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Changes in bioaccessibility, phenolic content and antioxidant capacity of novel crackers with turmeric (*Curcuma longa* L.) and mahaleb (*Prunus mahaleb* L.) powders

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RESEARCH ARTICLE

Abstract

The purpose of this study was to determine the suitability of supplementing turmeric and/or mahaleb powders in crackers to enhance phenolic content and antioxidant activity. They replaced wheat flour for 0, 5.0, or 7.5%. The highest bioaccessible phenolics (7,591.90 mg of gallic acid equivalents/100 g dry weight) and phenolic bioaccessibility values (77.94%) were obtained in the 7.5M7.5T sample. Turmeric and/or mahaleb powders' addition had a positive effect on phenolic contents and bioaccessibilities of the cracker samples. In all assays, antioxidant capacities of the crackers supplemented with turmeric and/or mahaleb powders were significantly ($P \leq 0.05$) higher than the control crackers. The results showed that the samples with turmeric and/or mahaleb powders exhibited significantly ($P \leq 0.05$) higher bioaccessible antioxidants than the control sample. Bioaccessibilities of crackers based on antioxidant capacity increased linearly with supplementation increments. Antioxidant bioaccessibility of the crackers ranged between 9.00 to 47.29% for the $TEAC_{ABTS}$, 11.54 to 14.47% for the $TEAC_{CUPRAC}$ and 12.47 to 20.59% for the $TEAC_{DPPH}$. The highest antioxidant bioaccessibilities (47.29%, 14.47%, and 20.59%) in all assays (respectively ABTS, CUPRAC, and DPPH) were obtained in the 7.5M7.5T sample. According to sensorial evaluations, generally, all supplemented crackers scored higher than the control. The taste of the crackers improved by supplementation of turmeric and/or mahaleb powders, as these crackers had typical pleasant mahaleb and turmeric flavour. Overall results suggest that turmeric and mahaleb powders are functional food additives with high phenolic content, bioaccessibility and antioxidant capacity. They can be used in foods, especially in bakery products, without any adverse effect on sensory properties.

Keywords: bioaccessibility, functional food, healthy food, anti-oxidant

1. Introduction

Crackers are a crispy, unsweetened, salty cookie type mainly used as snack food (Manley, 1991). Crackers contain medium or high fat (10-20%) based on flour weight, but contain little or no sugar (Hoseney, 1998). Among snack foods, crackers are highly consumed all over the world, due to their alternative taste, longer shelf life and relatively low price (Ahmed and Abozed, 2015). Snack crackers are leavened by addition of sodium bicarbonate or ammonium bicarbonate (Han *et al.,* 2010).

As modern consumers are more interested in healthy, natural and functional foods, the demand for such products in the market has recently been increasing. Herewith, to improve content, various raw materials with positive effect on health are incorporated into cereal products. In this context, some natural and functional plant sources, like apple pomace, leaf tea powder, and green banana flour which are especially rich in phenolic compounds and dietary fibre are added to baked goods, such as wheat bread, rice cake, and snacks (Kim *et al.,* 2005; Masoodi and Chauhan, 1998).

Numerous plant species are known to include natural bioactive phytochemicals with antioxidative features (Liu and Ng, 2000; Yu *et al.,* 2005). By virtue of its reliable, nutritive and therapeutic effects, natural antioxidants

are particularly attractive. Anti-allergic, antiviral, anti-inflammatory and anti-mutagenic activities are beneficial bioactivities of natural phenolic compounds (Peng *et al.,* 2010). In this study, mahaleb and turmeric powders were used as ingredients in the cracker formulation.

Mahaleb (*Prunus mahaleb* L.) belongs to the *Rosaceae* subfamily *Prunoideae*, a leafy tree and abundant in West Asia. The mahaleb fruit is a small, thin-fleshed cherry-like and bitter drupe. Its immature state has a green colour, and as it matures, its colour changes from red to dark purple and eventually becomes black (Blando *et al.,* 2016). Mahaleb fruit of dark blue or red colour has the highest antioxidant capacity among common fruits and vegetables (Wu *et al.,* 2004).

Mahaleb flour is obtained from fruit kernels and is generally used as a flavouring agent in bakery products, such as bagels, cakes, muffins, and pies (Mariod *et al.,* 2010). Furthermore, it is often used in liqueur, wine, and vinegar production. In addition to these, mahaleb kernels and its powder are used as a folk medicine for diuretic, antidiabetic, tonic, aphrodisiac, and sputum remover in Turkey (Ozturk *et al.,* 2014). In Sudan, mahaleb kernels are also used for various medicinal purposes, for example, as a sedative and vasodilator, and also against diarrhoea for children (Mariod *et al.,* 2010).

Herken *et al.* (2017) reported that substitution with mahaleb resulted in a significant increase ($P<0.05$) in the amount of protein, total phenolic compounds and antioxidant activity of cookies and that final products enriched with mahaleb have potency to be a healthy functional food for consumers.

Turmeric (*Curcuma longa* L.) is a herbaceous plant that belongs to the *Zingiberaceae* family and used for centuries all over the world in food, cosmetics, medicine and dye industry (Ak and Gulcin, 2008; Gupta *et al.,* 2012). It also has strong antioxidant activity due to its yellow phenolic pigment (curcumin) (Miquel *et al.,* 2002). Curcumin, demethoxycurcumin, and bisdemethoxycurcumin are known as curcuminoids and are the main active components of plant (Ireson *et al.,* 2001). Curcumin is one of the major components and had a markable antioxidant effect and showed the higher hydrogen peroxide scavenging effect than butylated hydroxyanisole (BHA), butylated hydroxytoluene, a-tocopherol and Trolox (Ak and Gulcin, 2008). Besides antioxidative activities, curcumin has anti-carcinogenic and anti-tumorigenic (Buhrmann *et al.,* 2014; Huang *et al.,* 1991; Pereira *et al.,* 1996; Rao *et al.,* 1995; Shakibaei *et al.,* 2014; Toden *et al.,* 2015), anti-inflammatory, anti-arthritis and anti-depression properties (Chandran and Goel, 2012; Sanmukhani *et al.,* 2014). In literatures, only a few studies about the use of turmeric powder in foodstuffs have been reported, including use in rabbit burgers (Mancini *et al.*, 2016), *yukwa* (Lim and Han, 2016) and processed cakes (Lean and Mohamed, 1999).

In a study made by Hefnawy *et al.* (2016), turmeric extract had an excellent antioxidant effect on the biscuits compared with the effect of synthetic antioxidants. They reported that turmeric extract could be used as natural antioxidants replacing BHA in the biscuit manufacturing.

The aim of this study was to determine the prospects of enhancing the functional and antioxidative attributes of novel snack crackers supplemented with turmeric (*Curcuma longa* L.) and mahaleb (*Prunus mahaleb* L.) powder. For this purpose, they were used as substitute for wheat flour in the cracker formulation at two different levels (0, 5 and 7.5% w/w).

2. Material and methods

Materials

Commercially available wheat flour, obtained from Bandırma, Turkey; contains 13% water content, 0.65% dw ash content, 9% dw protein content was used in the formulation of crackers. Salt, sugar, baking powders, shortening and dry yeast were purchased from the market; turmeric (*Curcuma longa* L.) and mahaleb (*Prunus mahaleb* L.) powder were purchased in a spice store.

Methods

Cracker preparation

The crackers were made according to Nammakuna *et al.* (2016), Ahmed and Abozed (2015) and Yilmaz *et al.* (2014) with some modifications. On flour basis, consisted of wheat flour (100%, dw), salt (2%), sugar (2%), baking powders [sodium bicarbonate (0.5%) and ammonium bicarbonate (1.5%)], shortening (20%), dry yeast (2%) and depending upon the percent of turmeric and/or mahaleb powders in the formula (Table 1). Turmeric and/or mahaleb powders were used individually and as a blend. They replaced wheat flour in different combinations of 0, 5.0, and 7.5% (Table 1). Different amounts of water (40.2-42.4%) were added to prepare cracker dough on flour basis. The amount of water was based on preliminary trials. Water is added at the minimum level to develop a dough that is wet enough to obtain a dough layer. At the same time, it is ensured that the dough is dry enough to prevent the formation of elastic dough. After mixing flour, sugar, yeast, and water (Kitchen-Aid model 5SS, St. Joseph, MI, USA) for 5 min, remaining ingredients were added into mixture. The mix was kneaded for 7 min more before proofing the dough at 25-30 °C for 60 min. After proofing, the dough was formed into a thin sheet using the Lamination Machine (Commercial Food Preparing Machine, TMM

Table 1. The formulations of crackers.[1]

Sample	WF (%)	MP (%)	TP (%)	Sugar (%)	Shortening (%)	Dry yeast (%)	Sodium bicarbonate (%)	Ammonium bicarbonate (%)	Salt (%)	Water (%)
Control	100	0	0	2	20	2	0.5	1.5	2	40.2
5M	95	5	0	2	20	2	0.5	1.5	2	41.3
7.5M	92.5	7.5	0	2	20	2	0.5	1.5	2	41.8
5T	95	0	5	2	20	2	0.5	1.5	2	40.6
7.5T	92.5	0	7.5	2	20	2	0.5	1.5	2	40.9
5M5T	90	5	5	2	20	2	0.5	1.5	2	41.6
7.5M5T	87.5	7.5	5	2	20	2	0.5	1.5	2	42.0
5M7.5T	87.5	5	7.5	2	20	2	0.5	1.5	2	41.7
7.5M7.5T	85	7.5	7.5	2	20	2	0.5	1.5	2	42.4

[1] WF = wheat flour; MP = mahaleb powder; TP = turmeric powder.

Inc., Turkey) to reduce the thickness until 1.5 mm. The dough sheet was then transferred onto a specially designed cutter-docker. A rolling pin was rolled on the dough sheet three times; in this way the dough sheet was cut into a cracker size of 5×5 cm. The docked cracker dough sheets were then transferred onto an oven tray and baked for 15 min at 180-200 °C in the oven. Baked crackers were cooled down at room temperature for 30 min then stored in sealed polypropylene bags at room temperature before further analysis. Cracker powder, obtained by grinding in a laboratory blender (Waring, Torrington, CT, USA), was used in all analyses, except for sensory analysis.

Baking performance of crackers

Moisture, protein and crude oil contents of crackers were determined according to standard methods of AOAC (2000). The hardness of the cracker was determined by a TA-XTPlus Texture Analyzer (Texture Technologies Corp., Scarsdale, NY, USA) using the three-point bending apparatus (model TA-92). The pre-test speed, test speed, and post-test speed were adjusted as 2.0, 3.0 and 10.0 mm/s, respectively. The maximum force (N) needed to break the cracker was recorded as hardness of the cracker. Each sample was analysed with at least three replicates. Thickness of the cracker before and after baking was measured by Vernier callipers with five replicates. The sample puffiness (%) was calculated from the difference of cracker thicknesses as shown (Nammakuna *et al.,* 2016):

$$\%\text{puffiness} = \frac{\text{thickness of baked cracker-thickness of cracker dough}}{\text{thickness of cracker dough}} \times 100$$

Colour measurement

The colour measurement of crackers was carried out by Minolta Spectrophotometer CM-3600d (Osaka, Japan) on the basis of the CIE L^*, a^*, b^* colour system.

Determination of phenolic contents

Extraction of total phenolic content and antioxidant capacity analysis was determined with respect to the method of Vitali *et al.* (2009), with some modifications. Samples (2.0 g weight) were mixed with 20 ml HCl conc/methanol/water (1:80:10, v/v/v) extraction solution and shaken with a laboratory rotary shaker (JB50-D; Shanghai, China P.R.) at 250 rpm for 2 h at 20 °C, after which the extracts were centrifuged at 3,500 rpm for 10 min at 20 °C (Sigma 3 K 30, Osterode am Harz, Germany). Supernatant was used as *extractable phenolics* in the analysis of total phenolic content and antioxidant capacity analysis. The residue was mixed with 20 ml of methanol/H_2SO_4-conc (10:1, v/v) and shaken with a laboratory rotary shaker at 250 rpm for 20 h at 85 °C, and then cooled to room temperature. The mixture was centrifuged at 3,500 rpm for 10 min at 4 °C and supernatant was used as *hydrolysable phenolics* in the analysis of total phenolic content and antioxidant capacity analysis.

Phenolic contents of the extractable and hydrolysable extracts were determined separately according to a modified Folin-Ciocalteu colorimetric spectrophotometric method (Apak *et al.,* 2008). Absorbance of samples were measured spectrophotometrically at 750 nm (Jenway, 6405 UV/Vis; Keison Products, Chelmsford, UK) and results were expressed as mg gallic acid equivalents (GAE) per 100 g weight sample. Each sample was analysed with least three replications. Total phenolic contents of the cracker samples

were calculated as the sum of phenolic contents of the extractable and hydrolysable extracts.

Evaluation of antioxidant capacity

The antioxidant capacity of the extracts was determined by cupric ion reducing antioxidant activity (CUPRAC) assay, 2,2-azinobis-[3-ethylbenzothiazoline-6-sulphonicacid] (ABTS) assay and 2,2-diphenyl-1-picrylhydrazyl (DPPH) assay according the methods of Apak *et al.* (2008) and Boskou *et al.* (2006). The results were expressed as l μmol Trolox equivalent (TE) per g sample.

Determination of bioaccessible phenolics and antioxidants

For bioaccessible phenolics and antioxidants, an artificial *in vitro* enzymatic digestion system was built using the method of Bouayed, *et al.* (2012). Cracker samples were subjected to pepsin enzyme (40 mg/ml in 0.1 M HCl) digestion at pH 2-2.5 at 37 °C for 1 h (shaken in water bath at 100 rpm), then intestinal digestion with porcine pancreatin enzyme (2 mg/ml) and porcine bile mixture (12 mg/ml) at pH 7.2-7.5 at 37 °C for 2.5 h (shaken in water bath at 100 rpm). After that, the mixture was centrifuged at 3,500 rpm/10 min at 15 °C and supernatant was used as bioaccessible phenolics in analysis of total phenolic content and antioxidant capacities. All obtained extracts were stored at -18 °C until analysing. The bioaccessibility of antioxidants and phenolics (%) were calculated according to Anson *et al.* (2009), in accordance with total phenolic content and antioxidant capacity analysis results.

Sensory evaluation

Evaluation of the sensory characteristics of the crackers was carried out by 55 untrained panellists. The samples were presented in random order and labelled with three-digit numbers. Cracker samples were evaluated in terms of shape, uniformity, surface, internal colour, external colour, flavour, aroma, crispness and overall acceptability. A 9-point hedonic scale (with 9 – like extremely; 8 – like very much; 7 – like moderately; 6 – like slightly; 5 – neither like or dislike; 4 – dislike slightly; 3 – dislike moderately; 2 – dislike very much; and 1 – dislike extremely) was used. Final evaluation was calculated as the mean value of the individual scores given by all panellists.

Statistical analysis

All statistical analyses were carried out using the SPSS statistical package (SPSS 16.0, Chicago, IL, USA). The differences between means were considered significant when $P<0.05$. One-way analysis of variance (ANOVA) and Duncan's multiple range tests were used as statistical comparison methods.

3. Results and discussion

Baking performances of crackers

Baking performances of the crackers supplemented with different percentages of turmeric and/or mahaleb powders are presented in Table 2. Moisture contents of the samples containing turmeric and/or mahaleb powders were significantly ($P\leq0.05$) lower than that of control sample. The shelf life of the cracker is extended thanks to its low moisture content (Wang *et al.,* 2016). In the present study, lower moisture contents in the cracker samples with an increase of turmeric and/or mahaleb powders in formulation were observed.

Moisture content of cracker effects its texture (Wang *et al.,* 2016). Ahmed and Abozed (2015) also noted that the degree of crunchiness of bakery products is affected by the moisture content. Crackers with lower moisture contents would be much easier to break than those with higher moisture contents. Too low breaking force also means the crackers are too fragile and could cause too

Table 2. Baking performances of cracker samples.[1]

Sample	Moisture (%)	Protein (%)	Crude fat (%)	Hardness (N)	Puffiness (%)	*L**	*a**	*b**
Control	7.92±0.08^{a}	10.60±0.10^{e}	17.10±0.10^{e}	0.54±0.00^{a}	10.26±0.04^{d}	56.21±2.82^{a}	5.34±0.94^{c}	28.14±0.66^{f}
5M	7.64±0.31^{b}	11.10±0.10^{d}	17.90±0.20^{c}	0.53±0.01^{b}	10.27±0.02^{d}	53.40±3.64^{b}	5.91±1.38^{b}	28.86±1.87^{f}
7.5M	7.30±0.02^{b}	11.70±0.10^{c}	18.70±0.20^{a}	0.52±0.01^{b}	10.28±0.04^{d}	53.19±1.95^{b}	6.32±0.67^{a}	28.64±0.77^{f}
5T	7.22±0.15^{c}	10.10±0.10^{h}	17.40±0.30^{d}	0.52±0.00^{b}	10.30±0.01^{d}	53.88±0.98^{b}	3.19±0.63^{e}	46.24±1.17^{b}
7.5T	7.10±0.08^{c}	10.27±0.07^{g}	17.32±0.10^{d}	0.52±0.02^{b}	10.31±0.02^{d}	53.12±0.88^{c}	2.18±0.57^{f}	49.40±1.55^{a}
5M5T	6.92±0.04^{d}	11.80±0.11^{b}	18.87±0.10^{a}	0.51±0.01^{c}	12.02±0.02^{c}	52.78±0.72^{c}	4.39±0.52^{d}	42.10±2.62^{e}
7.5M5T	6.80±0.11^{d}	10.43±0.11^{f}	17.18±0.10^{e}	0.51±0.01^{c}	12.18±0.02^{b}	49.72±1.60^{d}	4.24±0.75^{d}	44.94±0.84^{bc}
5M7.5T	6.73±0.03^{d}	11.85±0.05^{b}	18.48±0.10^{b}	0.50±0.02^{c}	12.56±0.04^{a}	50.65±1.51^{d}	4.31±1.14^{d}	43.08±1.68^{d}
7.5M7.5T	6.56±0.16^{e}	12.17±0.08^{a}	18.44±0.10^{b}	0.50±0.03^{c}	12.64±0.04^{a}	46.77±2.53^{e}	4.14±0.50^{d}	46.49±2.26^{b}

[1] Mean values ± standard deviation with different superscript in the same row are significantly different ($P\leq0.05$).

Table 3. Phenolic contents and their bioaccessibilities.[1]

Samples	Extractable phenolics (mg/100 g GAE)	Hydrolysable phenolics (mg/100 g GAE)	TPC (mg/100 g GAE)	Bioaccessible phenolics (mg/100 g GAE)	Phenolic bioaccessibility (%)
Control	708.69±4.28^{a}	7,091.00±0.62^{h}	7,252.65±38.29^{a}	5,546.94±19.02^{a}	71.12±0.57^{g}
5M	758.97±4.14^{c}	7,354.71±0.59^{g}	7,531.96±35.02^{b}	5,792.36±27.59^{b}	71.39±0.33^{f,g}
7.5M	739.59±4.23^{b}	7,554.24±0.25^{f}	7,957.07±87.11^{c}	6,050.51±35.41^{c}	72.48± 0.28^{f}
5T	839.25±11.28^{d}	7,674.59±0.75^{e}	8,791.08±51.30^{d}	6,291.41±54.98^{d}	73.90±0.51^{e}
7.5T	867.89±13.18^{e}	7,928.42±0.67^{e}	8,796.31±64.05^{d}	6,615.76±37.42^{e}	75.21±0.79^{d}
5M5T	918.96±6.08^{f}	8,064.26±1.11^{d}	8,983.22±112.63^{e}	6,829.63±45.42^{f}	76.04±1.45^{c,d}
7.5M5T	930.83±15.83^{g}	8,301.17±0.57^{c}	9,232.01±68.48^{f}	7,053.42±7.20^{g}	76.40±0.49^{b,c}
5M7.5T	1,073.99±19.23^{h}	8,485.35±0.11^{b}	9,590.86±36.70^{g}	7,409.16±15.1^{9h}	77.51± 0.20^{a,b}
7.5M7.5T	1,088.04±6.53^{h}	8,652.22±0.45^{a}	9,740.27±49.19^{h}	7,591.90±80.76^{i}	77.94±0.49^{a}

[1] Mean values ± standard deviation with different superscript in the same row are significantly different ($P \leq 0.05$). GAE = gallic acid equivalents; TPC = total phenolic content.

much breakage in packaging. On the contrary, cracker with high moisture content and stack weight tends to have more leathery texture, which increases breaking force (Wang *et al.,* 2016). In the present study, additions of turmeric and/or mahaleb powders led to a significant ($P \leq 0.05$) decrease in the hardness and moisture contents of the crackers when compared to the control sample. The lowest hardness (0.50 N) and the lowest moisture content (6.56%) were determined in the sample with 7.5M7.5T mixture (Table 2). Kulthe *et al.* (2014) indicated that the decreased hardness may be due to the competition of flour proteins for water, which resulted in lesser gluten network formation.

The puffiness slightly increased with individually usage of turmeric or mahaleb powders, but it was not significantly affected (Figure 1). However, usage of turmeric and mahaleb powders' mixtures in the formula caused a significantly ($P<0.5$) increase in puffiness (Table 2). These results were in accordance with the findings of Nammakuna *et al.* (2016) who reported that the addition of hydrocolloids to the flour blended-rice cracker formula caused an increase in puffiness for all hydrocolloids. Li *et al.* (2014) found the higher amount of whole grain soft wheat flour tended to produce an uneven and less puffiness internal texture of the cracker.

Colour values of crackers

Table 2 shows the effects of turmeric and/or mahaleb powders on the colour values of the cracker samples. The L^* values which correspond to brightness decreased in the samples supplemented with mahaleb and/or turmeric powders ranged from 56.21 (control) to 46.77 (the sample with 7.5M7.5T mixture), the colour of the end products gradually became darker with the increased ratio of them. Similarly, Herken *et al.* (2017) stated that the lower L^* values observed for mahaleb cookies were possibly related to the specific darker colour of mahaleb. Lim and Han (2016) also determined that the lightness (L* value) of *yukwa* decreased with increased turmeric powder. The a^* values which correspond to redness ranged from 2.18 (7.5T sample) to 6.32 (7.5M sample). Individually turmeric supplementation significantly ($P<0.5$) decreased the a^* values of the samples compared to control. Contrary, individually mahaleb powder supplementation slightly increased a^* values of the crackers. These observations are in agreement with Herken *et al.* (2017) who found that the control sample was brighter colour than cookies made with mahaleb, and generally cookies' colour results were not significantly different but substitution was caused lower lightness, higher redness and yellowness. The b^* values which corresponded to yellowness ranged from

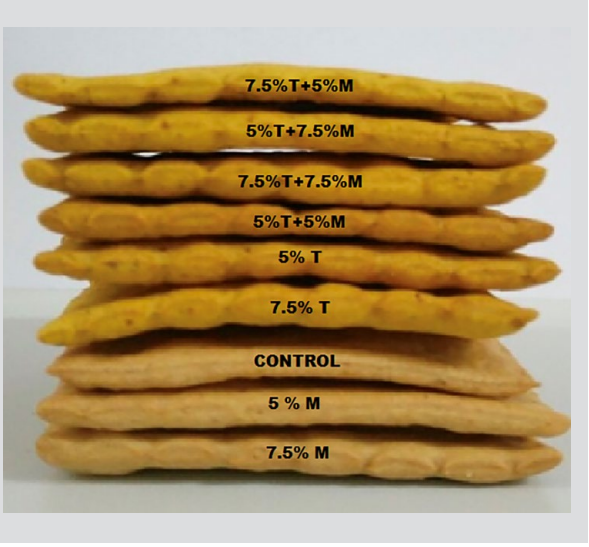

Figure 1. Side view of the crackers. Percentages show wheat flour replacement with turmeric (T) and/or mahaleb (M) powder.

28.14 (control) to 49.40 (7.5T sample). Higher b^* values indicate the samples exhibited more yellowish colour. As the turmeric rate increased, b^* values significantly ($P<0.5$) increased and the attractive yellow colour was obtained. Lim and Han (2016) also determined that the yellowness (b^* value) of *yukwa* dramatically increased with increased turmeric powder. They reported that turmeric powder had a predominant yellow colour, and this had a significant effect on the product colour.

Total phenolic contents, antioxidant capacities and their bioaccessibilities

Total phenolic contents (TPC) were shown in Table 3. Extractable phenolics of crackers ranged from 708.69 mg/100 g GAE (control) to 1,088.04 mg/100 g GAE (7.5M7.5T sample). Hydrolysable phenolic content was increased about 1.22 times and reached from 7,091.00 mg/100 g GAE (control) to 8,652.22 mg/100 g GAE (7.5M7.5T sample). Total phenolic contents of the samples with turmeric and/or mahaleb powders were significantly ($P\leq0.05$) higher than those of control sample. The highest total phenolic content (9,740.27 mg of GAE/100 g DW) was found in the 7.5M7.5T sample.

Patras *et al.* (2010) reported that the hydrolysis might have a role in degradation of phenolics. Ahmed and Abozed (2015) stated that the moisture content of bakery products is effective on the stability of the phenolic compounds and the loss of water in the form of steam during baking may prevents hydrolysis of phenolics. Similarly, in our study, the addition of mahaleb and/or turmeric powders also significantly ($P\leq0.05$) reduced the moisture content of the final product.

Bioaccessible phenolics of cracker samples were determined in order to assess turmeric and mahaleb powders as sources of accessible phenolics. The values of bioaccessible phenolics ranged from 5,546.94 to 7,591.90 mg of GAE/100 g DW in the samples. The highest bioaccessible phenolics (7,591.90 mg of GAE/100 g DW) and phenolic bioaccessibility values (77.94%) were obtained in the 7.5M7.5T sample. Turmeric powder addition caused more increase in bioaccessible phenolics of the crackers than mahaleb powder addition. The results also showed that turmeric and/or mahaleb powders' addition had a positive effect on extractable, hydrolysable and total phenolics and their bioaccessibilities of the cracker samples (Table 3).

In the antioxidant capacity analysis, after extraction of bioactive compounds efficiently, measurement is caring out various determination methods based on different principles. In this study, DPPH, ABTS and CUPRAC assays are the selected among the most common antioxidant capacity measurement methods and the results are presented in Table 4. According to the results of all assays (ABTS, CUPRAC and DPPH), antioxidant activities of the crackers supplemented with mahaleb and/or turmeric powders, which have been reported in the literature to be rich in phenolic compounds, have been found to be higher when compared to the control. The higher levels of phenolics might be responsible of the higher antioxidant activities of mahaleb and turmeric powders.

For extractable phenolics; the highest $TEAC_{ABTS}$ value (2.25 µmol Trolox/g) was observed in the sample with 7.5M and 7.5T mixture. It was also observed that the crackers supplemented with turmeric and/or mahaleb powders had significantly ($P\leq0.05$) higher $TEAC_{ABTS}$ values than control cracker. $TEAC_{CUPRAC}$ value of the control was 7.62 µmol Trolox/g sample, and the value increased to

Table 4. Antioxidant capacities of the cracker samples.[1]

Sample	Antioxidant capacities of extractable phenolics (µmol Trolox/g)			Antioxidant capacities of hydrolysable phenolics (µmol Trolox/g)		
	ABTS	CUPRAC	DPPH	ABTS	CUPRAC	DPPH
Control	1.24±0.02^{h}	7.62±0.20^{a}	15.79±0.60^{g}	35.55±0.39^{f}	103.52±0.66^{h}	66.10±0.78^{f}
5M	1.34±0.02^{g}	7.70±0.58^{b}	16.80±0.42^{f,g}	36.55±0.21^{e}	103.80±1.22^{h}	66.37±0.39^{f}
7.5M	1.40±0.02^{f}	8.66±0.50^{c}	18.16±0.76^{f}	36.93±0.30^{e}	106.49±0.79^{g}	68.77±0.72^{e}
5T	1.49±0.03^{e}	9.68±0.14^{d}	20.62±0.36^{e}	37.85±0.15^{d}	113.88±0.55^{f}	71.11±0.96^{d}
7.5T	1.55±0.01^{d}	10.06±0.12^{e}	21.31±0.72^{d,e}	38.27±0.47^{c,d}	122.99±2.35^{e}	71.65±0.17^{c,d}
5M5T	1.97±0.02^{c}	10.86±0.30^{e}	22.08±0.84^{d}	38.76±0.72^{c}	130.55±1.52^{d}	72.02±0.42^{b,c,d}
7.5M5T	2.13±0.03^{b}	11.95±0.20^{f}	23.62±0.69^{c}	39.55±0.40^{b}	135.95±0.72^{c}	72.28±0.78^{a,b,c}
5M7.5T	2.20±0.04^{a}	13.50±0.22^{g}	24.82±0.75^{b}	39.97±0.39^{a,b}	143.92±1.67^{b}	72.82±0.52^{a,b}
7.5M7.5T	2.25±0.02^{a}	14.22±0.21^{g}	26.19±0.98^{a}	40.52±0.39^{a}	148.43±0.83^{a}	73.09±0.28^{a}

[1] Mean values ± standard deviation with different superscript in the same row are significantly different ($P\leq0.05$).

14.22 µmol Trolox/g sample upon addition of 7.5M and 7.5T mixture, which is approximately 2 times higher than that of the control. These findings are in accordance with results of Herken *et al.* (2017) who reported that substitution with mahaleb resulted in a significant increase on the antioxidant activity. $TEAC_{DPPH}$ value of the control was 15.79 µmol Trolox/g sample, and the value increased to 26.19 µmol Trolox/g sample upon addition of 7.5M and 7.5T mixture. The results of the analysis indicated that turmeric supplementation was caused higher antioxidant content than mahaleb supplementation. In all assays, antioxidant capacities of hydrolysable phenolics of the crackers supplemented with turmeric and/or mahaleb powders were also significantly ($P \leq 0.05$) higher than that of control (Table 4).

The antioxidant capacity of foods arise from compounds with different chemical properties in their contents. Effectiveness of antioxidative compounds (bioactive compounds) hinges on their chemical features, interactions between food matrix and physical position within a food structure like nearness to membrane phospholipids, emulsion interfaces, or being in the aqueous phase (Gonzalez-Aguilar *et al.,* 2017; Watanabe *et al.,* 2000). The bioaccessibility and bioavailability of these bioactive compounds after human digestion determine their biological action in the body (Etcheverry *et al.,* 2012). For this reason, these compounds must be absorbed during digestion to reveal the protective effects in the human body (Hemery *et al.,* 2010). Several researches showed that dietary matrix, pH changes, enzymatic activity, interactions with dietary compounds are the factors that have the greatest impact on the stability and release of antioxidant compounds after gastrointestinal digestion (Alminger *et al.,* 2014; Kroll *et al.,* 2003). To estimate the potential function of a compound it is necessary to focus on the amount after gastrointestinal digestion rather than the original quantity (Mosele *et al.,* 2016). It is difficult to fully simulate the complex physiological conditions of living organisms, however, *in vitro* digestive models are widely used in recent research to mimic the *in vivo* situation (Mosele *et al.,* 2015). In recent years, *in vitro* bioaccessibility studies have become increasingly important in determining the profile and structural properties of food and components (Gonzalez-Aguilar *et al.,* 2017). Some studies have carried on the potential application of *in vitro* models for creating *in vivo* conditions by enzymes for obtaining bioaccessible extraction and investigation of bioactive compounds efficacy (Bouayed *et al.,* 2012; Chen *et al.,* 2016; Juániz *et al.,* 2016; Minekus *et al.,* 2014; Mosele *et al.,* 2015).

According to all assay (ABTS, CUPRAC and DPPH) results, 7.5M7.5T sample had the highest values of bioaccessible antioxidants. The results showed that the samples with turmeric and/or mahaleb powders exhibited significantly ($P \leq 0.05$) higher bioaccessible antioxidants than those of control sample (Table 5). Antioxidant bioaccessibility of the crackers ranged between 9.00 to 47.29% for the $TEAC_{ABTS}$, 11.54 to 14.47% for the $TEAC_{CUPRAC}$ and 12.47 to 20.59% for the $TEAC_{DPPH}$. Bioaccessibilities of crackers based on antioxidant capacity analysis increased linearly with supplementation increments and the supplemented crackers had significantly ($P \leq 0.05$) higher results than the control sample (Table 5).

The higher antioxidant capacities of the crackers with turmeric and/or mahaleb powders may be related to their higher phenolic content with regards to the control cracker made with wheat flour. Accordingly, crackers supplemented with turmeric and/or mahaleb powders could be developed as a functional food with more effective antioxidant properties.

Table 5. Bioaccessible antioxidants and antioxidant bioaccessibilities.[1]

Sample	Bioaccessible antioxidants (µmol Trolox/g)			Bioaccessibility of antioxidant (%)		
	ABTS	CUPRAC	DPPH	ABTS	CUPRAC	DPPH
Control	3.31±0.09^{i}	12.89±0.17^{h}	10.21±0.67^{g}	9.00±0.16^{h}	11.54±0.21^{f}	12.47±0.79^{e}
5M	5.19±0.10^{h}	13.27±0.29^{h}	12.01±0.74^{f}	13.70±0,16^{g}	11.88±0.24^{e,f}	14.44±0.82^{d}
7.5M	5.94±0.08^{g}	14.02±0.37^{g}	12.68±0.74^{e,f}	15.49±0.35^{f}	12.31±0.42^{d,e}	14.58±0.65^{d}
5T	9.61±0.27^{f}	15.58±0.29^{f}	13.61±0.51^{e}	24.44±0.79^{e}	12.57±0.21^{c,d}	14.84±0.47^{d}
7.5T	12.33±0.18^{e}	17.03±0.27^{e}	15.72±0.96^{d}	30.95±0.21^{d}	12.80±0.32^{c,d}	16.92±1.20^{c}
5M5T	12.94±0.23^{d}	18.48±0.46^{d}	17.01±0.90^{d,c}	31.77±0.54^{d}	13.08±0.39^{b,c}	18.07±0.95^{b,c}
7.5M5T	13.95±0.24^{c}	19.79±0.27^{c}	17.75±0.88^{b,c}	33.48±0.88^{c}	13.37±0.23^{b}	18.52±1.03^{b}
5M7.5T	16.10±0.16^{b}	21.25±0.46^{b}	18.67±0.97^{b}	38.18±0.02^{b}	13.36±0.41^{b}	19.13±1.14^{a,b}
7.5M7.5T	20.22±0.05^{a}	23.44±0.20^{a}	20.44±0.61^{a}	47.29±0.48^{a}	14.47±0.06^{a}	20.59±1.14^{a}

[1] Mean values ± standard deviation with different superscript in the same row are significantly different ($P \leq 0.05$).

Sensory analyses

The sensorial properties of the crackers were evaluated in terms of colour, appearance, texture, crispness, aroma, flavour-taste and overall acceptability (Table 6). Generally, all crackers supplemented with turmeric and/or mahaleb powders scored higher than control sample. Meanwhile, these crackers were acceptable since the mean scores were greater than a score of 5 (neither like nor dislike). According to colour evaluation of the control sample had the lowest score (4.0), while 7.5M7.5T blend had the highest (9.0) score. Individual supplementation of mahaleb and/or turmeric increased the colour value by 20%, when used both the colour was increased by 90%. Appearance of the turmeric and/or mahaleb incorporated crackers received higher scores, compared to control sample. Mahaleb and/or turmeric powders improved the crispiness compared to the control (score: 5.0) and the highest crispness score was obtained from 7.5M5T and 7.5M7.5T mixtures (score: 8.0). Incorporation of turmeric and/or mahaleb powders was increased the crispness by reducing the hardness of crackers. Similar results were obtained in another study using carboxylmethylcellulose and hydroxylpropylmethylcellulose in cracker production (Nammakuna *et al.,* 2016). According to aroma evaluation, comparatively contribution of mahaleb, 7.5M7.5T mixtures had the twice as much scores than the control. The highest increase of sensorial scores was obtained in flavour-taste properties of the crackers. Even though mahaleb taste was liked more than turmeric taste, incorporation of 7.5M7.5T increased appreciation 2.5 times. Besides overall acceptability of the control sample was increased 2 times with mahaleb and turmeric supplementation. The sensory properties of the crackers with powders were significantly ($P \leq 0.05$) higher than those of control cracker. The results of sensory evaluation indicated that the crackers supplemented with turmeric and/or mahaleb powders have desirable sensory properties and were acceptable.

It can be said that turmeric and/or mahaleb powders may be used in cracker formulations without producing a negative impact on the sensory properties. These results are in accordance with the findings of Herken *et al.* (2017) who reported that the cookies made with 1% mahaleb substitution got 4; 2% mahaleb substitution got 3.9, overall acceptability, which is excessively acceptable for consumer. Lim and Han (2016) also reported that the addition of turmeric powder up to 5% to waxy rice flour for *yukwa* was acceptable.

4. Conclusions

The aim of our research was to improve the functional properties of the cracker by adding different amounts of turmeric and mahaleb powders. It was found that as the amount of powders increased; hardness and moisture of crackers decreased. Crackers produced with turmeric and/or mahaleb powder exhibited higher puffiness compared to control cracker. As the turmeric rate increased, the attractive yellow colour was obtained. Crackers supplemented with turmeric and/or mahaleb powders had significantly ($P \leq 0.05$) higher extractable phenolics, hydrolysable phenolics, total phenolics and bioaccessibilities than those of control cracker. High phenolic content had also a positive contribution on nutritional and functional quality of the cracker. They were also characterised with significantly higher ($P \leq 0.05$) antioxidant capacities ($TEAC_{ABTS}$, $TEAC_{CUPRAC}$ and $TEAC_{DPPH}$ assays) in comparison to control cracker. The results also showed that the samples with turmeric and/or mahaleb powders exhibited significantly ($P \leq 0.05$) higher bioaccessible antioxidants than those of control sample. The results of sensory evaluation indicated that the crackers supplemented with turmeric and/or mahaleb powders had desirable sensory properties and were acceptable.

This study showed that the turmeric and/or mahaleb powders having high phenolic content, antioxidant capacity and bioaccesibility can be suitable for use as a functional

Table 6. Sensory evolution of cracker samples.[1]

Sample	Colour	Appearance	Texture	Crispness	Aroma	Flavour-taste	Overall acceptability
Control	4.0±0.30^{f}	5.0±0.30^{d}	4.0±0.10^{d}	5.0±0.30^{d}	3.6±0.01^{d}	3.0±0.10^{f}	4.0±0.20^{e}
5M	6.0±0.10^{d}	6.0±0.10^{c}	5.0±0.20^{c}	6.0±0.10^{c}	5.6±0.02^{c}	6.0±0.10^{d}	6.0±0.10^{c}
7.5M	5.0±0.10^{e}	6.0±0.20^{c}	5.0±0.30^{c}	6.0±0.20^{c}	6.6±0.01^{b}	7.0±0.30^{c}	6.0±0.20^{c}
5T	6.0±0.50^{d}	6.0±0.30^{c}	5.0±0.10^{c}	5.0±0.30^{d}	5.6±0.01^{c}	5.0±0.10^{e}	5.0±0.10^{d}
7.5T	6.0±0.10^{d}	6.0±0.50^{c}	5.0±0.30^{c}	6.0±0.10^{c}	5.3±0.02^{c}	6.0±0.30^{d}	5.0±0.30^{d}
5M5T	7.0±0.40^{c}	7.0±0.10^{b}	6.0±0.20^{b}	6.0±0.20^{c}	6.6±0.01^{b}	8.0±0.20^{b}	7.0±0.30^{b}
7.5M5T	7.0±0.40^{c}	7.0±0.10^{b}	7.0±0.10^{a}	8.0±0.20^{a}	5.6±0.03^{c}	9.0±0.20^{a}	8.0±0.10^{a}
5M7.5T	8.0±0.40^{b}	8.0±0.20^{a}	6.0±0.10^{b}	7.0±0.20^{b}	7.3±0.01^{a,b}	7.0±0.10^{c}	6.0±0.10^{c}
7.5M7.5T	9.0±0.40^{a}	8.0±0.20^{a}	7.0±0.20^{a}	8.0±0.10^{a}	7.6±0.02^{a}	7.0±0.30^{c}	8.0±0.20^{a}

[1] Mean values ± standard deviation with different superscript in the same row are significantly different ($P \leq 0.05$).

additive, in foods, especially in bakery products, without any negative effect.

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