VARIATION OF BIOACTIVE COMPOUNDS CONTENT IN FERMENTED CABBAGE: INFLUENCE OF FERMENTATION TEMPERATURE

PROMENA SADRŽAJA BIOAKTIVNIH JEDINJENJA U TOKU FERMENTACIJE KUPUSA NA RAZLIČITIM TEMPERATURAMA

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ABSTRACT

The aim of this study was to analyze the effect of different fermentation temperature on bioactive compounds content of cabbage heads (*Brassica oleracea* var. *capitata*). Fermentation process was carried out at the temperature intervals 16-18 °C, 18-20 °C and 20-22 °C for 40 days. Dry weight, soluble dry weight, pH value, water activity, salt and sugar concentration, total acidity, penetration force, total color change, total phenolic compounds and organic acids were investigated as the most important quality parameters. The highest content of total phenol compounds, as well as the highest contents of oxalic and acetic acids were obtained in cabbage and brine sample fermented at 16-18 °C. The highest content of lactic acid in the cabbage sample fermented at 20-22 °C was obtained. In the case of brine samples, the highest contents of oxalic and lactic acids in samples fermented at 16-18 °C were observed, while the highest content of acetic acid in the sample fermented at 20-22 °C was obtained. Formic acid in cabbage and brine samples only in samples fermented at 20-22 °C was detected.

Key words: cabbage, bioactive compounds, biological fermentation, fermentation temperature.

REZIME

Cilj ovog rada bio je analiziranje uticaja različitih temperatura fermentacije na sadržaj bioaktivnih jedinjenja kupusa (*Brassica oleracea* var. *capitata*) u glavicama. Fermentacija kupusa odvijala se u poljoprivrednom gazdinstvu na temperaturama 16-18°C, 18-20°C i 20-22°C u trajanju od 40 dana. Uzorak kupusa i rasola uzet je za svaki ispitivani interval temperatura. Sadržaj suve materije i rastvorljive suve materije, pH vrednost, aktivnost vode, ukupna koncentracija soli i šećera, ukupan sadržaj kiselina, sila presecanja, ukupna promena boje, sadržaj fenolnih jedinjenja i sadržaj organskih kiselina ispitivani su u cilju praćenja procesa fermentacije. Najveći sadržaj fenolnih jedinjenja zabeležen je u uzorku kupusa i uzorku rasola fermentisanom na temperaturi 16-18°C. Takođe, najveći sadržaj oksalne i sirćetne kiseline zabeležen je u uzorku kupusa fermentisanom na temperaturi 16-18°C, dok je najveći sadržaj mlečne kiseline zabeležen u uzorku kupusa fermentisanom na 20-22°C. U slučaju ispitivanih uzoraka rasola, najveći sadržaj oksalne i mlečne kiseline zabeležen je u uzorku fermentisanom na temperaturi 16-18°C, dok je najveći sadržaj sirćetne kiseline zabeležen u uzorku fermentisanom na temperaturi 20-22°C. Mravlja kiselina zabeležena je samo u uzorku kupusa i rasola fermentisanom na temperaturi 20-22°C.

Ključne reči: kupus, bioaktivne materije, biološka fermentacija, temperatura fermentacije.

INTRODUCTION

Serbian households traditionally made biologically fermented cabbage sliced into stripes or as whole heads. Cabbage (*Brassica oleracea* var. *capitata*) is a widespread vegetable crop and it is very important for both health and economic reasons. This nutritionally valuable foodstuff could be consumed fresh, or as a coleslaw and as abiologically fermented cabbage (Harbaum-Piayda et al., 2016). Biological fermentation is the most convenient way of cabbage preservation in terms of usage out of the season. The best domestic varieties, suitable for fermentation, are futoški prevalent in Vojvodina, and srpski melez, in Central Serbia (Niketić-Aleksić, 1988). In addition to these varieties, cabbage hybrids are also widely cultivated due to heads uniformity, better yield and good storage possibilities. Cabbage hybrid bravo has a good yield and it is widely consumed in the form of fresh and fermented cabbage. Growing season of this hybrids approximately 90-95 days with recommended harvest time in the late fall. The outer leaves are bluish green, heads are round and tightly packed with mass between 2 and 3 kg per cabbage head (Cvetković, 2014).

During cabbage fermentation lactic acid is produced from sugar under the influence of microorganism activity. Afermented products are characterized with an appealing aroma, flavor, texture, nutritional enrichment and health promotion (Jevšnik et al., 2009; Terefe, 2016). During spontaneous fermentation microorganisms are growing and reproducing under the influence of external factors (Batt, 2016). The manufacture of fermented cabbage heads depends on the metabolism and successive growth of lactic-acid bacteria, naturally present in a raw material (Hutkins, 2006). The metabolism of lactic-acid bacteria is well reported in the literature (Kumar and Pranay, 2010; Gänzle, 2015), as well as fermentation process of the whole cabbage heads (Pederson et al., 1962; Cvetković et al., 2013; Cvetković et al., 2015; Beganović et al., 2014). The main goal of this study was to monitor changes of bioactive compounds from raw cabbage head to the biologically fermented product obtained on different temperature intervals. The brine which belongs to each sample was also taken for the purpose of the analysis. Dry weight, soluble dry weight, pH value, water activity, salt concentration, total sugar concentration, total acidity, penetration force, total color change, total phenolic compounds and organic acids are investigated as the most suitable quality indicators of the cabbage fermentation.

MATERIAL AND METHOD

Sample

Cabbage heads (*Brassica oleracea* var. *capitata*) were harvested from a field in Futog (Vojvodina, Serbia). Fresh cabbage hybrid bravo was picked in September and used for the purpose of analysis. Three fermented cabbage samples, with corresponding brine samples, were taken from the places with three different temperatures after 40 days of fermentation process. After finished fermentation cabbage samples were shredded to pulp and, together with brine samples, frozen and stored at -20 °C prior to analysis in order to prevent potential deteriorative processes in the samples.

Chemicals

Folin-Ciocalteu reagent was purchased from Sigma ("Sigma-Aldrich" GmbH, Steinheim, Germany). Orto-phosphoric acid was purchased from "Kemika" Zagreb, acetic acid standard from J.T. Baker (Holland), formic acid standard from "Sigma Aldrich", Steinheim, lactic and oxalic acid standards from Laborat. Laphoma Hemikalifrom Skopje and succinic acid standard from "Supelco Analytical", Bellefonte. All other chemicals and reagents were of analytical reagent grade.

Fermentation procedure

Cabbage hybrid bravo has been subjected to spontaneous fermentation process in "Agricultural holding Predrag Kurjakov", Futog. Primarily, fresh raw cabbage heads were selected in order to discard diseased and injuries. Afterwards, leaves on the top of each head were removed to reduce impurities and some undesirable extraneous microorganisms. Cabbage cores were notched in the shape of a cross in order to facilitate salt diffusion into the cabbage heads.

After the preparation of raw material, two whole cabbage heads were stacked in the plastic vats and the third one in the pool. In both vats and pool, 6 % NaCl water solution was added. Temperature intervals in pool and vats were 16-18 °C, 18-20 °C and 20-22 °C, respectively. The vat, which was held at temperature 18-20 °C was located in the basement. All three spontaneous fermentation processes lasted for 40 days.

Analyses

Dry weight

Dry weight was determined by drying approximately 2 g of samples at 105 °C until reaching the constant weight. The samples were mixed with quartz sand in order to increase surface evaporation and shorten the drying time. Experiments were performed in three replicates and expressed as percentage (%).

Soluble dry weight

Soluble dry weight content was read from the universal Abbe refractometer scale after placing the samples. Experiments were performed in three replicate and expressed as percentage (%).

pH value

Results were obtained by immersing the pH electrode in the cabbage pulp and brine samples and reading the values on WTW Inolab 720 pH-meter (Netherlands), at 25 °C. pH values were recorded after equilibration.

Water activity

Water activity was determined by placing approximately 3 g of cabbage pulp or brine in the sample holder of a Lab Swifta_w-meter "Novasina" (Switzerland) at 25 °C. *a_w* values were recorded after equilibration.

Salt concentration

The salt concentration in the samples were determined by method according to Mohr (Kolarov *et al.*, 1996). Analyzes have been conducted in two replicates and results were expressed as percentage (%).

Total sugar concentration

In the order to track changes of sugar concentration from raw to fermented cabbage, samples were analyzed following the Luff-Schoorl method (Vračar, 2001). The chemical analyzes have been conducted twice and results were expressed as percentage (%).

Total acidity

Total acidity of cabbage pulp and brine samples, expressed as lactic acid, was measured by titration using 0.1 M NaOH with phenolphthalein as indicator (Vračar, 2001). All chemical analyzes have been conducted twice and results were expressed as percentage (%).

Penetration force

Measurements were carried out immediately after samples were defrosted. For the purpose of these experiments whole cabbage leaves were used as the samples. Instrumental texture measurements were performed using a Texture Analyzer (TE32, Stable Micro Systems, UK) by using penetration-force test. The penetration test was carried using 2 mm stainless Cylinder probes and Heavy Duty Platform. TA settings – 2.0 mm/s; distance – 20 mm; load cell – 5 kg were set for penetration force analysis. Penetration force has been expressed as force (g) required for penetration through the samples.

Total color change

Total color change (ΔE) measuring was carried out immediately after samples were defrosted and whole cabbage leaves were used as the samples. The CIE $L^*a^*b^*$ color coordinates were measured by using Chroma Meter CR-400 (Minolta Co., Ltd., Osaka, Japan). The surface color of all cabbage leaves samples was measured in terms of L (degree of darkness), a (degree of redness and greenness) and b (degree of yellowness and blueness). Total color change between raw cabbage sample (L_0^* , a_0^* and b_0^*) and fermented cabbage samples (L^* , a^* and b^*) was determined according to Equation (1):

$$\Delta E = \sqrt{[(L_0^* - L^*)^2 + (a_0^* - a^*)^2 + (b_0^* - b^*)^2]} \quad (1)$$

Measure head of Chroma Meter was placed on each sample and measurements of color were performed for all prepared samples. A standard white color was used for calibration and experiments were replicated seven times for statistical purpose.

Total phenolics content

Cabbage pulp samples were defrosted prior extraction. Approximately 10 g of pulp sample was transferred to volumetric flask and 50 mL of methanol was added as extraction solvent. Extraction was carried out for 24h at the room temperature for each pulp sample. The obtained extracts and brine samples (after defrosting) were filtered, placed into a glass bottles and stored to prevent oxidative damage until analysis. The content of total phenolic compounds in methanolic extracts and brine filtrates was determined by Folin-Ciocalteu procedure (Singleton and Rossi, 1965; Kähkönen *et al.*, 1999) using chlorogenic acid as a standard. Absorbance was measured at 765 nm (6300 Spectrophotometer, Jenway, UK). The content of total phenolic compounds has been expressed as mg of chlorogenic acid equivalents per 100g of dry weight for cabbage samples and as mg of chlorogenic acid equivalents per 100 mL for brine samples (mg CAE/100 g DW and mg CAE/100 mL, respectively). Experiments were replicated two times and results are expressed as mean values.

Organic acids content

Approximately 20 g of each cabbage sample was shredded into pulp with bidistilled water in the ratio 1:1.75. The pulps were homogenized by using ultraturrax Heidolph Diastax900 ("Gemini BV", Nederland) and magnetic stirrer MSH-420

("Boeco", Germany) and then centrifuged ("Janetzki", Deutschland) at 4000 rpm. The supernatants were used for further analysis. The brine samples were filtered through a filter paper prior analysis. Determination of organic acids in cabbage pulp and brine samples was performed using the reversed phase HPLC, with Agilent 1100 Series HPLC (USA) according to *Kordiš-Krapež et al. (2001)* with slight modifications in terms of column type, detection wavelength and column temperature. System was equipped with degasser, binary pump, ZORBAX® SB-C18 column (4.6x150 mm, 5-Micron) and UV-DAD detector. Analysis was performed in isocratic mode with 6 mmol/L phosphoric acid (pH 2.1) as a mobile phase. LC parameters were set as follows: flow rate 1.0 mL/min, column temperature 28 °C, detection wavelength for oxalic, formic, lactic, acetic and succinic acid was 220 nm. Organic acids standards were used for external standard method of calibration. Results were expressed as mg/100 g DW and mg/mL for cabbage samples and brine samples, respectively. All analyses were done in duplicate.

RESULTS AND DISCUSSION

Seven samples (one raw and three fermented cabbages and three brine samples) were used for experiments. The alterations from raw to fermented cabbage at different temperature intervals was observed by monitoring of physico-chemical properties. Physico-chemical parameters followed in this study were: dry weight (DW), soluble dry weight (SDW), pH value (pH), water activity (a_w), salt concentration (NaCl), total sugar concentration (TSC), total acidity (TAC), penetration force (PF), total color changes (ΔE), total phenolic content (TPC) and organic acids contents. Experimentally obtained values of DW, SDW, pH, a_w , NaCl, TSC and TAC of raw cabbage sample (C_0), cabbage samples fermented at the temperature intervals 16-18 °C (C_1), 18-20 °C (C_2) and 20-22 °C (C_3) and corresponding brine samples (B_1 , B_2 , B_3) are presented in Table (1). Presented results are the average of the obtained values. Number of repetitions are presented in chapter Material and Method for each analyzed separately.

Table 1. Experimentally obtained values of dry weight, soluble dry weight, pH value, water activity, salt concentration, total sugar concentration and total acidity of raw and fermented cabbage and brine samples

Sample	DW (%)	SDW (%)	pH	a_w	NaCl (%)	TSC (%)	TAC (%)
C_0	9.45	5.97	5.90	0.997	0.05	3.91	0.15
C_1	7.88	6.00	3.49	0.981	0.79	1.70	0.69
C_2	7.69	6.00	3.12	0.976	2.19	0.58	0.79
C_3	7.97	7.00	2.97	0.967	2.45	0.27	0.75
B_1	4.64	4.63	3.00	0.972	2.84	nd*	0.67
B_2	5.26	5.00	3.16	0.972	3.18	nd*	0.23
B_3	5.95	4.90	3.08	0.974	3.27	nd*	0.39

*not identified

Physico-chemical properties

Dry weight (DW) depends on growing conditions and cultivation manner of a cabbage and it is a very important indicator of a raw and fermented cabbage quality and maturity. Late fall cabbage varieties and hybrids have higher DW and give fermented cabbage with higher quality compared to early cultivars (*Červenski, 2010*). DW in raw cabbage was 9.45 % which is similar with the results of *Mirecki (2001)* where it is

reported that DW is in the range of 9.21 % and 10.46 %. In all cabbage samples DW was between 7.69 % and 7.97 % which indicates that the temperature of fermentation did not influence DW significantly during the fermentation. The range of DW in brine samples varied between 4.64 % and 5.95 %. It was noticed that DW of brine samples increase with the increasing of fermentation temperature.

Soluble dry weight (SDW) of fresh cabbage is consisted of water-soluble compounds such as sugars, acids, etc. More than 3 % of these compounds content is generally required for a successful fermentation (*Dobričević and Plietić, 2004*). Soluble dry weight of the raw cabbage was 5.97 %. As in the case of DW, in both cabbage and brine samples there were no significant differences between SDW of cabbage samples. Also, the range of SDW observed for cabbage samples was higher than the range of SDW obtained for brine samples.

Lactic-acid bacteria produces lactic acid until all sugars are consumed, thus pH during the fermentation usually drops from 6.0 to 3.4 (*Bamfort, 2005*). Reducing pH value during the fermentation process inhibits the formation of lactic acid (*Hui and Evranuz, 2012; National Research Council, 1992*). Given that, pH value presents a very good indicator of the process of cabbage fermentation. pH value of the raw sample was 5.90, while pH values of cabbage samples varied between 2.97 and 3.49. It could be seen that pH values obtained for cabbage samples (2.97, 3.12, 3.49) increased with the reduction of temperature intervals (20-22 °C, 18-20 °C, 16-18 °C). However, there was no significant difference in pH values obtained from brine samples, so it could be concluded that the temperature did not influence significantly on pH of brine samples during fermentation.

Water activity (a_w) is used for predicting the subsistence and growth of microorganisms in food and it directly influences the product quality and stability (*Barbosa-Cánovas et al., 2007*). Microorganisms generally grow best between a_w values 0.995-0.980 (*Gibbs and Gekas, 1998*). a_w value of raw cabbage sample was 0.997. It could be seen that in the case of cabbage samples a_w values decrease with the increasing of fermentation temperature. a_w values obtained from brine samples did not show any significant influence of the fermentation temperature. The highest a_w value of all samples was obtained in C_1 , on the lowest temperature used for investigation (16-18 °C).

NaCl is the main promoter of the lactic-acid bacteria producing and growing during a fermentation process. Based on this, it also presents a good indicator of the fermentation process quality. NaCl addition stimulates the secretion of the cabbage cell juice due to osmotic difference of salt content in water and in cabbage. This also causes a reduction of a_w value. NaCl in the raw cabbage was 0.05 %. For cabbage fermentation, Tuzlanska salt (Solana d.d. Tuzla, Bosnia and Herzegovina) was used. NaCl content in C_1 , C_2 and C_3 was 0.79 %, 2.19 % and 2.45 %, respectively and it increased with increase of fermentation temperature 16-18 °C, 18-20 °C, 20-22 °C, respectively. It was noticed that the highest content of NaCl in cabbage samples was obtained in C_3 , where was also obtained the lowest a_w value of all cabbage samples. These could be expected since these two parameters are in direct correlation. NaCl contents in all brine samples were in the range from 2.84 % to 3.27 % which is higher compared to the range of NaCl content obtained in cabbage samples. These results could be expected, since NaCl (6 %) was added in water solution for fermentation and thus most of this amount was retained in brine. The highest NaCl content of all brine samples was obtained in B_3 , e.t. on the highest temperature used for investigation (20-22 °C).

Sugar is being converted into lactic acid during fermentation process and so the initial total sugar content (TSC) in raw cabbage is very important indicator for cabbage fermentation. Optimal content of sugar for fermentation varied between 3.5 % and 6.5 % and it should not be less than 3 % (Niketić-Aleksić, 1988; Červenski, 2010). TSC of the raw cabbage was 3.91 % and it could be seen that in terms of sugar content, the cabbage used for fermentation was suitable for fermentation. In fermented cabbage samples C₂ and C₃ were obtained very low TSC (0.58 % and 0.27 %, respectively) which indicates that 40 days of fermentation was enough for a satisfactory fermentation of these two samples. However, TSC obtained in C₁ was quite higher and it could be concluded that combination of the temperature (16-18 °C) and duration of the fermentation (40 days) influenced less good than the other fermentation combinations in terms of TSC in fermented samples. As it was expected, TSC in brine samples were not detected.

Total acids content of the raw cabbage sample was 0.15 % which fits well with the literature data obtained in Vračar (2001) where titratable acidity in raw cabbage varied between 0.1 % and 0.4 %. However, results obtained for total acids content (TAC) are expressed on the lactic-acid considering that it is dominant acid in biologically fermented products. TAC in cabbage samples varied between 0.69 % and 0.79 % while this range for brine samples was quite lower and between 0.23 % and 0.67 %.

A lot of factors influence the texture of cabbage leaves during fermentation process. NaCl addition influences positively on the cabbage leaves texture, since it prevents the softening of the tissue. The softening of cabbage leaves can also be caused by bacteria such as *Enterobacter*, *Flavobacterium*, and *Pseudomonas* when the fermentation temperature is lower than 10 °C and when the content of added NaCl is lower than 2 % (Hutkins, 2006). Since the investigated fermentation temperature intervals were between 16 °C and 22 °C and NaCl was added more than 2 % it was noticed that there was no significant difference in texture between fermented and raw cabbage leaves. Penetration force (PF) of raw cabbage leaves was 315 g, while the PF of fermented cabbage leaves varied between 307 and 418 g. The lowest PF was obtained in C₃ (20-22 °C) while the highest was obtained in C₂ (18-20 °C). These results indicates that temperatures used for the cabbage fermentation did not cause softening of cabbage products and that there was no significant difference between investigated cabbage samples.

Along with the texture, color is the main characteristic that makes a product appealing to consumers. Significant changes in color are usually occurred with the less good fermentation process. Brown color of cabbage usually occurs due to oxidation of phenolic compounds. Red, pink and gray colors may appear on cabbage during fermentation due to the metabolism of undesirable microorganisms (Niketić-Aleksić, 1988; Červenski, 2010). The obtained total color change (TCC) of cabbage samples varied between 10.32 and 12.14. These results did not present significantly high difference since it is assumed that the ΔE less than 1 is not sensory notable (Filimon et al., 2011). The highest TCC was obtained in C₃ which could be explained with the influence of the highest investigated temperature used for the cabbage fermentation.

Phenolic compounds belong to the group of biologically active substances important for human health due to antimicrobial, antiviral and anti-inflammatory properties (Ignat et al., 2011). Cabbage is known as a source of compounds with significant antioxidant activity since it is rich in polyphenolic compounds located in cabbage cells as a free molecule or in

bond form (Shahidi and Priyatharini, 2015). Total phenol content and antioxidant activities increases during the fermentation process since *Lactobacillus plantarum* and *Lactobacillus brevis* are capable to release bonded phenolic compounds during fermentation. Additionally, proteolytic enzymes from fermentable microorganisms hydrolyze phenolic compounds into more biologically active forms (Acosta-Estrada et al., 2014). Cabbage samples showed significantly higher total phenol content (TPC) in comparison with the raw cabbage sample (Graph 1). It was noted that the lower fermentation temperature influenced on higher TPC in cabbage samples. However, TPC in C₁, C₂ and C₃ were 240.1 %, 197.3 % and 171.1 % higher compared to the raw cabbage sample, respectively. TPC obtained in brine samples (Graph 2) varied between 4.75 and 8.35 mg CAE/100 mL. The highest TPC in brine samples was obtained in B₁ (16-18 °C) while the lowest TPC in brine samples was obtained in B₂ (18-20 °C). On the basis of these results it could be seen that the highest content of TPC was obtained on the lowest fermentation temperature, as it was the case with cabbage samples.

Figure 1. Total phenolic content in raw and fermented cabbage samples

Number of repetitions are presented in chapter Material and Method

Figure 2. Total phenolic content in brine samples

Number of repetitions are presented in chapter Material and Method

Short chain organic acids possess antimicrobial activity and sometimes they are also used as disinfectants for fresh fruits and vegetables (Huang and Chen, 2011). Some of them, including oxalic acid, are naturally present in the raw cabbage (Sinha, 2011). Oxalic acid has positive effects on cabbage properties during the storage before processing, since it increases the antioxidant capacity and inhibits the degradation of raw material (Wang et al., 2016). During the fermentation process, the change in the pH and oxygen concentration levels led to

formation of other organic acids such as lactic, acetic, formic and succinic acid (Farnworth, 2008). Sugar biotransformation causes formation of lactic acid which gives a sharp taste to a fermented cabbage and also compounds such as acetic acid, ethanol and CO₂ (Sinha, 2011). Acetic and formic acids possess higher inhibitory properties compared to lactic acid and these acids also increase protective effects of the desirable lactic-acid bacteria (Marthand Steele, 2001). Obtained oxalic acid content in the raw cabbage sample was 4716.6 mg/100 g DW and it was noticed that the content of oxalic acid in cabbage samples decreased during the fermentation. The higher temperatures caused lower oxalic acids contents in C₁, C₂ and C₃ samples (4200.9 mg/100 g DW, 3082.7 mg/100 g DW, and 1123.3 mg/100g DW, respectively). Lactic, acetic, formic and succinic acids were not detected in raw cabbage samples. With the increase of temperature during fermentation, the lactic acid contents in C₁, C₂ and C₃ samples (3069.4 mg/100 g DW, 4581.9 mg/100 g DW, 5201.0 mg/100 g DW, respectively) also increased. As in the case of oxalic acid, the contents of acetic acid in C₁, C₂ and C₃ samples (4134.3 mg/100 g DW, 2342.8 mg/100 g DW to 1767.4 mg/100 g DW, respectively) also decreased. Formic acid was detected only in C₃ sample (1334.1 mg/100 g DW) on the higher fermentation temperature 20-22 °C. Organic acids contents obtained for cabbage and brine samples are presented in Table 2. Succinic acid was detected in all cabbage and brine samples but it was not quantified.

Table 2. Experimentally obtained values of organic acids contents offered cabbage and brine samples

Sample	Oxalic acid	Lactic acid	Acetic acid	Formic acid
C ₁ ¹	4200.9	3069.4	4134.3	/
C ₂ ¹	3082.7	4581.9	2342.8	/
C ₃ ¹	1123.3	5201.0	1767.4	1334.1
B ₁ ²	1.16	2.53	0.86	/
B ₂ ²	0.46	0.91	0.31	/
B ₃ ²	0.19	2.17	1.01	0.69

¹ (mg/100 g DW); ² (mg/mL)

As it was the case with cabbage samples, oxalic acid contents of B₁, B₂ and B₃ samples (1.16 mg/mL, 0.46 mg/mL, and 0.187 mg/mL, respectively) decreased with an increase of the temperature of the fermentation. Lactic and acetic acid contents of the brine samples varied between 0.91 mg/mL and 2.53 mg/mL and between 0.31 mg/mL and 1.01 mg/mL, respectively. In the case of brine samples, higher value of lactic acid was obtained in B₁ (16-18 °C) and also for acetic acid B₃ (20-22 °C) which is opposite compared to C₁ and C₃ samples. As in the case of cabbage samples, formic acid was detected only in B₃ (20-22 °C).

CONCLUSIONS

On the basis of the obtained results it could be inferred that the highest content of total phenol compounds in cabbage and brine samples (414.71 mg CAE/100g DW and 8.35 mg CAE/100 mL, respectively), the highest contents of oxalic and acetic acid in cabbage samples (4200.9 mg/100g DW and 4134.3 mg/100g DW, respectively) and the highest contents of oxalic and lactic acid in brine samples (1.16 mg/mL and 2.53 mg/mL) were obtained in samples fermented at the lowest investigated temperature interval (16-18 °C). The highest content of lactic acid in cabbage samples (5201.0 mg/100g DW) and the highest

content of acetic acid in brine samples (1.01 mg/mL) were observed in samples fermented at the highest investigated temperature interval (20-22 °C). Formic acid in cabbage and brine samples (1334.1 mg/100 g DW and 0.69 mg/mL) was detected only in samples fermented at the highest fermentation temperature interval (20-22 °C).

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