Available online at www.sciencedirect.com
ScienceDirect
Food Chemistry 108 (2008) 198–204
Food Chemistry
www.elsevier.com/locate/foodchem

Comparison of lactic acid contents between dried and frozen tarhana

Onur Bozkurt [a], Ozan Gürbüz [b,*]

[a] Burgaz Alcoholic Beverages Company, Lüleburgaz, Kırklareli, Turkey
[b] University of Uludag, Agricultural Faculty, Department of Food Engineering, 16059 Bursa, Turkey

Received 14 February 2007; received in revised form 10 October 2007; accepted 22 October 2007

Abstract

The lactic acid content of tarhana produced with different dough treatments was determined. Trials were performed to see the effects of different parameters on organic acid produced during fermentation. In these trials, fermentation time, yogurt content and preservation method parameters were varied. Increasing fermentation time had a significant effect on lactic acid formation as well as total organic acid content of tarhana ($p < 0.01$). In the samples of tarhana with 50% yogurt, total acidity increased 29.9% in the first 48 h of fermentation. During the subsequent 48 h the increase was only 3.6%. Lactic acid increased 17.7% during the first 48 h followed by an increase of 3.1% during the next 48 h of fermentation in these same samples. On the other hand, when yogurt content was increased from 50% to 75%, total acidity in the first 48 h was 17.0% greater than the samples with 50% yogurt. There was also a 20.2% increase in lactic acid as well.

The highest acidity and lactic acid levels were determined in the samples using 75% yogurt. Yogurt level had a significant effect on all the analytic parameters ($p < 0.01$). However, it is possible that increasing the amount of yogurt to this level would cause technological problems because of the increase in water and fat contents.

Of the two preservative methods utilized in this study, sun drying produced higher organic acid (1.97 g/100 g) and lactic acid (1.29 g/100 g) levels than samples that were frozen (1.64 g/100 g; 1.06 g/100 g, respectively). Preservative methods had a significant effect on moisture, total acidity, lactic acid ($p < 0.01$) and oil ($p < 0.05$) content of tarhana.

Keywords: Tarhana; Fermentation; Lactic acid; HPLC

1. Introduction

Tarhana is a traditional Turkish fermented cereal food produced both commercially and in homes. It is mainly used in the form of a thick and creamy soup consumed at lunch or dinner and is easily digested (Bilgiçli & Elgun, 2005). Cereal flours, yogurt and a variety of vegetables are the primary ingredients and therefore a good source of B vitamins, minerals, organic acids and free amino acids which make it healthy for children, the elderly and medical patients (Dağlıoğlu, 2000). In addition to tarhana being a good source of vitamins such as thiamine, riboflavin and vitamin B12 (İbanoğlu, Ainsworth, Wilson, & Hayes, 1995), ascorbic acid, niacin, pantothenic and folic acid are also present (Ekinci, 2005; Ekinci & Kadakal, 2005). Lactic acid bacteria (LAB) from the yogurt also aids in absorption of nutrients, which would otherwise be indigestible or poorly digestible. (Farnworth, 2003) Similar products are known as "trahana" in Greece, "kishk" in Egypt, "kushuk" in Iraq and "tahanya/talkuna" in Hungary and Finland (Hayta, Alpaslan, & Baysar, 2002; Köse & Çağındı, 2002). Regional diversity of the amount and the type of ingredients, as well as the processing techniques, affect chemical compositions, nutritional content and sensory attributes of tarhana (Dağlıoğlu, 2000; Tarakçı, Doğan, & Koca, 2004).

Fermentation of Tarhana dough is generally carried out using yogurt bacteria, such as *Lactobacillus bulgaricus*, *Streptococcus thermophilus* and baker's yeast (*Saccharomyces cerevisiae*) (Bilgiçli & İbanoğlu, 2007; Ekinci, 2005). This is similar to other natural systems (e.g. kefir grains)

* Corresponding author.
E-mail address: ozang@uludag.edu.tr (O. Gürbüz).

0308-8146/$ - see front matter © 2007 Elsevier Ltd. All rights reserved.
doi:10.1016/j.foodchem.2007.10.063

in which associations of LAB and yeasts are used in food fermentation (Gobbetti, 1998).

The fermentations occur simultaneously during this aspect of production (Bilgiçli et al., 2006). Yeast fermentation proceeds through the Embden–Meyerhof pathway (EMP), in which glucose is transformed into ethanol (via piruvate and acetaldehyde), carbon dioxide, and traces of other acids and carbonyl compounds (Gelinas & McKinnon, 2000; Gobbetti, 1998). Mugula, Narvhus, and Sorhaug (2003) found that a combined culture of yeasts and lactobacilli was reported to bring about a more significant decrease in pH (increase in acidity) in fermented millet than with the use of single cultures.

The microorganisms in yogurt are responsible for formation of acids during both the fermentation and leavening processes (İbanoğlu, Kaya, & Kaya, 1999). EMP (fructose diphosphate) is one of the most common carbohydrates metabolisms by microorganisms. In the presence of microaerophylic conditions, the dehydrogenase enzymes produce ethanol, carbon dioxide, acetic acid, hydrogen, and lactic acid. Piruvic acid is a key compound in this process. It is used as an intermediate metabolite in the synthesis of aldehyde, alcohol, organic acid and amino acid. Hetero- or homo-fermentative lactic acid bacteria produce a lactic acid reduction of piruvic acid by the lactate dehydrogenase enzyme in relation to pH and temperature conditions. Acetaldehyde and carbon dioxide occur because of this decarboxilation of piruvic acid by fermentative yeast.

In the oxidation process, acetaldehyde turns to acetic acid and the acid is reduced to ethanol. The yeast also produces lesser amounts of other organic acids such as acetic acid, lactic acid and piruvic acid (Gelinas & McKinnon, 2000; Kulp & Ponte, 2000; Şahin & Başoğlu, 2002).

Homofermentative LAB is able to convert hexoses almost completely (85%) into lactic acid (Gelinas & McKinnon, 2000). Products from the fermentation of sugars and organic acids are essential in this process. Sugars are the preferred substrates of the heterofermentative LAB. Lactic acid fermentation occurs through the metabolic activity of LAB originally present in the flour. Both microorganisms, LAB and yeast, are able to liberate aroma precursors such as free amino acids and it has been previously shown that the concentrations of free amino acids are increased significantly during sourdough fermentation (Hansen & Schieberle, 2005). However, heterofermentative LAB degrades hexoses into lactic acid, acetic acid/ethanol, and carbon dioxide.

In wheat flour, the total concentration of maltose, sucrose, glucose, and fructose varies from 1.55% to 1.85% depending on the balance between starch hydrolysis, by microbial enzymes and microbial consumption. The utilization of soluble carbohydrates by LAB and, consequently, their energy yield, and lactic and acetic acid production are greatly influence by the associated sourdough yeasts and LAB. LAB utilizes different kinetics for carbohydrate consumption (Gobbetti, 1998; Lefebvre, Gabriel, Vayssier, & Fontagne-Faucher, 2002).

The major organic acid formed in tarhana is lactic acid. The other acids formed, besides lactic acid, are a very small amount of the total (Damir, Salama, & Safwat, 1992; Economidou & Steinkrauss, 1983). In an earlier study lactic acid levels were found to be three times higher in tarhana than other organic acids such as acetic, propionic, citric, and piruvic acids (Erbaş, Uslu, Erbaş, & Certel, 2006).

LAB also produces acetic acid, ethanol, aroma compounds, bacteriocins, exopolysaccharides, and several enzymes (Gobbetti, 1998; Leroy & DeVuyst, 2004; Schieberle, 1996).

The organic acid causes rapid acidification (reducing pH) as the K_a of lactic acid is 1.38×10^{-4} at 25 °C. These bacteria in yogurt and wheat flour and yeasts are the main factors of fermentation and leavening (Ekinci, 2005).

After kneading and fermentation, excess moisture in the dough is removed by drying. The fermented dough is usually sun-dried in homes or oven-dried at an industrial level and then ground to fine particles (<1 mm) (Köse & Çağındı, 2002; Tarakçı et al., 2004). Drying reduces the moisture content to 6–10%. This, in addition to a pH between 3.3 and 5.0, has a bacteriostatic effect on pathogenic microorganisms (Bilgiçli, Elgün, & Türker, 2006a; Dağlıoğlu, 2000; Dağlıoğlu, Arıcı, Konyalı, & Gümüş, 2002). Tarhana is not hygroscopic and can be stored for 2–3 years without any sign of deterioration (İbanoğlu, Kaya, et al., 1999).

The objective of this study was to observe the level of lactic acid by altering the amount of yogurt and fermentation times of dried and frozen tarhana samples.

2. Materials and methods

2.1. Ingredients

Wheat flour Type 550 (Toru Wheat Flour Cooperation, Bandırma, Turkey) with a moisture content of 14.5%, ash content of 0.55%, crude protein content of 11%, on dry weight basis, was used. The yogurt (Sütaş¸ Bursa, Turkey) was full fat (3.5%) plain yogurt with 4.5% protein. Tomato paste and paprika paste (Penguen, Bursa, Turkey) were concentrated to a solids content of 30% and 26%, respectively. Fresh pressed baker's yeast (Akmaya, Kırklareli, Turkey), salt (NaCl), onion, green pepper, and mint were purchased from the local markets in Bursa, Turkey.

2.2. Chemicals

HPLC-grade methanol was purchased from Carlo Erba Reagent (Milan, Italy). Standards for lactic acid were supplied from Sigma (St. Louis, MO, USA). The standard compounds of potassium hexacyanoferrate(II)-trihydrate solution (Carrez I), zinc acetate-dihydrate (Carrez II), potassium dihydrogen phosphate, sodium hydroxide and zinc sulfate were purchased from Aldrich (Steinheim, Germany) and Sigma (St. Louis, MO, USA).

2.3. Analytical methods

Moisture and salt levels were determined using Tarhana Standard Methods (Anonymous, 1981). Total acidity (as lactic acid) values of the samples were determined with a titrimetric method described by İbanoğlu et al. (1995) and also İbanoğlu (1999). Total ash levels were determined using the methods of İbanoğlu (1999) and Göçmen, Gürbüz, and Şahin (2002) in a 550 °C oven. Results were given on the basis of dry weight. Crude protein was determined using the Foss Kjeltec 2200 apparatus (Hilleroed, Denmark) with ICC Standard No: 105/2 and results were expressed as percent protein on dry weight basis (AOCC, 1984). Oil content was established with Soxtec Avanti 2055 extraction apparatus (Fisher, USA) on a dry weight basis (AACC, 1990). Lactic acid content of tarhana samples was determined by HPLC using the procedures of Lefebvre et al. (2002) and is described below.

2.4. Chromatographic procedure

Several parameters such as the flow, pH, and concentration of the buffer or column temperature were tested in order to obtain the best resolution of the analytes. Lactic acid levels in dried and frozen samples were measured using a Shimadzu CLASS-VP V6.13 SP1 HPLC (Kyoto, Japan) system. The method of Lefebvre et al. (2002) was used with slight modifications. The HPLC system consisted of a SCL-10A VP system control unit, LC-10AT VP liquid chromatography unit, DGU-14A degazer, FCL-10AV VP flow control unit, SIL-10AD VP autosampler and a SPD-10A VP UV detector (220 nm). Lactic acid was separated on C18 Hypersil H5 ODS (150 × 4.6 mm i.d.) Phenomenex column (Phenomenex, Aschaffenburg, Germany) used with an isocratic elution of methanol (flow rate 0.7 mL/min). The mobile phase consisted of 50 mM (0.05 M) potassium dihydrogen phosphate/methanol (95:5) with detection of UV-absorbance at 220 nm (v/v) (Lefebvre et al., 2002; PCCS, 2004/05).

To prepare the column for each run, water and then methanol were run for 5 min and 15 min, respectively, after each injection. Tarhana samples (20 g) were centrifuged (Sigma 3K30 Osterode am Harz, Germany) at 10*g* for 5 min and were placed in a thermostat-controlled autosampler (+4 °C). The injection volume was 100 μL of sample or standard. All measurements were performed in triplicate, values were averaged, and the standard deviation calculated. Lactic acid peaks were identified by the comparison of retention times and UV spectrums with commercial standards of lactic acid. To evaluate the efficiency of the HPLC procedure, each sample was also spiked with standards (100 ng for tarhana samples) before the run. Chromatograms were analyzed with the Shimadzu (Kyoto, Japan) software (CLASS-VP V6.13 SP1), and quantification was done using linear regression analysis. A retention time for lactic acid of 4.3 min was found in samples prepared according to this method (Fig. 1).

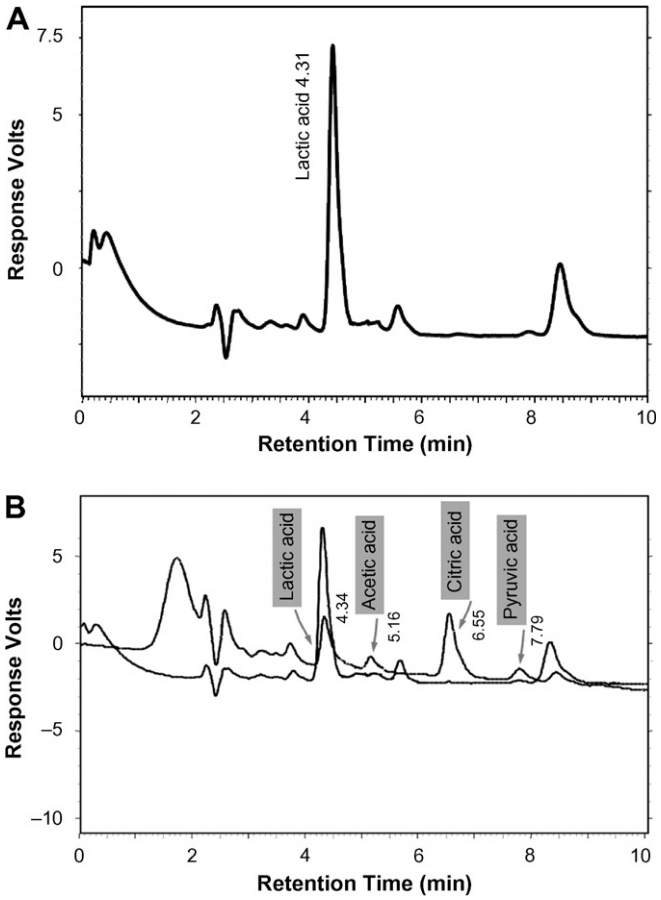

Fig. 1. HPLC chromatograms of lactic acid in tarhana. Chromatogram A: Lactic acid standard(10 ppm) and Chromatogram B: Overlay of tarhana + lactic acid standard. The concentrations of the lactic acid standard injected into the column were 1 mg LA/mL, integration of values expressed as mean ± standard deviation.

2.5. Preparation of tarhana dough

Proportions of the components for tarhana dough production are expressed as a percent of total flour weight. Onion and green pepper were blended for 30 s in a Moulinex Masterchef 70 electronic blender (Ecully Cedex, France). Flour (1000 g), yogurt 50%, blended onion 10%, blended green pepper 5%, tomato paste 5%, Paprika paste 7.5%, salt (NaCl) 7.5%, baker's yeast 1% and dry-ground mint herb 1% were mixed together and kneaded in a commercial percussion kneader (50 rpm) for 10 min. Another quantity of dough was prepared using the same ingredients and quantities with the exception of the yogurt quantity, which was 75% in this second sample. All of the dough was fermented at 30 °C. A portion of the dough was removed after 48 hours and triplicate samples of 1 kg each were taken for chemical analyses. The remaining dough continued to ferment an additional 48 h. This method of preparation was a modified procedure used by Ünal (1989). Each quantity of dough mixture was blended manually prior to sampling, to ensure homogeneity of the samples. After fermentation, the dough was separated into

pieces between 5–6 g each. Samples were sealed in a 1 L glass jar and kept at +4 °C.

Each type of dough was divided into two parts. One-half of each type was sun-dried for 3 h at which point the moisture content of ~10% was reached. Dough was then ground in a hammer mill into rough powder and sifted through a 1 mm screen sieve. The resulting samples were then stored in glass jars (1 L) and refrigerated (+4 °C) until tested. The second half of each type of dough was frozen within 30 min. then kept at −18 °C. Sample codes are shown in Table 1.

2.6. Extraction/sample preparation

Following the organic acid extraction steps outlined by Lefebvre et al. (2002) 20 g of sample was homogenized with 60 mL of distilled water in a laboratory blender for 30 s at maximum speed. The homogenized sample volume was adjusted to 100 mL. It was then centrifuged for 15 min (4000*g* at 15 °C) and the supernatant was filtered under vacuum using 1.2 μm glass microfilters (Whatman). A 20 mL aliquot of filtrate with 60 mL of distilled water was stirred with 5 mL of Carrez I solution (potassium hexacyanoferrate(II)-trihydrate 0.085 M) and 5 mL of Carrez II solution (zinc sulfate 0.25 M) and then neutralized (pH 8.0 ± 0.5) with 0.1 M sodium hydroxide. The volume of the sample was adjusted to 100 mL with distilled water and the solution was filtered.

2.7. Statistical analysis

The concentration of lactic acid was measured and analyzed using one-way analysis of variance (ANOVA). Values ($n = 3$) were reported as mean concentration ± standard deviation. The standard deviation was calculated by ANOVA using a Minitab statistical package (Anonymous, 1998). In addition, Duncan's multiple range test was used to determine the differences between variances by using a MSTAT statistical package (Anonymous, 1980).

Table 1
Tarhana specifications and sample codes

Sample code	Yogurt rate (%)	Fermentation time (h)	Treatment
A.0.1	50	0	Dried
A.0.2			Frozen
A.1.1	50	48	Dried
A.1.2			Frozen
A.2.1	50	96	Dried
A.2.2			Frozen
B.0.1	75	0	Dried
B.0.2			Frozen
B.1.1	75	48	Dried
B.1.2			Frozen
B.2.1	75	96	Dried
B.2.2			Frozen

A – samples with 50% yogurt content, B – samples with 75% yogurt content. First numeral in code identifies the length of fermentation: 0 – 0 h fermentation, 1 – 48 h fermentation, 2 – 96 h fermentation. Second numeral in code identifies treatment of samples: 1 – samples that have been dried, 2 – samples that have been frozen.

3. Results and discussion

3.1. Yogurt levels

A 50% yogurt level is the more common amount to be used in tarhana preparation. As seen in Table 2, using 75% yogurt resulted in higher tarhana moisture levels which would allow for microbial growth and negatively impacts the potential shelf-life of the commodity (Göçmen et al., 2002; Göçmen, Gürbüz, & Şahin, 2003; İbanoğlu, Kaya, et al., 1999; Şahin, 1999; Şahin and Başoğlu 2002; Temiz & Pirkul, 1990, 1991).

Oil rancidity is another problem for long-term storage. The 50% yogurt samples contained 35% less oil than those samples with 75% yogurt. Oil exposed to heat, light, or oxygen deteriorates quickly resulting in a rancid taste. Therefore, the use of 50% yogurt is more suitable for achieving lower moisture and lower oil levels in tarhana fermentation yet maintaining beneficial lactic acid levels.

The major organic acid in fermented tarhana dough is lactic acid and is produce by the fermentable carbohydrates found in a cereal flour and yogurt mixture (Değirmencioğlu, Göçmen, Dağdelen, & Dağdelen, 2005; İbanoğlu, İbanoğlu, & Ainsworth, 1999). In addition to lactic acid, other organic acids such as acetic, propionic acid and pyruvic acids are formed (Lefebvre et al., 2002; İbanoğlu, Kaya, et al., 1999). A small amount of citric acid is produced from vegetables used in the preparation of tarhana (Erbaş et al., 2006). The relationship between total organic acid and lactic acid concentrations of tarhana is shown, both for 50% and 75% levels of yogurt, in Table 3. Although there is continual increase in levels of lactic acid over time, it does not increase at the same rate as the other organic acids present. However, lactic acid remains the primary organic acid, ranging from 60% to 73% of the total organic acids and therefore always greater than the total of the other organic acids combined. Trace levels of citric acid were found. The source of this acid was not from fermentation but from the miscellaneous vegetables added to the tarhana. Therefore, it was not included in Table 3. During the 96 h tarhana fermentation period for dried samples, total organic acidity increased from 1.50 to 2.42 g/100 g; lactic acid increased from 1.06 to 1.53 g/100 g; acetic acid increased from 0.24 to 0.49 g/100 g; and pyruvic acid increased from 0.19 to 0.40 g/100 g. Similar increases were found in the frozen samples and are shown in Table 3.

The lactic acid rate of increase within the first 48 h was greater than the time from 48 to 96 h. Within the dough of all samples that had been sun-dried, lactic acid increased 19% over 96 h. Lactic acid increases in frozen samples averaged a 24% increase during the same time span.

Table 2
Chemical composition of tarhana samples

	Code	Moisture*	Salt[a]	Oil**	Protein[a]	Ash[a]
Dried	A.0.1	12.89 ± 0.25	8.00 ± 0.03	2.35 ± 0.05	14.50 ± 0.11	8.55 ± 0.05
	A.1.1	12.56 ± 0.29	8.03 ± 0.03	2.34 ± 0.05	14.48 ± 0.12	8.61 ± 0.04
	A.2.1	12.38 ± 0.21	8.02 ± 0.03	2.37 ± 0.05	14.52 ± 0.09	8.61 ± 0.07
	B.0.1	13.40 ± 0.28	8.13 ± 0.03	3.09 ± 0.04	15.60 ± 0.10	8.75 ± 0.06
	B.1.1	13.41 ± 0.20	8.12 ± 0.03	3.10 ± 0.04	15.58 ± 0.10	8.78 ± 0.07
	B.2.1	13.42 ± 0.25	8.17 ± 0.02	3.14 ± 0.04	15.52 ± 0.09	8.79 ± 0.05
Frozen	A.0.2	42.10 ± 0.26	7.95 ± 0.02	2.30 ± 0.05	14.55 ± 0.11	8.55 ± 0.05
	A.1.2	42.41 ± 0.24	8.01 ± 0.02	2.33 ± 0.06	14 48 ± 0.11	8.61 ± 0.07
	A.2.2	41.55 ± 0.28	7.98 ± 0.01	2.28 ± 0.04	14.52 ± 0.18	8.51 ± 0.04
	B.0.2	45.10 ± 0.20	8.09 ± 0.02	3.15 ± 0.04	15.50 ± 0.10	8.80 ± 0.07
	B.1.2	45.50 ± 0.19	8.15 ± 0.02	3.12 ± 0.04	15.54 ± 0.11	8.86 ± 0.07
	B.2.2	45.52 ± 0.21	8.14 ± 0.02	3.09 ± 0.03	15.57 ± 0.10	8.82 ± 0.07

Values are expressed as mean value ± standard deviation of three determinations. Chemical composition of tarhana samples was computed on dry matter basis of tarhana (g/100 g). Mean values for each column are significantly different at 0.01(*) and 0.05(**) levels (Duncan's multiple range test).
[a] Not significant.

Table 3
Acid levels of tarhana samples with fermentation times

	Fermentation time (h)	Sample code	Total organic acids[a]* (g/100 g)	Lactic acid[b]* (g/100 g)	Pyruvic acid[b]* (g/100 g)	Acetic acid[b]* (g/100 g)
Dried	0	A.0.1	1.50 ± 0.052	1.06 ± 0.009	0.19 ± 0.014	0.24 ± 0.016
	48	A.1.1	1.90 ± 0.057	1.22 ± 0.009	0.31 ± 0.010	0.37 ± 0.007
	96	A.2.1	2.05 ± 0.046	1.26 ± 0.010	036 ± 0.011	0.43 ± 0.012
	0	B.0.1	1.72 ± 0.048	1.25 ± 0.009	021 ± 0.010	0.26 ± 0.021
	48	B.1.1	2.24 ± 0.056	1.48 ± 0.008	0.34 ± 0.006	0.42 ± 0.009
	96	B.2.1	2.42 ± 0.040	1.53 ± 0.008	0.40 ± 0.008	0.49 ± 0.010
Frozen	0	A.0.2	1.23 ± 0.049	0.87 ± 0.007	0.16 ± 0.006	0.20 ± 0.007
	48	A.1.2	1.58 ± 0.057	1.00 ± 0.006	0.26 ± 0.011	0.32 ± 0.008
	96	A.2.2	1.73 ± 0.040	1.03 ± 0.008	0.32 ± 0.016	0.38 ± 0.010
	0	B.0.2	1.39 ± 0.049	1.01 ± 0.008	0.17 ± 0.015	0.21 ± 0.010
	48	B.1.2	1.88 ± 0.057	1.21 ± 0.007	0.30 ± 0.007	0.37 ± 0.005
	96	B.2.2	2.06 ± 0.040	1.26 ± 0.008	0.36 ± 0.006	0.44 ± 0.013

Values are expressed as mean value ± standard deviation of three determinations. All concentrations are expressed in 1 g of acidity/100 g of dry milled tarhana and 1 g of acidity/100 g of wet fermented tarhana dough (w/w).
[*] Mean values for each column are significantly different ($p < 0.01$).
[a] Total organic acid was determined by titration.
[b] The individual acids were determined using HPLC.

3.2. Fermentation

Originally, lactic acid fermentation was utilized primarily to increase shelf-life of products. Further research proved it not only played a role in food preservation but also allowed important nutritional benefits to be maintained (Farnworth, 2003). With the more current emphasis on reducing additives to food processes and increasing the use of natural processes, our study looked at the changes in lactic acid, moisture, salt (NaCl), oil, protein, and ash contents of tarhana as a result of fermentation times. From 0 h to 96 h, the amount of lactic acid increased 18.8% for 50% yogurt and 22.7% for 75% yogurt. Likewise, total acidity was increased 36.1% and 40.6% for 50% and 75% yogurt rate, respectively. Table 3 shows the rate of increase for lactic acid levels according to the fermentation times of 0, 48, and 96 h. During the first 48 h the increase is greater than that of the final 48 h in both yogurt levels. This increase in lactic acid for the first 48 h is similar to an earlier study (İbanoğlu, Kaya, et al., 1999).

Highest lactic acid content (1.53 g/100 g) developed in the 98 h tarhana samples (B.2.1). Conversely, the lowest lactic acid (0.87 g/100 g) was found in samples that had zero fermentation time (A.0.2). İbanoğlu et al. (1995) reported lactic acid content of tarhana between 1.8 and 2.3 g/100 g on a dry weight basis.

The crude protein contents of all samples were between 14.48% and 15.6%. For this reason, tarhana is a good source of protein (Köse & Çağındı, 2002). Çopur, Göçmen, Tamer, and Gürbüz (2001) observed higher protein levels of tarhana using similar fermentation times with quantities of 50% yogurt and 1% yeast.

The general pattern, throughout the fermentation time of all tarhana samples, was a slight increase in levels of salt,

oil, protein, and ash. Changes to the levels were less than one percent in most of the samples. However moisture levels in the sun-dried samples (50% yogurt) decreased nearly by 4% over the 96 h (Table 2).

3.3. Preservation (moisture removal)

Sun drying is a slower but a more common and economical approach for traditional tarhana production. The critical moisture value is 13–15% for the inhibition of undesirable microbial growth in dry recipes produced from wheat flour (Şahin & Başoğlu, 2002).

Drying and freezing are physical techniques for preservation. Drying not only reduces moisture, but also lactic acid concentrations increase as water is removed. However, it takes a longer period of time to get a critical moisture concentration as well as development of sufficient lactic acid (Şahin, 1999; Şahin & Başoğlu, 2002). It is partly because the moisture content of tarhana is low, that it can be stored for 2 or 3 years without deterioration (Tarakçı et al., 2004; İbanoğlu, Kaya, et al., 1999). Erbaş, Certel, and Uslu (2005) reported wet tarhana could be stored for only 6 months under refrigeration (+4 °C) without any preservative. According to the Institute of Turkish Standards (TSI 2282) the standard moisture value of dried tarhana should be 10% or less (Anonymous, 1981). The average moisture content of dried tarhana samples in this study was found to be above the standard. However, these levels are still suitable for long-term storage without deterioration (Tarakçı et al., 2004). The results of the chemical analyses on dried and frozen tarhana samples are given in Table 2. The lowest average moisture content was found to be 13% in the 50% yogurt, sun-dried samples (A.0.1, A.2.1). Göçmen et al. (2002) reported similar moisture levels in dried tarhana. Although levels are similar between the 48 and 96 h fermentation and between the 50% and 75% yogurt levels, the difference in moisture levels between drying and freezing is significant. The average moisture levels of sun-dried samples were 13% and the average in frozen samples, 44%. Sun-dried tarhana produced with 75% yogurt was found to have nearly a 1% higher moisture level than the tarhana produced with 50% yogurt. In the frozen tarhana with 75% yogurt there was found to be nearly a 3% higher moisture level than the tarhana fermented with 50% yogurt (Table 2).

Freezing and sun-drying methods had different effects on the lactic acid content of tarhana samples. The range of total acidity was 1.7% in the dried samples with zero fermentation time to 1.4% in the frozen samples with no fermentation time. Extended fermentation time consistently resulted in dried tarhana samples with higher lactic acid levels compared to similar times with frozen samples. The highest acidity level was reached in sun-dried tarhana with 96 h of drying. Dry tarhana contained an average of 22.3% higher lactic acid levels than frozen tarhana.

The preservative methods used in this study did not influence, on a significant level, the salt, protein and ash concentrations ($p < 0.01$; $p < 0.05$).

4. Conclusions

It can be concluded from the results of this study that increasing fermentation time and the ratio of yogurt in the tarhana dough also increased the total organic acids of which lactic acid is the primary. However, significant differences between sun-dried samples and frozen samples were found in the moisture levels. Although using the higher percentage of yogurt results in more lactic acid, the higher moisture and oil content would create a risk for a long-term shelf-life of tarhana. Further shelf-life studies should be conducted to determine levels of lactic acid over longer periods than were used in this study.

Acknowledgment

The helpful assistance of June Rouseff in proofreading the manuscript is gratefully acknowledged.

References

Phenomenex Chromatography Columns and Supplies 04/05 Catalog (2004/05). Torrence, CA: Phenomenex, Inc.

AACC (1990). Approved methods of the American Association of Cereal Chemists, Method 55-20. *Approved Methods of the AACC*. St. Paul, MN, USA: The Association of Cereal Chemists, Inc.

Anonymous (1980). *Mstat Users Guide, Statistics*. East Lansing: Michigan State University.

Anonymous (1981). *Official methods of analysis* (vol. TS 2282). Ankara: The Institute of Turkish Standards.

Anonymous (1998). *Minitab Reference Manual*. Harrisburg, PA: Pennsylvania State University.

AOCC (1984). *Official Methods of Analysis*. Washington, DC: Association of Official Analytical Chemists.

Bilgiçli, N., & Elgun, A. (2005). Changes in some physical and nutritional properties of tarhana, a Turkish fermented cereal food, added various phytase sources. *Food Science and Technology International, 11*(5), 383–389.

Bilgiçli, N., Elgün, A., Herken, E. N., Türker, S., Ertaş, N., & İbanoğlu, Ş. (2006). Effect of wheat germ/bran addition on the chemical, nutritional and sensory quality of tarhana, a fermented wheat flour-yogurt product. *Journal of Food Engineering, 77*(3), 680–686.

Bilgiçli, N., Elgün, A., & Türker, S. (2006a). Effects of various phytase sources on phytic acid content, mineral extractability and protein digestibility of tarhana. *Food Chemistry, 98*(2), 329–337.

Bilgiçli, N., & İbanoğlu, Ş. (2007). Effect of wheat germ and wheat bran on the fermentation activity, phytic acid content and colour of tarhana, a wheat flour–yoghurt mixture. *Journal of Food Engineering, 78*(2), 681–686.

Çopur, Ö. U., Göçmen, D., Tamer, C. E., & Gürbüz, O. (2001). The effects of different applications in tarhana production of product quality. *Food, 26*(5), 339–346.

Dağlıoğlu, O. (2000). Tarhana as a traditional Turkish fermented cereal food. Its recipe, production and composition. *Nahrung FIELD Full Journal Title: Die Nahrung, 44*(2), 85–88.

Dağlıoğlu, O., Arıcı, M., Konyalı, M., & Gümüş, T. (2002). Effects of tarhana fermentation and drying methods on the fate of *Escherichia coli* O157:H7 and *Staphylococcus aureus*. *European Food Research and Technology, 215*(6), 515–519.

Damir, A. A., Salama, A. A., & Safwat, M. (1992). Acidity, microbial, organic and free amino acids development during fermentation of skimmed milk in Kishk. *Food Chemistry, 43*(4), 265–269.

Değirmencioğlu, H., Göçmen, D., Dağdelen, A., & Dağdelen, F. (2005). Influence of tarhana herb (*Echinophara sibthorpiano*) on fermentation of tarhanas, Turkish traditional fermented food. *Food Technology Biotechnology, 43*(2), 175–179.

Economidou, P. L., & Steinkrauss, K. H. (1983). *Handbook of indigenous fermented foods*. New York, NY, USA: Marcel Dekker.

Ekinci, R. (2005). The effect of fermentation and drying on the water-soluble vitamin content of tarhana, a traditional Turkish cereal food. *Food Chemistry, 90*(1–2), 127–132.

Ekinci, R., & Kadakal, C. (2005). Determination of seven water-soluble vitamins in tarhana, a traditional Turkish cereal food, by high-performance liquid chromatography. *Acta Chromatographica, 15*, 289–297.

Erbaş, M., Certel, M., & Uslu, M. K. (2005). Microbiological and chemical properties of tarhana during fermentation and storage as wet-sensorial properties of tarhana soup. *Swiss Society of Food Science and Technology, 38*, 409–416.

Erbaş, M., Uslu, M. K., Erbaş, M. O., & Certel, M. (2006). Effects of fermentation and storage on the organic and fatty acid contents of tarhana, a Turkish fermented cereal food. *Journal of Food Composition and Analysis, 19*(4), 294–301.

Farnworth, E. R. (2003). *Handbook of fermented functional foods*. Boca Raton, FL: CRC Press.

Gelinas, P., & McKinnon, C. (2000). *Fermentation and microbiological processes in cereal foods*. In K. Kulp & J. J. Ponte (Eds.). *Handbook of cereal science and technology* (vol. 99, pp. 741–754). New York: Marcel Dekker, Inc.

Gobbetti, M. (1998). The sourdough microflora: interactions of lactic acid bacteria and yeasts. *Trends in Food Science and Technology, 9*(7), 267–274.

Göçmen, D., Gürbüz, O., & Şahin, İ. (2002). A research on commercial tarhana soup. In: *Cereal Product Technology Symposium* (pp. 211–218). Gaziantep, Turkey.

Göçmen, D., Gürbüz, O., & Şahin, İ. (2003). A research on commercial Tarhana soup. *Food, 28*(1), 13–18.

Hansen, A., & Schieberle, P. (2005). Generation of aroma compounds during sourdough fermentation: applied and fundamental aspects. *Trends in Food Science and Technology, 16*, 85–94.

Hayta, M., Alpaslan, M., & Baysar, A. (2002). Effect of drying methods on functional properties of tarhana: a wheat flour-yogurt mixture. *Journal of Food Science, 67*(2), 740–744.

İbanoğlu, S. (1999). Functional properties of spray dried tarhana. *Drying Technology, 17*(1–2), 327–333.

İbanoğlu, Ş., Ainsworth, P., Wilson, G., & Hayes, G. D. (1995). The effect of fermentation conditions on the nutrients and acceptability of tarhana. *Food Chemistry, 53*(2), 143–147.

İbanoğlu, Ş., İbanoglu, E., & Ainsworth, P. (1999). Effect of different ingredients on the fermentation activity in tarhana. *Food Chemistry, 64*(1), 103–106.

İbanoğlu, Ş., Kaya, S., & Kaya, A. (1999). Evaluation of sorption properties of Turkish tarhana powder. *Nahrung, 43*(2), 122–125.

Köse, E., & Çağındı, O. S. (2002). An investigation into the use of different flours in tarhana. *International Journal of Food Science and Technology, 37*(2), 219–222.

Kulp, K., & Ponte, J. G. Jr., (2000). *Handbook of cereal science and technology*. New York: Marcel Dekker.

Lefebvre, D., Gabriel, V., Vayssier, Y., & Fontagne-Faucher, C. (2002). Simultaneous HPLC determination of sugars, organic acids, and ethanol in sourdough process. *Lebensmittel-Wissenschaft und-Technologie, 35*(5), 407–414.

Leroy, F., & DeVuyst, L. (2004). Lactic acid bacteria as functional started cultures for the food fermentation industry. *Trends in Food Science and Technology, 15*, 67–78.

Mugula, J. K., Narvhus, J. A., & Sorhaug, T. (2003). Use of starter cultures of lactic acid bacteria and yeasts in the preparation of togwa, a Tanzanian fermented food. *International Journal of Food Microbiology, 83*(3), 307–318.

Şahin, İ. (1999). *General microbiology*. Bursa, Turkey: University of Uludag Press, Agricultural Faculty.

Şahin, İ., & Başoğlu, F. (2002). *Food microbiology*. Bursa, Turkey: University of Uludag Press, Agricultural Faculty.

Schieberle, P. (1996). Intense aroma compounds useful tools to monitor the influence of processing and storage on bread aroma. *Advances in Food Science, 18*, 237–244.

Tarakçı, Z., Doğan, İ. S., & Koca, A. F. (2004). A traditional fermented Turkish soup, tarhana, formulated with corn flour and whey. *International Journal of Food Science and Technology, 39*(4), 455–458.

Temiz, A., & Pirkul, T. (1990). Chemical and microbiologica changes in tarhana fermentation. *Gida, 15*(2), 119–126.

Temiz, A., & Pirkul, T. (1991). Chemical and sensorial properties of tarhana samples produced with different components. *Gida, 16*(1), 7–13.

Ünal, S. S. (1989). *Cereal processing technology*. Izmir, Turkey: Publications of Aegean University.