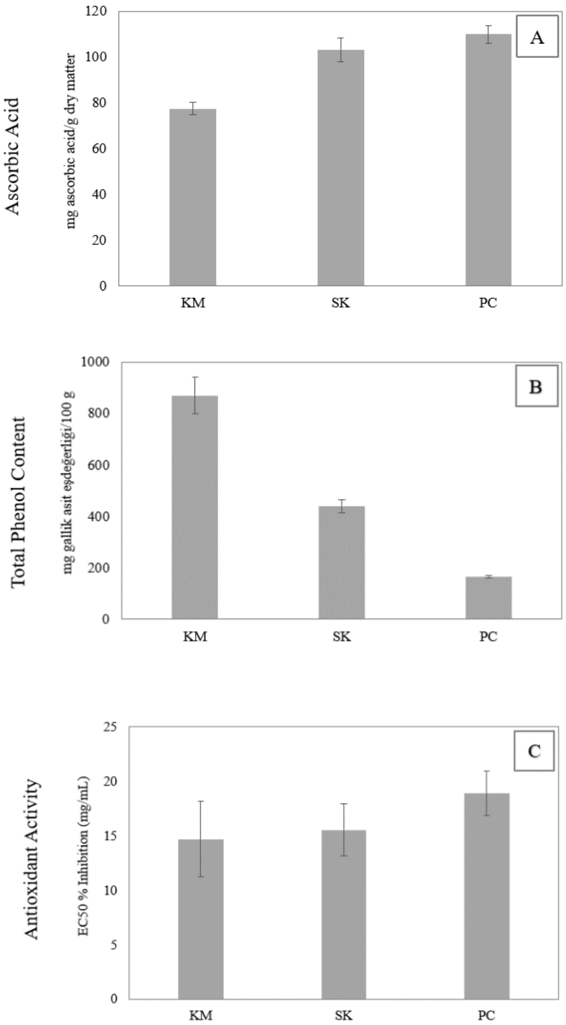

Figure 2 The level of ascorbic acid (A), total phenol content (B) and antioxidant capacity (C) of fermented-cabbage products (pickled cabbage, kimchi and sauerkraut). Bars indicate standard error of means ± SD (n=4).

Total Phenol Content

The impact of fermentation on bioactive compounds a phenols was also evaluated. Among the fermented-cabbage products, KM exhibited the highest TPC of 869.64±70.16 mg GAE/100 g f.w. ($P<0.05$), followed by SK and PC. TPC of KM (869.64 mg GAE/100g) was higher than that of SK (438.26 mg GAE/100g) by two times (Table 1). According to literature data, TPC of SK was found 108.7 mg/100g f.w. expressed as chlorogenic acid (Kapusta-Duch et al., 2017). TPC of various SK products (57.3, 58.3 and 85.5 mg GAE/100 g f.w.) was determined by Chun et al. (Chun et al., 2004). Hallmann et al (Hallmann et al., 2017) found that TPC of sauerkraut juices was 5.39-9.05 mg/100 g f.w. TPC results of white cabbage and sauerkraut samples were 5.72 mg/g and 8.25 mg/g, respectively (Ciska et al., 2005). In the spontaneous fermentation of leek kimchi, TPC was found between 315.47-351.98 mg GAE/liter (Yang et al., 2014). In another study regarding mustard leaf kimchi done by Park et al. (Park et al., 2017), was demonstrated higher TPC in methanol-extracts (474.8-482.4 mg chlorogenic acid/g) than water extracts (78.3-100.3 mg chlorogenic acid/g). Results of TPC showed considerable variation depending on the sample ingredients, fermentation process and sample extraction with water, methanol and ethanol decomposing large molecules into small phenolics. Meantime, extraction solvent influenced on degradation of phenolic compounds and changes in the TPC of fermented products. The total phenol data in present study and literature exhibit a great difference in the results given by various authors. It was indicated that present considerable variability parameter for fermentation. Type of used cabbage, harvest time, fermentation period could have an important effect on TPC. Comparing with other studies, fermentation cause releasing of phenolic compounds as the structure of aglycone (Park et al., 2017). However, some factors such as heat, oxidation and acid stress during process of cabbage products may influence on changes of bioactive compounds in negative way (Yang et al., 2014). TPC of white cabbages and Napa cabbages were 97.8 mg and 75.1 mg GAE/100 g f.w., respectively, according to Chun et al. (Chun et al., 2004). In another study, TPC of fresh white cabbages varied from 15.3 to 58.0 mg/100 g (Podsedek et al., 2006; Kapusta-Duch et al., 2017). Ingredients used during fermentation may also have a significant impact on increasing TPC in fermented-cabbage products.

Antioxidant Activity

DPPH radical-scavenging assay were conducted to evaluate the antioxidant capacities of three different types of fermented-cabbage products, the results are shown in Figure 2. EC50 was used to express the antioxidant activity. EC50 values of the 80% ethanol-extracts of KM, SK and PC showed high DPPH scavenging activities with 14.66, 15.52 and 18.88 mg/ml, respectively (Table 1). The results demonstrated similar tendency to these of DPPH activities. Chun et al. (Chun et al., 2004) and Kusznierewicz et al. (Kusznierewicz et al., 2008) reported that the antioxidant activity of cabbages could vary among the different process and fermenting conditions. According to Kusznierewicz et al. (Kusznierewicz et al., 2008), before fermentation of SK, shredding of cabbage increased antioxidant activity of cabbages and initial increment of antioxidant activity proceed from wounding of cabbages and chemical treatment.

Table 1 Nutritional characteristics and analysis results of cabbage-origin fermented products

Extraction solvent	AA	TPC	ANAC	DM
	0.4% oxalic acid	80% methanol	80% ethanol	
Fermented products				
Pickled cabbage	109.89±4.74[b]	165.64±4.18[a]	18.88±2.04[a]	10±0.003% - 90±0.003%
Sauerkraut	103.10±6.28[b]	438.26±25.1[b]	15.52±2.39[a]	13±0.006% - 87±0.006%
Kimchi	77.42±3.32[a]	869.64±70.16[c]	14.66±3.47[a]	15±0.004% - 85±0.004%

[a, b, c]Values are presented as mean value ±standard deviation (n=4). Data with different superscript letters in the same column are showed significantly different (P<0.05), AA: Ascorbic acid (mg ascorbic acid/100 g d.w.), TPC: Total Phenol Content (mg GAE/100 g f.w.), GAE, gallic acid equivalent, ANAC: Antioxidant activity (DPPH; EC50 (mg/ml)), DM: Dry matter rate - moisture content (%), d.w.: dried weight; f.w.: fresh weight, EC50 extract concentration providing 50% of the scavenging effect

When compared to study done by Park et al. (Park et al., 2017), the EC50 values of the 80% ethanol KM extracts ranged from 24.99 to 33.10 mg/ml, whereas methanol KM extracts showed 19.49-19.35 mg/ml and water-extracts of KM 42.08-40.82 mg/ml. In the present study, the radical scavenging activity of the different fermented-cabbage samples was significantly stronger with EC50 values. By the considering of various extraction solvent, methanol presented more efficient to extract antioxidant from the fermented samples. Similarly, Park et al. (Park et al., 2017) reported that 80% methanolic-extract of mustard leaf KM showed strong antioxidant activity between 9.9-10.6 mg/ml. However, in the same study it was reached that the water-extracts of KM exhibit lower activities than the methanolic-extracts varied from 25.5 to 33.3 mg/ml (Park et al., 2017). For the SK fermentation, antioxidant activity was determined 20.0 μmol TE/g f.w. by Kapusta-Duch et al. (Kapusta-Duch et al., 2017).

In the meantime, according to literature data, it was concluded that during the early stages of fermentation antioxidant activity of different fermented-cabbage products increased, but afterwards decreased. These findings are in good agreement with that fermentation periods effect on antioxidant activity. It was also claimed that antioxidant activity of fermented products could be affected by several factors including temperature, pH, fermentation time and process, extraction solvent, (*Lactobacillus* strains) (Jeong et al., 2011; Hur et al., 2014; Lai et al., 2014; Yang et al., 2014; Hashemi et al., 2017; Park et al., 2017).

Conclusion

This study provided an overview of the three types of cabbage-origin fermented products and evaluated the antioxidant activities of sauerkraut, kimchi and pickled cabbage at different fermentation parameters. Vitamin C contents, total phenol contents and antioxidant activity were determined as indicators of antioxidant contents. Hence, consumption of pickled cabbage and its brines could be recommended due to their high content of vitamin C. Among cabbage-origin products, kimchi seems to be a very good source of phenolic compounds. In addition, sauerkraut and kimchi also showed higher antioxidant activity. The results indicated that these fermented products may be assumed as dietary foods possessing high antioxidant activities demonstrating the presence of valuable bioactive compounds with high functionalities as fermented foods.

Future Prospect

Spontaneous fermentation of natural traditional products provides autochthonous LAB present in the surface of the raw materials. Additionally, these traditional products are excellent sources of starter microorganisms to be used during controlling of fermentation process and consistency of end-product, to improve safety and quality of traditional fermented products, to characterize functional starters and to tolerate gastric-intestinal conditions. Moreover, characterization (isolation, purification and identification) of new strains from traditional fermented product could provide new advantages in terms of health-promoting, nutritional, technologic and economical aspect. Considering these results the isolation, purification and identification of new strains are going on under our project. Consequently, next stage of this experimental study will be understand bacterial diversity and community during fermentation of these fermented products.

Acknowledgments

This research was supported by the Scientific Research Projects, Ege University, project number 17-MÜH-014.

Conflict of Interest

The authors have no conflict of interest to declare.

References

Aktan N, Kalkan Yıldırım H. 2012. Table Olive Technology. Meta Press: İzmir; 45–57.

Aktan N, Yücel U, Kalkan H. 1998. Pickle Technology. Ege University Publications, No:23: İzmir; 1–98.

Beganović J, Pavunc AL, Gjuračić K, Špoljarec M, Šušković J, Kos B. 2011. Improved Sauerkraut Production with Probiotic Strain Lactobacillus plantarum L4 and Leuconostoc mesenteroides LMG 7954. Journal of Food Science (J. Food Sci.).,76.

Cemeroglu B. 2007. *Food Analysis* (B Cemeroglu, Ed). Ankara.

Cheigh H, Park K, Lee CY. 1994. Biochemical, microbiological, and nutritional aspects of kimchi (Korean fermented vegetable products). Critical Reviews in Food Science and Nutrition (Crit. Rev. Food Sci. Nutr.).,34: 175–203.

Chun OK, Smith N, Sakagawa A, Lee CY. 2004. Antioxidant properties of raw and processed cabbages. International Journal of Food Sciences and Nutrition (Int. J. Food Sci. Nutr.).,55: 191–199.

Ciska E, Karamac M, Kosinska A. 2005. Antioxidant activity of extracts of white cabbage and sauerkraut. Polish Journal of Food and Nutrition Sciences (Polish J. Food Nutr. Sci.).,14: 367–373.

Frias J, Martinez-Villaluenga C, Peñas E. 2017. Fermented foods in health and disease prevention. Elsevier.

Hallmann E, Kazimierczak R, Marszałek K, Drela N, Kiernozek E, Toomik P, Matt D, Luik A, Rembiałkowska E. 2017. The Nutritive Value of Organic and Conventional White Cabbage (Brassica Oleracea L. Var. Capitata) and Anti-Apoptotic Activity in Gastric Adenocarcinoma Cells of Sauerkraut Juice Produced Therof. Journal of Agricultural and Food Chemistry (J. Agric. Food Chem.).,65: 8171–8183.

Hashemi SMB, Mousavi Khaneghah A, Barba FJ, Nemati Z, Sohrabi Shokofti S, Alizadeh F. 2017. Fermented sweet lemon juice (Citrus limetta) using Lactobacillus plantarum LS5: Chemical composition, antioxidant and antibacterial activities. Journal of Functional Foods (J. Funct. Foods).,38: 409–414.

Hışıl Y. 2007. *Instrumental Food Analysis- Laboratory Experiments*. Ege University Engineering Department Academic Press: İzmir.

Holzapfel W. 2014. *Advances in Fermented Foods and Beverages: Improving Quality, Technologies and Health Benefits*. Elsevier.

Hur SJ, Lee SY, Kim YC, Choi I, Kim GB. 2014. Effect of fermentation on the antioxidant activity in plant-based foods. Food Chemistry (Food Chem.).,160: 346–356.

Jagannath A, Raju PS, Bawa AS. 2012. A TWO-STEP CONTROLLED LACTIC FERMENTATION OF CABBAGE FOR IMPROVED CHEMICAL AND MICROBIOLOGICAL QUALITIES*. Journal of Food Quality (J. Food Qual.).,35: 13–20.

Jeong JK, Kim YW, Choi HS, Lee DS, Kang SA, Park KY. 2011. Increased quality and functionality of kimchi when fermented in Korean earthenware (onggi). International Journal of Food Science and Technology (Int. J. Food Sci. Technol.).,46: 2015–2021.

Jung JY, Lee SH, Jeon CO. 2014. Kimchi microflora: History, current status, and perspectives for industrial kimchi production. Applied Microbiology and Biotechnology (Appl. Microbiol. Biotechnol.).,98: 2385–2393.

Kapusta-Duch J, Kusznierewicz B, Leszczyńska T, Borczak B. 2017. Effect of Package Type on Selected Parameters of Nutritional Quality of Chill-Stored White Sauerkraut. Polish Journal of Food and Nutrition Sciences (Polish J. Food Nutr. Sci.).,67: 137–144.

Kim HW, Jang JJ, Kim NH, Lee NY, Cho TJ, Kim SH, Rhee MS. 2018. Factors that determine the microbiological quality of ready-to-use salted napa cabbage (Brassica pekinensis): Season and distribution temperature. Food Control (Food Control).,87: 1–8.

Kusznierewicz B, Śmiechowska A, Bartoszek A, Namieśnik J. 2008. The effect of heating and fermenting on antioxidant properties of white cabbage. Food Chemistry (Food Chem.).,108: 853–861.

Lai YJ, Tsai SH, Lee MY. 2014. Isolation of exopolysaccharide producing Lactobacillus strains from sorghum distillery residues pickled cabbage and their antioxidant properties. Food Science and Biotechnology (Food Sci. Biotechnol.).,23: 1231–1236.

Liang H, Zhang A, Wu Z, Liu C, Zhang W. 2016. Characterization of Microbial Community during the Fermentation of Chinese Homemade paocai, a Traditional Fermented Vegetable Food. Food Science and Technology Research (Food Sci. Technol. Res.).,22: 467–475.

Liu A, Li X, Pu B, Ao X, Zhou K, He L, Chen S, Liu S. 2017. Use of Psychrotolerant Lactic Acid Bacteria (Lactobacillus spp. and Leuconostoc spp.) Isolated from Chinese Traditional Paocai for the Quality Improvement of Paocai Products. Journal of Agricultural and Food Chemistry (J. Agric. Food Chem.).,65: 2580–2587.

Lu Y, He Z, Diao J, Xu P, Wang P, Zhou Z. 2011. Stereoselective behaviour of diclofop-methyl and diclofop during cabbage pickling. Food Chemistry (Food Chem.).,129: 1690–1694.

Lu Y, Yang Z, Shen L, Liu Z, Zhou Z, Diao J. 2013. Dissipation Behavior of Organophosphorus Pesticides during the Cabbage Pickling Process: Residue Changes with Salt and Vinegar Content of Pickling Solution. Journal of Agricultural and Food Chemistry (J. Agric. Food Chem.).,61: 2244–2252.

Martinez-Villaluenga C, Peñas E, Frias J, Ciska E, Honke J, Piskula MK, Kozlowska H, Vidal-Valverde C. 2009. Influence of fermentation conditions on glucosinolates, ascorbigen, and ascorbic acid content in white cabbage (Brassica oleracea var. capitata cv. Taler) cultivated in different seasons. Journal of Food Science (J. Food Sci.).,74: C62–C67.

Martinez-Villaluenga C, Peñas E, Sidro B, Ullate M, Frias J, Vidal-Valverde C. 2012. White cabbage fermentation improves ascorbigen content, antioxidant and nitric oxide production inhibitory activity in LPS-induced macrophages. LWT - Food Science and Technology (LWT - Food Sci. Technol.).,46: 77–83.

Mozzi F, Raya RR, Vignolo GM. 2016. *Biotechnology of lactic acid bacteria : novel applications*.

Park S-Y, Jang H-L, Lee J-H, Choi Y, Kim H, Hwang J, Seo D, Kim S, Nam J-S. 2017. Changes in the phenolic compounds and antioxidant activities of mustard leaf (Brassica juncea) kimchi extracts during different fermentation periods. Food Science and Biotechnology (Food Sci. Biotechnol.).,26: 105–112.

Park S, Ji Y, Park H, Lee K, Park H, Beck BR, Shin H, Holzapfel WH. 2016. Evaluation of functional properties of lactobacilli isolated from Korean white kimchi. Food Control (Food Control).,69: 5–12.

Patra JK, Das G, Paramithiotis S, Shin H-S. 2016. Kimchi and Other Widely Consumed Traditional Fermented Foods of Korea: A Review. Frontiers in Microbiology (Front. Microbiol.).,7: 1493.

Peñas E, Martínez-Villaluenga C, Pihlava JM, Frias J. 2015. Evaluation of refrigerated storage in nitrogen-enriched atmospheres on the microbial quality, content of bioactive compounds and antioxidant activity of sauerkrauts. LWT - Food Science and Technology (LWT - Food Sci. Technol.).,61: 463–470.

Podsedek A, Sosnowska D, Redzynia M, Anders B. 2006. Antioxidant capacity and content of Brassica oleracea dietary antioxidants. International Journal of Food Science and Technology (Int. J. Food Sci. Technol.).,41: 49–58.

Seong G-U, Hwang I-W, Chung S-K. 2016. Antioxidant capacities and polyphenolics of Chinese cabbage (Brassica rapa L. ssp. Pekinensis) leaves. Food Chemistry (Food Chem.).,199: 612–618.

Soltan Dallal MM, Zamaniahari S, Davoodabadi A, Hosseini M, Rajabi Z. 2017. Identification and characterization of probiotic lactic acid bacteria isolated from traditional persian pickled vegetables. GMS hygiene and infection control (GMS Hyg. Infect. Control).,12: Doc15.

USDA, Agricultural Research Service, February, 2018. USDA National Nutrient Database for Standard Reference. National Agricultural Library. Retrieved from: http://ndb.nal.usda.gov/.

Woo M, Kim M, Noh JS, Park CH, Song YO. 2017a. Kimchi attenuates fatty streak formation in the aorta of low-density lipoprotein receptor knockout mice via inhibition of endoplasmic reticulum stress and apoptosis. Nutrition Research and Practice (Nutr. Res. Pract.).,111111445.

Woo M, Kim M, Noh JS, Song YO. 2017b. Kimchi methanol extracts attenuate hepatic steatosis induced by high cholesterol diet in low-density lipoprotein receptor knockout mice through inhibition of endoplasmic reticulum stress.

Xiong T, Peng F, Liu Y, Deng Y, Wang X, Xie M. 2014. Fermentation of Chinese sauerkraut in pure culture and binary co-culture with Leuconostoc mesenteroides and Lactobacillus plantarum. LWT - Food Science and Technology (LWT - Food Sci. Technol.).,59: 713–717.

Xiong T, Li J, Liang F, Wang Y, Guan Q, Xie M. 2016. Effects of salt concentration on Chinese sauerkraut fermentation. LWT - Food Science and Technology (LWT - Food Sci. Technol.).,69: 169–174.

Yang J, Ji Y, Park H, Lee J, Park S, Yeo S, Shin H, Holzapfel WH. 2014. Selection of functional lactic acid bacteria as starter cultures for the fermentation of Korean leek (Allium tuberosum Rottler ex Sprengel.). International Journal of Food Microbiology (Int. J. Food Microbiol.).,191: 164–171.

Yücel U, Üren A. 2008. Biogenic amines in Turkish type pickled cabbage: Effects of salt and citric acid concentration. Acta Alimentaria (Acta Aliment.).,37: 115–122.

Zhang Q, Chen G, Shen W, Wang Y, Zhang W, Chi Y. 2016. Microbial safety and sensory quality of instant low-salt Chinese paocai. Food Control (Food Control).,59: 575–580.

Zhang W, Tian G, Feng S, Wong JH, Zhao Y, Chen X, Wang H, Ng TB. 2015. Boletus edulis Nitrite Reductase Reduces Nitrite Content of Pickles and Mitigates Intoxication in Nitrite-intoxicated Mice. Scientific reports (Sci. Rep.).,5: 14907.

Zhao D, Du RP, Ge JP, Wang XY, Mu LQ, Ping WX. 2016. Impact of Lactobacillus paracasei HD1.7 as a Starter Culture on Characteristics of Fermented Chinese Cabbage (Brassica rapa var. pekinensis). Food Science and Technology Research (Food Sci. Technol. Res.).,22: 325–330.