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ORIGINAL ARTICLE

Microbiological and chemical properties of wet tarhana produced by different dairy products

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Abstract This study investigated the use of kefir, yogurt and their combination in the production of wet tarhana with an aim to increase the nutritional value of the end product. Along with microbiological and chemical properties, the volatile compound composition of wet tarhana was also evaluated. Wet tarhana revealed an increase in the lactic acid bacteria count (LAB) with the addition of kefir. After fermentation, counts of total yeast, LAB, and total mesophilic aerobic bacteria were 7.57, 8.26 and 7.64 log CFU/g, respectively. The values of pH and titratable acidity were measured as 4.78 and 4.68% in terms of lactic acid, respectively, at the end of fermentation. Lactic acid content increased from 3.31 to 10.82 g/kg throughout fermentation. A total of 72 volatile compounds were recorded during fermentation and 44 of these were identified by GC–MS. The most abundant compounds identified in the tarhana samples were hexadecanoic acid and 9,12-octadecadienoic acid. Moreover, ABTS antioxidant activity results of all formulations were measured in the range of 15.86 and 19.31 μmol TE/g at the end of fermentation and it was independent of the fermentation period.

Keywords Cereal · Fermentation · Lactic acid bacteria · Volatile components

Introduction

Tarhana is a traditional fermented cereal product, which is generally consumed as a form of soup. Although tarhana might be known by different names, such as kiskh, kushuk, trahana or tahanya in different parts of the world (Bayrakci and Bilgicli 2015; Bozkurt and Gurbuz 2008), wheat and yogurt form the base for all the type of traditional products. Tarhana can be prepared by mixing wheat flour, yogurt, different vegetables (tomatoes, onions, green and red peppers) and herbs (mint, thyme, dill and tarhana herb) followed by fermentation process with bakery yeast (*Saccharomyces cerevisiae*) and lactic acid bacteria (LAB), from yogurt, about 1–7 days at room temperature (Bayrakci and Bilgicli 2015; Degirmencioglu et al. 2005; Erbaş et al. 2005a; Ibanoglu et al. 1999).

After fermentation tarhana is dried either domestically—under the sun, or industrially—by a conventional hot air dryer. Preferably, tarhana can also be consumed as wet without drying process. From a nutritional standpoint, the consumption of wet tarhana is more desirable than dried tarhana (Erbaş et al. 2005a), since drying process results in a considerable decrease in the counts of LAB and yeast. According to a study conducted by Ibanoglu et al. (1999), the drying process decreased the counts of total bacteria, LAB, and yeast nearly 4 log cycle. A scan of literature also compares the storage time of both dried and wet tarhana. While dried tarhana can be stored up to 3 years at room temperature (Ibanoglu et al. 1999) this time frame is limited to 6 months for wet tarhana under refrigerated conditions (Erbaş et al. 2005a).

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Tarhana plays an important role in the diet of many people in Eastern Europe, Turkey, and the Middle East, due to its high nutritional value and long shelf-life (Kabak and Dobson 2011). Since tarhana is a fermented food product, composed of cereal, vegetable as well as yogurt, it is a great source of water-soluble vitamins, minerals, organic acids and free amino acids, especially for babies and children (Bozkurt and Gurbuz 2008).

Bilgicli (2009) determined the protein, fat, ash, and starch content of tarhana.

Moreover, Erbaş et al. (2005b) recorded the total free amino acid and essential amino acids content of tarhana as 1345 mg/100 g and 766 mg/100 g after 3 days of fermentation, respectively. Additionally, ascorbic acid, niacin, pantothenic acid, pyridoxine, thiamine, folic acid, and riboflavin were detected as water-soluble vitamins in tarhana (Ekinci 2005).

Most studies in the field of tarhana production have focused on replacing the wheat flour with several other cereal sources (Degirmencioglu et al. 2016, Demir 2014; Kumral 2015). However, there is a limited number of studies that replace yogurt with more nutritious milk products. From a nutritional point of view, yogurt contains two LAB cultures; *Streptococcus thermophilus* and *L. delbrueckii* subsp. *bulgaricus* only, whereas kefir consist of a variety of yeast and LAB species (Kabak and Dobson 2011).

Kefir is an acidic, mildly alcoholic dairy product that originates in the Caucasus (Kabak and Dobson 2011). Kefir grains are found in granular form and surrounded by a polymeric matrix, called kefiran (Gomez et al. 2014). These grains are gelatinous, yellowish, irregularly shaped like popped corn, and have different diameter sizes ranging between 0.3 and 3.5 cm (Kabak and Dobson 2011). A number of potential health benefits of kefir have been reported, including stimulation of the immune system due to bioactive ingredients and metabolites formed during fermentation (Ebner et al. 2015; Gamba et al. 2016; Gomez et al. 2014; Kabak and Dobson 2011).

In recent years, there has been an increasing interest in cereal products enriched with kefir due to their symbiotic and synergistic effects, when used together. Kefir can be used as a milk ingredient in bread formulations, because of its high nutritional content, functional benefits, improved sensory properties and enhanced shelf life (Filipcev et al. 2007; Gomez et al. 2014; Plessas et al. 2007). Moreover, kefir has been added to different non-dairy substrates such as honey, vegetables, tea and juices for the production of functional probiotic beverages with distinct sensory characteristics (Fiorda et al. 2016).

Since yeast and LAB are responsible for fermentation in both kefir and tarhana (Bozkurt and Gurbuz 2008), kefir could also be used as a potent ingredient for tarhana. Although extensive research has been carried out on tarhana production, no single study exists in the literature which aims to use kefir as a yogurt replacement. The present study, therefore, aims to use kefir as an alternative ingredient to yogurt in formulating wet tarhana, as well as determine the volatile compounds and investigate microbiological and other chemical properties of the end product.

Materials and methods

Materials

Tarhana ingredients such as wheat flour, vegetables, herbs and bakery yeast were purchased from a local market of high quality. In the study, full-fat yogurt produced by cow milk (Pınar, İzmir, Turkey; 4.2% protein, 3.5% fat and 7% carbohydrate) and kefir fitrate (Pınar, İzmir, Turkey; 2.8% protein, 2.7% fat and 4.7% carbohydrate) were purchased. Chemicals and chromatographic standards used in the analysis were obtained from Merck (Darmstadt, Germany) and Sigma (Taufkirchen, Germany).

Production of wet tarhana

Tarhana was produced according to the method described by Erbaş et al. (2006). Chili pepper (13.2%), tomato (13.2%), onion (6.6%), mint (1%), dill (1%), and tarhana herb (*Echinophora sibthorpiana*, 1%) were blended separately in a blender (Waring, 8011S, Torrington, CT, USA) and pasteurized at 65 °C for 30 min. All these ingredients were cooled down to room temperature after pasteurization and mixed together with, wheat flour (35.3%), salt (2.2%) and bakery yeast (0.4%).

After mixing, tarhana dough was divided into three equal parts and coded as Y, K, and KY. Yogurt (26.4%) was added to one part and mixed carefully (sample of Y) and, kefir (26.4%) was added to the second part instead of yogurt (sample of K). Please note that kefir slurry was used in the tarhana production rather than kefir grains. Additionally, a mixed sample was produced by the addition of both yogurt and kefir at an equal ratio of 13.2% as a third part of the formulation (sample of KY).

The wet tarhana samples produced were fermented at 25 °C for 3 days and were mixed daily. During fermentation, the formulations were taken out daily and stored at − 18 °C for further analysis.

Microbiological analysis

Microbiological properties of wet tarhana were investigated as follow: 10 g of each sample was weighed into

90 mL of sterile Ringer solution and serial dilutions were aseptically prepared. The total yeast count was enumerated on spread plates of yeast extract glucose chloramphenicol agar (YGC) and the plates were incubated at 25 °C for 5 days. Following the enumeration of the LAB on pour plates of de Man, Rogosa, and Sharpe (MRS) agar, the plates were incubated at 45 °C for 72 h in anaerobic conditions. This was followed by the count of total mesophilic aerobic bacteria (TMAB) on pour plates of Plate Count Agar (PCA) and the plates were incubated at 30 °C for 72 h.

pH and total titratable acidity

A 2 g of wet tarhana sample was diluted by 20 mL of distilled water and its pH value was determined using pH meter (3410, WTW, Wellheim, Germany). The total titratable acidity (TTA) was measured via titration of the sample using 0.1 N NaOH in the presence of phenolphthalein as an indicator, and the results were expressed in terms of lactic acid (Erbaş et al. 2005a).

Organic acids and sugars

The organic acid and sugar contents of the wet tarhana samples were determined according to the method described by Arslan et al. (2016) and Cocchi et al. (2006). The extraction procedure and gas chromatography-mass spectrometry (GC–MS) analysis were carried out under the same conditions.

Peak identification of sugars and organic acids were done based on the main ion fragments (galactose: 73, 147, 205, 319, 538 (m/z); fructose: 73, 103, 147, 217, 307; glucose: 73, 103, 147, 205, 319; lactic acid: 73, 117, 147, 191; malic acid: 73, 147, 233, 335; citric acid: 73, 147, 273, 465) and retention times. Quantification of sugars and organic acids were performed using areas belonging to the internal standard (phenyl-*β*-D-glucopyranoside for sugars and *p*-hydroxybenzoic acid for organic acids) and analytes.

Volatile compounds

Volatile compounds of samples formed during fermentation were determined according to the procedure outlined by Sereshti et al. (2014) with some modifications. For the extraction of volatile compounds, 2.5 g each wet tarhana sample was weighed into a conical tube and 50 mL of a mixed solvent of methanol and acetonitrile (38:62) was added. The mixtures were then ultrasonicated in an ultrasonic bath (DL102H, Bandelin, Berlin, Germany) for 22 min, and centrifuged at 4000 rpm for 5 min. Afterward, 1.3 mL of chloroform containing 200 µg/mL 1-octanol (as an internal standard) was added into supernatants and ultrasonicated for 2 min. After sonication, 2.5 mL of the solution was enriched with 10 mL of 10% NaCl solution and centrifuged again at 4000 rpm for 5 min. After centrifugation, the lower chloroform phase was taken into micro-vial and 1 µL of the sample was injected into the gas chromatography system (Agilent 7890A GC, Agilent G4513A automatic sampler, Agilent 5975C MSD, Wilmington, DE, USA) with HP-5 ms capillary column (30 m × 0.25 mm × 0.25 µ, Wilmington, DE, USA). The injection was performed using 1:15 split mode. Oven temperature was started at 40 °C and held for 1 min, then increased to 250 °C at a rate of 5 °C/min and held for 20 min. The temperatures of the inlet and mass detector were set to 220 and 250 °C, respectively. Helium was used as a carrier gas and its flow rate was programmed as 1 mL/min (Sereshti et al. 2014).

The peaks were identified with the mass spectral libraries of Wiley and NIST and the Kovats retention index of alkane standard (Sigma-Aldrich 49451-U, Taufkirchen, Germany). Additionally, quantification of volatile compounds was performed using areas belonging to the internal standard and analytes.

Antioxidant activity

Each sample (1g) was extracted in a 10 mL of phosphate buffer solution (75 mM, pH adjusted to 7.4) with an orbital shaker for 60 min at ambient temperature. After incubation, samples were centrifuged at 7500 rpm for 10 min and supernatants were placed in sample tubes (Arslan et al. 2016).

ABTS stock solution was dissolved in distilled water at a concentration of 7 mM. To prepare the $ABTS^{+}$ radical, 25 mL of this stock solution was mixed with 12.5 mL potassium persulphate (2.45 mM) and incubated at ambient temperature for 12–16 h. Prior to analysis, the $ABTS^{+}$ radical solution was diluted with PBS to ensure an absorbance of 0.70 at 734 nm in the UV-Spectrometer (UV-1800, Shimadzu, Kyoto, Japan). After that, a 5, 10, 15 and 20 µL of each sample extract was added to 1 mL of $ABTS^{+}$ radical solution, and the inhibition rate was determined after 6 min (Re et al. 1999).

Quantification of antioxidant activity was measured by the calibration of standard Trolox solutions, which were prepared at the concentrations of 0, 5, 10, 15 and 20 µM/mL as the inhibition rates. The results were expressed as µM TEAC/g.

Sensory analysis

The sensory analysis of each formulation was carried out after 3 days of fermentation of wet tarhana samples. For this purpose, wet tarhana was added to water in a ratio of 7% and boiled for 5 min. The solution was then cooled down to 70 °C and put into white cups. Ten trained panelists evaluated samples according to its color, flavor, appearance, viscosity, acidity and taste properties. The acceptability of the samples was scored on a 5-point hedonic scale (Erbaş et al. 2005).

Statistical analysis

Tarhana was produced in duplicate and analyses were performed in parallel. All statistical calculations, except those of volatile compounds, were performed using SAS Statistical Software (SAS Institute Inc., Cary, NC, USA). Significance was evaluated by analysis of variance followed by Duncan's multiple range test ($p < 0.05$). Additionally, the volatile compound was evaluated with principal component analysis (PCA) and agglomerative hierarchical cluster analysis (HCA) by using XLSTAT software (Addinsoft, New York, NY).

Table 1 The changes of microorganism counts (log CFU/g) of wet tarhana samples during fermentation time (± SE)

Type of tarhana	Fermentation		
	Yeast	LAB	TMAB
Y	$7.75^{a} \pm 0.06$	$7.45^{b} \pm 0.07$	$7.72^{a} \pm 0.08$
K	$7.71^{a} \pm 0.08$	$7.84^{a} \pm 0.19$	$7.76^{a} \pm 0.08$
KY	$7.72^{a} \pm 0.08$	$7.87^{a} \pm 0.17$	$7.78^{a} \pm 0.09$
Sign		*	
Time (days)			
0	$7.51^{b} \pm 0.04$	$7.38^{b} \pm 0.03$	$7.49^{c} \pm 0.02$
1	$7.91^{a} \pm 0.02$	$7.67^{b} \pm 0.06$	$7.96^{a} \pm 0.04$
2	$7.91^{a} \pm 0.03$	$7.55^{b} \pm 0.15$	$7.92^{a} \pm 0.06$
3	$7.57^{b} \pm 0.03$	$8.26^{a} \pm 0.20$	$7.64^{b} \pm 0.05$
Sign	**	**	**

Y, wet tarhana produced with yogurt; K, wet tarhana produced with kefir; KY, wet tarhana produced both of yogurt and kefir

Superscript letters beside the mean values in the same column note that are significantly different by Duncan's multiple range test ($p < 0.05$). *Sign* Statistical significance: *$p < 0.05$, **$p < 0.01$, $n = 8$ in type of tarhana and $n = 6$ in fermentation time

Results and discussion

Microbiological properties of wet tarhana samples

It is apparent from the Table 1 that the addition of kefir significantly affected ($p < 0.05$) LAB count while fermentation time significantly affected all the parameters (yeast, LAB and TMAB counts).

Average yeast count of all tarhana formulations was 7.73 log CFU/g due to the use of bakery yeast. Similarly, Degirmencioglu et al. (2005) reported that yeast counts of tarhana samples varied in the range of 6.9–7.2 log CFU/g. During the first 2 days of the fermentation, yeast count increased from 7.51 to 7.91 log CFU/g, whereas it was noted as 7.57 log CFU/g at the end of fermentation. These results were supported by Ibanoglu et al. (1999), who determined that the yeast count started to decrease after the first day of fermentation. A possible explanation behind such a trend might be due to the competition between bacteria and yeast for substrates or increased acidity of the fermentation media. It could be seen that the addition of kefir increased the LAB count of the wet tarhana samples. LAB increased continuously and reached to 8.26 log CFU/g until the end of the fermentation. This could be attributed to the high LAB count of the kefir used in tarhana production (7.02 log CFU/g). These findings also supported the idea that tarhana dough was rich with micronutrients for the proliferation of LAB. In addition, using tarhana herb might have affected the LAB growth. (Degirmencioglu et al. 2005).

Average TMAB count of samples was 7.75 log CFU/g. It increased the first day of fermentation and then decreased from 7.96 to 7.64 log CFU/g at the end of fermentation. Our results were in agreement with other studies that suggested an increase in the count of TMAB over 24 h, followed by a decrease till the end of fermentation (Erbaş, Certel, and Kemal Uslu 2005). This decrease might be due to an increase in acidity of the product and the formation of compounds such as carbon dioxide, diacetyl, and ethanol in fermentation media (Erbaş et al. 2005). However, Degirmencioglu et al. (2005) reported contradictory results with a continuous increase in the TMAB count during fermentation.

pH, TTA, and organic acid content

As can be seen from Table 2, while the type of tarhana had a significant ($p < 0.01$) effect on TTA only, fermentation time had a significant ($p < 0.01$) effect on both pH value and TTA.

The addition of kefir decreased the pH value of the tarhana samples. During fermentation, the pH value

Table 2 The changes of pH, TTA (%), organic acid and sugar content (g/kg) of wet tarhana samples during fermentation time (± SE)

Type of tarhana	pH	TTA	Lactic acid	Malic acid	Citric acid	Galactose	Fructose	Glucose
Y	$4.77^b \pm 0.03$	$4.41^a \pm 0.17$	$6.80^a \pm 0.41$	$0.39^a \pm 0.08$	$0.58^a \pm 0.11$	$1.09^b \pm 0.31$	$0.07^a \pm 0.02$	$0.03^a \pm 0.01$
K	$4.85^a \pm 0.04$	$3.92^b \pm 0.11$	$6.83^a \pm 1.92$	$0.21^a \pm 0.06$	$0.08^b \pm 0.03$	$1.63^a \pm 0.71$	$0.10^a \pm 0.04$	$0.02^a \pm 0.00$
KY	$4.85^a \pm 0.03$	$3.93^b \pm 0.15$	$5.34^a \pm 1.40$	$0.23^a \pm 0.03$	$0.09^b \pm 0.05$	$1.57^a \pm 0.59$	$0.09^a \pm 0.06$	$0.02^a \pm 0.01$
Sign	*	**			**	**		
Time (days)								
0	$4.92^a \pm 0.02$	$3.63^c \pm 0.08$	$3.31^c \pm 0.70$	$0.31^a \pm 0.08$	$0.32^a \pm 0.12$	$3.89^a \pm 0.56$	$0.26^a \pm 0.04$	$0.07^a \pm 0.02$
1	$4.74^b \pm 0.03$	$3.99^b \pm 0.12$	$4.24^c \pm 0.98$	$0.31^a \pm 0.09$	$0.24^a \pm 0.14$	$1.04^b \pm 0.15$	$0.05^b \pm 0.02$	$0.02^b \pm 0.01$
2	$4.85^a \pm 0.04$	$4.13^b \pm 0.15$	$6.92^b \pm 0.36$	$0.29^a \pm 0.08$	$0.24^a \pm 0.15$	$0.53^c \pm 0.11$	$0.02^b \pm 0.00$	$0.01^b \pm 0.00$
3	$4.77^b \pm 0.03$	$4.60^a \pm 0.15$	$10.82^a \pm 1.69$	$0.21^a \pm 0.05$	$0.20^a \pm 0.11$	$0.27^c \pm 0.03$	$0.01^b \pm 0.00$	$0.01^b \pm 0.00$
Sign	**	**	**			**	**	**

TTA, total titratable acidity; Y, wet tarhana produced with yogurt; K, wet tarhana produced with kefir; KY, wet tarhana produced both of yogurt and kefir

Superscript letters beside the mean values in the same column note that are significantly different by Duncan's multiple range test ($p < 0.05$). *Sign* Statistical significance: $*p < 0.05$, $**p < 0.01$, $n = 8$ in type of tarhana and $n = 6$ in fermentation time

decreased from 4.92 to 4.77 due to the formation of organic acid. However, there was a slight increase in pH which might be due to the formation of new peptides that have the buffering capacity. Similar pH values were reported in previous studies on the second day of fermentation (Erbaş et al. 2005a; Koca et al. 2002).

TTA results showed that the addition of kefir decreased the titratable acidity content of tarhana samples. The highest TTA content was detected on the first day of fermentation, following a decrease to 4.68%, afterward. Erbaş et al. (2005a) determined that TTA increased from 2.5 to 4% after 3 days of tarhana fermentation.

The organic acids detected in the wet tarhana samples were lactic, malic and citric acid. The average lactic and malic acid content of the wet tarhana samples were measured to be 6.32 and 0.28 g/kg, respectively. Among the organic acids, citric acid resulted in the minimum content expect sample of Y. Bozkurt and Gurbuz (2008) pointed out that such trace levels of citric acid could be caused by the low amount of vegetables used in tarhana formulation rather than the fermentation process.

Lactic acid production during fermentation is desirable since it increases the shelf life and nutritional quality of the end product. Monitoring lactic acid formation during fermentation showed an increase in the lactic acid content from 3.31 to 10.82 g/kg due to microorganism activity. The lactic acid level of dried tarhana was as 15.3 g/kg in dried tarhana samples (Bozkurt and Gurbuz 2008). Erbaş et al. (2006) reported that the lactic acid content of tarhana samples increased nearly 50% during fermentation.

Sugar content of the wet tarhana samples

Fermentation time had a significant effect on galactose, fructose and glucose content of samples while the type of tarhana affected galactose content of samples only (Table 2).

The galactose content of all samples was found to be higher than fructose and glucose. Galactose content increased with the addition of kefir and the lowest galactose content was found in the sample of Y at a level of 1.09 g/kg. The results indicated that kefir was more fermented than yogurt, and its galactose content might have been increased. The main galactose in tarhana formulations comes from both kefir and yogurt sources. As a result of LAB activity, lactose may have converted to galactose during fermentation. Additionally, galactose content decreased from 3.89 to 0.27 g/kg during fermentation time.

The average fructose and glucose content was determined to be 0.57 and 0.23 g/kg, respectively. During fermentation, there was a sharp decrease in all sugar content due to the process of fermentation.

Volatile compounds

The list of volatile compounds detected in the wet tarhana samples is given in Table 3 and their concentrations are given in Table 4. During fermentation, a total of 72 compounds were found and 44 of them were identified. Furthermore, the most abundant compounds identified were hexadecanoic and 9,12-octadecadienoic acid.

During fermentation of the wet tarhana samples, some new compounds such as esters formed, while the concentration of the existing compounds increased. The results

Table 3 Volatile compounds detected in wet tarhana samples

No	Compound	Retention time	Retention ındex
1	Unidentified 1	2.64	712
2	Butanoic acid methyl ester	2.92	731
3	2-Methyl-butanoic acid methyl ester	3.71	781
4	Octane	4.02	800
5	3-Methyl-octane	5.40	864
6	Ethenyl-benzene	5.58	870
7	Nonane	6.28	900
8	4-Methyl-nonane	8.02	964
9	Decane	9.07	1000
10	α-Phellandrene	9.16	1003
11	*p*-Cymene	9.75	1023
12	Limonene	9.88	1028
13	5-Methyl-decane	10.75	1057
14	Phenylethyl alcohol	12.42	1114
15	Octanoic acid	14.21	1175
16	Anethofuran	14.53	1186
17	Estragole	14.89	1199
18	Carvone	16.18	1245
19	Unidentified 2	17.17	1280
20	2,4-Decadienal	17.58	1295
21	*trans*-2,4-Decadienal	18.17	1316
22	4,6-Dimethyl-dodecane	18.42	1326
23	*n*-Decanoic acid	19.63	1371
24	Decanoic acid, ethyl ester	20.30	1397
25	Methyleugenol	20.51	1405
26	Caryophyllene	20.93	1422
27	Germacrene D	22.47	1484
28	Unidentifed 3	22.63	1489
29	Unidentifed 4	22.77	1495
30	Pentadecan	22.86	1499
31	Unidentifed 5	22.92	1501
32	2,4-Di-*tert*-butylphenol	23.27	1516
33	Unidentifed 6	23.86	1541
34	Dodecanoic acid	24.37	1562
35	Dodecanoic acid, ethyl ester	25.16	1596
36	Unidentifed 7	27.05	1679
37	Unidentifed 8	27.41	1695
38	Unidentifed 9	27.53	1703
39	2,6,10,14-Tetramethylpentadecane	27.73	1710
40	Unidentifed 10	27.91	1719
41	Unidentifed 11	28.66	1753
42	Tetradecanoic acid	28.83	1761
43	Tetradecanoic acid, ethyl ester	29.57	1796
44	Pentadecanoic acid	30.91	1858
45	Hexadecanoic acid	33.17	1975
46	*cis*-9,12-Octadecadienoic acid	35.43	2095
47	Phytol	35.79	2115
48	9,12-Octadecadienoic acid	36.51	2155
49	Ethyl linoleate	36.67	2164
50	Octadecanoic acid	36.79	2169

Table 3 continued

No	Compound	Retention time	Retention ındex
51	Ethyl oleate	36.84	2179
52	Unidentifed 12	37.28	2199
53	11,14-Eicosadienoic acid, methyl ester	38.38	2263
54	Unidentifed 13	39.26	2313
55	Unidentifed 14	39.73	2343
56	(Z)-9-Octadecenamide	39.82	2349
57	Unidentifed 15	40.07	2365
58	Unidentifed 16	40.92	2417
59	Unidentifed 17	41.43	2449
60	Unidentifed 18	41.50	2454
61	Unidentifed 19	42.01	2486
62	Hexadecanoic acid, 2-hydroxy-1-(hydroxymethyl)ethyl ester	42.44	2516
63	Unidentifed 20	42.72	2531
64	Unidentifed 21	43.05	2552
65	Unidentifed 22	43.15	2659
66	Unidentifed 23	43.50	2681
67	Unidentifed 24	43.63	2589
68	Unidentifed 25	45.47	2690
69	Unidentifed 26	46.23	2725
70	Unidentifed 27	47.46	2779
71	Unidentifed 28	47.74	2792
72	Squalene	48.67	2827

show that the concentration of *p*-cymene, carvone, and phytol decreased, while estragole, germacrene D, *trans*-2,4, decadienal and ethyl oleate increased. Moreover, some compounds converted to their esters, such as ethyl esters of decanoic, dodecanoic and tetradecanoic acid, and the methyl ester of 11,14-eicosadienoic acid. Esters were produced as a result of the lipid metabolism of yeast (Gocmen et al. 2004) and are of great importance to form the flavor of both fermented and non-fermented food products. Furthermore, some other volatile compounds might form as a result of the herbs used in tarhana e.g. α-phellandrene, *p*-cymene, limonene, anethofuran are the main volatile compounds of dill (Huopalahti 1985).

Tarhana formulation played a role in the changing of some volatile compounds. For example, there was a sharp increase in the concentration of 5-methyl-decane, octanoic acid and ethyl linoleate in sample of K. Moreover, the concentration of phenyl ethyl alcohol and some unidentified volatile compounds increased only in sample of Y. 2,4-decadienal and 2,4-di-*tert*-buthylphenol were detected only in sample of K and KY which might be due to the oxidation of some fatty acids (Gocmen et al. 2004).

PCA projection of the wet tarhana samples obtained during fermentation is given in Fig. 1. The first two principal components showed 96% of the variance in the data. Generally, samples on the first and second day of the fermentation had similar PCA projection trend, due to volatile compounds of hexadecanoic acid, octadecanoic acid, and 9,12-octadecadienoic acid.

According to the HCA results (Fig. 1) of the wet tarhana samples, it can be clearly seen that three different groups were clustered. These clusters form as a result of the volatile compounds, as mentioned previously. In addition, the variety of volatile compounds in sample K was different than the other formulations in the first day of fermentation, however, the similarity in the type of volatile compounds increased the progression of fermentation.

The information on volatile compounds of tarhana are scarce (Carpino et al. 2010; Gocmen et al. 2004; Temiz and Tarakçı 2017). To the best of our knowledge, this is the first study reporting the effect of kefir addition in the volatile formulation in tarhana samples. Temiz and Tarakçı (2017) detected of a total 38 compounds in tarhana samples which of 7 (phenyl ethyl alcohol, octanoic acid, 2,4-decadienal, hexadecanoic acid and ethyl esters of dodecanoic acid, decanoic acid, and tetradecanoic acid) were also identified in the current study. The different volatile compounds obtained in other studies might be as a result of different tarhana production methods employed and raw materials used.

Table 4 The change of volatile compound concentrations (mg/kg) in wet tarhana samples during fermentation

No.	Y				K				KY			
	0: day	1: day	2: day	3: day	0: day	1: day	2: day	3: day	0: day	1: day	2: day	3: day
1	11.3 ± 2.8	10.9 ± 4.6	13.3 ± 3.1	11.4 ± 4.9	14.4 ± 6.9	14.9 ± 6.9	7.0 ± 3.2	10.7 ± 3.6	12.3 ± 2.7	11.2 ± 5.3	9.9 ± 3.2	15.5 ± 0.1
2	18.2 ± 0.5	16.5 ± 2.6	18.3 ± 0.7	16.1 ± 6.8	19.9 ± 1.3	16.7 ± 2.6	16.2 ± 1.2	18.5 ± 0.2	17.6 ± 1.4	18.7 ± 0.1	17.7 ± 1.2	18.6 ± 0.5
3	5.1 ± 0.1	4.5 ± 0.7	5.0 ± 0.1	5.1 ± 0.7	5.8 ± 1.0	4.8 ± 0.4	4.8 ± 0.2	5.1 ± 0.1	5.0 ± 0.2	5.1 ± 0.1	5.0 ± 0.2	4.8 ± 0.3
4	10.9 ± 1.8	7.2 ± 3.4	13.0 ± 0.3	11.4 ± 0.5	13.1 ± 3.4	9.7 ± 0.5	10.8 ± 3.2	11.4 ± 1.7	11.7 ± 0.9	11.7 ± 0.3	12.2 ± 1.4	9.8 ± 2.6
5	4.5 ± 0.4	3.2 ± 1.5	5.0 ± 0.2	4.8 ± 0.0	5.3 ± 1.2	4.6 ± 0.3	4.6 ± 1.1	5.5 ± 0.8	4.8 ± 0.4	4.9 ± 0.3	5.7 ± 0.6	4.0 ± 1.3
6	5.1 ± 0.2	3.8 ± 0.5	5.3 ± 0.6	5.0 ± 0.6	5.4 ± 1.3	4.8 ± 0.6	4.8 ± 1.2	5.5 ± 0.3	4.8 ± 0.5	5.0 ± 0.5	5.5 ± 0.6	4.4 ± 0.3
7	25.3 ± 2.7	18.8 ± 6.9	27.5 ± 0.7	25.8 ± 0.7	28.8 ± 6.4	21.2 ± 4.5	24.9 ± 6.2	23.1 ± 0.6	26.9 ± 1.2	26.2 ± 1.2	26.8 ± 3.2	22.5 ± 5.3
8	3.6 ± 0.1	3.2 ± 1.0	3.6 ± 0.6	3.0 ± 0.8	4.2 ± 0.5	3.3 ± 0.5	3.3 ± 0.6	3.7 ± 1.1	3.7 ± 0.2	3.6 ± 0.1	3.9 ± 0.7	2.5 ± 0.2
9	37.3 ± 3.1	35.8 ± 9.8	41.7 ± 2.5	41.8 ± 1.8	40.3 ± 8.6	36.6 ± 5.6	41.4 ± 5.9	41.8 ± 3.6	41.9 ± 4.5	39.3 ± 2.8	36.3 ± 9.5	36.6 ± 6.2
10	24.4 ± 0.2	22.5 ± 6.2	20.8 ± 4.2	17.0 ± 1.3	21.1 ± 10.7	19.3 ± 5.5	20.3 ± 6.4	26.3 ± 3.9	19.9 ± 2.8	18.5 ± 5.1	22.6 ± 1.6	22.7 ± 6.3
11	11.5 ± 0.2	9.7 ± 1.5	10.8 ± 3.1	9.9 ± 1.5	12.2 ± 1.4	12.0 ± 1.4	9.4 ± 0.9	8.4 ± 0.5	12.2 ± 1.7	10.6 ± 1.6	10.4 ± 1.4	9.6 ± 2.5
12	25.9 ± 1.7	20.8 ± 5.1	28.0 ± 7.3	26.4 ± 6.3	26.9 ± 3.8	28.0 ± 0.9	28.1 ± 8.9	22.5 ± 0.4	24.9 ± 2.6	26.1 ± 2.1	28.4 ± 5.4	26.7 ± 7.6
13	4.4 ± 0.0	3.9 ± 0.4	3.4 ± 1.4	4.2 ± 0.4	1.8 ± 0.2	4.8 ± 0.6	6.7 ± 0.6	7.5 ± 1.7	4.4 ± 1.1	4.0 ± 0.5	4.3 ± 0.2	3.4 ± 1.6
14	nd	5.0 ± 0.7	8.2 ± 0.0	9.3 ± 0.3	4.2 ± 0.2	4.1 ± 0.1	2.8 ± 0.3	7.5 ± 0.6	nd	4.7 ± 0.3	8.5 ± 1.0	10.6 ± 0.1
15	3.5 ± 0.1	4.2 ± 0.0	6.1 ± 1.1	1.5 ± 2.1	4.3 ± 1.2	4.6 ± 0.4	6.8 ± 3.2	5.6 ± 1.0	1.7 ± 0.0	4.5 ± 0.5	5.0 ± 0.3	3.8 ± 0.7
16	5.7 ± 0.1	5.2 ± 1.5	4.2 ± 2.0	4.5 ± 3.3	6.5 ± 1.6	5.6 ± 0.7	4.8 ± 0.3	4.0 ± 0.5	5.8 ± 0.8	4.6 ± 0.4	3.9 ± 1.4	6.9 ± 0.9
17	10.6 ± 1.6	24.2 ± 3.7	35.4 ± 8.4	36.2 ± 7.7	7.9 ± 0.5	26.8 ± 4.4	40.9 ± 6.5	38.4 ± 2.9	8.5 ± 1.3	22.4 ± 1.3	29.7 ± 2.6	27.9 ± 1.3
18	54.6 ± 5.8	39.1 ± 4.9	27.2 ± 4.9	18.7 ± 7.4	56.7 ± 9.7	39.6 ± 4.4	23.5 ± 0.4	15.4 ± 1.2	50.6 ± 1.9	34.4 ± 4.1	21.3 ± 3.4	10.7 ± 0.6
19	4.3 ± 0.5	3.3 ± 0.9	3.4 ± 1.6	2.8 ± 0.1	2.6 ± 0.4	3.2 ± 1.0	2.1 ± 0.6	3.7 ± 0.7	4.2 ± 0.7	4.1 ± 2.1	3.8 ± 0.5	3.5 ± 1.6
20	nd	nd	nd	nd	22.7 ± 6.1	19.8 ± 5.2	5.2 ± 1.4	4.4 ± 1.8	1.5 ± 0.0	2.1 ± 0.8	3.9 ± 0.5	3.7 ± 1.8
21	5.1 ± 2.1	2.8 ± 0.7	5.6 ± 0.0	5.5 ± 0.4	7.9 ± 2.7	5.6 ± 1.2	9.6 ± 0.3	5.9 ± 1.1	4.0 ± 1.0	6.2 ± 0.6	4.2 ± 0.1	7.1 ± 1.7
22	5.2 ± 0.6	4.6 ± 1.0	4.6 ± 0.6	4.0 ± 0.5	3.9 ± 0.9	4.2 ± 0.9	4.4 ± 0.8	5.4 ± 0.6	4.6 ± 0.2	4.5 ± 1.0	5.0 ± 1.5	4.9 ± 0.5
23	5.6 ± 1.2	5.5 ± 3.3	8.8 ± 3.1	9.5 ± 3.5	4.9 ± 1.8	10.0 ± 2.0	12.1 ± 1.7	10.9 ± 2.7	26.4 ± 10.0	7.0 ± 1.0	8.5 ± 0.3	11.6 ± 5.0
24	2.2 ± 0.0	6.5 ± 1.9	11.5 ± 4.2	11.9 ± 5.3	nd	8.7 ± 1.3	12.9 ± 1.8	12.8 ± 1.2	3.7 ± 0.1	5.9 ± 0.5	10.1 ± 0.7	10.8 ± 1.2
25	10.4 ± 1.0	10.2 ± 2.5	11.0 ± 1.8	7.2 ± 1.0	11.5 ± 2.7	11.1 ± 1.8	10.4 ± 0.6	12.0 ± 2.2	9.7 ± 0.4	10.4 ± 0.5	10.5 ± 0.5	9.8 ± 2.6
26	7.5 ± 0.5	6.9 ± 0.1	8.0 ± 2.5	7.8 ± 2.7	8.2 ± 0.8	8.6 ± 2.2	7.9 ± 1.9	8.6 ± 1.4	7.2 ± 1.2	7.7 ± 0.4	7.5 ± 0.3	7.8 ± 2.3
27	5.6 ± 1.4	7.4 ± 0.8	12.5 ± 2.2	14.2 ± 5.9	6.9 ± 4.3	5.7 ± 1.2	9.2 ± 3.8	11.9 ± 2.2	4.7 ± 1.5	9.3 ± 3.6	6.7 ± 2.6	6.6 ± 4.5
28	4.6 ± 1.0	4.3 ± 0.3	6.1 ± 0.9	5.0 ± 0.7	4.2 ± 0.8	7.4 ± 4.3	4.1 ± 0.8	5.5 ± 0.3	3.9 ± 0.5	3.6 ± 0.8	5.5 ± 0.1	5.2 ± 0.3
29	8.2 ± 0.4	4.8 ± 3.6	9.2 ± 0.6	1.7 ± 0.7	6.4 ± 1.9	6.2 ± 2.1	7.0 ± 1.0	4.4 ± 1.8	5.8 ± 2.7	9.1 ± 2.3	5.8 ± 4.0	7.3 ± 3.1
30	7.2 ± 2.1	5.5 ± 1.8	6.4 ± 1.4	8.5 ± 1.2	6.1 ± 0.8	6.2 ± 2.7	4.5 ± 2.2	10.2 ± 0.3	7.8 ± 4.3	5.8 ± 1.4	7.9 ± 1.8	7.5 ± 0.4
31	6.9 ± 0.4	4.8 ± 1.2	4.9 ± 1.5	6.2 ± 0.6	3.8 ± 0.4	5.7 ± 1.2	5.2 ± 0.2	7.5 ± 0.3	3.5 ± 0.9	4.8 ± 1.2	5.7 ± 1.7	5.7 ± 0.5
32	nd	nd	nd	nd	1.5 ± 0.1	4.1 ± 0.9	9.2 ± 2.7	2.2 ± 0.6	7.6 ± 5.3	3.2 ± 0.3	1.8 ± 0.3	2.2 ± 0.2
33	5.6 ± 0.5	5.1 ± 0.7	6.0 ± 1.5	6.1 ± 1.0	5.1 ± 1.1	6.8 ± 1.4	4.3 ± 0.3	7.2 ± 0.2	5.4 ± 0.1	5.2 ± 0.5	6.4 ± 0.4	6.3 ± 1.0
34	9.4 ± 0.5	11.8 ± 2.3	13.0 ± 2.5	1.4 ± 1.0	9.2 ± 3.3	9.6 ± 5.4	18.3 ± 0.8	15.4 ± 2.0	9.5 ± 0.6	11.8 ± 0.8	6.8 ± 0.0	20.1 ± 3.8
35	4.4 ± 1.6	5.4 ± 0.4	6.5 ± 0.9	9.3 ± 5.3	nd	12.0 ± 7.0	10.2 ± 3.0	13.2 ± 3.7	3.9 ± 0.1	4.6 ± 0.3	6.5 ± 0.9	7.1 ± 3.0
36	3.9 ± 0.4	5.1 ± 0.4	3.9 ± 1.9	3.7 ± 1.4	2.6 ± 0.2	5.3 ± 1.8	3.1 ± 1.1	5.3 ± 0.5	4.4 ± 0.3	3.7 ± 2.0	4.7 ± 0.1	3.6 ± 2.0
37	nd	nd	nd	nd	nd	3.5 ± 0.7	8.2 ± 1.3	1.7 ± 0.3	nd	nd	nd	nd

Table 4 continued

No.	Y				K				KY			
	0: day	1: day	2: day	3: day	0: day	1: day	2: day	3: day	0: day	1: day	2: day	3: day
38	3.7 ± 0.0	1.4 ± 0.3	3.6 ± 2.3	2.6 ± 1.1	3.7 ± 0.4	1.3 ± 0.3	6.0 ± 0.5	3.9 ± 1.1	4.5 ± 0.1	5.6 ± 0.5	4.1 ± 0.1	4.9 ± 0.9
39	6.3 ± 0.3	5.9 ± 0.7	7.2 ± 1.2	6.7 ± 1.6	5.3 ± 1.3	3.9 ± 2.9	5.4 ± 2.3	8.3 ± 0.0	5.8 ± 0.1	7.1 ± 2.3	6.8 ± 0.0	6.9 ± 1.6
40	4.0 ± 0.4	4.2 ± 1.3	5.3 ± 1.0	5.7 ± 0.9	4.0 ± 0.6	5.0 ± 1.2	4.9 ± 1.9	5.2 ± 0.2	5.0 ± 1.0	4.5 ± 1.2	5.0 ± 0.4	5.3 ± 0.1
41	6.8 ± 1.2	5.6 ± 1.5	8.4 ± 1.7	7.5 ± 2.2	7.0 ± 3.4	4.8 ± 0.2	9.5 ± 1.0	10.2 ± 1.4	4.6 ± 0.2	6.6 ± 0.5	9.5 ± 1.3	9.1 ± 2.7
42	36.3 ± 5.6	41.2 ± 8.5	45.1 ± 11.1	43.2 ± 17.3	36.0 ± 13.7	49.8 ± 10.5	62.1 ± 2.4	58.1 ± 7.3	32.8 ± 6.6	39.3 ± 0.3	59.1 ± 5.2	50.4 ± 9.8
43	nd	8.5 ± 3.4	12.8 ± 5.1	9.6 ± 1.5	1.8 ± 2.6	17.7 ± 5.0	25.5 ± 2.1	23.7 ± 5.8	1.7 ± 0.1	10.1 ± 2.3	14.8 ± 1.7	14.3 ± 0.9
44	9.0 ± 1.9	11.1 ± 1.4	10.9 ± 0.7	8.1 ± 0.1	8.3 ± 4.6	9.1 ± 2.5	13.5 ± 1.6	10.5 ± 4.2	8.4 ± 1.9	10.1 ± 1.3	15.7 ± 2.0	11.3 ± 0.8
45	868.1 ± 116	752.5 ± 267.6	837.1 ± 95.3	666.6 ± 250.4	990.8 ± 54.6	857.8 ± 179	933.6 ± 131.7	810.4 ± 258	850.8 ± 83.9	822.3 ± 58.6	699.6 ± 248.4	749.4 ± 15.0
46	9.9 ± 0.4	7.5 ± 1.5	7.8 ± 2.1	5.1 ± 0.2	15.7 ± 4.8	8.7 ± 1.1	13.2 ± 0.6	10.2 ± 0.4	11.5 ± 0.0	6.7 ± 1.4	8.1 ± 1.3	7.8 ± 0.1
47	8.6 ± 3.0	9.9 ± 1.8	11.7 ± 1.8	8.7 ± 1.3	20.9 ± 17.0	11.6 ± 1.5	16.2 ± 3.1	5.7 ± 1.1	8.5 ± 1.9	9.7 ± 0.3	11.9 ± 0.9	10.0 ± 0.1
48	940.0 ± 149	615.8 ± 128.7	820.2 ± 185.1	829.1 ± 17.6	1772.4 ± 118	921.1 ± 256	1115.6 ± 395.6	907.9 ± 81	1087 ± 5.6	1281.8 ± 488	894.7 ± 5.2	737.2 ± 39.9
49	143.5 ± 1.1	485.8 ± 190.1	202.0 ± 30.4	121.9 ± 20.9	100.7 ± 4.9	214.4 ± 45.2	451.8 ± 266.4	139.3 ± 20	81.2 ± 21.7	152.5 ± 57.4	545.8 ± 178.4	244.1 ± 85.8
50	132.0 ± 25.8	759.8 ± 10.4	629.9 ± 156.0	427.6 ± 27.8	47.9 ± 13.3	413.1 ± 122	972.1 ± 146.8	972.6 ± 240	99.6 ± 42.1	579.9 ± 6.1	681.3 ± 306.0	593.0 ± 36.5
51	67.6 ± 5.1	208.7 ± 5.2	248.0 ± 79.6	183.8 ± 24.9	404.6 ± 5.4	379.0 ± 59.8	445.9 ± 10.6	354.2 ± 75	42.1 ± 24.5	205.3 ± 21.9	258.0 ± 24.4	258.1 ± 33.1
52	nd	7.5 ± 1.8	9.5 ± 4.6	8.0 ± 2.1	nd	8.6 ± 1.3	15.3 ± 2.1	14.9 ± 2.3	nd	6.4 ± 0.6	11.2 ± 2.6	11.2 ± 3.3
53	nd	4.4 ± 0.2	8.6 ± 1.5	8.0 ± 3.3	nd	4.9 ± 1.0	11.1 ± 1.0	7.4 ± 2.0	nd	4.7 ± 0.2	6.8 ± 0.6	4.7 ± 0.1
54	43.9 ± 15.1	47.7 ± 11.7	86.1 ± 24.5	49.4 ± 1.1	50.3 ± 4.9	95.8 ± 20.2	82.8 ± 11.7	61.9 ± 14	62.8 ± 0.3	74.6 ± 3.8	62.9 ± 1.6	71.4 ± 2.0
55	5.3 ± 0.8	11.9 ± 0.9	18.2 ± 4.8	10.2 ± 4.3	47.8 ± 6.1	21.1 ± 1.7	31.2 ± 1.9	19.7 ± 0.1	3.3 ± 1.8	16.1 ± 3.9	19.6 ± 2.2	12.0 ± 3.7
56	4.3 ± 0.3	11.8 ± 0.8	19.2 ± 6.2	12.3 ± 1.3	27.6 ± 0.7	27.4 ± 3.8	32.9 ± 4.4	22.3 ± 0.0	3.9 ± 0.1	17.6 ± 3.7	19.7 ± 2.4	14.0 ± 3.4
57	3.8 ± 0.1	3.8 ± 0.6	8.3 ± 1.4	8.0 ± 0.6	3.9 ± 0.8	18.6 ± 10.8	6.6 ± 1.8	6.1 ± 2.0	3.9 ± 0.1	6.9 ± 0.8	6.1 ± 2.6	5.6 ± 0.7
58	3.6 ± 0.0	8.3 ± 4.1	32.0 ± 5.5	43.9 ± 6.0	4.3 ± 0.9	12.6 ± 2.6	19.2 ± 0.2	49.4 ± 0.7	3.6 ± 0.8	13.2 ± 8.3	41.5 ± 12.8	41.2 ± 7.7
59	nd	5.1 ± 0.0	9.0 ± 0.9	9.8 ± 4.1	nd	16.2 ± 2.6	14.2 ± 2.7	12.0 ± 2.2	nd	7.2 ± 0.8	7.0 ± 0.4	4.4 ± 0.8
60	1.5 ± 0.0	4.6 ± 0.8	6.1 ± 0.5	7.4 ± 1.4	3.4 ± 0.3	5.5 ± 1.2	11.6 ± 2.9	10.0 ± 0.6	nd	6.3 ± 2.6	7.1 ± 0.3	6.6 ± 0.2
61	nd	5.4 ± 1.1	7.9 ± 0.4	7.2 ± 2.5	nd	13.7 ± 3.5	9.8 ± 2.6	8.5 ± 1.7	3.3 ± 0.1	7.1 ± 0.3	8.5 ± 1.3	6.5 ± 0.4
62	86.5 ± 2.0	136.9 ± 60.3	150.9 ± 16.4	241.1 ± 12.9	128.4 ± 51.2	116.2 ± 19.4	522.3 ± 179.7	428.9 ± 45	348.6 ± 10.2	203.5 ± 81.9	344.6 ± 0.7	305.3 ± 72.3
63	7.9 ± 0.8	10.8 ± 2.6	16.4 ± 2.9	25.1 ± 8.6	74.8 ± 7.2	142.0 ± 29.9	16.4 ± 4.1	7.4 ± 0.1	9.3 ± 0.3	32.5 ± 27.5	45.6 ± 0.1	20.5 ± 4.9
64	6.1 ± 1.1	4.8 ± 1.1	4.8 ± 2.3	4.1 ± 2.5	45.5 ± 3.7	47.9 ± 10.1	9.6 ± 3.6	6.9 ± 0.4	7.5 ± 1.2	5.2 ± 0.8	5.8 ± 0.9	6.0 ± 0.2
65	4.3 ± 0.2	4.3 ± 0.4	5.3 ± 0.3	4.5 ± 0.5	14.8 ± 13.6	21.4 ± 3.6	6.7 ± 1.8	4.9 ± 0.3	4.6 ± 0.9	4.6 ± 0.3	5.4 ± 0.4	5.5 ± 0.5
66	5.4 ± 2.1	5.8 ± 2.2	10.3 ± 3.4	8.3 ± 1.0	16.8 ± 11.8	40.9 ± 20.1	14.1 ± 0.7	8.2 ± 2.4	5.0 ± 2.4	7.3 ± 0.9	12.4 ± 2.8	6.6 ± 0.8
67	10.1 ± 1.6	17.1 ± 4.9	20.8 ± 0.7	11.4 ± 1.1	25.4 ± 13.4	13.6 ± 1.8	20.2 ± 1.5	13.8 ± 1.5	9.4 ± 2.9	13.3 ± 1.6	15.2 ± 3.4	12.4 ± 2.2
68	77.6 ± 17.9	79.3 ± 19.1	91.2 ± 21.2	96.3 ± 54.4	113.5 ± 10.9	85.7 ± 13.8	141.3 ± 13.2	87.8 ± 1.0	121.4 ± 5.4	122.9 ± 13.6	176.7 ± 106.2	71.4 ± 5.4
69	1318.9 ± 397	1407.8 ± 757.1	836.1 ± 112.5	1830.7 ± 168.1	2406.0 ± 232	2314.4 ± 43.5	1747.9 ± 321.7	1800.9 ± 680	1020 ± 365	661.9 ± 161	1548 ± 13.2	1486 ± 398
70	20.2 ± 6.7	25.8 ± 9.5	60.1 ± 34.1	35.9 ± 9.2	9.7 ± 8.0	11.5 ± 7.3	38.7 ± 10.4	5.4 ± 1.0	10.4 ± 6.7	24.5 ± 1.1	51.2 ± 10.1	50.9 ± 9.5
71	23.3 ± 6.3	39.3 ± 8.2	39.0 ± 3.2	43.9 ± 16.0	26.6 ± 18.4	38.6 ± 9.8	43.1 ± 8.2	49.7 ± 9.0	22.1 ± 5.5	27.7 ± 8.3	70.7 ± 33.0	41.8 ± 10.1
72	20.9 ± 2.1	27.3 ± 1.5	30.2 ± 9.8	52.2 ± 15.9	12.9 ± 3.1	32.3 ± 8.8	51.4 ± 9.8	35.9 ± 6.5	17.7 ± 4.2	28.7 ± 5.2	34.2 ± 3.4	30.8 ± 7.5

Y, wet tarhana produced with yogurt; K, wet tarhana produced with kefir; KY, wet tarhana produced both of yogurt and kefir

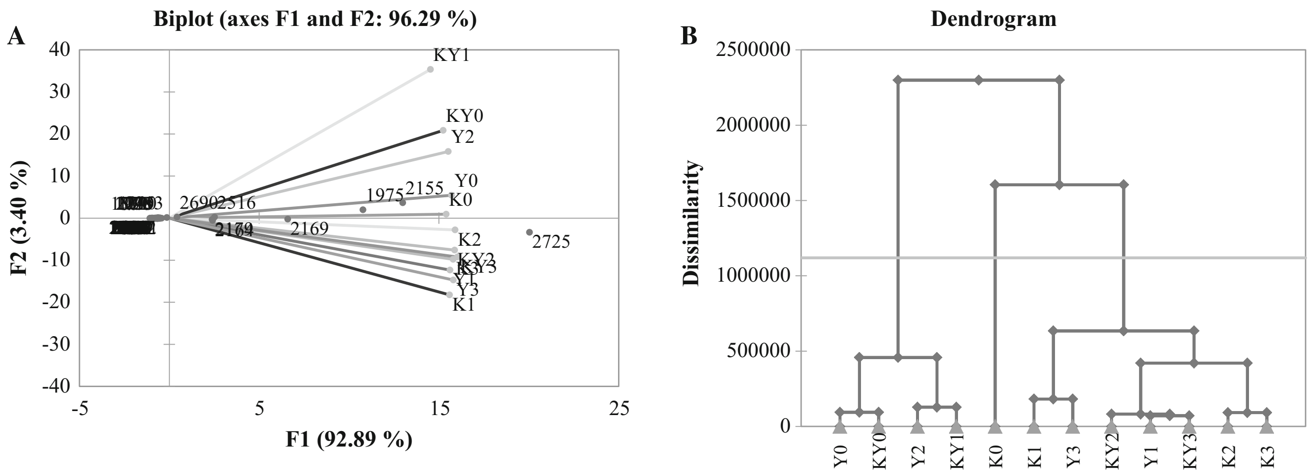


Fig. 1 **a**: principal component analysis (PCA) and **b**: agglomerative hierarchical cluster analysis (HCA) results of volatile compounds formed during tarhana fermentation (Y: yoghurt added, K: kefir added and KY: yoghurt and kefir added; 0, 1, 2 and 3: day of fermentation)

Antioxidant activity of the wet tarhana samples

TEAC antioxidant activity results in Fig. 2 show a significant difference between all formulations (K, Y, and KY). Individual use of yogurt and kefir resulted in the highest antioxidant activity. This activity remained stable throughout fermentation with nonsignificant differences.

Degirmencioglu et al. (2016), the antioxidant activity of tarhana formulated with oat flour varied between 1.99 and 6.01 µmol TE/g. The similar antioxidant activity of tarhana with oat flour was reported within the range of 2.39 and 3.05 µmol/g (Kilci and Gocmen 2014). The high antioxidant activity reported in the present study (15.86 and 19.31 µmol TE/g) could be attributed to the use of tarhana herb. So far, only a few studies reported the antioxidant activity of tarhana in the present of herbs (Gokbulut et al. 2013; Mileski et al. 2014).

Sensory analysis

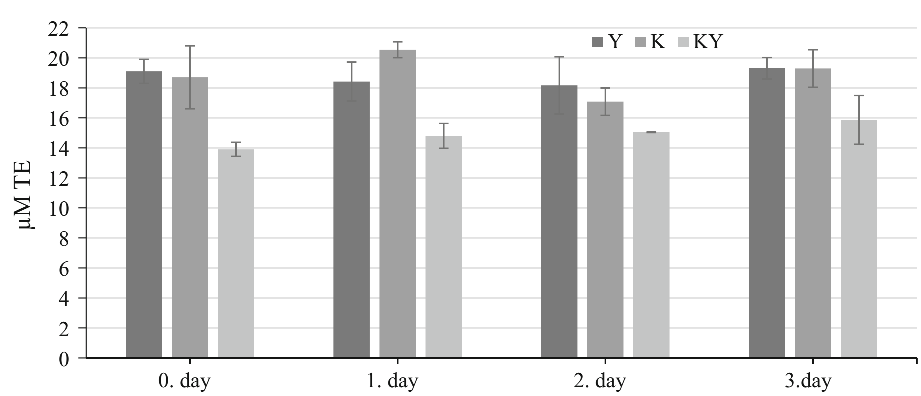
The sample of Y showed the highest score for flavor and appearance. On the other hand, sample K showed the highest viscosity and acidity. An increase in viscosity with kefir formulations might arise from the polymeric matrix, called kefiran (Gomez et al. 2014).

One of the most important factors in designing new food formulations is to maintain the sensory properties of the traditional product while increasing the nutritional quality and enhancing the shelf life. From this point of view, sensory analysis with panelists concluded that wet tarhana formulated with kefir was as desirable and acceptable analysis of Y sample.

Conclusion

The present study aimed to determine usability of kefir as a yogurt replacement in tarhana production. Microbiological results revealed that the addition of kefir increased the count of LAB while it affected insignificantly the count of

Fig. 2 Antioxidant activity of wet tarhana samples (± standard error)



yeast and TMAB. Lactic acid was determined to be the major organic acid in the tarhana samples. The value of pH and TTA were 4.78 and 4.68%, respectively, at the end of fermentation. It was also determined that the galactose, fructose and glucose content of the all formulations decreased continuously due to microbial activity. In addition, a total of 72 volatile compounds were recorded during fermentation and 44 of them were identified by GC–MS. The most abundant compounds identified were hexadecanoic acid and 9,12-octadecadienoic acid. Moreover, some volatile compounds, such as 2,4-decadienal and 2,4-di-*tert*-buthylphenol, were detected only in the formulations containing kefir. Moreover, the use of tarhana herb increased the antioxidant activity of samples. Finally, formulations containing kefir were desired as formulations containing only yogurt, according to sensorial analysis results.

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