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Sour cherry (*Prunus cerasus* L.) vinegars produced from fresh fruit or juice concentrate: Bioactive compounds, volatile aroma compounds and antioxidant capacities

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Acetic acid (PubChem Compound CID: 176)
Isobutyric acid (PubChem Compound CID: 6590)
Isovaleric acid (PubChem Compound CID: 10430)
Hexanoic acid (PubChem Compound CID: 12222600)
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ABSTRACT

In this study, it was aimed to determine the bioactive compounds and volatile aroma compounds of the sour cherry vinegar, and to investigate the usability of concentrated juice instead of the fresh fruit juice in vinegar production. And, two sour cherry vinegars were produced using juices prepareted fresh fruit (FSCJ) and concentrate juice (CSCJ), analyzed for functional and organoleptic aspects. The finding shown that both vinegars produced have rich functional compounds (gallic and chlorogenic acids) and volatile aroma compounds, and sour cherry is ideal for vinegar production. However, the vinegar produced using the CSCJ was more prominent, according to aromatic aspect. These aroma compounds were 3-methyl-1-butanol and eugenol, phenethyl alcohol, 2-phenethyl acetate, acetic, isobutyric, isovaleric, hexanoic and octanoic acids.

Within this study, a new way for sour cherry usage, independently of the season were proposed. And, aromatic and functional aspects of sour cherry vinegar were revealed for the first time.

1. Introduction

Prunus cerasus L. known as sour cherry or tart cherry is a fruit of the rosaceae family and it is native to northeastern Anatolia (Ferretti, Bacchetti, Belleggia, & Neri, 2010). With its characteristic sour taste and dark red color, sour cherry is a delicious fruit with a rich bioactive content (cyanidin, 3-rutinoside, peonidin, 3-glucoside, isorhamnetin, quercetin, ferulic acid, chlorogenic acid, p-coumaric acid) (Kirakosyan, Seymour, Llanes, Kaufman, & Bolling, 2009). These compounds provide the sour cherry with functional properties that prevent various diseases (neurological diseases, diabetes, obesity, cardiovascular and inflammatory diseases by strong antioxidant, antidiabetic, antiobesitic, antimutagenic and anticarcinogenic properties).

Vinegar is a flavoring agent to food. It, in addition to being used as condiment, is added to various foods including sauces and dressings (Budak and Guzel-Seydim, 2010; Guerrero, Marín, Mejías, & Barroso,

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2007). Vinegar is produced from fruits (especially grape) or vegetables containing sugar and starch, by a two-step system which consists of alcoholic and acidic fermentation processes (Ozturk et al., 2015). And, the vinegar composition is formed during the fermentation process. Due to the positive effects of the vinegar on the health like anticarcinogenic, antioxidant and antibacterial, the vinegar composition has been one of the most important study subject in recent years (Baldas & Altuner, 2018; Budak et al., 2011). Vinegar content varies depending on factors such as the raw material type, the conditions in which the raw material is grown and the production method – a traditional method or technological method (Ubeda et al., 2011). Therefore, other than grapes, there have been some studies on the functional and organoleptic properties and possible use of apple, pomegranate, cherry, blueberry, etc. in vinegar production (Budak, 2017; Coelho, Genisheva, Oliveira, Teixeira, & Domingues, 2017). However, only one study which analyzed traditional vinegars investigated sour cherry vinegar (Ozturk et al., 2015).

Since sour cherry season is short, the usege area of sour cherry is limited. Therefore, they are usually processed as sour cherry juice, sour cherry juice concentrate, jam, marmalade and as dried fruit to be consumed outside of the season (Lončarić, Pichler, Trtinjak, Piližota, & Kopjar, 2016). Although, in recent years, the use of sour cherry in wine making and the characteristics of sour cherry wine have been the subject of various studies (Čakar et al., 2016; Pantelić et al., 2014), there have been not enough scientific study on the use of sour cherry in vinegar production. The situation mentioned can be considered as an important deficiency for the food industry. For this reason, scientific studies should be conducted to reveal the functional and organoleptic properties of vinegar produced using fresh sour cherry fruit. Also, regardless of the season, it should be proposed a way in order to be able to use sour cherries in vinegar production.

First of all, this study was planned for two purposes. The first purpose was to determine the bioactive compounds and volatile aroma compounds of the sour cherry vinegar to reveal its functional and organoleptic properties. The second purpose, also was to investigate the usability of concentrated sour cherry juice instead of the fresh sour cherry juice in vinegar production, independently of the season and to examine its functional and organoleptic properties. Therefore, in this study, two sour cherry vinegars were produced using of fresh fruit or sour cherry concentrate. And, these vinegars were examined in terms of the functional and organoleptic properties of them during the fermentation process. Furthermore, the sour cherry wines obtained in the vinegar fermentation process were also examined in terms of the same properties.

2. Materials and methods

2.1. Materials chemicals and reagents

Chemicals and reagents utilized in the analyses in the present study were provided from Sigma-Aldrich Co. (St Louis, MO, USA), Merck Co. (Darmstadt, Germany) and Supelco Co. (Bellefonte, PA, USA). Rehydrated wine yeast (*Saccharomyces cerevisiae* strain, ConFerm Uni V yeast) was sourced from Eaton's Begerow® Product Line Co. (Nettersheim, Germany). For the production of the two vinegars planned, fresh sour cherry fruit and sour cherry juice concentrate were used as raw materials. First raw material; fresh sour cherries (*Prunus cerasus* L. var. Montmorency) were harvested from Egirdir, Isparta, Turkey. Second raw material; sour cherry juice concentrate (storaged for one year) obtained from the Department of Food Engineering-Suleyman Demirel University. And, this sour cherry juice concentrate had been produced by being concentrated to 65°Brix using a vacuum evaporator at 35 °C of the fruit juice prepared from the same sour cherry variety (*Prunus cerasus* L. var. Montmorency) of same region one year ago. And, it was not performed the recovery process for volatile compounds. As the last material, the two years-aged vinegar which required for 1/3 ratio according to the traditional vinegar production technique used by Budak and Guzel-Seydim (2010), obtained from the Department of Food Engineering-Suleyman Demirel University.

2.2. Preparation of sour cherry juices and inoculum

In this study, two sour cherry juices (FSCJ; Juice obtained from fresh sour cherry, and CSCJ; Juice obtained from concentrated sour cherry) obtained from before mentioned two raw materials were used for vinegar production. To prepare FSCJ, the fresh sour cherries were washed with tap water, the stems and cores were removed and the remaining fruit fresh were pressed using a hand press. The resulting juice was filtered through a multi-layer filter cloth to obtain the FSCJ juice. To prepare CSCJ juice, the sour cherry concentrate was used using sour cherry fruits obtained from the same region. The sour cherry concentrate was diluted with distilled water (dH_2O) and adjusted to produce an equal total soluble solids (TSS) value for the CSCJ juice that matched the FSCJ juice.

To prepare the inocula, the rehydrated yeast strain was activated in 100 mL of nutrient broth (Merck Co.) containing 20% (v/v) glucose (Sigma-Aldrich Co) at 30 °C for 6 h. The resulting culture was then re-activated at 30 °C for 24 h. Afterwards, the cells were centrifuged at 6000 × g (Hettich Co., East Westphalia, Germany) for 15 min, and the pellet was resuspended in 20 mL of sterile sodium phosphate-buffered-solution (PBS, Sigma-Aldrich Co.). The turbidity of the inoculate was adjusted to 0.5 McFarland value of in 20 mL of PBS to 980 mL of each sour cherry juice sample (10^6 log CFU/mL in juices).

2.3. Production of sour cherry vinegars

The sour cherry vinegars (FSCV; Vinegar producted from the fresh sour cherry juice, and CSCV; Vinegar producted from the concentrated sour cherry juice) were produced using FSCJ and CSCJ according to the traditional vinegar production technique used by Budak and Guzel-Seydim (2010). A flowchart of the process is presented in Fig. 1. Production consisted of two fermentation stages: alcoholic (30 days) and acidic (30 days), and was performed twice. The samples were taken at day 0, 15, 30, 45 and 60 from both fermentation stages. In addition, the samples taken 30 day was evaluated as sour cherry wines (FSCW; Wine producted from fresh sour cherry juice, and CSCW; Wine producted from concentrated sour cherry juice).

2.4. Proximate and microbiological analysis

The total titratable acidity and pH values in the present research were both measured according to AOAC (2000) by potentiometric titration using a pH-meter (WTW, Inolab, USA). The total titratable acidity values were expressed as a percentage of malic acid in the sour cherry juice and the sour cherry wine samples, and of acetic acid in vinegar samples. The total dry matter (%) was measured gravimetrically (AOAC, 2000), while the total soluble solids (TSS, °Brix) of the samples were examined by means of an Abbe refractometer (Bellingham Stanley Limit 60/70 Refractometer, England) (AOAC, 2000). The ethanol contents of the apple cider samples were measured with an alcoholometer (Dujardin-Salleron, France). The yeast counts and the acetic acid bacteria during the fermentation of samples was examined using a dichloran rose-bengal chloramphenicol agar (DRBC, Merck Co.) at 25 °C after 5 days (ISO 21527-1, 2008) aerobically and using GYC-Agar (glucose 50 g/L, yeast extract 10 g/L, agar 2 g/L pH 4) at 28 °C after 5 to 7 days (Cleenwerck et al., 2008) aerobically, respectively.

2.5. Total phenolic contents and antioxidant activity

Folin-Ciocalteu method was adopted for the determination of the total phenolic content by spectrophotometrical procedures (Shimadzu Scientific Instruments, Inc., Tokyo, Japan) according to the Singleton,

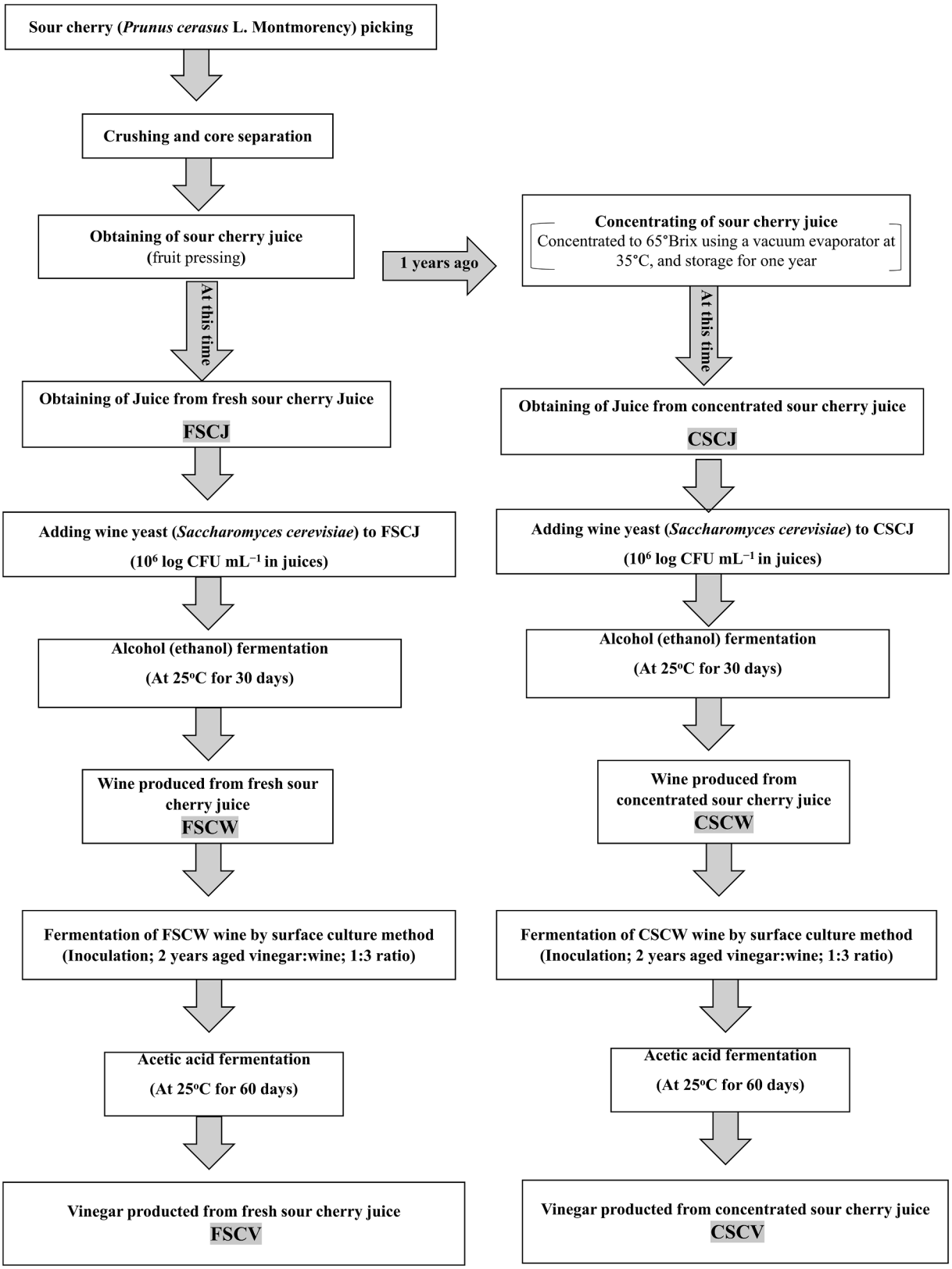

Fig. 1. Process of sour cherry vinegars. FSCJ, FSCW and FSCV: juice, wine and vinegar produced using fresh sour cherry juice. CSCJ, CSCW and CSCV: juice, wine and vinegar produced using concentrated sour sherry.

Orthofer, and Lamuela-Raventós (1999). Absorbance was read at 760 nm. The values are given in milligrams of gallic acid equivalents (GAE)/L.

The antioxidant activity of the samples was determined using the Oxygen Radical Absorbance Capacity (ORAC) and 2,2′-azinobis (3-ethylbenzothiazoline)-6-sulfonic acid (ABTS) methods. The spectro-fluorometrical procedure was adopted for the ORAC assay using a Synergy™ HT Multi-Detection Microplate Reader (Winooski, Vermont,

Table 1
The proximate composition and microbial contens of sour cherry vinegar samples during the fermantation.

Samples		Fermentation Days	Proximate Composition pH value	Total acidity (g/100 mL)	Total dry matter (%)	Total soluble solid (°Brix)	Alcohol amount (%)	Yeast count (CFU/mL)	Acetic acid bacteria count (CFU/mL)
Using Fresh Fruit	***FSCJ**	**0.**	3.10 ± 0.04^{AB}	2.16 ± 0.03^{D}	14.68 ± 0.01^{A}	16.28 ± 0.77^{A}	n.d.	n.d.	n.d.
		15.	3.27 ± 0.06^{A}	2.20 ± 0.11^{CD}	6.79 ± 0.03^{B}	9.05 ± 0.58^{BC}	6.33 ± 0.03^{A}	5.15 ± 0.23	n.d.
	FSCW	**30.**	3.07 ± 0.07^{AB}	2.30 ± 0.09^{C}	6.90 ± 0.08^{B}	9.08 ± 0.53^{BC}	6.32 ± 0.07^{A}	5.65 ± 0.19	n.d.
		45.	2.68 ± 0.05^{B}	3.72 ± 0.05^{B}	6.61 ± 0.12^{B}	9.25 ± 0.34^{B}	2.52 ± 0.02^{B}	n.d.	5.24 ± 0.13
	FSCV	**60.**	3.18 ± 0.06^{A}	4.62 ± 0.06^{A}	6.70 ± 0.06^{B}	9.02 ± 0.39^{BC}	n.d	n.d.	5.67 ± 0.13
Using Concentrate	**CSCJ**	**0.**	2.91 ± 0.04^{B}	1.96 ± 0.05^{D}	14.22 ± 0.11^{A}	16.75 ± 0.23^{A}	n.d.	n.d.	n.d.
		15.	2.95 ± 0.05^{B}	2.35 ± 0.04^{C}	6.54 ± 0.09^{B}	8.55 ± 0.52^{C}	6.35 ± 0.05^{A}	5.88 ± 0.11	n.d.
	CSCW	**30.**	3.41 ± 0.04^{A}	2.37 ± 0.02^{C}	6.56 ± 0.05^{B}	8.92 ± 0.32^{BC}	6.53 ± 0.08^{A}	6.34 ± 0.04	n.d.
		45.	3.03 ± 0.04^{B}	3.65 ± 0.05^{B}	6.53 ± 0.12^{B}	9.27 ± 0.45^{B}	2.10 ± 0.03^{B}	n.d.	5.21 ± 0.30
	CSCV	**60.**	3.00 ± 0.04^{B}	4.64 ± 0.03^{A}	6.54 ± 0.07^{B}	9.25 ± 0.41^{B}	n.d.	n.d.	4.92 ± 0.62

*FSCJ, FSCW and FSCV: juice, wine and vinegar produced using fresh sour cherry juice. CSCJ, CSCW and CSCV: juice, wine and vinegar produced using concentrated sour sherry. $^{A–E}$Different uppercase letters indicate significant differences between fermantation days of the same sample ($P < 0.05$). n.d.: not detection.

USA) by kinetic measurement (Dávalos, Bartolomé, & Gómez-Cordovés, 2005). The reading was performed at an excitation–emission wavelength of 485 to 520 nm using KC4™ Data Reduction Software (BioTek Instruments, Winooski, VT). The ABTS assay was carried out spectrophotometrically. Absorbance value was determined at 734 nm. Results for both analyses were given in micromoles of trolox equivalent (TE) per milliliter.

2.6. Phenolic compound (PC) analysis

PCs were measured using a high pressure liquid chromatography (HPLC; Shimadzu SCL-10A, Scientific Instruments, Inc., Tokyo, Japonya). The samples were diluted 10 times and passed through a 0.45 μm polytetrafluoroethylene (PTFE) filter (Membrane Solutions) to inject 20 μL into the HPLC system. They were run on the HPLC system with a flow rate 0.8 mL/min using 50 mmol/L of H_3PO_4 containing 15% CH_3CN (pH 4.50) solution as mobile phase in HPLC-column (Inertsil ODS-3 C18, 150 × 3.0 mm, 5 μm; GL Sciences Inc., USA) with oven temperature set to 30 °C. Using a Diode Array Detector (DAD) detector (SPD-M20A), the peaks obtained at a wavelength of 195 nm were evaluated using phenolic compound standard solutions (Caponio, Alloggio, & Gomes, 1999).

2.7. VAC analysis

The VACs were analyzed according to Guerrero et al. (2007) with some modifictions. For solid-phase micro extraction (SPME) procedure, a 2 mL sample was taken into a 15 mL vial, 0.8 g of NaCl and 6.60 μL of internal standard solution (2.27 g of 4-methyl-2-pentanol/L and 80 g of acetic acid/L in dH_2O) were added into the vial. Then the SPME injector (Supelco Co., Bellefonte, PA, USA) was inserted through the vial septum, and the vial submerged into a 40 °C water bath The SPME fiber (2 cm, 50/30 mm DVB/Carboxen/PDMS Stable Flex, Supelco Co.) was subjected to a headspace analysis at 500 rpm for 60 min. After the extraction, the fiber was placed in a gas chromatography (GC; Shimadzu GC-2010 Plus Capillary, Scientific Instruments, Inc., Tokyo, Japonya) injection port adjusted to 250 °C for 10 min in spitless mode for desorption. The samples were analyzed with Helium (99.9%) as the carrier gas at 2 mL/min flow rate and using a Stabilwax column (60 m, 0.32 mm id, 0.25 μm film thickness; Restek, Bellefonte, PA, USA). The samples were analyzed applying a GC program as follows: held 35 °C for 10 min, then increased to 100 °C with an increase 5 °C/min and held for 1 min; increased to 180 °C with an increase in the same rate and held for 1 min and then increased to 230 °C with increase 2 °C/min and held for 1 min. The peaks obtained were identified by the Wiley (McLafferty, 2005) and FFNSC (Flavors and Fragrances of Natural and Synthetic Compounds) libraries in a mass spectroscopy (MS). The values of the identified compounds were examined by using the relative peak area according to the internal standard. The retention times of *n*-alkanes (C7–C30) were utilized to determine the linear retention indices (LRIs).

2.8. Statistical analyses

The trials were carried out in three times. The results were given as mean ± standard deviation. The obtained data were analyzed by one-way analysis of variance (ANOVA) test by means of SPSS 18.0 (SPSS Inc., Chicago, IL, USA). The Duncan's test was utilized to asses the significantly different results ($P < 0.05$) between the fermentation times and the student's *t*-test was utilized to examine the significant differences ($P < 0.05$) between the samples. Additionally, heat-map graphics of the VACs selected according to positive z-scores versus the fermentation days of the vinegar samples were constructed using *R*-3.2 software (R Studio, Boston, MA, USA).

3. Results and discussions

3.1. Proximate composition and microbiological content

In this study, sour cherry vinegars (FSCV and CSCV) were produced from sour cherry juices (FSCJ and CSCJ, respectively), which were obtained from fresh sour cherry or sour cherry concentrate. The proximate composition, the bioactive compounds and VACs of the samples were evaluated during the fermentation. According to the proximate analyses (Table 1), slight increases and decreases in pH values were observed during fermentation; however, no statistically significant change was detected. ($P \geq 0.05$). While the total acidity values were different from each other at the beginning of fermentation and the lowest values of the fermentation process for both samples. ($P < 0.05$), they approached each other and increased, during the alcohol fermentation, which is the first stage of the fermentation process ($P \geq 0.05$). In production using concentrated sour cherry juice, acidity increased faster according them in other production. These results can be explained by the acidity developed during the storage period of concentrated fruit juice, one year prior to use. In the second-acidic stage of the fermetation, acidity values increased significantly in both samples ($P < 0.05$). No significant differences were found between the total acidity values of the vinegars (4.62% and 4.64%).

Given the alcohol contents were evaluated on 30th day. The alcohol values of the FSCW and CSCW wine samples were 6.32 and 6.53 v/v respectively. Additionally, thetotal acidity and the alcohol values were very similar to those obatined by Budak (2017) and Aykın, Budak, and Güzel-Seydim (2015) in apple and pomegranate vinegars. Also, the total dry matter and TSS values of the samples decreased fastduring the first 15 days of fermentation ($P < 0.05$). Accordingly, the reason for

this is that alcohol fermentation consists of the conversion of sugar in the sour cherry juice to ethanol (Crozier, Jaganath, & Clifford, 2009). Subsequently, no significant differences were observed in the further stages of fermentation ($P > 0.05$).

When examined the samples in terms of their yeast counts, the yeast count of CSCJ was ~0.69 log CFU/mL higher than that of FSCJ. This result showed that the production from CSCJ creates an appropriate environment for the development and adaptation of wine yeasts. It was thought that, with the partial hydrolization reactions of the components including aldehydes and ketons in the concentrate during the storage period, these compounds transformed into structures which wine yeast can better utilize. However, also, the production from FSCJ is suitable for wine and vinegar production. On the other hand, acetic acid bacteria (AAB) counts of the samples were determined during during the last 15 days of the second fermentation stage. The AAB count of CSCV was ~0.75 log CFU/mL lower than that of FSCV. Since, alcohol is a food source for acetic acid bacteria, this result can be attributed to the lower alcohol content in 45th day of the CSCW.

3.2. Total phenolic compound content (TPC) and antioxidant activity

Phenolic compounds are antioxidant agents that serve in the elimination of free radicals (Dávalos et al., 2005). In this study, the TPC contents of the juice samples (FSCJ, CSCJ) were determined to be 1422.73 and 2314.09 mg GAE/L, respectively (Fig. 2). These results were in line the results stated in some studies in published literature in which the TPC content of different cherry and sour cherry species was determined to be in the range from 849.6 to 3124 mg GAE/L (Kim, Heo, Kim, Yang, & Lee, 2005; Continella, Gentile, Amenta, Fabroni, & Rapisarda, 201). On the 30th day of fermentation, the values of wine samples (FSCW and CSCW) were 1709.39 and 2760.01 mg GAE/L, respectively. It was known that because phenolic substances bounds to sugars and organic acids, these substances are released by ethonol fermentation, in which sugar is converted to alcohol (Crozier et al., 2009). Also, in a study on ten types of fruit wines and four types of grape wine, it was determined that the TPC of wines produced from different fruits were between 1753 and 310 mg GAE/L, The TPC of wines of different grape cultivars ranged from 262.29 to 736.54 mg GAE/L (Rupasinghe & Clegg, 2007). At the end of fermentation, the TPC values for sour cherry vinegar samples (FSCV, CSCV) were determined to be 3511.67 and 3365.76 mg GAE/L, respectively ($P \geq 0.05$). Budak and Guzel-Seydim (2010) determined the TPC contents of grape vinegars to be from 2461 to 2690 mg GAE/L. These results showed that the use of both the fresh sour cherry and the concentrated sour cherry juice in vinegar production resulted in vinegar with a rich phenolic compound content.

Antioxidant activities of samples were determined according to two methods. The antioxidant values of sour cherry juices according to a TEAC assay were 9.60 and 26.94 mmol TE/mL, while these values were 4.57 and 9.70 μmol TE/mL according to an ORAC assay, respectively ($P < 0.05$). At the end of the alcohol fermentation, the antioxidant value of the CSCW sample (TEAC: 31.39 mmol TE/mL and ORAC: 9.21 μmol TE/mL) was significantly higher than that of the wine samples ($P < 0.05$). The difference between the two wine samples was higher according to the TEAC assay. While the antioxidant values in the acetic fermentation process remained stable according to the ORAC assay, the values slightly decreased again according to the TEAC assay. At the end of fermentation, the antioxidant values of the sour cherry vinegar were determined to be 8.14 mmol TE/mL in FSCV and 27.35 mmol TE/mL in CSCV (according to TEAC). Although it is known

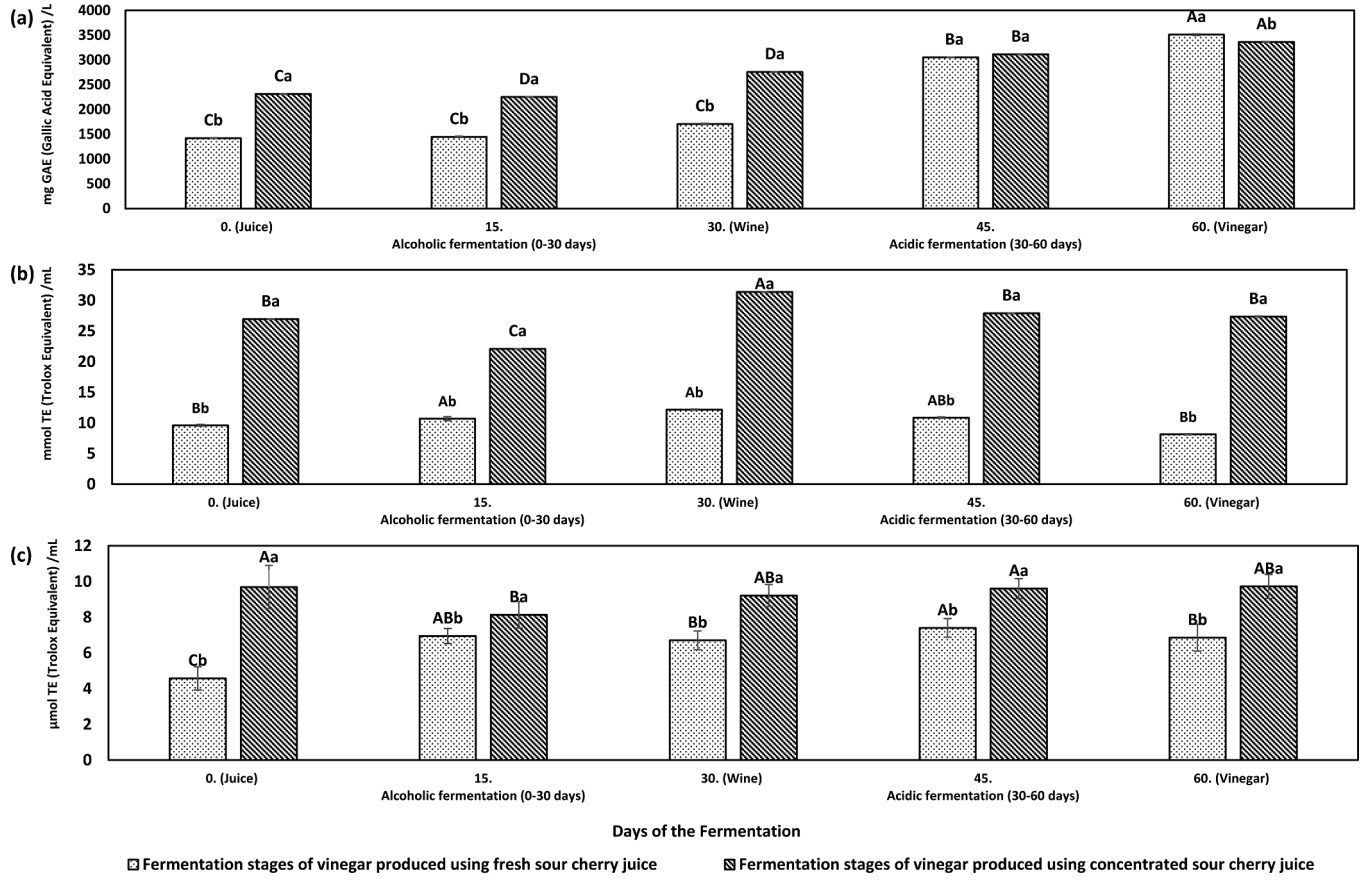

Fig. 2. Total phenolic contents (a), antioxidant activities according to TEAC (b) antioxidant activities according to ORAC (c) of sour cherry vinegar samples. Error bars indicate standard deviation. A–D Different uppercase letters indicate significant differences between fermantation days of the same sour cherry vinegar sample ($P < 0.05$). a–b Different lowercase letters indicate significant differences between the sour cherry vinegar samples on same days of fermentation ($P < 0.05$).

that acetic fermentation of wine can decrease some wine phenolics with high antioxidant activity throughout the vinegar production process from wine (Dávalos et al., 2005), in this study, the antioxidant values of the sour cherry juices and sour cherry vinegars (8.14 and 27.34 mmol TE/mL (TEAC); 6.85 and 9.72 (ORAC) μmol TE/mL, respectively) were close to each other. This was associated with the presence of compounds other than phenolic antioxidants, such as terpene antixodiants (eugenol, α-terpineol etc.) in sour cherry that are not affected by the acidic conditions (González-Burgos & Gomez-Serranillos, 2012; Politeo, Jukic, & Milos, 2007). In addition, the use of sour cherry concentrate in vinegar production had a geater positive effect on the antioxidant activity of the product compared to fresh sour cherry juice, and this can be associated with the terpene compounds.

3.3. Phenolic compound content

Sour cherry fruits have high levels of phenolic compounds (Levaj et al., 2010). In terms of individual phenolic acid contents at the production stages of sour cherry vinegar and in the sour cherry vinegar samples, seven compounds were determined in total: gallic acid, chlorogenic acid, p-coumaric acid, caffeic acid, ferulic acid, catechin and epicatechin phenolic compounds (Fig. 3). During fermentation and in the vinegar samples, gallic acid had higher values compared to other phenolic compounds, and it followed by chlorogenic acid ($P < 0.05$). Thus, it can be stated that these two phenolic compounds are major phenolic substances for the sour cherry vinegar.

It is known that phenolic substances are found to be bound to sugar and organic acid, these substances are released, due to conversion of sugar through the fermentation (Crozier et al., 2009). Therefore, in this study, the values of major phenolic compounds especially, increased in both the vinegar production processes in which fresh sour cherry and concentrated sour cherry juices were used as raw materials (Fig. 3a and b). At the end of fermentation time, the gallic acid and the chlorogenic acid values in the FSCV sample were determined to be 166.56 and 45.31 mg/mL, respectively, the values in the CSCV sample, were 183.12 and 67.04 mg/mL, respectively.

On the other hand, it was determined that while the important compounds in the vinegar produced from fresh sour cherry fruit were gallic acid, chlorogenic acid, and p-coumaric acid, the important compounds in the vinegar produced from concentrated sour cherry juice were gallic acid, chlorogenic acid, p-coumaric acid, and ferulic acid (Fig. 3). The only difference here was ferulic acid in the CSCV sample. The ferulic acid contents of the FSCV and CSCV samples were 0.94 and 5.11 mg/mL, respectively. Ferulic acid has been reported to have many physiological functions, including antioxidant, antimicrobial, anti-inflammatory, anti-thrombosis, and anti-cancer activities. In addition, it is a phenolic acid of low toxicity (Ou and Kwok, 2004). Additionally, it was determined that the amounts of the gallic acid and chlorogenic acid, which are the main phenolic compounds in the sour cherry vinegars, was higher in the CSCV sample, according to the FSCV sample. Therefore, in the production of sour cherry vinegar, it was observed that the use of concentrated sour cherry juice led to the production of sour cherry vinegar with a higher phenolic component content than fresh fruit. The reasons for this can be explained by the fact that the phenolic content of both juices is different and that the phenolic compounds in CSCJ have the higher values than in FSCJ.

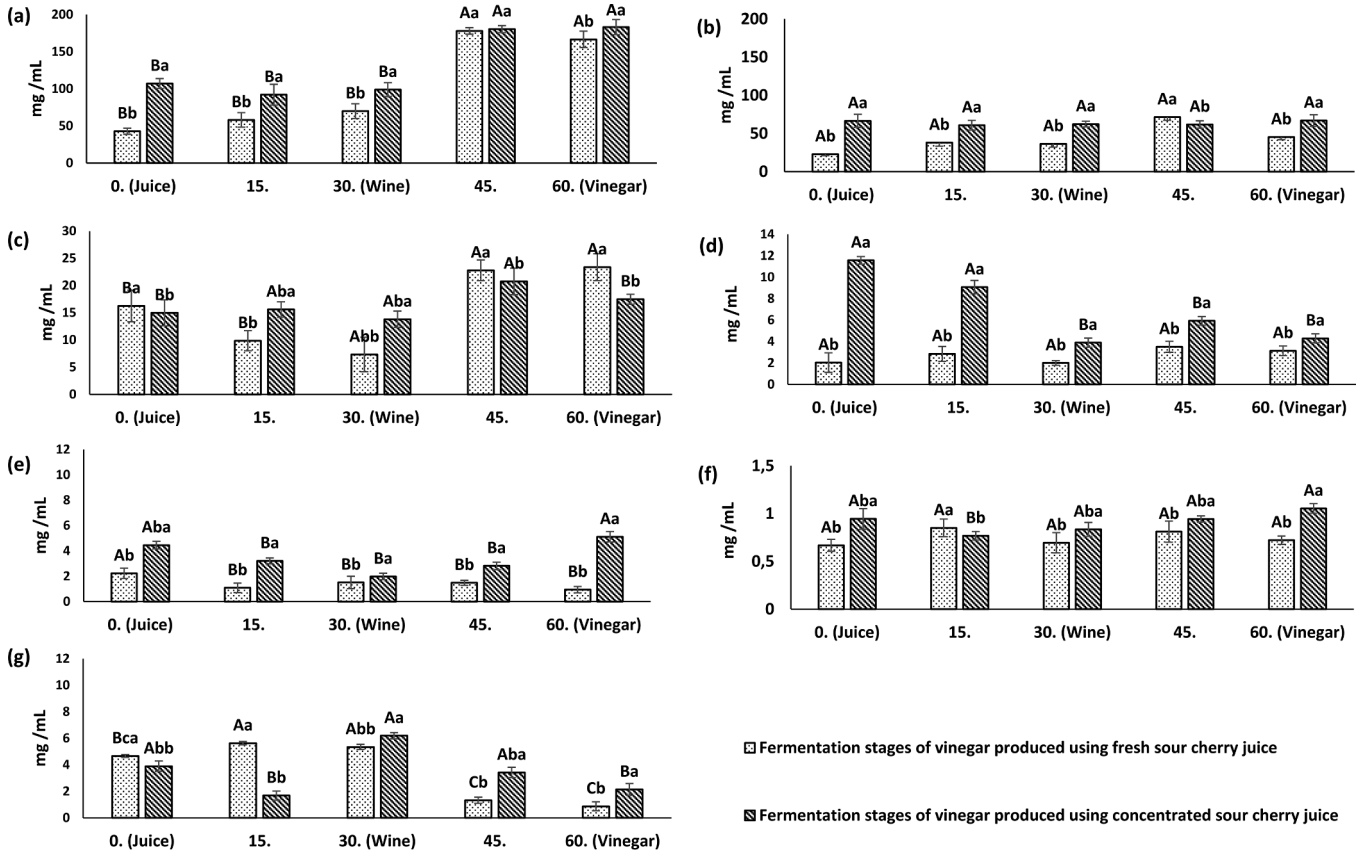

Fig. 3. Phenolic Compounds Content; gallic acid (a), chlorogenic acid (b), p-coumaric acid (c), caffeic acid (d), ferulic acid (e), catechin (f) and epicatechin (g) amounts of sour cherry vinegar samples. A–C Different uppercase letters indicate significant differences between fermantation days of the same sour cherry vinegar sample ($P < 0.05$). a–b Different lowercase letters indicate significant differences between the sour cherry vinegar samples on same days of fermentation ($P < 0.05$).

Chlorogenic acid has been reported to have a protective effect against cardiovascular diseases with inhibition of LDL oxidation, in additional to many physiological functions, including antimutagenic, carcinogenic and antioxidant activities (Laranjinha, Almeida, & Madeira, 1994). Besides, it is known that chlorogenic acid is one of the important polyphenols of the apple cider vinegar reported with many positive effects on health (Budak et al., 2011). The fact that chlorogenic acid were present in both sour cherry vinegar reveals the importance of using sour cherry in vinegar production. Also, it is predicted that sour cherry vinegar may have more potent positive effects on health, such as apple vinegar. According to this knowledges, it was reveal that both raw materials could be used in terms of phenolic compound content in sour cherry vinegar production.

3.4. VACs of sour cherry vinegars

As the main feature of vinegar is to give aroma to the products to which it is added, the most important of its compounds are VACs. In this study, the differences between the VAC profiles of the vinegars produced from fresh cherry juice and concentrated cherry juice were studied. Also, the changes in the VACs of the samples were investigated during their production (fermentation) processes. A total of 37 compounds related to alcohol, carboxylic acid, esters, terpenes, aldehydes and ketones were investigated (Table 2).

In the study examination of the VACs of the cherry juices prepared using concentrated and fresh juices for vinegar production, it was observed that the amount of alcohol, carboxylic acid, esters and terpene compounds in the CSCJ sample was higher than those of the FSCJ sample. During the storage process, it was thought that aroma precursors were formed by various chemical reactions (such as the synthesis of esters with the reaction of ethyl alcohol and carboxylic acids) and partial conversions started in the sour cherry concentrate. For example, the acetaldehyde compound was higher in the CSCJ example than the FSCJ example. Another reason was that the amount of the water added to the concentrated juice was adjusted to as that the TSS values of the juices which prepared from the concentrated juice and the fresh, would be equal each other. It was thought that this situation might be caused the amount of water added to the concentrated juice to be less than the amount of water removed at the production stage of its. Therefore, since the amount of VAC per unit volume increased, the CSCJ sample was highlighted in terms of theVAC content (especially, the terpenes). While the amounts of compounds such as eugenol, ethyl acetate, ethanol, 3-methyl-1-butanol were high in the CSCJ sample, benzaldehyde, one of the typical VACs in cherry (Wilkowska & Pogorzelski, 2017) were high in the FSCJ sample (Table 2). This result showed that the FSCJ sample was suitable for use as cherry juice, while the CSCJ sample was suitable as cherry juice after the addition of aromas as applied in industry. However, the CSCJ sample is considered to be highly suitable for use as a raw material in the production of fermented products, since the aromacompounds are rich in terms of the precursors of its aroma compounds.

In the alcohol fermentation process, which was the first fermentation stage of vinegar production, acid and ester compounds significantly increased in both samples following the alcohol group compounds ($P < 0.05$). In the CSCW sample of the sour cherry wines obtained at the end of the alcohol fermentation, the total amount of alcohol compounds, in particular the amount of ethanol (total alcohol compounds 543.64 mg/L and ethanol 337.05 mg/L) were higher than those obtained in the FSCW sample (total alcohol compounds 478.14 m/ L and ethanol 232.64 mg/L) ($P < 0.05$). However, in the FSCW sample, the diversity and amount of alcohol compounds other than ethanol were higher than those in the CSCW sample ($P < 0.05$). It is known that higher alcohol and esters compounds, which have substantial effects on the formation of the a characteristic wine aroma, comprise the largest groups in VACs (Valero, Moyano, Millan, Medina, & Ortega, 2002), and that higher alcohol levels may originate from fruit-derived aldehydes, by the reductive denitrification of amino acids or through yeast metabolism from compounds such as sugars that contain aldehyde and keton groups. Aldehyde group compounds were determined in the CSCW wine sample, while they could not be detected in the FSCW sample.

The total values of the ester compounds of wine samples were lower in the CSCW sample than those in the FSCW sample ($P < 0.05$). It is known that ester compounds may be produced either through esterification of carboxylic acid and alcohol compounds in the fermentation process or through yeast metabolism (González-Rompinelli et al., 2013). In addition, some alcohol and ester compounds, such as isobutyl alcohol, phenethyl alcohol, benzyl alcohol, 1-dodecanol 1-hexanol ethyl acetate, phenethyl acetate and isobutyl acetate (Niu et al., 2011; Sun, Jiang, & Zhao, 2011), which positively affect the wine flavor, were high in the FSCW sample. However, in this study, it was determined that hexanoic acid, ethyl hexanoate and isoamyl acetate (Sun, Jiang, & Zhao, 2012) in wines produced from cherry (*Prunus avium* L.) were higher in the CSCW sample. Moreover, the CSCW sample was found to have a much higher amount of terpene than the FSCW sample ($P < 0.05$). It is known that terpenes, which show strong aromatic activity are produced as a result of enzymic hydrolysis from terpene glycosides during alcohol fermentation and malolactic fermentation in fruits (García-Carpintero, Sánchez-Palomo, & González-Viñas, 2011). These results emphasize that since the amounts of large alcohol compounds and ester compounds were higher in the FSCW sample, the use of fresh fruit juice was more suitable for production of sour cherry wine. On the other hand, in the CSCW sample produced by using of sour cherry juice concentrate, in particular, the amounts of terpene compounds were determined as higher.

In the second stage of production (acidic fermentation stage), the decrease in pH value is highly effective in converting alcohols and aldehydes into VACs. Examining the vinegar samples formed at the end of this fermentation stage, it was determined that the compounds of the ester and carboxylic acid group were prominent, and the total values for these compounds were higher than the other CSCV vinegar samples ($P < 0.05$).

In the volatile aroma compound profile of the vinegar, esters and carboxylic acid groups are among the most important VAC groups. In particular, the amount of octanoic acid, nonanoic acid, decanoic acid, dodecanoic acid and tetradecanoic acid in the volatile fatty acid compounds of the carboxylic acid group in vinegars was twice as high in the CSCV sample than those in the others. It is known that volatile fatty acids are produced as a result of the oxidization of organic compounds by *Acetobacter* spp. (Şengün & Karabıyıklı, 2011).

In the CSCV sample, ester compounds other than methyl acetate and benzyl acetate had higher values than those of the FSCV sample ($P < 0.05$). However, the sum of the ester group compound, which is highly effective for aroma, was higher in the CSCV sample. Similarly, the total amount of terpene compounds that are also important for the aroma were also higher in the CSCV sample than those in the FSCV sample. All these results emphasize the use of concentrated cherry juice for vinegar production.

In order to identify the most important VAC in sour cherry vinegar, both vinegar samples were evaluated together. Firstly, the VAC data obtained were converted to z-scores to compare the values of aroma compounds on different days in the same sample, and the values in different samples on the same day. According to the z-scores obtained on day 60 of fermentation for both vinegars, nine VACs with positive z-scores were identified. Compounds important for the VAC profile of cherry vinegar are 3-methyl-1-butanol, phenethyl alcohol, acetic acid, isobutyric acid, isovaleric acid, hexanoic acid, octanoic acid, 2-phenethyl acetate and eugenol. These VACs are displayed in heatmap graphics (Fig. 4). As shown in Fig. 4, the most important compounds for the FSCV vinegar were isobutyric acid, isovaleric acid, hexanoic acid and eugenol (Fig. 4a), while the most important compounds for the CSCV vinegar were acetic acid, isovaleric acid and hexanoic acid

Table 2
Volatile aroma compounds (VAC) of sour cherry vinegar samples during the fermentation times and at the end day of fermentation (μg/100 mL).

Samples		Sour Cherry Vinegar Produced Using Fresh Sour Cherry Juice					Sour Cherry Vinegar Produced Using Concentrated Sour Cherry Juice				
Fermetation Days	**Retention Index**	**0. (*FSCJ; Juice)**	**15.**	**30. (FSCW; Wine)**	**45.**	**60. (FSCV; Vinegar)**	**0. (CSCJ; Juice)**	**15.**	**30. (CSCW; Wine)**	**45.**	**60. (CSCV; Vinegar)**
Aroma names		**Alcohol Fermentation**			**Acid Fermentation**		**Alcohol Fermentation**			**Acid Fermentation**	
Alcohols											
Ethanol	938	48.26 ± 0.37^{B}	18975.93 ± 2.91^{A}	23263.61 ± 3.44^{A}	125.24 ± 3.72^{B}	n.d.	194.68 ± 3.61^{B}	26680.63 ± 8.93^{A}	33704.93 ± 3.31^{A}	6182.88 ± 3.70^{B}	90.21 ± 0.01^{B}
Isobutyl alcohol	1099	n.d.	1578.50 ± 1.06^{A}	1800.49 ± 2.28^{A}	101.15 ± 3.84^{B}	44.75 ± 1.67^{B}	14.27 ± 0.25^{C}	1354.61 ± 1.65^{A}	1464.49 ± 0.66^{A}	694.48 ± 2.67^{B}	253.82 ± 1.65^{C}
3-Methyl-1-butanol	1214	n.d.	9274.44 ± 7.14^{B}	10584.78 ± 10.71-^{A}	376.01 ± 1.65^{A}	n.d.	139.95 ± 0.11^{C}	9931.15 ± 7.02^{A}	10673.98 ± 1.37^{A}	4091.57 ± 1.36^{B}	1380.1 ± 3.75^{C}
1-Hexanol	1358	3.70 ± 1.87^{B}	175.55 ± 0.13^{A}	189.03 ± 0.56^{A}	n.d.	9.51 ± 1.61^{B}	4.19 ± 1.77^{A}	n.d.	n.d.	n.d.	n.d.
1-Nonanol	1667	8.36 ± 3.57^{C}	n.d.	n.d.	35.59 ± 4.08^{A}	21.87 ± 4.21^{B}	5.27 ± 3.52^{A}	n.d.	n.d.	n.d.	n.d.
Benzyl alcohol	1891	32.28 ± 7.64^{D}	276.79 ± 0.51^{B}	403.12 ± 0.39^{A}	151.66 ± 7.93^{C}	162.56 ± 3.86^{C}	8.99 ± 0.08^{B}	n.d.	n.d.	91.19 ± 3.49^{A}	n.d.
Phenethyl alcohol	1926	4.16 ± 1.51^{D}	7520.57 ± 1.52^{B}	11423.07 ± 0.26^{A}	2398.58 ± 7.54^{C}	1800.13 ± 3.54^{CD}	22.51 ± 2.67^{B}	82.81 ± 0.58^{B}	8455.31 ± 3.45^{A}	7652.27 ± 2.58^{A}	28.87 ± 1.39^{B}
1-Dodecanol	1972	n.d.	44.46 ± 0.19^{A}	149.69 ± 1.15^{A}	98.82 ± 5.90^{A}	n.d.	12.75 ± 1.73^{B}	82.01 ± 1.23^{AB}	65.52 ± 5.16^{AB}	103.24 ± 0.66^{A}	42.65 ± 3.13^{AB}
Total compounds		**96.76 ± 1.06**	**37846.25 ± 5.33**	**47813.79 ± 5.08**	**3287.05 ± 0.52**	**2038.81 ± 0.41**	**402.61 ± 2.45**	**38131.2 ± 9.81**	**54364.23 ± 3.22**	**18815.64 ± 7.94**	**1795.64 ± 0**
Carboxylic Acids											
Acetic acid	1468	92.51 ± 1.42^{B}	177.06 ± 2.11^{B}	357.83 ± 0.73^{B}	13800.65 ± 4.27^{A}	13081.78 ± 2.74^{A}	89.13 ± 1.61^{B}	243.09 ± 5.37^{B}	373.11 ± 1.08^{B}	13869.49 ± 1.62^{A}	15999.55 ± 5.77^{AB}
Isobutyric acid	1582	n.d.	83.99 ± 0.34^{D}	204.08 ± 1.24^{C}	519.21 ± 2.12^{B}	770.08 ± 0.91^{A}	3.61 ± 0.92^{B}	90.40 ± 1.41^{B}	86.98 ± 0.32^{B}	225.14 ± 7.55^{A}	195.75 ± 5.52^{A}
Isovaleric acid	1681	6.70 ± 0.28^{C}	177.61 ± 1.54^{C}	531.12 ± 0.98^{C}	2823.07 ± 7.33^{B}	3370.21 ± 4.56^{A}	n.d.	104.77 ± 0.28^{B}	67.25 ± 0.17^{B}	2057.75 ± 6.71^{A}	1601.65 ± 0.28^{A}
Hexanoic acid	1858	9.79 ± 7.69^{E}	280.81 ± 2.16^{D}	363.15 ± 2.53^{C}	605.97 ± 7.13^{B}	722.81 ± 2.92^{A}	15.11 ± 4.02^{C}	912.94 ± 9.76^{AB}	1014.46 ± 4.80^{A}	932.53 ± 2.33^{AB}	786.85 ± 0.14^{B}
Octanoic acid	2068	15.77 ± 7.16^{C}	2189.49 ± 2.99^{B}	2151.02 ± 2.47^{B}	4326.41 ± 3.54^{A}	4115.69 ± 1.09^{A}	41.69 ± 5.62^{C}	194.26 ± 4.60^{C}	18938.51 ± 2.21^{A}	15211.53 ± 3.21^{A}	8002.48 ± 1.17^{B}
Nonanoic acid	2176	11.45 ± 1.88^{C}	183.84 ± 7.71^{BC}	423.52 ± 1.72^{A}	339.76 ± 0.33^{AB}	23.12 ± 0.04^{C}	21.93 ± 3.26^{B}	133.98 ± 2.94^{AB}	143.99 ± 6.02^{AB}	247.55 ± 1.02^{A}	136.51 ± 1.21^{AB}
Decanoic acid	2280	13.77 ± 1.91^{D}	516.46 ± 7.14^{B}	300.04 ± 0.83^{C}	807.66 ± 5.82^{D}	15.05 ± 1.18^{A}	33.05 ± 8.31^{C}	5593.05 ± 6.97^{A}	120.24 ± 0.03^{C}	3523.03 ± 2.57^{B}	59.28 ± 0.30^{C}
Dodecanoic acid	2492	6.09 ± 5.61^{D}	219.28 ± 2.69^{A}	107.80 ± 1.72^{B}	n.d.	68.49 ± 0.12^{C}	18.44 ± 1.42^{A}	37.21 ± 3.16^{A}	83.55 ± 2.45^{A}	144.54 ± 2.28^{A}	171.41 ± 1.83^{A}
Tetradecanoic acid	2705	2.27 ± 0.08^{B}	256.54 ± 9.22^{A}	96.21 ± 3.38^{B}	59.13 ± 4.8^{B}	n.d.	7.02 ± 0.96^{B}	134.44 ± 2.07^{A}	81.25 ± 0.41^{AB}	99.7 ± 0.15^{AB}	92.55 ± 1.01^{AB}
Total compounds		**158.36 ± 16.86**	**4085.09 ± 2.44**	**4534.74 ± 4.3**	**23281.85 ± 3.02**	**22167.21 ± 1.65**	**229.98 ± 9.41**	**7444.12 ± 9.35**	**20909.36 ± 22.82**	**36311.24 ± 4.31**	**27046.04 ± 0.94**
Esters											
Methyl acetate	827	n.d.	69.42 ± 1.54^{C}	101.17 ± 2.71^{B}	125.55 ± 5.55^{A}	61.27 ± 1.10^{C}	n.d.	n.d.	n.d.	33.15 ± 1.40^{A}	26.07 ± 0.46^{A}
Ethyl acetate	891	110.29 ± 22.73^{C}	29001.86 ± 4.02^{B}	34453.82 ± 1.87^{A}	1092.01 ± 5.64^{C}	60.43 ± 6.66^{C}	128.95 ± 9.64^{C}	6094.21 ± 1.68^{BC}	11383.70 ± 1.42^{B}	22180.43 ± 5.8^{A}	240.04 ± 1.48^{C}
Ethyl propanoate	953	n.d.	325.68 ± 3.51^{B}	463.12 ± 5.78^{A}	n.d.	n.d.	n.d.	98.99 ± 8.44^{B}	255.09 ± 6.27^{A}	n.d.	n.d.
Isobutyl acetate	1017	n.d.	306.61 ± 1.67^{B}	341.48 ± 7.52^{A}	135.85 ± 1.13^{C}	58.29 ± 0.78^{CD}	n.d.	112.03 ± 9.58^{B}	111.91 ± 4.60^{B}	594.44 ± 2.69^{A}	209.38 ± 7.95^{B}
Isoamyl acetate	1126	8.22 ± 8.03^{C}	2180.38 ± 3.5^{A}	1678.51 ± 3.11^{B}	75.56 ± 1.61^{C}	61.66 ± 0.18^{C}	10.18 ± 6.28^{C}	2111.03 ± 5.38^{AB}	2612.4 ± 1.07^{A}	1631.51 ± 0.89^{ABC}	350.61 ± 1.49^{BC}
Ethyl caproate	1237	2.62 ± 0.35^{C}	268.98 ± 2.63^{A}	217.58 ± 2.44^{B}	n.d.	n.d.	n.d.	232.53 ± 5.16^{AB}	488.14 ± 2.37^{A}	n.d.	n.d.
Ethyl caprylate	1439	2.56 ± 0.62C	773.19 ± 1.09A	373.54 ± 0.06B	n.d.	n.d.	2.98 ± 2.50^{C}	654.90 ± 2.50^{A}	n.d.	83.35 ± 2.53^{B}	45.58 ± 2.51^{B}
Ethyl decanoate	1644	n.d.	320.03 ± 0.12^{A}	n.d.	n.d.	n.d.	n.d.	474.56 ± 5.25^{AB}	1589.69 ± 9.72^{A}	n.d.	21.26 ± 4.51^{B}
Benzyl acetate	1741	n.d.	54.34 ± 2.13^{A}	55.54 ± 0.72^{A}	35.18 ± 0.82^{A}	55.68 ± 1.01^{A}	6.44 ± 0.26^{C}	n.d.	3346.31 ± 1.43^{A}	309.1 ± 5.37^{B}	n.d.
Phenethyl acetate	1829	4.71 ± 1.84^{C}	2261.22 ± 3.65^{A}	2351.47 ± 1.47^{A}	770.94 ± 0.97^{B}	654.38 ± 1.14^{B}	n.d.	3438.84 ± 8.74^{A}	n.d.	3840.85 ± 2.68^{A}	1039.03 ± 8.75^{B}
2-ethyl hexanoic acid	1959	n.d.	35.53 ± 1.08^{AB}	n.d.	68.89 ± 2.96^{A}	37.75 ± 1.49^{AB}	8.27 ± 4.76^{B}	18087.95 ± 4.33^{A}	n.d.	50.49 ± 0.21^{B}	53.43 ± 0.03^{B}
Total compounds		**128.4 ± 32.31**	**35597.23 ± 3.83**	**40036.21 ± 2.31**	**2303.98 ± 2.75**	**989.45 ± 5.89**	**156.82 ± 8.40**	**31305.03 ± 7.55**	**19787.23 ± 1.72**	**28723.32 ± 7.24**	**1985.41 ± 0.06**
Terpenes											
α-Terpineol	1706	7.47 ± 3.29^{C}	n.d. 55C	66.05 ± 1.49^{B}	100.92 ± 1.44^{A}	117.72 ± 1.81^{A}	26.91 ± 1.50^{B}	n.d.	145.71 ± 9.58^{A}	161.29 ± 4.42^{A}	108.32 ± 1.32^{A}
β-Citronellol	1883	4.30 ± 0.27^{B}	47.24 ± 1.84^{A}	n.d.	n.d.	n.d.	14.62 ± 1.25^{B}	n.d.	n.d.	n.d.	29.51 ± 1.08^{A}
L-Linalool	1555	18.3 ± 4.92^{B}	91.57 ± 51^{A}	99.08 ± 0.64^{A}	101.09 ± 1.71^{A}	91.09 ± 0.31^{A}	9.21 ± 7.82^{C}	64.78 ± 2.21^{A}	46.87 ± 0.82^{AB}	60.44 ± 1.44^{A}	35.91 ± 1.27^{B}
1-p-Menthen-9-al	1625	3.7 ± 0.33^{A}	n.d.	n.d.	n.d.	n.d.	6.76 ± 8.86^{A}	n.d.	n.d.	n.d.	n.d.
(E)-Geraniol	1855	6.83 ± 2.71^{C}	62.97 ± 1.77^{A}	55.73 ± 1.61^{A}	41.28 ± 4.42^{AB}	16.30 ± 2.59^{BC}	n.d.	n.d.	n.d.	n.d.	n.d.
Eugenol	2181	6.99 ± 1.80^{C}	173.3 ± 6.57^{AB}	238.91 ± 3.83^{A}	110.41 ± 2.9^{B}	165.4 ± 6.06^{AB}	1808.34 ± 3.78^{B}	n.d.	6037.48 ± 5.46^{A}	168.94 ± 2.94^{D}	1245.42 ± 2.74^{C}
Total compounds		**47.59 ± 12.77**	**375.08 ± 1.03**	**459.77 ± 4.02**	**353.69 ± 6.49**	**390.51 ± 7.92**	**1865.83 ± 3.97**	**64.78 ± 0.22**	**6230.06 ± 6.33**	**390.67 ± 4.81**	**1419.17 ± 2.85**
Aldehydes											
Acetaldehyde	704	2.12 ± 0.05^{A}	n.d.	n.d.	n.d.	11.21 ± 3.11^{B}	4.31 ± 0.23^{B}	26.79 ± 3.25^{A}	n.d.	n.d.	n.d.
Benzaldehyde	1926	140.31 ± 4.48^{A}	n.d.	n.d.	n.d.	n.d.	11.99 ± 2.12^{B}	n.d.	98.29 ± 3.44^{A}	n.d.	n.d.
Total compounds		**142.43 ± 4.43**	**n.d.**	**n.d.**	**n.d.**	**11.21 ± 3.1**	**16.3 ± 2.33**	**26.79 ± 7.25**	**98.29 ± 3.44**	**n.d.**	**n.d.**
Ketones											
Acetoin	1552	4.71 ± 1.42^{B}	n.d.	n.d.	123.93 ± 4.89^{B}	323.77 ± 1.1^{A}	n.d.	n.d.	2231.79 ± 4.78^{A}	115.17 ± 1.02^{B}	54.59 ± 7.84^{B}
Total compounds		**4.71 ± 1.42**	**n.d.**	**n.d.**	**123.93 ± 4.89**	**323.77 ± 1.1**	**n.d.**	**n.d.**	**2231.79 ± 4.78**	**115.17 ± 1.02**	**54.59 ± 7.84**

*FSCJ, FSCW and FSCV: juice, wine and vinegar produced using fresh sour cherry juice. CSCJ, CSCW and CSCV: juice, wine and vinegar produced using concentrated sour sherry. $^{A-E}$ Different uppercase letters indicate significant differences between fermentation days of the same sample ($P < 0.05$). n.d.: not detection.

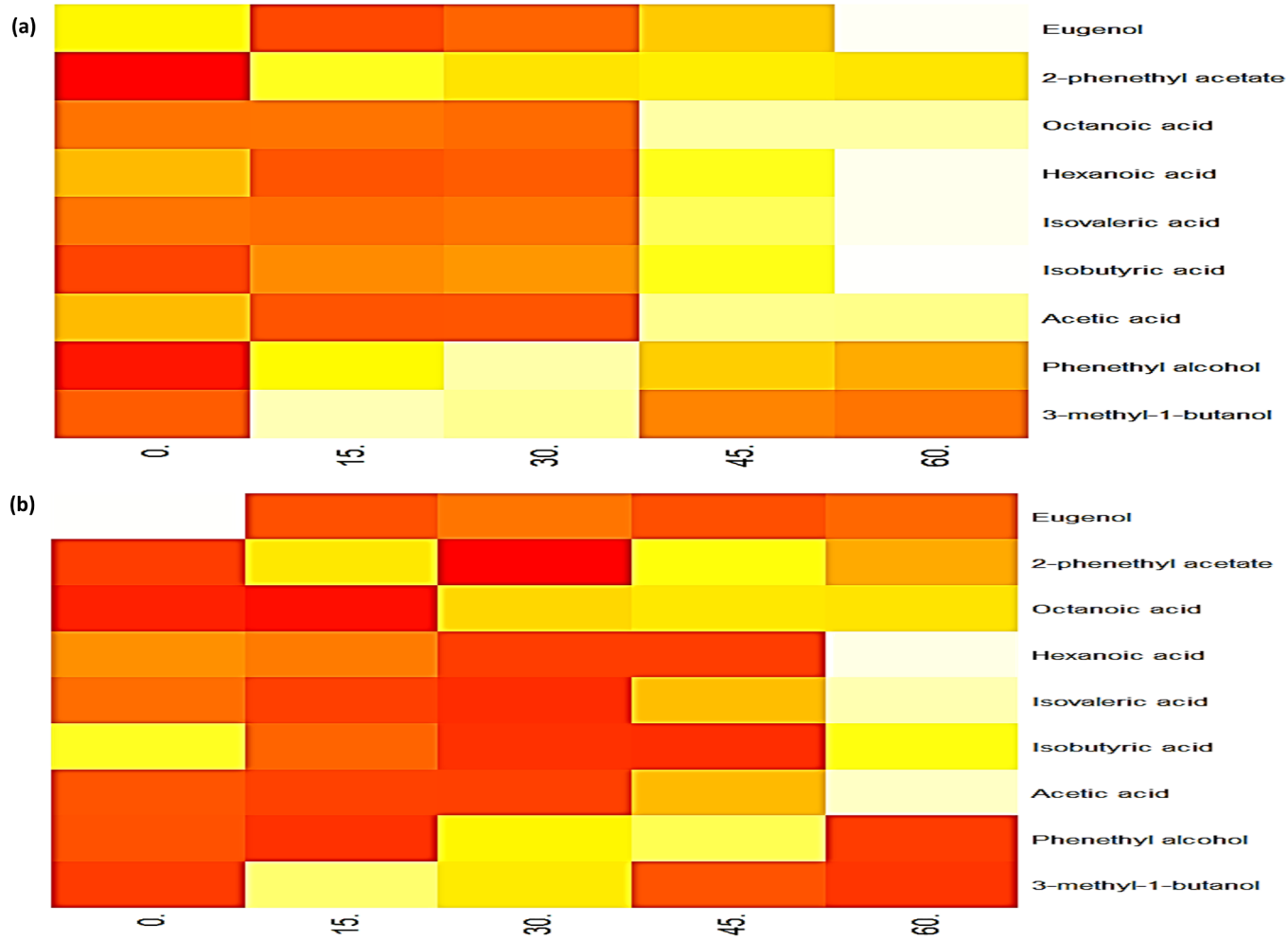

Fig. 4. The heat map graphics representing the change of the 9 important compounds for the sour cherry vinegars in the VAC profiles of the sour cherry vinegars upon fermentation days. Colored cells on the map corresponds to relative concentration values (converted to z-scores for showing the effect of the quantity of each of these 9 VACs amoung all the VACs on a given fermentation day in one of the vinegar samples). On the color scale, while the lightest color shows the highest value, the darkest color shows the lowest value. The color scale shows the range of white and dark orange colors (white color; highest z-score, dark orange color; lowest z-score). (a) The change of the 9 important VACs at the fermentation stages of the vinegar produced using fresh sour cherry juice (FSCV), (b) The change of the 9 important VACs at the fermentation stages of the vinegar produced using concentrated sour cherry juice (CSCV). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

(Fig. 4b).

The values in Table 2 were examined in order to compare these compounds between the two vinegar samples. Some of the noteworthy findings are as follows:

Phenethyl alcohol (rosy, floral) and isobutyric acid (acidic, bitter) compounds were higher in FSCV vinegar, whereas 3-methyl-1-butanol (fruity; fermented apple or banana odour) and eugenol (floral, clove) compounds were higher in CSCV vinegar (Table 2). VACs imparting a strong butter/cream/cheese-like odor are an undesirable compound for vinegar (Akasaka, Sakoda, Hidese, Ishii, & Fujiwara, 2013). Also, in this study, the isobutyric acid compound, which has a cheese-like odor, was found to be approximately four times lower in the CSCV sample than in the FSCV sample although the isobutyric acid value was lower than the threshold (8100 μg/L) in both vinegar samples. On the other hand, the 3-methyl-1-butanol compound, which is known to positively affect the organoleptic quality of vinegar, and ethyl acetate and phenethyl acetate, were found in high amounts in the CSCV sample (Pinu, De Carvalho-Silva, Trovatti Uetanabaro, & Villas-Boas, 2016). These findings show that the use of sour cherry concentrate in the production of sour cherry vinegar positively affected the vinegar aroma organoleptically compared to the use of fresh sour cherry fruit.

4. Conclusions

This study is the first report to be revealed the usability of fresh sour cherry or sour cherry juice concentrate in sour cherry vinegar production. In this study, it is concluded that both sour cherry vinegars produced have rich functional compounds and desirable volatile aroma compounds, and that sour cherry usage is ideal for vinegar production. However, it was determined that while, in terms of bioactive components and antioxidant activity, the difference between the sour cherry vinegars produced is very small, the sour cherry vinegar produced using the concentrate juice was more prominent, in terms of volatile aroma compounds. In additional, within this study, a new alternative way for sour cherry fruit usage which both in short sour cherry season and independently of the season has been proposed.

Thus, the use of sour cherry in vinegar production for the production of a new healthy and alternative product, as its usage in jam,

marmalade or dried fruit production as, will also make a significant contribution to the food industry. Production of cherry vinegar on an industrial scale is an interesting idea for producers, and it is also thought to be contribute to the economy. Consequently it is expected to increase the consumption of vinegar. This study should be corroborated by future studies related with usage of different fruit concentrate in vinegar production.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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