Utilization of citrus albedo in tarhana production

NERMIN BILGIÇLI – KÜBRA AKTAŞ – HACER LEVENT

SUMMARY

In this study, albedos of lemon, orange and grapefruit replaced wheat flour at 5% and 10% level in tarhana formulation. Selected chemical (ash, protein, cellulose, lipids, mineral, total phenolic content, antioxidant activity and pH), functional (water and oil absorption capacity, foaming capacity and stability) and sensory properties, colour values of tarhana were determined. All replacement levels of citrus albedo samples increased ($p < 0.05$) ash, cellulose, Ca, Fe, K contents and antioxidant activity of tarhana compared to control. Tarhana sample containing 10% lemon albedo had the highest antioxidant activity (220.50 mmol·kg^{-1}, expressed as Trolox equivalents), Cu (10.6 mg·kg^{-1}), Fe (36.9 mg·kg^{-1}), K (5378.0 mg·kg^{-1}) and Zn (13.1 mg·kg^{-1}) contents. Compared to control tarhana, 10% addition levels of citrus albedo gave lower lightness (L^*) and higher yellowness (b^*). Citrus albedo addition had a significant ($p < 0.05$) effect on oil absorption capacity and foam stability. Tarhana soup with orange and lemon albedo gained higher taste and sourness scores than tarhana soup containing grapefruit albedo.

Keywords

citrus by-products; albedo; tarhana; functional properties; nutrition

Citrus is an important crop due to its nutritional content and abundance all over the world. After processing of citrus fruits (lemon, orange, grapefruit, mandarin etc.) for producing juice and essential oils, approximately 50% of the original fruit mass is left as waste material. This remaining product used mainly for animal feed contains valuable nutrients such as pectin, as a kind of dietary fibre, soluble saccharides, essential oils, carotenoids, some vitamins, minerals polyphenols and antioxidant active substances [1, 2]. Citrus peels consist of two layers, namely, flavedo and albedo. Flavedo is the outer layer of citrus fruit with colour ranging from yellow to orange-red. Albedo is the soft, spongy white layer, which is located just below the flavedo layer [3]. Citrus albedo contains higher quality dietary fibres than cereal fibres due to the presence of associated bioactive compounds (flavonoids, carotenoids and vitamin C), which provides additional health benefits. Also, it has higher amount of total dietary fibre with higher soluble fraction than the peeled citrus fruit [4–6]. Dietary fibres can be classified into two major categories, namely, soluble and insoluble fibre, according to their water solubility. Soluble fibres (pectins, gums, mucilages and non-starch polysaccharides) form viscous solution, which delays gastric emptying and gives satiety. It decreases serum cholesterol, postprandial and blood glucose in human body. Insoluble fibres (lignins, cellulose and some hemicelluloses) serve almost exclusively as bulking agents that cause shorter transit time, increased fecal mass and thus improve the efficiency of the gut and colon, reduce the risk of colorectal cancer [7–9].

Tarhana, traditional fermented cereal product in Turkey, is prepared by mixing wheat flour, yoghurt, some vegetables (tomato, pepper, onion, etc.) and spices. After fermentation of dough (1–7 days), it is dried and milled to the particle size < 1 mm and used for soup making [10, 11]. It is known with different names in different countries, such as kishk and kushuk in Syria, Jordan, Palestina, Egypt, trahana in Greece, atole in Scotland, talkuna in Finland and thanu in Hungary [12, 13]. Tarhana soup is an important component

Nermin Bilgiçli, Department of Food Engineering, Faculty of Engineering and Architecture, Necmettin Erbakan University, Dr. Hulusi Balbay Street 12, Konya 42050, Turkey.
Kübra Aktaş, Department of Food Engineering, Faculty of Agriculture, Selçuk University, Hamdullah Suphi Tanriöver Street 1, Konya 42049, Turkey.
Hacer Levent, Mut Vocational School of Higher Education, Mersin University, University Street 69, Mersin 33600, Turkey.

Correspondence author:
Nermin Bilgiçli, tel.: +90-332-280 80 46; fax: +90-332-236 21 41, e-mail: nerminbil2003@hotmail.com

of diet in Turkey as it is a good source of B group vitamins, organic acids and free amino acids [14, 15]. Several studies analysed the effect of addition of buckwheat flour [11], whey concentrate [16], wheat germ and bran [17, 18], oat flour and steel cut oat [19] and carob flour [20] on chemical and functional quality of tarhana. However, no study focused on the use of citrus by-products in tarhana.

Tarhana contains high quality proteins due to the contents of both cereal and animal proteins. Yoghurt complements the amino acid profile of wheat flour by increasing the lysine content. Moreover, as a fermented product tarhana has several advantages. By using citrus albedos, which are rich in dietary fibre, minerals and bioactive compounds, the nutritional value of tarhana can be further improved. The purpose of this study was to determine changes in the chemical, functional and sensory properties of tarhana supplemented with lemon, orange and grapefruit albedo.

MATERIALS AND METHODS

Materials

Tarhana ingredients, commercial wheat flour, concentrated full fat yoghurt, tomato paste, onion, paprika, baker's yeast and salt were purchased from local markets in Konya, Turkey. Lemons, oranges and grapefruits were obtained from Mersin, Turkey. Lemon albedo (LA), orange albedo (OA) and grapefruit albedo (GA) were produced according to Çoksever and Sariçoban [21] with some modification. Albedo layer was picked and collected with hand from the lemon, orange and grapefruit samples. Albedo samples were dried at room temperature for 5 days and then at 40 °C for 8 h. Dehydrated albedo sample was ground with a grinder to < 400 μm particle size, and dry powders of albedo were stored vacuum-packed until use.

Tarhana production

Tarhana samples were prepared with and without albedo. For control tarhana (without albedo) preparation, 400 g wheat flour, 160 g yoghurt, 40 g tomato paste, 20 g chopped onions, 8 g paprika, 10 g yeast and 4 g salt were mixed in a Hobart Mixer (N 50; Hobart, North York, Ontario, Canada). After that, the dough was incubated at 30 °C for 72 h in plastic containers and dried at 55 °C for 48 h in an air convection oven (PFS-9; Özköseoğlu, Istanbul, Turkey). Dried samples were ground in a hammer mill equipped with 1 mm opening screen [22]. Tarhana samples containing albedo were prepared as described above with the replacement of wheat flour with LA, OA and GA at 5% and 10% (w/w) levels. Tarhana samples were kept in polyethylene bags at room temperature until used.

Chemical analyses

Moisture, ash, protein, cellulose and lipid contents of the samples were determined according to the methods of American Association of Cereal Chemists [23]. The pH was measured by a digital pH meter (WTW pH 315i/set; WTW, Weilheim, Germany) after mixing a 5 g sample with 100 ml distilled water.

Total phenolic content (*TPC*) was determined colorimetrically using Folin-Ciocalteu reagent as described by Paśko et al. [24] with some modifications. The extracts were prepared according to Chlopicka et al. [25]. Powdered samples (0.5 g) were extracted for 2 h with 10 ml solvent (methanol : HCl (0.16 mol·l^{-1}) : water, 8 : 1 : 1, v/v/v) at room temperature (25 °C). The extracts were separated by decantation and the residues were extracted again with 10 ml acetone (700 g·kg^{-1}) for 2 h and the extract was mixed with the initial methanol extract. For total phenolics assay, 0.3 ml of aliquot extract was mixed with 2.7 ml deionized water, 0.3 ml Na_2CO_3 (20% w/w), and 0.15 ml Folin-Ciocalteu reagent. The absorbance was measured at 725 nm by a spectrophotometer (DR 5000; Hach Lange, Düsseldorf, Germany). *TPC* was expressed as milligrams of gallic acid equivalents (GAE) per kilogram of dry weight (dw).

Antioxidant activity (*AA*) was measured using a free radical 2,2-diphenyl-1-picrylhydrazyl (DPPH) solution in methanol according to the method of Brand-Williams et al. [26] with some modifications. Ground samples (1 g) were extracted with 10 ml methanol during 2 h and centrifuged at 3000 × g for 10 min. The supernatant (100 μl) reacted with freshly made DPPH solution (3.9 ml, 25 mg·l^{-1}) in methanol. The absorbance at 515 nm was measured at 0 min and 30 min using a methanol blank. *AA* was calculated as percentage of discoloration:

$$AA = (1 - A_S/A_C) \times 100 \quad (1)$$

where A_S is absorbance of the sample at 30 min, A_C is absorbance of the control at 0 min. *AA* was expressed as millimoles of Trolox (6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid) equivalents (TE) per kilogram of dry weight.

For mineral matter analysis, dry samples were digested using closed vessel microwave digestion oven (MARS-5; CEM, Matthews, North Carolina, USA) with concentrated nitric acid and sulphuric acid, and the mineral element contents were determined by inductively coupled plasma atomic emission spectrometry (ICP–AES) using Varian Vista instrument (Agilent Technologies, Santa Clara, California, USA) [27].

Colour measurement

Colour measurement was conducted using a Minolta chroma meter CR-400 (Minolta, Osaka, Japan). The L^*, a^* and b^* values were determined according to the CIELab colour space system, where L^* corresponds to light/dark chromaticity, a^* to green/red chromaticity and b^* to blue/yellow chromaticity. Hue angle (arctan $[b^*/a^*]$) and the saturation index ($[a^{*2} + b^{*2}]^{1/2}$) values were calculated using a^* and b^* values.

Water absorption capacity and oil absorption capacity

Tarhana (5.0 g) was mixed with distilled water and sunflower oil (25 ml) in 50 ml centrifuge tubes, to measure for water and oil absorption capacity, respectively. Dispersions were stirred at 15 min intervals over a 60 min period and then centrifuged at 4000 $\times g$ for 20 min. Water and oil absorption capacity values were expressed as grams of water or oil absorbed per gram of tarhana [28].

Foaming capacity and foam stability

Tarhana (10 g) was mixed with distilled water and the tarhana-water mixture was stirred for 20 min. Then it was centrifuged at 4000 $\times g$ for 20 min. After centrifugation, supernatant was filtered and transferred to a Waring blender (Model 8011 E; Waring Products, New Hartford, Connecticut, USA) and whipped for 2 min at high speed. The solution was slowly poured into a graduated cylinder, and the volume of the foam was recorded after 10 s. Foaming capacity was expressed as the volume (in millilitres) of gas incorporated per millilitre of solution. Foam stability was recorded as the time passed until the half of the original foam volume had disappeared [28].

Sensory analysis

For sensory analysis, tarhana soups were prepared using tarhana powder. Tarhana powder (100 g) was mixed with 1000 ml distilled water (20 °C) and simmered for 12 min over medium heat with constant stirring. Tarhana soups were served to the panellists in porcelain plates at 50 °C. The samples were coded with numbers and served at random. Sensory assessment was made by fifteen trained panellists (7 females and 8 males) aged from 27 to 55 years. The panellists were asked to score the soups in terms of colour, taste, consistency, cohesiveness, sourness and grittiness using 9-point hedonic scale: 1 – dislike extremely, 2 – dislike very much, 3 – dislike moderately, 4 – dislike slightly, 5 – neither like nor dislike, 6 – like slightly, 7 – like moderately, 8 – like very much, 9 – like extremely.

Statistical analyses

Statistical analyses were performed using TARIST software, version 4.0 (Ege University, Izmir, Turkey). Duncan's multiple range tests was used to differentiate between the mean values.

RESULTS AND DISCUSSION

Raw material properties

The chemical composition of wheat flour and citrus albedo samples, which were used to replace wheat flour in tarhana formulations, are given in Tab. 1. The ash contents of all albedo samples were found between 24.9 $g \cdot kg^{-1}$ and 31.9 $g \cdot kg^{-1}$, which was 4.8 $g \cdot kg^{-1}$ for wheat flour. Albedo samples contained relatively low amounts of proteins and lipids compared to wheat flour. These values are in agreement with those reported by Romero-Lopez et al. [29]. Albedo samples were found to have significantly ($p < 0.05$) higher *TPC* and *AA* compared to wheat flour. In literature, citrus fruits were reported to have a high content of antioxidants and polyphenols [30–32]. The lowest pH value (4.65) was obtained for OA.

Ca, Fe, K and Mg contents in albedo samples were found higher than those of wheat flour. The high mineral content of citrus and citrus by products were reported previously [4, 33]. All albedo samples had higher yellowness (b^*) and saturation index value compared to wheat flour. Among albedo samples, OA had the lowest value of lightness (L^*) and the highest values of yellowness and saturation index (Tab. 1).

Chemical properties of tarhana samples

Chemical properties of tarhana samples containing different kinds of citrus albedo are summarized in Tab. 2. Tarhana samples prepared with LA, OA and GA contained more ash and cellulose, had higher values of *TPC* (except 5% OA) and *AA* compared to control tarhana, which was produced without albedo. The ash and cellulose contents of tarhana samples increased from 23.5 $g \cdot kg^{-1}$ and 15.8 $g \cdot kg^{-1}$ (control) up to 26.1 $g \cdot kg^{-1}$ and 32.8 $g \cdot kg^{-1}$, respectively, with 10% LA albedo addition. The protein contents of tarhana samples containing albedo decreased significantly ($p < 0.05$) at all addition levels com-

Tab. 1. Chemical composition and colour values of wheat flour and citrus albedo samples.

	Wheat flour	Lemon albedo	Orange albedo	Grapefruit albedo
Ash [g·kg^{-1}]	4.8±0.4^{c}	31.1±1.8^{a}	24.9±2.0^{b}	31.9±1.7^{a}
Proteins [g·kg^{-1}]	113.1±0.8^{a}	30.7±0.7^{b}	26.2±0.7^{c}	30.5±0.6^{b}
Lipids [g·kg^{-1}]	6.2±0.3^{a}	2.6±0.3^{b}	2.7±0.6^{b}	2.9±0.8^{b}
Total phenolic content [mg·kg^{-1}]	720.2±30.6^{d}	7110.4±41.4^{b}	6352.2±70.5^{c}	8440.7±61.3^{a}
Antioxidant activity [mmol·kg^{-1}]	32.13±0.18^{d}	1333.86±0.16^{a}	739.25±0.35^{c}	909.92±0.25^{b}
pH	6.28±0.04^{a}	4.92±0.03^{c}	4.65±0.03^{d}	5.01±0.03^{b}
Minerals [mg·kg^{-1}]				
Ca	253.2±5.6^{d}	6122.1±25.4^{b}	7156.4±36.7^{a}	3384.7±33.9^{c}
Cu	7.5±0.4^{b}	75.1±1.1^{a}	6.5±0.4^{bc}	5.6±0.2^{c}
Fe	12.3±0.7^{c}	239.7±1.5^{a}	238.0±1.4^{a}	125.2±1.0^{b}
K	1302.6±11.2^{d}	7981.4±12.4^{a}	6962.1±11.3^{c}	7412.3±11.4^{b}
Mg	381.2±18.1^{c}	712.3±19.4^{a}	532.6±19.0^{b}	513.1±19.7^{b}
P	1422.1±11.3^{a}	512.3±17.0^{b}	398.2±15.2^{c}	396.4±13.2^{c}
Zn	5.4±0.3^{c}	59.8±1.6^{a}	15.1±0.6^{b}	7.6±0.4^{c}
Colour values				
L^*	90.77±0.16^{c}	92.42±0.22^{b}	82.48±0.16^{d}	93.60±0.20^{a}
a^*	1.21±0.06^{a}	–1.74±0.13^{c}	–0.51±0.10^{b}	–0.69±0.13^{b}
b^*	10.42±0.16^{d}	22.10±0.17^{c}	28.19±0.08^{a}	27.32±0.16^{b}
Saturation index	10.49±0.16^{d}	22.17±0.17^{c}	28.19±0.16^{a}	27.33±0.17^{b}
Hue angle	83.39±0.25^{c}	94.51±0.39^{a}	91.03±0.42^{b}	91.45±0.49^{b}

Means with the same superscript within a row are not significantly different ($p < 0.05$).
Chemical compositions are on dry weight basis. Total phenolic content is expressed as milligrams of gallic acid equivalents per kilogram of dry weight. Antioxidant activity is expressed as millimoles of Trolox equivalents per kilogram of dry weight.

pared to control tarhana, due to the lower protein contents of citrus by products (Tab. 1, Tab. 2). Lipid contents of tarhana samples were not affected significantly ($p > 0.05$) by albedo at all addition levels. Similar results were obtained by Romero-Lopez et al. [29] for lipid contents of muffins containing fibre concentrate (10–15%) obtained from orange bagasse. Nassar et al. [34] reported that protein, lipid and saccharide contents of biscuits decreased, whereas ash and total dietary fibre increased, with the increasing level (up to 25%) of citrus by-products (orange peel and pulp). In the present study, the highest *TPC* (2450.6 mg·kg^{-1}) was obtained with 10% GA addition, and tarhana samples containing 10% LA gave highest *AA* (220.50 mmol·kg^{-1}) values. Ghasemi et al. [35] reported that *TPC* values were usually higher in peels than in tissues obtained from edible parts of the fruits. Bocco et al. [36] reported that citrus peels were a major source of natural antioxidants, and that lemon possessed the highest antioxidant potential among citrus fruits. Albedo addition to tarhana formulation did not change the pH values significantly compared to control tarhana. This can be attributed to low available saccharide content of albedo for growing bacteria and yeast in tarhana formulation.

Mineral contents of tarhana samples are given in Tab. 3. When compared to control tarhana, albedo addition increased the Ca, Fe, K and Zn (except GA) contents of tarhana samples. Mg content of tarhana did not change significantly with albedo addition. However, a significant ($p < 0.05$) decrease was observed in P contents of tarhana with albedo. In literature, depending on the ingredients used in tarhana formulation (different cereal flours, dairy products, vegetables), Ca, Fe, K, Mg and Zn contents of tarhana ranged between 590 mg·kg^{-1} and 1910 mg·kg^{-1}, 21 mg·kg^{-1} and 59 mg·kg^{-1}, 600 mg·kg^{-1} and 1820 mg·kg^{-1}, 300 mg·kg^{-1} and 1340 mg·kg^{-1} and 8 mg·kg^{-1} and 32 mg·kg^{-1}, respectively [15]. The main elements found in citrus fruits were Ca, K and Mg, which agrees with the fact that citrus peels are considered good sources of these minerals [37, 38]. Gorinstein et al. [4] reported that Fe contents of peeled lemons and lemon peels were significantly higher than those of peeled oranges and grape-

Tab. 2. Chemical properties of tarhana samples.

	Control	Lemon albedo		Orange albedo		Grapefruit albedo	
Albedo level [%]	0	5	10	5	10	5	10
Moisture [g·kg^{-1}]	61.5 ± 2.1^{a}	61.1 ± 1.9^{a}	60.9 ± 2.6^{a}	61.5 ± 2.4^{a}	61.6 ± 1.9^{a}	61.2 ± 3.2^{a}	60.5 ± 3.5^{a}
Ash [g·kg^{-1}]	23.5 ± 0.3^{c}	25.3 ± 0.4^{ab}	26.1 ± 0.4^{a}	25.5 ± 0.6^{ab}	26.0 ± 0.3^{a}	24.8 ± 0.4^{b}	25.6 ± 0.1^{ab}
Proteins [g·kg^{-1}]	131.2 ± 1.0^{a}	126.8 ± 1.6^{b}	124.5 ± 1.4^{bcd}	125.7 ± 1.0^{bc}	122.5 ± 1.4^{d}	126.5 ± 1.0^{b}	123.1 ± 1.1^{cd}
Cellulose [g·kg^{-1}]	15.8 ± 0.8^{f}	24.4 ± 0.6^{d}	32.8 ± 1.0^{a}	21.8 ± 0.4^{e}	26.5 ± 0.4^{c}	22.2 ± 0.3^{e}	30.3 ± 0.3^{b}
Lipids [g·kg^{-1}]	58.1 ± 0.6^{a}	57.8 ± 0.4^{a}	57.7 ± 0.3^{a}	57.9 ± 0.6^{a}	57.7 ± 0.7^{a}	57.8 ± 0.4^{a}	57.6 ± 0.8^{a}
Total phenolic content [mg·kg^{-1}]	1710.2 ± 20.1^{d}	2140.4 ± 80.4^{b}	2281.0 ± 52.6^{b}	1820.4 ± 82.5^{cd}	1864.1 ± 30.0^{c}	2220.3 ± 91.4^{b}	2450.6 ± 71.2^{a}
Antioxidant activity [mmol·kg^{-1}]	36.29 ± 0.19^{g}	123.48 ± 0.12^{b}	220.50 ± 0.14^{a}	57.64 ± 0.20^{e}	99.05 ± 0.16^{c}	38.53 ± 0.10^{f}	74.58 ± 0.12^{d}
pH	4.22 ± 0.03^{ab}	4.20 ± 0.01^{b}	4.33 ± 0.07^{a}	4.23 ± 0.03^{ab}	4.28 ± 0.04^{ab}	4.21 ± 0.01^{ab}	4.28 ± 0.10^{ab}

Means with the same superscript within a row are not significantly different ($p < 0.05$).
Chemical compositions are expressed on dry weight basis. Total phenolic content is expressed as milligrams of gallic acid equivalents per kilogram of dry weight. Antioxidant activity is expressed as millimoles of Trolox equivalents per kilogram of dry weight.

Tab. 3. Mineral content of tarhana samples.

	Control	Lemon albedo		Orange albedo		Grapefruit albedo	
Albedo level [%]	0	5	10	5	10	5	10
Ca [g·kg^{-1}]	562.1 ± 9.5^{f}	869.4 ± 7.5^{d}	1150.2 ± 7.4^{b}	923.5 ± 4.5^{c}	1265.0 ± 6.6^{a}	724.1 ± 6.1^{e}	873.4 ± 7.6^{d}
Cu [g·kg^{-1}]	2.7 ± 0.3^{c}	7.1 ± 0.6^{b}	10.6 ± 0.6^{a}	2.7 ± 0.4^{c}	2.6 ± 0.1^{c}	2.6 ± 0.1^{c}	2.5 ± 0.3^{c}
Fe [g·kg^{-1}]	13.4 ± 0.2^{e}	24.9 ± 0.6^{b}	36.9 ± 0.6^{a}	22.7 ± 0.3^{c}	37.9 ± 0.6^{a}	19.2 ± 0.6^{d}	24.5 ± 0.4^{b}
K [g·kg^{-1}]	4652.1 ± 17.2^{e}	5036.3 ± 17.0^{d}	5378.0 ± 17.0^{a}	5003.3 ± 8.5^{d}	5188.7 ± 9.9^{c}	5024.0 ± 19.8^{d}	5274.0 ± 16.5^{b}
Mg [g·kg^{-1}]	424.0 ± 13.9^{a}	441.2 ± 11.1^{a}	455.3 ± 12.1^{a}	431.0 ± 12.2^{a}	440.6 ± 15.6^{a}	434.0 ± 17.0^{a}	437.3 ± 16.1^{a}
P [g·kg^{-1}]	1754.4 ± 19.8^{a}	1702.2 ± 10.7^{b}	1662.6 ± 11.3^{c}	1688.0 ± 9.9^{bc}	1627.1 ± 11.6^{d}	1680.4 ± 14.1^{bc}	1629.0 ± 12.7^{d}
Zn [g·kg^{-1}]	7.5 ± 0.3^{d}	10.5 ± 0.4^{b}	13.1 ± 0.6^{a}	8.1 ± 0.6^{cd}	8.9 ± 0.6^{c}	7.6 ± 0.1^{d}	7.8 ± 0.1^{d}

Means with the same superscript within a row are not significantly different ($p < 0.05$). Contents are expressed on dry weight basis.

Tab. 4. Colour values of tarhana samples.

	Control	Lemon albedo		Orange albedo		Grapefruit albedo	
Albedo level [%]	0	5	10	5	10	5	10
L^*	88.41 ± 0.29^{a}	88.34 ± 0.31^{a}	87.60 ± 0.21^{b}	87.54 ± 0.27^{b}	87.10 ± 0.13^{b}	88.30 ± 0.25^{a}	87.21 ± 0.27^{b}
a^*	6.81 ± 0.20^{a}	5.52 ± 0.14^{b}	5.47 ± 0.17^{b}	6.54 ± 0.17^{a}	6.62 ± 0.14^{a}	6.48 ± 0.23^{a}	6.41 ± 0.14^{a}
b^*	34.75 ± 0.14^{e}	35.45 ± 0.37^{de}	35.87 ± 0.37^{d}	38.25 ± 0.35^{ab}	38.79 ± 0.48^{a}	37.51 ± 0.25^{bc}	37.42 ± 0.38^{c}
Saturation index	35.41 ± 0.28^{d}	35.88 ± 0.32^{cd}	36.28 ± 0.29^{c}	38.81 ± 0.28^{a}	39.35 ± 0.35^{a}	38.07 ± 0.27^{b}	37.97 ± 0.29^{b}
Hue angle	78.91 ± 0.29^{c}	81.16 ± 0.27^{a}	81.33 ± 0.45^{a}	80.30 ± 0.22^{b}	80.32 ± 0.33^{b}	80.20 ± 0.37^{b}	80.28 ± 0.40^{b}

Means with same superscript within a row are not significantly different ($p < 0.05$).

fruits and their peels. In contrast to the findings of these researchers, in our study, LA, OA and tarhana samples containing LA and OA (at 10% level) had the same ($p > 0.05$) Fe contents. These differences with published data may be caused by the variety, growing conditions and different origin of the fruits in the two studies.

Colour of tarhana samples

Colour values are presented in Tab. 4. LA and GA addition at a low level (5%) did not significantly affect the lightness values (L^*) of tarhana samples, whereas this value decreased significantly ($p < 0.05$) at high addition levels (10%) of LA, OA or GA. Albedo at 10% level increased the yellowness values (b^*) of tarhana samples, whereas LA addition at 5–10% level decreased the redness values (a^*) of tarhana samples significantly ($p < 0.05$), compared to the control. All addition levels of OA or GA did not change the redness of tarhana significantly. Raw material LA had the lowest redness/greenness value among raw materials. All albedo samples had higher yellowness values compared to the wheat flour (Tab. 1). The colour values of raw materials (LA, OA and GA) had significant effect on the colour of the final product. In the study conducted by Lario et al. [39], dried raw lemon fibre had lower lightness and higher redness, due to the Maillard reaction. Fernández-López et al. [40] reported that raw and cooked lemon albedo addition (up to 10%) decreased the lightness ($p < 0.05$) and increased the redness values of dry-cured sausages. Like yellowness value, saturation index values of tarhana samples containing 10% citrus albedo were found higher than that of control tarhana. Tarhana samples containing LA had the highest hue angle values.

Functional properties of tarhana samples

Functional properties are important for process design, sensory quality and consumer acceptability. Tarhana ingredients, fermentation, drying method and storage affect the functional properties of tarhana [11, 20, 28]. In the present study, functional properties of tarhana containing citrus albedo are given in Fig. 1. Water absorption capacity and foaming capacity were not affected by LA, OA and GA addition level. Water holding capacity of fibre depends on its chemical and physical structure, processing and soluble dietary fibre content [39, 41]. Oil absorption capacity values of tarhana samples generally were not found significantly ($p < 0.05$) different compared to control tarhana, except for samples containing 10% OA. In this study, the level of albedo could be too low to observe significant changes in water and oil holding capacity of tarhana samples. Tarhana samples containing OA had similar foam stability as control tarhana, whereas LA and GA addition decreased the foam stability of tarhana samples significantly ($p < 0.05$). Bilgiçli [11] found a significant increase in foaming capacity and stability, but significant decrease in water and oil absorption capacity of tarhana prepared with whole buckwheat flour (rich in dietary fibre) at an addition level above 60%.

Sensory properties of tarhana samples

Some sensory properties of tarhana soup are given in Tab. 5. Colour values of tarhana samples containing LA were evaluated by lower scores

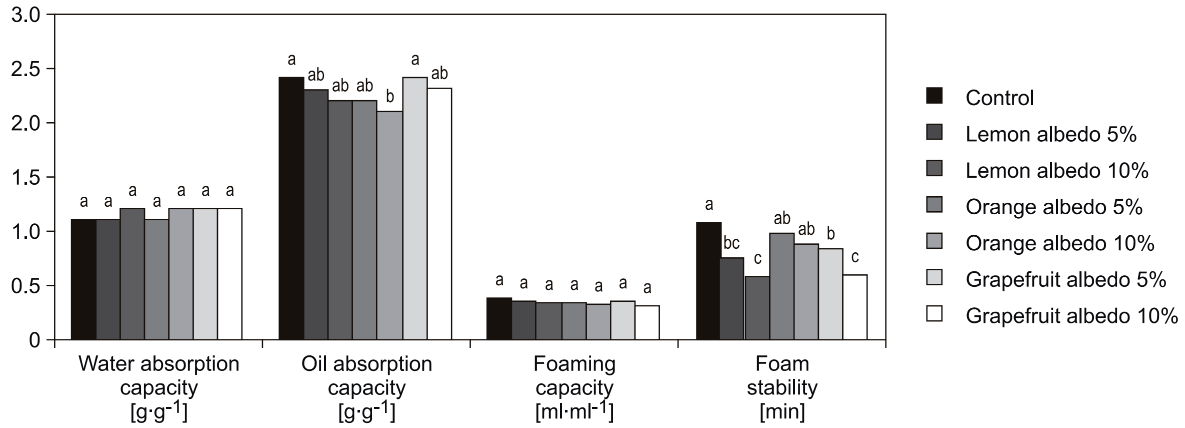

Fig. 1. Functional properties of tarhana samples.

Means with the same superscript are not significantly different ($p < 0.05$).

Tab. 5. Sensory properties of tarhana samples.

	Control	Lemon albedo		Orange albedo		Grapefruit albedo	
Albedo level [%]	0	5	10	5	10	5	10
Colour	7.8 ± 0.42^{ab}	6.5 ± 0.28^{de}	6.1 ± 0.14^{e}	7.2 ± 0.28^{bc}	8.2 ± 0.28^{a}	7.1 ± 0.14^{cd}	7.7 ± 0.28^{ab}
Taste	8.0 ± 0.28^{a}	6.1 ± 0.42^{b}	5.5 ± 0.28^{b}	8.1 ± 0.28^{a}	7.3 ± 0.42^{a}	4.5 ± 0.57^{c}	3.1 ± 0.28^{d}
Consistency	6.7 ± 0.57^{c}	7.5 ± 0.28^{bc}	7.5 ± 0.42^{bc}	7.5 ± 0.28^{bc}	8.2 ± 0.28^{ab}	8.1 ± 0.28^{ab}	8.5 ± 0.42^{a}
Cohesiveness	8.1 ± 0.28^{a}	7.8 ± 0.42^{a}	7.9 ± 0.42^{a}	7.8 ± 0.42^{a}	7.9 ± 0.57^{a}	8.2 ± 0.42^{a}	7.6 ± 0.57^{a}
Sourness	8.0 ± 0.42^{ab}	7.5 ± 0.28^{abc}	7.1 ± 0.28^{cd}	8.2 ± 0.28^{a}	7.9 ± 0.42^{ab}	6.4 ± 0.42^{d}	6.3 ± 0.28^{d}
Grittiness	8.0 ± 0.28^{a}	7.1 ± 0.57^{b}	7.0 ± 0.28^{b}	7.5 ± 0.28^{ab}	7.5 ± 0.14^{ab}	8.1 ± 0.14^{a}	7.5 ± 0.42^{ab}

Means with the same superscript within a row are not significantly different ($p < 0.05$).

by panellists. Tarhana containing 5–10% LA or OA gained higher taste score than that containing GA. Tarhana samples with OA had taste score similar to control tarhana. Naringin, a phenolic, bitter compound (flavanoid), which is contained in some varieties of citrus, mainly in grapefruit (*Citrus paradisi*) and shaddock (*Citrus grandis*), may be responsible for this decrease in taste score of tarhana [42, 43]. All tarhana soups containing citrus albedo had similar or higher consistency scores compared to control tarhana soup. Higher pectin contents of citrus by-products may cause an increase in viscosity/consistency of tarhana soup. Liu et al. [44] found that pectin was present mainly in the albedo, not in flavedo of the orange peels. Dietary fibre of citrus by-products had a higher content of the soluble fraction, including pectin. Sendra et al. [45] found that orange fibre increased the viscosity of yoghurt. Cohesiveness scores of tarhana soups did not change significantly with albedo addition. Acidic and sour taste is a typical property of tarhana. Sourness of the tarhana soups containing 5% LA and 5–10% OA were found similar with control tarhana. The lowest sourness scores were obtained for GA addition into tarhana formulation. Compared to control tarhana, LA addition decreased the grittiness scores of tarhana soups. Romero-Lopez et al. [29] reported that control muffins and muffins containing 10% dietary fibre-rich orange bagasse product (DFROBP) were similarly accepted in sensory analysis, whereas highest DFROBP levels decreased the acceptability score of muffins. In the study conducted by Nassar et al. [34], biscuits with 5% and 15% orange pulp and peel had the highest level of acceptance for all sensory characteristics. In another study, orange peel powders were found suitable for addition to the biscuit formulation at levels of up to 10%, without any adverse effects on sensory characteristics of biscuits [46].

CONCLUSIONS

The effects of LA, OA and GA on the chemical, nutritional and functional properties of tarhana were investigated in this study. LA, OA and GA increased the ash and cellulose contents and antioxidant activity values of tarhana samples compared to control tarhana, which was produced without albedo. Significant ($p < 0.05$) increase was determined for Ca, Fe and K contents of tarhana samples with albedo. While tarhana samples containing OA had similar foam stability values to the control tarhana, foaming capacity of samples did not change with citrus albedo addition. While all kinds of citrus albedo at 10% level decreased lightness of tarhana samples, citrus albedo increased yellowness of tarhana. GA samples increased the consistency of tarhana soups significantly ($p < 0.05$). It can be concluded that OA and LA can be used in tarhana formulation successfully at levels of up to 10% and 5%, respectively.

REFERENCES

1. Braddock, R. J.: By-products of citrus fruits. Food Technology, *49*, 1995, pp. 74–77.
2. Topuz, A. – Topakci, M. – Çanakci, M. – Akinci, I. – Özdemir, F.: Physical and nutritional properties of four orange varieties. Journal of Food Engineering, *66*, 2005, pp. 519–523.
3. Turhan, I. – Tetik, N. – Karhan, M.: Turunçgil kabuk yağlarinin elde edilmesi ve gida endüstrisinde kullanimi. Gida Teknolojileri Elektronik Dergisi, *3*, 2006, pp. 71–77.
4. Gorinstein, S. – Martín-Belleso, O. – Park, Y. – Haruenkit, R. – Lojek, A. – Číž, M. – Caspi, A. – Libman, I. – Trakhtenberb, S.: Comparison of some biochemical characteristics of different citrus fruits. Food Chemistry, *74*, 2001, pp. 309–315.
5. Schieber, A. – Stintzing, F. C. – Carle, R.: By-products of plant food processing as a source of functional compounds. Recent developments. Trends in Food

Science and Technology, *12*, 2001, pp. 401–413.
6. Chou, C. F. – Huang, Y. L.: Comparison of the chemical composition and physical properties of different fibre prepared from the peel of *Citrus sinengis* L. cv. Liucheng. Journal of Agricultural and Food Chemistry, *51*, 2003, pp. 2615.
7. Charalampopoulos, D. – Wang, R. – Pandiella, S. S. – Webb, C.: Application of cereals and cereal components in functional foods: a review. International Journal of Food Microbiology, *79*, 2002, pp. 131–141.
8. Brown, L. – Rosner, B. – Willett, W. W. – Sacks, F. M.: Cholesterol-lowering effects of dietary fibre: a meta-analysis. American Journal of Clinical Nutrition, *69*, 1999, pp. 30–42.
9. Ekici, L. – Ercoşkun, H.: Et ürünlerinde diyet lifi kullanimi. Gida Teknolojileri Elektronik Dergisi, *1*, 2007, pp. 83–90.
10. Ibanoğlu, Ş. – Ainsworth, P. – Wilson, G. – Hayes, G. D.: The effect of fermentation conditions on the nutrients and acceptability of tarhana. Food Chemistry, 53, 1995, pp. 143–147.
11. Bilgiçli, N.: Effect of buckwheat flour on chemical and functional properties of tarhana. LWT–Food Science and Technology, *42*, 2009, pp. 514–518.
12. Temiz, A. – Pirkul, T.: Tarhana fermentasyonunda kimyasal ve mikrobiyolojik değişimler, Gida, *15,* 1990, pp. 119–126.
13. Tamime, A. Y. – Muir, D. D. – Khaskheli, M. – Barclay, M. N. I.: Effect of processing conditions and raw materials on the properties of kishk. I. Compositional and microbiological qualities. Lebensmittel-Wissenschaft und Technologie, *33*, 2000, pp. 444–451.
14. Ibanoğlu, S. – Ainsworth, P. – Hayes, G.: Extrusion of tarhana: effect of operating variables on starch gelatinization. Food Chemistry, *57*, 1996, pp. 541–544.
15. Dağlioğlu, O.: Tarhana as a traditional Turkish fermented cereal food. Its recipe, production and composition. Nahrung, *44*, 2000, pp. 85–88.
16. Ertaş, N. – Sert, D. – Demir, M. K. – Elgün, A.: Effect of whey concentrate addition on the chemical, nutritional and sensory properties of tarhana (a Turkish fermented cereal-based food). Food Science and Technology Research, *15,* 2009, pp. 51 – 58.
17. Bilgiçli, N. – Elgün, A. – Herken, E. N. – Türker, S. – Ertaş, N. – Ibanoğlu, Ş.: Effect of wheat germ/bran addition on the chemical, nutritional and sensory quality of tarhana. Journal of Food Engineering, *77*, 2006, pp. 680–686.
18. Bilgiçli, N. – Ibanoğlu, Ş.: Effect of wheat germ and wheat bran on the fermentation activity, phytic acid cpntent and colour of tarhana, a wheat flour-yohurt mixture. Journal of Food Engineering, *78*, 2007, pp. 681–686.
19. Kilci, A. Y. – Goçmen, D.: Dietary fibre and beta-glucan content of oat tarhana: Turkish fermented product. Journal of Agricultural Science, *4*, 2012, pp. 72–77.
20. Çağlar, A. – Erol, N. – Elgün, M. S.: Effect of carob flour substitution on chemical and functional properties of tarhana. Journal of Food Processing and Preservation, *37*, 2013, pp. 670–675. DOI: 10.1111/j.1745-4549.2012.00708.x.
21. Çoksever, E. – Saricoban, C.: Effects of bitter orange albedo addition on the quality characteristics of naturally fermented Turkish style sausages (sucuks). Journal of Food, Agriculture and Environment, *8*, 2010, pp. 34–37.
22. Bilgiçli, N. – Ibanoğlu, Ş. – Herken, E..: Effect of dietary fibre addition on the selected nutritional properties of cookies. Journal of Food Engineering, *78*, 2007, pp. 86–89.
23. AACC Approved methods of the American Association of Cereal Chemists. 8th ed. St Paul: American Association of Cereal Chemists, 1990. ISBN 0913250317
24. Paśko, P. – Bartoń, H. – Zagrodzki, P. – Gorinstein, S. – Folta, M. – Zachwieja, Z.: Antocyanins, total phenols and antioxidant activity in amaranth and quino seeds and sprouts during their growth. Food Chemistry, *115*, 2009, pp. 994–998.
25. Chlopicka, J. – Pasko, P. – Gorinstein, S. – Jedryas, A. – Zagrodzki, P.:. Total phenolic and total flavonoid content, antioxidant activity and sensory evaluation of pseudocereal breads. LWT–Food Science and Technology, *46*, 2012, pp. 548–555.
26. Brand-Williams, W. – Cuvelier, M. E. – Berset, C.: Use of free radical method to evaluate antioxidant activity. Lebensmittel–Wissenschaft und Technologie, *28*, 1995, pp. 25–30.
27. Bubert, H. – Hagenah, W. D.:. Detection and measurement. In: Boumans, P. W. J. M. (Ed.): Inductively coupled plasma emission spectroscopy. New York: Wiley-Interscience, 1987, pp. 536–567.
28. Hayta, M. – Alpaslan, M. – Baysar, A.: Effect of drying methods on functional properties of tarhana: a wheat flour-yoghurt mixture. Journal of Food Science, *67*, 2002, pp. 740–744.
29. Romero-Lopez, M. – Osorio-Diaz, P. – Bello-Perez, L. A. – Tovar, J. – Bernardino-Nicanor, A.: Fibre concentrate from orange (*Citrus sinengis* L.) Bagase: Characterization and application as bakery product ingredient. International Journal of Molecular Sciences, *12*, 2011, pp. 2174–2186.
30. Baker, R. A.: Potential dietary benefits of citrus pectin and fibre. Food Technology, *48*, 1994. pp. 133–139.
31. Jayaprakasha, G. K. – Patil, B. S.: In vitro evaluation of of the antioxidant activities in fruit extracts from citron and blood orange. Food Chemistry, *101*, 2007, pp. 410–418.
32. O'Shea, N. – Arendt, E. K. – Gallagher, E.: Dietary fibre and phytochemical characteristics of fruit and vegetable by-products and their recent applications as novel ingredients in food products. Innovative Food Science and Emerging Technologies, *16*, 2012, pp. 1–10.
33. Ting, S. V.: Nutrients and nutrition of citrus fruits. In: Nagy, S. – Attaway, J. A. (Ed.): Citrus nutrition and quality. ACS Symposium Series. Washington, D. C.: American Chemical Society, 1980, pp. 1–24. ISBN 9780841205956. DOI: 10.1021/bk-1980-0143.ch001
34. Nassar, A. G. – AbdEl-Hamied, A. A. – El-Naggar, E. A.: Effect of citrus by-products flour incorporation on chemical, rheological and orga-

noleptic characteristics of biscuit. World Journal of Agricultural Sciences, *4*, 2008, pp. 612–616.
35. Ghasemi, K. – Ghasemi, Y. – Ebrahimzadeh, M. A.: Antioxidant activity and phenol and flavonoid contents of 13 citrus species peels and tissues. Pakistan Journal of Pharmaceutical Sciences, *22*, 2009, pp. 277–281.
36. Bocco, A. – Cuvelier, M. E. – Richard, H. – Berset, C.:. Antioxidant activity and phenolic composition of citrus peel and seed extracts. Journal of Agricultural and Food Chemistry, *46*, 1998, pp. 2123–2129.
37. Bampidis, V. A. – Robinson, P. H.: Citrus by-products as ruminant feeds: A review. Animal Feed Science and Technology, *128*, 2006, pp. 175–217.
38. Barros, H. R. M. – Ferreira, T. A. P. C. – Genovese, M. I.: Antioxidant capacity and mineral content of pulp and peel from commercial cultivars of citrus from Brazil. Food Chemistry, *134*, 2012, pp. 1892–1898.
39. Lario, Y. – Sendra, E. – García-Pérez, J. – Fuentes, C. – Sayas-Barberá, E. – Fernández-López, J. – Pérez-Alvarez, J. A.: Preparation of high dietary fibre powder from lemon juice by-products. Innovative Food Science and Emerging Technologies, *5*, 2004, pp. 113–117.
40. Fernández–López, J. – Fernández-Ginéz, J. M. – Aleson-Carbonell, L. – Sendra, E. – Sayas-Barberá, E. – Pérez-Alvarez, J. A.: Application of functional citrus by-products to meat products. Trends in Food Science and Technology, *15*, 2004, pp. 176–185.
41. Grigelmo-Miguel, N. – Martín-Belloso, O.: Comparison of dietary fibre from by-products of processing fruits and greens and from cereals. Lebensmittel-Wissenschaft and Technologie, *32*, 1999, pp. 503 –508.
42. González-Molina, E. – Domínguez-Perles, R. – Moreno, D. A. – García-Viguera, C.: Natural bioactive compounds of *Citrus limon* for food and health. Journal of Pharmaceutical and Biomedical Analysis, *51*, 2010, pp. 327–345.
43. Ting, S. V.: Fruit glycoside hydrolysis, enzymic hydrolysis of naringin in grapefruit. Journal of Agricultural and Food Chemistry, *6*, 1958, pp. 546–549.
44. Liu, Y. – Shi, J. – Langrish, T. A. G.: Water-based extraction of pectin from flavedo and albedo of orange peels. Chemical Engineering Journal, *120*, 2006, pp. 203–209.
45. Sendra, E. – Kuri, V. – Fernández-Lopez, J. – Sayas-Barberá, E. – Navarro, C. – Pérez-Alvarez, J. A.: Viscoelastic properties of orange fibre enriched yoghurt as a function of fibre dose, size and thermal treatment. LWT–Food Science and Technology, *43*, 2010, pp. 708–714.
46. Magda, R. A. – Awad, A. M. – Selim, K. A.: Evaluation of mandarin and navel orange peels as natural sources of antioxidant in biscuits. Alexandria Journal of Food Science and Technology, Special volume conference, 2008, pp. 75–82.

Received 23 September 2013; 1st revised 28 October 2013; accepted 6 November 2013; published online 24 April 2014.