

# Effect of fermentation on some quality properties of cornelian cherry tarhana produced from different cereal/pseudocereal flours

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## RESEARCH ARTICLE

### Abstract

Cornelian cherry tarhana (CCT), which is a traditional, cereal based powder product for making soup, has a geographical mark in Turkey. CCT is quite different than the traditional fermented tarhana: there is no fermentation process during traditional production from refined wheat flour. The aim of this study was to investigate the effect of fermentation on quality properties of CCT samples produced with wheat flour (as control), buckwheat flour, durum wheat clear flour or whole grain hull-less barley flour. Ash, protein, fat and total dietary fibre contents of the samples increased when clear flour and whole grain hull-less barley flour were used compared to control CCT. Total sugar contents of fermented samples decreased compared to non-fermented ones. The results indicated that fermented CCT samples had significantly higher total phenolic compounds and DPPH radical scavenging activity, however they had lower ascorbic acid and anthocyanin contents. Non-fermented CCT produced with buckwheat flour had the highest general acceptability in sensory properties. CCT produced with buckwheat flour could be an alternative gluten-free soup product for celiac and gluten sensitive people.

**Keywords:** cornelian cherry tarhana, fermentation, quality properties, cereal flours, buckwheat flour

### 1. Introduction

Traditional foods reflect each country or community's history, culture, lifestyle and beliefs and vary based on climatic, agricultural and economic conditions, dietary and regional habits (Trichopoulou *et al.*, 2007). Fermentation has been known for thousands of years and was developed by ancient people to preserve food products (Ross *et al.*, 2002; Tamang and Samuel, 2010). Most of the ethnic fermented foods are produced by natural fermentation (Tamang and Samuel, 2010). Many traditional fermented foods are produced in homes, villages, small-scale industries and on slightly large commercial scale. In the distant past, there were no verified data on characteristics of traditional foods. In recent years, the number of studies about traditional fermented foods around the world has rapidly increased (Blandino *et al.*, 2003).

Fermentation is one of the oldest and most economical ways of food processing and preservation (Achi, 2005; Ross *et al.*,

2002). Biochemical activities of microorganisms or enzymes during fermentation cause significant modifications in foods (Tamang and Samuel, 2010). Cereal fermentation has been shown to enhance the nutritional value of grain, decrease the content of anti-nutrients (such as phytates, tannins), release flavour compounds and inhibit spoilage microorganisms (Kohajdova and Karovičová, 2007).

Turkey plays an important role in cornelian cherry (*Cornus mas* L.) production; especially Northern Anatolia region has the largest production (Ercisli *et al.*, 2011). The Turkish Statistical Institute reported that 10.962 tons of cornelian cherry were produced in Turkey in 2016. Cornelian cherry is either consumed directly or processed into jam, marmalade, paste, sherbet, dried fruit and tarhana (Ercisli *et al.*, 2011). Cornelian cherry was also targeted in the EU FP7 project entitled 'BaSeFood: Sustainable exploitation of bioactive components from the Black Sea Area traditional foods' in which the composition of cornelian cherry and its utilisation on traditional foods were investigated in a cross-country

perspective (D'Antuono *et al.*, 2017). They also indicated that high content of bioactive compounds can increase the utilisation of cornelian cherry in food products.

Cornelian cherry tarhana (CCT) is a traditional soup product in Turkey, as well as in Balkan countries and Eastern Europe. It is prepared by mixing cornelian cherry pulp, wheat flour and salt followed by dividing it into small pieces of dough, drying, sieving and final drying in a sunless environment for six days, followed by sieving and packaging. There is not any fermentation process during the traditional production. CCT is sold in powder form and mixed with water and cooked with some spices or garlic and served hot.

Buckwheat flour is nutritionally superior compared to cereal grains in terms of amino acid balance (Steadman *et al.*, 2001) and rich in antioxidants, trace elements and total dietary fibre. Buckwheat proteins have a high biological value, but low true digestibility (Bonafaccia *et al.*, 2003). As buckwheat flour does not contain gluten, CCT with buckwheat flour can be a new product for the celiac and gluten sensitive people.

Durum wheat clear flour, which is a by-product of the semolina industry, is obtained for approximately 5-15% during durum wheat milling to semolina (Sayaslan *et al.*, 2018). Sayaslan *et al.* (2018) reported the chemical compositions of clear flours obtained from three different semolina manufacturers, like starch (66.7-70.5%), non-starch carbohydrates (11.6-13.1%), protein (14.4-14.9%), crude oil (2.1-3.7%) and ash (1.28-1.72%). If the yield and nutritional value of clear flour is considered, the use for food products is evident.

It has been reported that barley has several potential health benefits due to the balanced protein content, and is rich in minerals and vitamins, phenolics and dietary fibres, particularly  $\beta$ -glucan (Baik and Ullrich, 2008). Hull-less barley contains higher protein and starch content compared to hulled barley. Baik and Ullrich (2008) stated that hull-less barley contains 11-20% total dietary fibre, and 11-14% and 3-10% of this amount are in insoluble and soluble forms, respectively.

The objective of this study was to investigate the effect of fermentation on some chemical, nutritional, colour and sensory properties of cornelian cherry tarhana produced with wheat flour (as control), buckwheat flour, whole grain hull-less barley flour and durum wheat clear flour. It was hypothesised that a fermentation process could increase the nutritional and bioactive properties and also develop sensory properties of cornelian cherry tarhana formulated with different cereal or pseudocereal flours.

## 2. Materials and methods

Cornelian cherry fruits were collected from the mountainous regions of the West Black-Sea in Turkey and purchased from the local producers in Bolu, Turkey. They were washed followed by removing the seeds and processed into fruit pulp. Bread wheat flour (WF) was provided from the local milling company in Bolu, Turkey. Buckwheat (cv. Güneş) was obtained from the Bahri Dağdaş International Agricultural Research Institute, Konya, Turkey and roller-milled (Roller Mill Quadrumat Junior, Brabender GmbH & Co., Duisburg, Germany) into fine buckwheat flour (BWF). Durum wheat clear flour (CF) as by-product of semolina industry was provided from the pasta company in Düzce, Turkey. Hull-less barley (cv. Özen) was acquired from the Field Crops Central Research Institute (Ankara, Turkey), and stone-milled (A700 Genuine Wood; Good Mills Company, Lienz, Austria) into whole grain hull-less barley flour (WHBF).

### Cornelian cherry tarhana production

CCT produced with wheat flour (TWF), buckwheat flour (TBW), clear flour (TCF) and whole grain hull-less barley flour (THB) were entirely prepared according to the traditional production process. The amounts of the ingredients of CCT dough were expressed as percent of total dough weight and are shown in Table 1. Cornelian cherry pulp (P) was mixed (Kitchen Aid, Benton Harbor, MI, USA) with appropriate flour until catching suitable dough consistency after which table salt was added. For the production of non-fermented CCT samples, the dough mixture was kneaded followed by dividing into small pieces of dough, drying in a sunless environment for 24 h, then sieving through a 2 mm sieve, final drying in a sunless environment at room temperature for six days and then sieving through a 1 mm sieve. For the production of

**Table 1. Cornelian cherry tarhana formulations prepared similar dough consistencies.<sup>1</sup>**

Ingredients (%)	Cornelian cherry tarhanas			
	TWF	TBW	TCF	THB
Cornelian cherry pulp	52.7	55.3	58.0	59.4
Salt	5.3	5.5	5.8	5.9
Wheat flour	42.0	–	–	–
Buckwheat flour	–	39.2	–	–
Clear flour	–	–	36.2	–
Whole grain hull-less barley flour	–	–	–	34.7

<sup>1</sup> TWF = tarhana with wheat flour (control); TBW = tarhana with buckwheat flour; TCF = tarhana with clear flour; THB = tarhana with whole grain hull-less barley flour.

fermented CCT samples, the dough samples were allowed to bulk fermentation at 25 °C temperature and 60% relative humidity for 72 h. The next production steps were similar with the production of non-fermented samples. CCT produced with wheat flour (TWF) was used as control sample. The sample of CCT with buckwheat flour (TBW) was produced in separate production environment in order to prevent gluten contamination. The production of non-fermented and fermented CCT samples was carried out as duplicate in separate days. CCT products were stored in powder form in plastic bags at 4 °C temperature until analysed.

### Chemical analyses

AACCI Approved Methods of Analysis were followed for determinations of moisture (44-15.02), ash (08-01.01), protein (46-12.01) and crude oil (30-25.01) contents of the flours and CCT samples (AACCI, 2010). Total starch content and total dietary fibre contents were determined using Megazyme Total Starch Assay Kit and Total Dietary Fibre Assay Kit (Megazyme International Ireland Limited, Wicklow, Ireland), respectively. Total and reducing sugar contents of the pulp and CCT products were determined according to the Lane-Eynon Method (AOAC, 2016). The pH values of CCT products were determined according to İbanoglu *et al.* (1995). The total titratable acidity of the samples was calculated as sulfuric acid and/or malic acid as described by Turkish Tarhana Standard Method No: TS 2282 (Turkish Standards Institution, 2004). Salt contents of the CCT products were determined according to the Mohr method. The results were given on dry weight basis.

### Determination of nutritional properties

$\beta$ -glucan contents of WF and WHBF and CCT samples made of WF and WHBF flours were determined by using Megazyme Mixed-Linkage  $\beta$ -glucan Assay Kit. L-ascorbic acid contents of the cornelian cherry pulp and the CCT products were determined by using Megazyme L-Ascorbic Acid Assay Kit. Total anthocyanin contents of the cornelian cherry pulp and the CCT products were determined according to Giusti and Wrolstad (2001) and Yilmaz *et al.* (2009). In this assay procedure, total anthocyanin content was measured according to pH differential absorbance method. The results were reported on dry weight basis.

### Determination of phenolic compounds

Phenolic compound contents of the cornelian cherry pulp and the CCT products were determined as total (free and bound) and free forms on the basis of the modified Folin-Ciocalteu method. Total phenolic compound (TPC) contents were determined by using dimethyl sulfoxide (DMSO) solvent according to the methods of Gutfinger (1981) and Singleton *et al.* (1999). In the TPC

extraction, sample to DMSO solvent ratio was 1:25. Free phenolic compounds (FPC) were determined according to the methods of Ragaee *et al.* (2006) and Zielinski and Kozłowska (2000). FPC contents of the pulp and the CCT products were determined using 50 and 80% methanol solvents. The absorbance values of extracts were measured in the spectrophotometer (Shimadzu 1700, Shimadzu Corporation, Kyoto, Japan) at the wavelength of 725 nm. The standard lines with each extraction solvent were prepared by using gallic acid. The results were expressed as mg gallic acid equivalent/g sample on dry weight basis.

### Determination of antioxidant activities

Antioxidant activity of the cornelian cherry pulp and the CCT products were determined according to the 2,2-diphenyl-1-picrylhydrazyl (DPPH) scavenging activity (%) method as described by Yu *et al.* (2002). In addition, antioxidant activity was detected as Trolox equivalent antioxidant capacity (TEAC, mmol Trolox equivalent/kg sample) by using 2,2'-azinobis-3-ethylbenzotiazolin-6-sulfonate (ABTS<sup>•+</sup>) as free radical compound as described by Ragaee *et al.* (2006) with slight modifications. The results were given on dry weight basis.

### Determination of colour properties

Colour properties of cornelian cherry pulp, cereal/pseudocereal flours and CCT products were detected by measuring the L\* (lightness), a\* (redness) and b\* (yellowness) values using a Konica Minolta CR-400 (Osaka, Japan). The samples were measured as triplicate and the mean values were reported with standard deviations.

### Sensory analysis

Cornelian cherry tarhana soups were prepared according to traditional method, like 60 g CCT powder was mixed with 400 ml water, and then mixture was cooked and stirred for 10 min. Then, the soups were served to panellists as hot. Twenty-four panellists were asked to score the soups in terms of colour, taste, odour, mouth feel, consistency, sourness and overall acceptability using a 9-point hedonic scale with 1 – dislike extremely, 5 – neither like nor dislike, and 9 – like extremely.

### Statistical analysis

All experiments were performed in triplicate and the mean values and corresponding standard deviations were reported. Data were analysed by one-way analysis of variance (ANOVA) in SPSS (Version 20.0 for Windows, SPSS, Chicago, IL, USA) statistical programme. The Duncan's multiple range tests was used to determine the differences among means at 5% significance level.

### 3. Results and discussion

#### Chemical compositions of the raw materials

Chemical compositions of cornelian cherry pulp and cereal/pseudocereal flours were shown on dry weight basis (dwb) in Table 2. Moisture and ash contents of the flours varied in the ranges of 11.0-14.0% and 0.60-2.27%, respectively. CF and WF had the highest (2.27%) and the lowest (0.60%) ash values, respectively. BWF had the lowest protein content (8.3%) while WHBF had the highest protein content (16.6%) in this study. Besides, the highest and the lowest titration acidity values were determined in CF and in WF and BWF, respectively. High titration acidity in CF is attributed to contain the bran and germ fractions that are rich in fatty acids, phenolic acids and phytic acid. CF also had the highest crude oil content (3.6%), WHBF followed the CF in terms of crude oil content (2.8%). BWF and WHBF included the highest (73.4%) and the lowest (52.5%) total starch contents, respectively. Cornelian cherry pulp had 78.6% moisture content. Its titration acidity values were indicated as sulphuric acid and malic acid species and found as 1.15% and 1.53%, respectively.

Colour properties of cornelian cherry pulp and cereal/pseudocereal flours were also shown in Table 2. The highest  $L^*$ ,  $a^*$  and  $b^*$  values were determined in WF (92.4), CF and WHBF (0.7) and CF (15.8) flours, respectively. The  $L^*$ ,  $a^*$  and  $b^*$  values of cornelian cherry pulp were in the order of 28.5, 22.4, 8.3, respectively.

#### Chemical characteristics of cornelian cherry tarhanas

The pH measurements showed that the pH ranges of the tarhana doughs in non-fermented and fermented processes were 3.84-4.08 and 3.86-4.15, respectively, and slightly decreased after final drying in both processes. The pH values after final drying of non-fermented CCT samples ranged between 3.76 (TWF) and 4.05 (TCF), while that of fermented samples ranged between 3.81 (TWF) and 4.10 (TCF). It was seen that the pH values of TWF (control) and TCF had the lowest and the highest values in both processes, respectively.

Some chemical characteristics of CCT products are presented on dwb in Table 3. The moisture contents of the tarhana products ranged between 10.5 and 11.9%. The ash contents of the CCT products were in the range of 1.05-4.20%. The fermented TCF sample had the highest ash content (4.20%) while the fermented TWF (control) sample had the lowest ash content (1.05%,  $P < 0.05$ ) as expected from the ash contents of respective flours. After the fermentation process, the ash content of CCT samples with buckwheat flour and clear flour considerably increased on dwb ( $P < 0.05$ ). It has been reported that this might be due to the degradation of phytic acid during fermentation (Onipe *et al.*, 2015). In comparison to the CCT samples, CCT with clear flour had the highest crude oil content before and after fermentation ( $P > 0.05$ ). This could be due to contain the bran and germ fractions that have a high amount of crude oil (Fustier *et al.*, 2007). The protein contents of CCT products in non-fermented and fermented forms were between 6.4-11.0% and 6.4-11.3%, respectively. After the fermentation process, the protein content of TWF, TCF and THB slightly increased on dwb ( $P < 0.05$ ), except

**Table 2. Chemical composition and colour properties of cornelian cherry pulp and flours.<sup>1</sup>**

Chemical compound	P	WF	BWF	CF	WHBF
Moisture (%)	78.6±0.17	14.0±0.06	13.0±0.06	12.2±0.04	11.0±0.02
Ash <sup>2</sup> (%)	n.a.	0.60±0.025	1.21±0.133	2.27±0.021	2.13±0.014
Crude oil <sup>2</sup> (%)	n.a.	1.6±0.12	1.6±0.12	3.6±0.09	2.8±0.16
Protein <sup>2</sup> (%)	n.a.	12.4±0.12	8.3±0.06	14.9±0.11	16.6±0.23
Total starch <sup>2</sup> (%)	n.a.	70.4±3.29	73.4±3.75	54.3±1.49	52.5±1.35
Titration acidity <sup>3</sup> (%)	1.15±0.094	0.11±0.028	0.11±0.028	0.55±0.073	0.27±0.028
Titration acidity <sup>4</sup> (%)	1.53±0.199	0.15±0.038	0.15±0.038	0.75±0.100	0.37±0.038
$L^*$ brightness	28.5±0.18	92.4±0.03	86.3±0.19	84.6±0.05	88.0±0.16
$a^*$ redness	22.4±0.24	0.6±0.01	0.3±0.03	0.7±0.02	0.7±0.04
$b^*$ yellowness	8.3±0.20	10.8±0.04	7.2±0.03	15.8±0.08	11.3±0.02

<sup>1</sup> P = cornelian cherry pulp; WF = wheat flour; BWF = buckwheat flour; CF = clear flour; WHBF = whole-grain hull-less barley flour; Values are mean ± standard deviation (n=6). n.a. = not analysed.

<sup>2</sup> Values are on dry weight basis.

<sup>3</sup> Values are based on sulphuric acid.

<sup>4</sup> Values are based on malic acid.

**Table 3. Chemical compositions and colour properties (L\*, a\*, b\*) of non-fermented (N-) and fermented (F-) cornelian cherry tarhanas (CCT) produced with different flours.<sup>1</sup>**

CCT product <sup>2</sup>	Moisture (%)	Ash <sup>3</sup> (%)	Crude oil <sup>3</sup> (%)	Protein <sup>3</sup> (%)	Salt <sup>3</sup> (%)	Total starch <sup>3</sup> (%)	L* (brightness)	a* (redness)	b* (yellowness)
N-TWF	10.5±0.16 <sup>d</sup>	1.07±0.232 <sup>c</sup>	1.0±0.04 <sup>cd</sup>	9.1±0.12 <sup>f</sup>	9.2±0.55 <sup>b</sup>	50.9±2.22 <sup>a</sup>	69.29±0.85 <sup>c</sup>	19.42±1.15 <sup>a</sup>	6.70±0.34 <sup>g</sup>
N-TBW	10.9±0.17 <sup>c</sup>	1.48±0.292 <sup>c</sup>	1.1±0.08 <sup>c</sup>	6.4±0.24 <sup>g</sup>	8.8±0.32 <sup>b</sup>	44.7±3.01 <sup>b</sup>	74.63±1.15 <sup>ab</sup>	11.46±0.89 <sup>c</sup>	9.65±0.11 <sup>cd</sup>
N-TCF	11.6±0.23 <sup>a</sup>	2.72±0.228 <sup>b</sup>	2.4±0.15 <sup>a</sup>	10.1±0.07 <sup>d</sup>	11.6±0.33 <sup>a</sup>	35.4±1.44 <sup>c</sup>	67.62±1.54 <sup>c</sup>	12.44±1.35 <sup>c</sup>	10.41±0.84 <sup>bc</sup>
N-THB	11.9±0.19 <sup>a</sup>	2.40±0.872 <sup>b</sup>	1.7±0.16 <sup>b</sup>	11.0±0.09 <sup>b</sup>	9.0±1.50 <sup>b</sup>	35.8±0.91 <sup>c</sup>	67.75±1.66 <sup>c</sup>	13.94±0.80 <sup>b</sup>	9.12±0.76 <sup>de</sup>
F-TWF	10.1±0.21 <sup>e</sup>	1.05±0.088 <sup>c</sup>	0.9±0.08 <sup>d</sup>	9.3±0.12 <sup>e</sup>	9.0±1.46 <sup>b</sup>	51.9±0.78 <sup>a</sup>	76.93±1.08 <sup>a</sup>	11.73±0.57 <sup>c</sup>	7.63±0.26 <sup>fg</sup>
F-TBW	10.5±0.08 <sup>d</sup>	2.81±0.160 <sup>b</sup>	0.9±0.09 <sup>cd</sup>	6.4±0.09 <sup>g</sup>	9.7±0.36 <sup>b</sup>	46.3±2.00 <sup>b</sup>	75.14±1.53 <sup>ab</sup>	7.89±0.14 <sup>d</sup>	11.03±0.06 <sup>b</sup>
F-TCF	11.4±0.13 <sup>b</sup>	4.20±0.179 <sup>a</sup>	2.2±0.12 <sup>a</sup>	10.4±0.09 <sup>c</sup>	11.4±0.12 <sup>a</sup>	35.2±1.56 <sup>c</sup>	69.33±1.91 <sup>c</sup>	8.71±0.39 <sup>d</sup>	12.86±1.06 <sup>a</sup>
F-THB	11.2±0.04 <sup>b</sup>	2.41±0.309 <sup>b</sup>	1.6±0.03 <sup>b</sup>	11.3±0.10 <sup>a</sup>	8.7±1.00 <sup>b</sup>	32.7±2.00 <sup>d</sup>	73.76±2.77 <sup>b</sup>	8.85±0.44 <sup>d</sup>	10.36±0.41 <sup>bc</sup>

<sup>1</sup> Values are mean ± standard deviation (n=4). Means with different letters within each column are significantly different ( $P<0.05$ ).

<sup>2</sup> TWF = tarhana with wheat flour (control); TBW = tarhana with buckwheat flour; TCF = tarhana with clear flour; THB = tarhana with whole grain hull-less barley flour.

<sup>3</sup> Values are on dry weight basis.

for TBW ( $P>0.05$ ). This can be attributed to an increase in yeast single cell proteins due to the growth of the yeast population during fermentation; different yeast populations were detected microbiologically in fermentation samples (data not shown). The salt content of CCT products produced in non-fermented and fermented forms were in the range of 8.7-11.6%. The fermentation process did not significantly change the salt contents of the CCT samples ( $P>0.05$ ) except for the TBW in which the salt content increased on dwb. Fermented TCF had the highest salt content among the fermented samples ( $P<0.05$ ). Table salt is traditionally used as a natural preservative in order to prevent undesirable bacteria and mould growth. The total starch content of non-fermented CCT samples was between 35.4 and 50.9%, while the total starch content of fermented CCT samples was between 32.7 and 51.9%. The fermentation process significantly decreased the total starch content of CCT produced with WHBF (32.7%) on dwb ( $P<0.05$ ), while the total starch content of the other tarhana products did not significantly change ( $P>0.05$ ). This can be explained by the high amyolytic activity originating from the hull-less barley flour and microorganisms that convert starch into dextrins.

### Colour properties of cornelian cherry tarhanas

Colour properties of CCT produced with different cereal/pseudocereal flours are also shown in Table 3. The brightness (L\*) values of non-fermented and fermented CCT products were in the ranges of 67.62-74.63 and 69.33-76.93, respectively. The brightness (L\*) values of the control (TWF, 76.93) and THB (73.76) increased significantly after fermentation ( $P<0.05$ ). The redness (a\*) values of non-fermented and fermented CCT products were in the ranges

of 11.46-19.42 and 7.89-11.73, respectively. The redness (a\*) values of all CCT products significantly decreased after fermentation ( $P<0.05$ ). This might arise from the oxidation of phenolic compounds, especially anthocyanins, during fermentation. The yellowness (b\*) values of non-fermented and fermented CCT products were in the ranges of 6.70-10.41 and 7.63-12.86, respectively. The yellowness (b\*) values significantly increased in all CCT samples ( $P<0.05$ ) after fermentation, except for the control product (TWF,  $P>0.05$ ). CCT produced with CF had the highest yellowness (b\*) values in both processes, probably due to its high flavonoid and lutein contents (Boyacıoğlu and D'Appolonia, 1994).

### Nutritional properties of cornelian cherry tarhanas

Total and invert sugar contents of the CCT products were presented on dwb in Table 4. The total and invert sugar content of cornelian cherry pulp was 10.52 and 9.10%, respectively. Total sugar contents of non-fermented samples ranged between 10.42-16.41%, while total sugar contents of fermented samples ranged between 8.20-12.18%. The fermentation process significantly decreased the total sugar contents in all products ( $P<0.05$ ). The highest and the lowest total sugar contents among the fermented CCT samples were obtained with TCF (12.18%) and TBW (8.20%), respectively. Boyacıoğlu and D'Appolonia (1994) indicated that the outer layer or bran fraction of clear flour has a higher sugar content than the endosperm fraction. Invert sugar contents of CCT products generally decreased ( $P<0.05$ ) after fermentation process except for the sample of TCF whose invert sugar content did not change ( $P>0.05$ , Table 4).

**Table 4. Nutritional properties of non-fermented (N-) and fermented (F-) cornelian cherry tarhanas (CCT) produced with different flours.<sup>1</sup>**

CCT product <sup>2</sup>	Total sugar (%)	Invert sugar (%)	Total dietary fibre (%)	$\beta$ -glucan (%)	Ascorbic acid (g/100 g)	Anthocyanin (mg cyanidin-3-o-galactoside/g)
P	10.52±0.57	9.10±0.11	n.a.	n.a.	1.0±0.01	318.7±25.1
N-TWF	10.42±0.80 <sup>ef</sup>	10.78±1.26 <sup>de</sup>	11.1±0.65 <sup>f</sup>	0.26±0.02 <sup>c</sup>	0.33±0.02 <sup>a</sup>	142.8±2.5 <sup>b</sup>
N-TBW	12.51±0.41 <sup>bc</sup>	10.72±0.49 <sup>de</sup>	11.3±0.56 <sup>f</sup>	n.a.	0.24±0.01 <sup>b</sup>	32.1±2.6 <sup>ef</sup>
N-TCF	16.41±0.87 <sup>a</sup>	12.73±1.16 <sup>b</sup>	17.7±0.76 <sup>d</sup>	n.a.	n.d.	210.8±8.6 <sup>a</sup>
N-THB	12.91±0.56 <sup>b</sup>	12.98±0.70 <sup>b</sup>	21.3±1.02 <sup>b</sup>	2.72±0.04 <sup>b</sup>	0.17±0.01 <sup>c</sup>	88.0±6.4 <sup>c</sup>
F-TWF	8.79±0.70 <sup>h</sup>	9.48±0.26 <sup>fg</sup>	12.5±0.52 <sup>e</sup>	0.22±0.01 <sup>c</sup>	0.16±0.01 <sup>c</sup>	65.2±6.7 <sup>d</sup>
F-TBW	8.20±1.65 <sup>h</sup>	9.75±0.62 <sup>efg</sup>	13.4±0.19 <sup>e</sup>	n.a.	0.12±0.01 <sup>d</sup>	29.2±1.6 <sup>ef</sup>
F-TCF	12.18±0.73 <sup>bc</sup>	12.90±0.55 <sup>b</sup>	19.4±0.30 <sup>c</sup>	n.a.	n.d.	34.6±4.1 <sup>e</sup>
F-THB	11.66±1.42 <sup>cd</sup>	10.04±0.49 <sup>ef</sup>	23.1±1.06 <sup>a</sup>	2.77±0.02 <sup>a</sup>	n.d.	25.5±1.6 <sup>f</sup>

<sup>1</sup> Values are on dry weight basis and shown as mean  $\pm$  standard deviation (n=6). Means with different letters within each column are significantly different ( $P<0.05$ ). n.a. = not analysed; n.d. = not detected.

<sup>2</sup> P = cornelian cherry pulp; TWF = tarhana with wheat flour (control); TBW = tarhana with buckwheat flour; TCF = tarhana with clear flour; THB = tarhana with whole grain hull-less barley flour.

Total dietary fibre (TDF),  $\beta$ -glucan, ascorbic acid and anthocyanin contents of CCT products are also presented on dwb in Table 4. The TDF contents of WF, BWF, CF and WHBF were 11.3, 8.0, 14.1 and 21.8% on dwb, respectively. The TDF contents of non-fermented CCT samples were between 11.1 and 21.3%, while the TDF contents of fermented ones were between 12.5 and 23.1% on dwb. The TDF contents of CCT products increased after fermentation ( $P<0.05$ ) due to the decrease in total starch content and change of the total and invert sugar rates on dwb. Besides, it can be contributed to arise from dietary fibres, such as cellulose, hemicellulose and lignin due to the degradation of cornelian cherry cell walls by yeasts originating from cornelian cherry pulp (Martian-Cabrejas *et al.*, 2004). Using WHBF and CF in the CCT production had an advantage for providing CCT products with high dietary fibre contents. Among the fermented CCT products, CCT produced with WHBF (THB) had the highest TDF content (23.1%).

It was determined that  $\beta$ -glucan contents of WF and WHBF were 0.26% and 3.52%, respectively. CCT produced with WHBF had significantly higher  $\beta$ -glucan content than that of the control sample in both non-fermented (2.72%) and fermented (2.77%) forms. After the fermentation process, the  $\beta$ -glucan content of CCT produced with WHBF slightly increased ( $P<0.05$ ) while the  $\beta$ -glucan content of the control sample did not change ( $P>0.05$ , Table 4). Baik and Ullrich (2008) reported the physiological health benefits of barley  $\beta$ -glucans extensively.

The ascorbic acid content of cornelian cherry pulp was 1.0 g/100 g in this study. The ascorbic acid content of non-fermented samples ranged between 0.17 and 0.33 g/100 g

and the control sample had the highest ascorbic acid content ( $P<0.05$ ). The fermentation process significantly decreased the ascorbic acid content in all CCT products ( $P<0.05$ ). This might be due to the oxidative reactions during the fermentation and drying process (Table 4).

The anthocyanin content of cornelian cherry pulp was 318.7 mg cyanidin-3-o-galactoside/g in this research. The anthocyanin content of non-fermented CCT products ranged between 32.1 and 210.8 mg cyanidin-3-o-galactoside/g while the anthocyanin content of fermented CCT products ranged between 25.5-65.2 mg cyanidin-3-o-galactoside/g. Among the CCT products, the non-fermented CCT sample with CF had the highest anthocyanin content compared to the control sample. However, the fermentation process caused a significant decrease on the anthocyanin contents of all products ( $P<0.05$ , Table 4).

#### Phenolic compounds of cornelian cherry tarhanas

Phenolic compound contents of cornelian cherry pulp and non-fermented and fermented CCT products in different extraction solvents are shown in Table 5. Total phenolic compound (TPC) contents of CCT products analysed with DMSO solvent decreased after fermentation, except for the control CCT sample in which TPC content increased to 6.12 mg gallic acid/g of flour. TPC contents of non-fermented CCT samples produced with BWF, CF and WHBF were similar ( $P>0.05$ ). After fermentation, their TPC contents were in the range of 5.62-7.16 mg gallic acid/g of flour. By using DMSO solvent, CCT produced with WHBF had the highest TPC content in both processes. Baik and

Ulrich (2008) reported that barley grain had a higher TPC compared to the other cereal grains.

Free phenolic compound (FPC) contents of cornelian cherry pulp in 50 and 80% methanol solvents were 20.94 and 17.26 mg gallic acid/g of pulp, respectively. Extractable FPC contents of all CCT products obtained from both processes were higher in 50% methanol than that of 80% methanol solvent. FPC contents of all CCT products extracted from both methanol solvents were higher than that of the control products produced in both processes. After fermentation, FPC contents of all CCT products generally increased on dwb, however, these increments were not significant compared to non-fermented CCT products while using 80% methanol ( $P>0.05$ ). Besides, when 50% methanol solvent was used, the increment in FPC contents of the TWF and THB was found as significant ( $P<0.05$ ). The highest FPC content (4.36 mg gallic acid/g) was achieved with the fermented THB by using 50% methanol solvent. Barley grain phenolics are concentrated in the hull, testa, and aleurone layers (Baik and Ulrich, 2008). Phenolic compounds are also bound to dietary fibres and the increase of FPC by fermentation can be related to releasing of phenolic compounds as a result of degradation or modifying of these grain constituents by endogenous enzymes and micro-organisms, especially yeasts (Hole *et al.*, 2012; Katina *et al.*, 2007).

#### Antioxidant activities of cornelian cherry tarhanas

Antioxidant activity properties of cornelian cherry pulp, non-fermented and fermented CCT products are shown in Table 5. The DPPH radical scavenging activity of cornelian

cherry pulp was 292.8%. The DPPH radical scavenging activity of non-fermented CCT products ranged between 18.0 and 33.5%. Besides, the DPPH radical scavenging activity of fermented CCT products was in the range of 20.8 and 40.0%. CCT products that were produced with different flours had higher DPPH radical scavenging activity than that of the control sample in both processes ( $P<0.05$ ). After the fermentation process, the DPPH radical scavenging activity of control and other CCT products significantly increased ( $P<0.05$ ). This increment was more pronounced in the CCT produced with BWF (TBW) in which DPPH radical scavenging activity increased from 33.5 to 40.0% ( $P<0.05$ ).

The Trolox equivalent antioxidant capacity (TEAC) of cornelian cherry pulp was 220.0 mmol TE/kg of pulp. The TEAC values of non-fermented CCT samples ranged between 46.1 and 102.1 mmol TE/kg while the TEAC values of fermented samples ranged between 63.9 and 82.9 mmol TE/kg of sample. CCT products that were produced with different flours had higher TEAC values than that of the control sample in both processes; non-fermented control product had the lowest TEAC value (46.1 mmol TE/kg of sample,  $P<0.05$ ). Besides, CCT produced with WHBF (THB) had the highest TEAC values in non-fermented (102.1 mmol TE/kg of sample) and fermented (82.9 mmol TE/kg of sample) forms. Barley is an excellent source of natural antioxidants for preventing chronic diseases. The total phenolic content of barley is, like other cereals, significantly correlated with the antioxidant capacity, as measured by the DPPH and ABTS assays (Fardet *et al.*, 2008).

**Table 5. Phenolic compounds and antioxidant activities of cornelian cherry pulp and cornelian cherry tarhanas produced with different flours.<sup>1,2</sup>**

Sample	Phenolic compound <sup>3</sup> (mg GAE/ g of sample)			Antioxidant activities <sup>3</sup>	
	DMSO	50% methanol	80% methanol	DPPH scavenging activity (%)	TEAC (mmol TE/kg)
P	n.a.	20.94±0.424	17.26±0.824	292.8±13.4	220.0±5.07
N-TWF	4.73±0.225 <sup>d</sup>	3.16±0.259 <sup>d</sup>	2.91±0.950 <sup>c</sup>	18.0±1.03 <sup>e</sup>	46.1±5.63 <sup>e</sup>
N-TBW	7.06±0.052 <sup>a</sup>	4.09±0.128 <sup>ab</sup>	3.68±0.085 <sup>b</sup>	33.5±2.4 <sup>b</sup>	62.2±5.61 <sup>d</sup>
N-TCF	7.35±0.484 <sup>a</sup>	3.97±0.191 <sup>b</sup>	3.46±0.217 <sup>b</sup>	23.4±1.93 <sup>cd</sup>	89.1±4.60 <sup>b</sup>
N-THB	7.39±0.385 <sup>a</sup>	3.98±0.169 <sup>b</sup>	4.02±0.404 <sup>a</sup>	26.0±1.74 <sup>c</sup>	102.1±6.90 <sup>a</sup>
F-TWF	6.12±0.156 <sup>b</sup>	3.45±0.115 <sup>c</sup>	2.92±0.161 <sup>c</sup>	20.8±1.22 <sup>d</sup>	63.9±5.54 <sup>cd</sup>
F-TBW	5.62±0.119 <sup>c</sup>	4.28±0.211 <sup>a</sup>	3.72±0.204 <sup>b</sup>	40.0±4.29 <sup>a</sup>	70.2±3.43 <sup>c</sup>
F-TCF	6.05±0.303 <sup>b</sup>	4.15±0.122 <sup>ab</sup>	3.66±0.240 <sup>b</sup>	34.6±1.64 <sup>b</sup>	67.8±4.71 <sup>cd</sup>
F-THB	7.16±0.145 <sup>a</sup>	4.36±0.144 <sup>a</sup>	4.10±0.075 <sup>a</sup>	38.2±2.4 <sup>a</sup>	82.9±6.04 <sup>b</sup>

<sup>1</sup> Values are mean ± standard deviation (n=4). Means with different letters within each column are significantly different ( $P<0.05$ ). n.a. = not analysed.

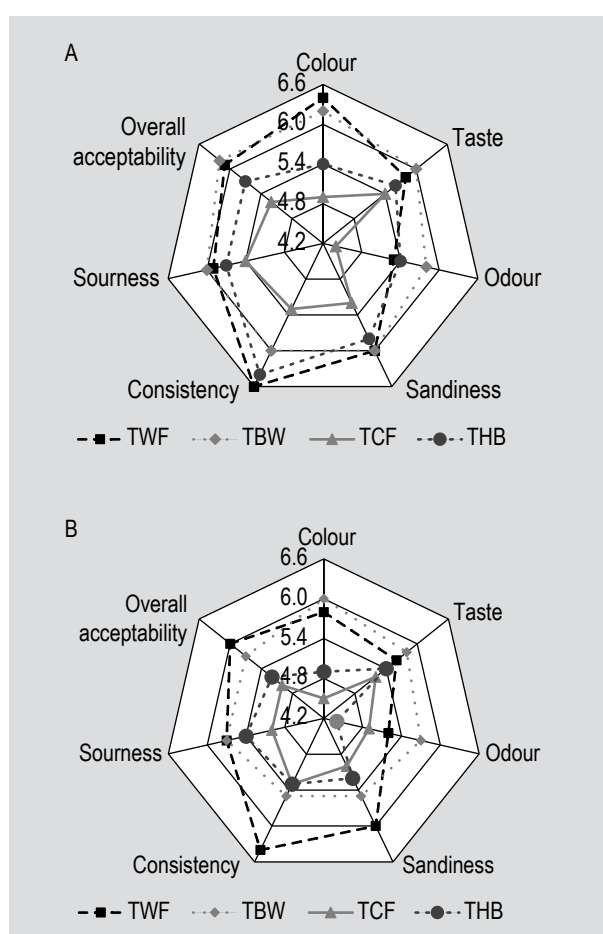
<sup>2</sup> P = cornelian cherry pulp; TWF = tarhana with wheat flour (control); TBW = tarhana with buckwheat flour; TCF = tarhana with clear flour; THB = tarhana with whole grain hull-less barley flour; DMSO = dimethyl sulfoxide; GAE = gallic acid equivalent; TE = Trolox equivalent; TEAC = Trolox equivalent antioxidant capacity; DPPH =  $\alpha$ -diphenyl- $\beta$ -picrylhydrazyl.

<sup>3</sup> Values are on dry weight basis.

### Sensory properties of cornelian cherry tarhanas

Sensory properties of non-fermented CCT products are presented in Figure 1A. Accordingly, the control CCT had the highest colour score and this was statistically not different from the colour score of CCT produced with BWF (TBW,  $P>0.05$ ). This can also be stated for the sandiness property for both products. For traditional CCT product, a high sandiness score means that the soup has a low sandiness property or feels smooth. The product of TBW had the highest score in terms of taste, odour, sourness and overall acceptability, however, overall acceptability was not so different from the control product ( $P>0.05$ ). The highest consistency score was achieved with the control sample (TWF,  $P<0.05$ ).

Sensory properties of fermented CCT products are presented in Figure 1B. Respectively, CCT produced with BWF (TBW) had the highest score in terms of colour, taste and odour ( $P<0.05$ ). On the other hand, the control



**Figure 1.** Sensory properties of non-fermented (A) and fermented (B) cornelian cherry tarhanas produced with different cereal/pseudocereal flours. TWF = tarhana with wheat flour (control); TBW = tarhana with buckwheat flour; TCF = tarhana with clear flour; THB = tarhana with whole grain hull-less barley flour.

product (TWF) had the highest sandiness, consistency and overall acceptability scores. The sourness was similar in the CCT products produced with WF, BWF and WHBF flours ( $P>0.05$ ).

Generally, the sensory properties of CCT products decreased after fermentation, however, the effect of fermentation on sensory properties was not statistically significant compared to non-fermented products. The samples of TBW and TWF (control) had the highest general acceptability scores in non-fermented and fermented processes, respectively.

### 4. Conclusions

CCT, which is a traditional soup product with a unique purple-red colour, is made of wheat flour without applying a fermentation process. In this research, effect of a fermentation process on the quality properties of cornelian cherry tarhanas produced either with wheat flour as control or with different cereal/pseudocereal flours was extensively studied for the first time. Using clear flour and whole grain hull-less barley flours in the CCT production increased the protein and dietary fibre contents. A new functional soup product could be made for celiac and gluten sensitive people, which is CCT produced with buckwheat flour with an increase on total and free phenolic compound contents and antioxidant properties. The sensory studies showed that non-fermented CCT produced with buckwheat flour was most preferred by the panellists. Substitution by clear flour increased anthocyanin content compared to the control sample and improved antioxidant properties. Fermentation increased total dietary fibre content and DPPH radical scavenging activity of the products on dry weight basis while fermentation was destructive on ascorbic acid and anthocyanin contents. Fermentation did not affect the  $\beta$ -glucan content negatively. The redness ( $a^*$ ) values of all CCT products decreased by fermentation. The natural bioactivity of cereal-based foods can be developed using fermentation bioprocesses to produce nutritionally exclusive healthy meals.

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