Functional crackers: incorporation of the dietary fibers extracted from citrus seeds

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Abstract Dietary fibers extracted from defatted press meals of orange and grapefruit seeds were used in the production of crackers and the crackers were evaluated for physicochemical, textural, sensory properties, and bioactive compounds. The unexplored fibers (grapes seeds and orange seeds) and wheat fiber were added at 2.9% levels. The effects of incorporation of different fibers on composition and consumer acceptability were evaluated. The textural stability during storage was also monitored. Although there were no significant differences for proximate compositions; fiber contents, antioxidant capacities, and phenolics compositions were significantly higher in the crackers containing orange seeds fiber. Sensory analysis showed that taste/flavor attribute scores were low, while appearance scores were equal to the control sample. The fracturability, hardness and water activity values remain constant up to 90 days storage at room temperature. The crackers containing orange seed and grapes seed fiber could provide some health benefits to consumers due to their high fiber and flavonoid contents.

Keywords Orange seed fiber · Grapefruit seed fiber · Cracker · Quality · Consumer · Flavonoid

Introduction

Humans have long been consuming dietary fiber as part of the carbohydrate fraction within their foods, although its importance has been recognized scientifically more lately. Dietary fiber includes mixture of plant carbohydrate polymers, e.g. cellulose, hemicellulose, pectic substances, gums, resistant starch, inulin, and other non-carbohydrate components like lignin, polyphenols, waxes, saponins, cutin, phytates and resistant proteins. While there is still no universally accepted definition for dietary fiber, all definitions agree that it is not digested in the small intestine and passes into large bowel where it is fermented by gut microflora to different degrees (Elleuch et al. 2011; Fuller et al. 2016). It is now well accepted that dietary fiber provides some health benefits to the consumers through enhancement of fecal bulk, stimulation of colonic fermentation, reduction of postprandial blood glucose and pre-prandial cholesterol level. These clinical effects are associated with reduced risk of diseases such as cardiovascular diseases, cancer, diabetes, respiratory diseases, infections, and others (Elleuch et al. 2011; Huang et al. 2015). Hence, dietary guidelines mostly suggest diets rich in fiber like vegetables and grains to support healthy lifestyle. The Academy of Nutrition and Dietetics suggests adequate intake of fiber as 14 g total fiber per 1000 kcal, or daily intake of 25 g for adult women and 38 g for adult men based on researches demonstrating protective effects against coronary heart diseases (AND 2015).

Dietary fibers from many plant sources, food processing by-products and even some animal sources have been extracted, characterized and used in various food formulations (Elleuch et al. 2011; O'Shea et al. 2012; Russo et al. 2015). Health benefits are not only the sole reason of fiber enrichment to foods, in addition some functional properties

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are imparted to foods by fiber addition, like increase in water and oil holding capacity, emulsion and foam formation, modification of texture and eating properties, stabilization of structure and extension of shelf-life. Furthermore, some dietary fibers provide other bioactive ingredients (phenolics, aromas, anti-microbials, etc.) depending on the primary plant source and production technique (Elleuch et al. 2011; O'Shea et al. 2012; Huang et al. 2015). Citrus processing yields peels, seeds and pulps as valuable by-products which comprise around 50% of fresh fruit weight (El-Adawy et al. 1999). There are studies about dietary fibers extracted from various citrus albedos and flavedos (Gorinstein et al. 2001; Chau and Huang 2003; Figuerola et al. 2005; Marin et al. 2007; Russo et al. 2014, 2015). On the other hand, we could not found any study reporting dietary fiber extracts from citrus seeds.

The objectives of this study were to utilize the dietary fibers extracted from citrus seeds in cracker production, and to evaluate the compositions, properties and potential nutritional benefits of the new cracker products. Physico-chemical, nutritional, and sensory properties of the fiber enriched crackers were evaluated in addition to their three months storage stability for textural properties against control sample, containing no fiber.

Materials and methods

Materials

Wheat flour (Soke Un, Aydin, Turkey), wheat fiber (Smart Kimya, Izmir, Turkey), bakery shortening (Alba-Unipro, Cihan Gida Co., Istanbul, Turkey), table salt and table sugar were purchased from local stores. Megazyme enzyme kit (α -amylase—3000 units/mL, protease -350 tyrosine units/mL and amyloglucosidase—3300 units/mL) were used for dietary fiber analysis (Megazyme International Ireland Limited, Bray Co., Wicklow, Ireland). The flavonoid standards eriocitrin ($\geq 98\%$), rutin hydrate ($\geq 94\%$), naringin ($\geq 95\%$), hesperidin ($\geq 80\%$), neohesperidin ($\geq 90\%$), and naringenin ($\geq 98\%$) were purchased from Sigma Chem. Co. (St. Louis, USA). The phenolic acid standards gallic acid (97%), 2-*trans*-hydroxybenzoic acid (97%), vanillic acid (97%), caffeic acid ($\geq 98\%$), syringic acid (analytical), *p*-coumaric acid ($\geq 98\%$), sinapic acid ($\geq 98\%$), *trans*-ferulic acid (99%), hydroxycinnamic acid (97%), (+)-catechin hydrate ($\geq 98\%$), chlorogenic acid ($\geq 95\%$), and kaempferol ($\geq 97\%$) were purchased from Sigma-Aldrich and Fluka Chemicals (Sigma Chem Co., St. Louis, USA). All other solvents used during the analyses were of analytical grade and purchased from Merck Co. (Darmstadt, Germany).

Dietary fiber extraction from the seeds

The cold press meals from orange and grapefruit seeds were first defatted with hexane (1:2.5 = seed: hexane, w/v, 45 °C, 140 rpm, 12 h, 3 times), and then the defatted seed meals were used to extract the seed dietary fibers. The defatted meal and ultrapure water were mixed at 1:20 ratio, and ultraturaxed (Yellow line D125 basic) at 13,500 rpm for 5 min. Then, the solution was placed in an ultrasound chamber (Sonics VCX750, Connecticut, USA), and treated with 70% amplitude ultrasound for 5 min application and 5 min pause mode until the temperature of the mixture reached to 40 °C. Temperature of the mixture was monitored with a thermocouple. Finally, the mixture was filtered through 0.150 mm screen, and the remaining solids were washed with water ten times before vacuum drying at 50 °C for 3 days, and grinding in order to obtain fine particles as the seed dietary fibers.

Cracker preparation

Crackers were prepared with the recipe formulation of wheat flour (57.14%), shortening (11.42%), dietary fiber (2.90%), table salt (1.13%), sugar (1.13%) and water (26.28%). Control group did not contain fiber. The fiber enriched samples were three groups (wheat, orange seed and grapefruit seed fibers). All ingredients were mixed in a mixer (Arisco) at medium speed for 15 min. The dough was then flattened with a noodle former (Imperia, Moncalieri, Italy) to uniform thickness. The flattened dough was cut in standard round shape. The shaped crackers were cooked in an electric oven (Coruh Oven, Bursa, Turkey) at 175 °C for 15–20 min. Finally, the crackers were placed into zippered bags and stored at room temperature in the dark. For the storage study, crackers were sampled at every 15 days to monitor texture, water activity and color changes. No microbiological study was conducted. The whole crackers production study was replicated two times.

Physical analyses of the crackers

The dimensions (radius and thickness) of the crackers were measured with a digital caliper (CD-15CP, Mitutoyo Ltd., Andover, UK). The surface color of at least 10 randomly selected samples was measured with Minolta CR-400 (Osaka, Japan) colorimeter.

Cracker hardness and fracturability were determined with a TA-XT2i texture analyzer (Stable Microsystems, Surrey, UK). The method of 74-09.01 (AACC 2010) and Yilmaz and Ogutcu (2015) was modified. Cracker fracturability was measured with 3-point bending rig probe. The test was performed with gradients of 2.5 mm s^{-1} .

pretest entrance speed, 2.0 mm s^{-1} test speed, and 10 mm s^{-1} backing speed until 15 mm depth with 20 g triggering force. Similarly, the hardness of the samples was measured with 3 mm cylindrical probe by 2.0 mm s^{-1} pretest entrance speed, 0.5 mm s^{-1} test speed, and 10 mm s^{-1} backing speed until 3 mm depth with 5 g triggering force. From the force–time curves, the hardness was calculated from the peak maximum, and fracturability was calculated from the point at which the first peak occurred during probe's first compression into the sample. Texture Exponent software (v.6.1.1.0, Stable Microsystems) was used for curve calculations.

Chemical analyses of the crackers

Cracker moisture content was measured with an Ohaus MB45 moisture analyzer (Switzerland), water activity at room temperature—with Aqua Lab 4TE instrument (Decagon Devices, USA), crude protein content—by method 46-12 (AOAC 2000), crude fat—by method 30-10 (AOAC 2000), and ash—by method 30-10 (AOAC 2000). All results are given in terms of dry weight (% dw).

The total, insoluble and soluble dietary fiber contents (% dw) of the cracker samples were estimated by the enzyme-gravimetric method 991.43 (AOAC 2000) with commercial enzyme kit Megazyme. Corrections for remaining protein by Kjeldahl and ash content were also completed.

The antioxidant capacities of the crackers were measured in the phenolic extracts collected for free and bound phenolic compounds. The extraction technique of Challacombe et al. (2012) was followed. This extract was used for both phenolic compounds analysis and antioxidant capacity measurements. The collected extracts were evaporated and reconstituted to 2 mL with deionized water. Before phenolic compound analysis, both fractions were passed through $0.45 \mu\text{m}$ membrane filter.

Trolox equivalent antioxidant capacity (TEAC) was determined for both free and bound phenolics extracts collected separately. The methodology of Re et al. (1999) was applied for the measurements of total antioxidant capacity. The results are given as μmole Trolox equivalence per gram sample.

Phenolics compositions of the crackers

Both free and bound phenolic compounds were extracted according to Challacombe et al. (2012) as described above, and analyzed according to Moulehi et al. (2012) with a RP-HPLC system coupled by SPD-M20A diode array detector (Shimadzu Corporation, Kyoto, Japan). The separation was carried out on Zorbax Eclipse Plus C18 (Agilent Technologies, USA) column ($250 \times 4.6\text{-mm}$, $5 \mu\text{m}$) at 25°C . The mobile phase consisted of 0.2% sulphuric acid (solvent

A) and acetonitrile (solvent B) and the flow rate was kept at 0.5 mL/min . The gradient program was as follows: 0–0.1 min 0% A/100% B, 0.1–18 min 80% A/20% B, 18–24 min 70% A/30% B, 24–30 min 67.5% A/32.5% B, 30–36 min 45% A/55% B, 36–40 min 0% A/100% B, 40–45 min 60% A/40% B, 45–47 min 80% A/20% B. The injection volume was $20 \mu\text{L}$, and the peaks were monitored at 280 nm. The phenolic compounds were identified according to the retention times with comparison of commercially available standards, and the results were calculated as mg phenolic compound per gram sample.

Mineral compositions of the crackers

The wet burning of the cracker samples (0.5 g) was achieved in a microwave burner (Berghof speedwave v1.2.2 506) with 7 mL HNO_3 and 3 mL HCl under gradual heating process (50°C —5 min, 150°C —10 min, 200°C —20 min, 200°C —10 min, 200°C —10 min) until clear color was achieved. Then, the clear solution was diluted to 25 mL with distilled-deionized (DI) water. Finally, the solution was diluted again 10 times before mineral content determination with ICP-OES Spectrometer (Perkin Elmer Optima 8000, Boston, US) with appropriate dilutions of AccuTrace reference standards (New Haven, USA) for curve calibration (Yilmaz et al. 2016).

Consumer evaluations of the crackers

Consumer acceptances of the crackers were assessed by 5-point hedonic scale (1-dislike extremely to 5-like extremely) for appearance, hardness, taste/flavor and aroma attributes. 140 volunteer consumers tested the 4 cracker samples coded with three digit numbers. In another session, the same consumer group tested the replicate samples.

Cracker storage stability

Two batches of crackers were produced with the previously described procedure for the storage part of the study. The crackers were placed into zippered polypropylene bags and stored at room temperature under dark for 90 days. There was no atmosphere control over the bags. Cracker samples were withdrawn at every 15th day and analyzed for instrumental color (L , a^* , b^*), texture (hardness and fracturability) and water activity (a_w) values.

Statistical analysis

All data are given as means with standard deviation. The cracker samples were compared with Anova and Tukey's tests. The non-parametric Kruskal–Wallis and Dunn's test were used for sensory analysis data. Minitab ver. 17.1.0.

(Minitab 2010) and SPSS package (SPSS 1994) software programs were used for the analyses. The level of confidence was at least 95% for all statistics.

Results and discussion

Physical properties

All measured physical and chemical properties of the four different cracker samples are summarized in Table 1. Although during cracker shaping, the crackers were cut to obtain equal thickness and radius, after baking some dimensional differences occurred. Crackers showed 43–45 mm of radius and 5.0–5.2 mm of thickness. Although the difference among the samples was statistically significant, the luminosity (L value) was around 65–68 for all crackers. The lightest sample was the wheat fiber cracker (WFC); followed by grapefruit seed fiber cracker (GFC), control cracker (CTC) and orange seed fiber cracker (OFC). The other color value, a^* shows the level of redness and greenness from positive to negative numerical directions. Clearly, the control sample showed greater redness than the others. Likewise, level of yellowness-blueness indicated by the b^* value and only GFC sample has different b^* value (Pomeranz and Meloan 1994). Overall, additions of different fibers to the cracker formulations created some statistically significant color

differences, but the differences were not so high to create visually different samples. Cooking temperature and duration might affect color of baked foods by the Maillard reactions, as well as added ingredients and dyes (Bilgili et al. 2007). Since the samples in this study were prepared under the same conditions, the color differences were due to the natural color differences of the added fibers.

Textural properties are very important quality attribute for crackers. It was indicated that most consumers expect a crisp, fragile, and crunchy texture for crackers (Howard et al. 2009; Civile 2011). The measured fracturability and hardness values of the crackers are the most commonly accepted instrumental properties of product crispiness or crunchiness. This property is manifested by a characteristic sound when subjected to applied force. During first biting and chewing most consumers expect a crunchy texture for crackers and similar products. Usually, a small amount of force like biting and chewing can create material to fracture or crack, and these materials display high hardness and low cohesiveness and generally they are dry snack products (Howard et al. 2009; Saeleaw and Schleining 2010; Civile 2011; Fradinho et al. 2015). It could be observed that the WFC had significantly higher fracturability and hardness compared to the other crackers (Table 1), while OFC and GFC samples had a little higher hardness values than the control sample. Hence, it could be said that crackers with added fibers are usually more fractural and harder than the control sample, which does not contain any added fiber. In

Table 1 Physicochemical properties and antioxidant capacity values of the crackers

Property	CTC	WFC	OFC	GFC
Radius (mm)	43.68 ± 0.39 ^{b*}	45.12 ± 0.43 ^a	45.80 ± 0.34 ^a	45.28 ± 0.12 ^{ab}
Thickness (mm)	5.09 ± 0.05 ^{ab}	5.08 ± 0.01 ^b	5.15 ± 0.02 ^{ab}	5.19 ± 0.01 ^a
Color <i>L</i>	65.75 ± 0.81 ^{ab}	68.84 ± 0.94 ^a	64.93 ± 0.75 ^b	67.88 ± 0.64 ^{ab}
a^*	8.15 ± 0.21 ^a	6.63 ± 0.33 ^{bc}	7.63 ± 0.41 ^{ab}	5.99 ± 0.23 ^c
b^*	29.39 ± 0.47 ^a	28.97 ± 0.35 ^a	28.17 ± 0.40 ^a	26.17 ± 0.40 ^b
Fracturability (g force)	7316 ± 76 ^{bc}	11,883 ± 12 ^a	9888 ± 830 ^{ab}	6096 ± 651 ^c
Hardness (g force)	4307 ± 47 ^b	6155 ± 50 ^a	5994 ± 313 ^{ab}	5693 ± 331 ^{ab}
Moisture (%)	1.67 ± 0.06 ^b	1.71 ± 0.02 ^b	1.92 ± 0.03 ^a	1.94 ± 0.05 ^a
Water activity (a_w)	0.15 ± 0.01 ^a	0.10 ± 0.02 ^{ab}	0.11 ± 0.02 ^{ab}	0.10 ± 0.00 ^b
Protein (% dw)	11.27 ± 0.94 ^a	11.31 ± 0.63 ^a	11.00 ± 0.29 ^a	11.61 ± 0.48 ^a
Fat (% dw)	15.98 ± 0.69 ^a	14.11 ± 0.65 ^a	14.88 ± 0.49 ^a	15.19 ± 0.30 ^a
Ash (% dw)	1.78 ± 0.09 ^a	1.64 ± 0.09 ^a	1.74 ± 0.07 ^a	1.62 ± 0.12 ^a
TDF (% dw)	4.53 ± 0.33 ^c	9.16 ± 0.28 ^a	6.89 ± 0.11 ^b	6.69 ± 0.14 ^b
IDF (% dw)	2.52 ± 0.17 ^c	6.97 ± 0.29 ^a	5.29 ± 0.16 ^b	5.27 ± 0.28 ^b
SDF (% dw)	2.02 ± 0.35 ^a	2.19 ± 0.28 ^a	1.59 ± 0.07 ^a	1.42 ± 0.21 ^a
TEAC-Free (μmole Trolox/g)	5.36 ± 0.01 ^{ab}	2.67 ± 0.28 ^b	7.21 ± 1.09 ^a	6.35 ± 0.09 ^a
TEAC-bound (μmole Trolox/g)	2.59 ± 0.01 ^b	2.63 ± 0.18 ^b	4.88 ± 0.53 ^a	4.34 ± 0.01 ^a

CTC control cracker, WFC wheat fiber cracker, OFC orange seed fiber cracker, GFC grapefruit seed fiber cracker, TDF total dietary fiber, IDF insoluble dietary fiber, SDF soluble dietary fiber, TEAC trolox equivalent antioxidant capacity

* Means in the same row followed by different superscript letters were significantly different ($P < 0.05$)

terms of products expectancy, this situation can be perceived good for cracker type products. In one study (Howard et al. 2009), peanut flour added crackers were shown to be softer than commercial samples. In another study (Fradinho et al. 2015), addition of up to 6% Psyllium fiber enhanced the firmness of the biscuits significantly. On the other hand, incorporation of a hibiscus by-product to snack products has not created large differences for proximate composition, while dietary fiber content increased significantly (Ahmed and Abozed 2015).

Chemical properties

The proximate composition of the crackers is reported in Table 1. There were small differences among the samples for moisture content and water activity. There were no statistically significant differences for the protein, fat, and ash contents of the cracker samples. The proximate composition of any formulated food mostly depends on the recipe formulae, expectedly. Additions of 2.9% dietary fiber did not create any difference for proximate composition in this study. Likewise, addition of up to 10% rice bran have not created large differences among the proximate compositions of the crackers (Yilmaz et al. 2014), while dietary fiber content increased significantly due to the added bran.

Total (TDF), insoluble (IDF) and soluble (SDF) dietary fiber contents of the cracker samples were also measured (Table 1). For TDF and IDF, the highest contents were measured in the WFC sample, followed by the OFC, GFC and control samples. Clearly, commercial wheat fiber is providing more fiber components than our extracted orange seed and grapefruit seed fibers. At the same addition levels, both extracted fibers still provide significantly higher amounts of dietary fibers to the crackers than the control sample. In a study (Yilmaz et al. 2014), addition of up to 10% rice bran provided around 9.63% total dietary fiber to crackers. In another study (Ahmed and Abozed 2015), addition of 5% hibiscus by-product yielded around 8.17% total dietary fiber in the cracker product. Another study reported around 8–10% of total dietary fiber in the crackers made with whole wheat or buckwheat flours (Sedej et al. 2011). It is well known that dietary fibers, and especially IDF enhance fecal bulk and reduce delayed intestinal transit time to provide positive health effects to the consumers (Elleuch et al. 2011; Fuller et al. 2016). Hence, OFC and GFC samples could provide the expected health effects like WFC sample.

The free and bound fractions of the phenolic compounds were extracted from the cracker samples, and their antioxidant capacities were measured (Table 1). Except WFC sample, there was no difference among the samples for free Trolox equivalence antioxidant capacity (TEAC)

value, while for the bound TEAC value, the highest capacities were observed in the OFC and GFC samples. When the total of free and bound TEAC values were considered, the OFC and GFC samples had the highest capacity followed by the control and WFC samples. Clearly, enrichment of the crackers with citrus seed dietary fibers enhanced their antioxidant capacity. In the study of Bilgicli et al. (2007), addition of different fibers in cookie formulations created some little decreases in total antioxidant capacity values. Contrary to this, addition of hibiscus by-product yielded significant enhancements in the radical scavenging activities of the snacks produced (Ahmed and Abozed 2015).

Phenolics composition

Both free and bound phenolic compounds were extracted from the cracker samples and analyzed (Table 2). The flavonoids; eriocitrin, rutin, naringin, hesperidin, neohesperidin and naringenin; and the phenolic acids; gallic, 3,4-hydroxybenzoic, vanilic, caffeic, syringic, *p*-coumaric, sinapic, *trans*-ferulic and *trans*-2-hydroxycinnamic acids were quantified. For each compound in Table 2, the bound form is given under the free form within brackets. The control and WFC samples did not contain any flavonoids, expectedly, while phenolic acids were present in all samples. There were significant differences among the samples for both free and bound phenolics composition. Some samples had both free and bound forms of phenolic compounds, while some contained only one form. As long as the cumulative total amounts of the flavonoids and phenolic acids were considered, the highest content was in the GFC sample (12.93 mg/g sample), followed by CTC (10.39 mg/g sample), WFC (8.99 mg/g sample) and OFC (8.76 mg/g sample). Phenolic compounds are regarded to have potential beneficial health effects. Possible anti-inflammation, anti-oxidation, anticancer, cardiovascular protection, anti-diabetes, renal protection, protection against Alzheimer's disease and antihyperuricemic activities were reported for naringenin (Mir and Tiku 2015). In another study (Chtourou et al. 2016), naringenin was shown to improve renal failure and platelet alterations in rats. Similarly, hamsters were fed with nobiletin and tangeretin and it was observed that their plasma triglycerides and weight gain significantly reduced (Lei et al. 2016). Hence, these new crackers could be assigned as functional products due to their high dietary fiber and flavonoid compositions.

Mineral compositions

Ten different minerals (Na, Ca, K, Mg, Fe, Mn, Zn, Ba, B, Cr) were quantified in the cracker samples (Table 3).

Table 2 Flavonoid and phenolic acid compositions of the crackers

	CTC	WFC	OFC	GFC
<i>Flavonoids (mg/g sample)</i>				
Eriocitrin	–	–	0.16 ± 0.0003 ^{a*}	0.074 ± 0.004 ^b
(bound)	–	–	(0.088 ± 0.000 ^b)	(0.104 ± 0.0005 ^a)
Rutin	–	–	0.383 ± 0.0003 ^b	1.044 ± 0.0003 ^a
(bound)	–	–	(1.096 ± 0.033 ^b)	(2.602 ± 0.006 ^a)
Naringin	–	–	–	1.455 ± 0.095
(bound)	–	–	(0.122 ± 0.003 ^a)	(0.132 ± 0.004 ^a)
Hesperidin	–	–	0.425 ± 0.002	–
(bound)	–	–	–	(0.225 ± 0.001)
Neohesperidin	–	–	0.247 ± 0.005 ^b	0.325 ± 0.006 ^a
(bound)	–	–	–	–
Naringenin	–	–	0.310 ± 0.003 ^a	0.109 ± 0.001 ^b
(bound)	–	–	–	–
<i>Phenolic acids (mg/g sample)</i>				
Gallic acid	2.809 ± 0.38 ^a	2.276 ± 0.18 ^a	2.511 ± 0.089 ^a	2.472 ± 0.039 ^a
(bound)	(0.180 ± 0.017 ^{ab})	(0.159 ± 0.003 ^b)	(0.195 ± 0.008 ^{ab})	(0.206 ± 0.005 ^a)
3,4-Hydroxybenzoic acid	0.373 ± 0.025 ^b	0.374 ± 0.023 ^b	0.635 ± 0.030 ^{ab}	0.752 ± 0.012 ^a
(bound)	(0.001 ± 0.000 ^c)	(0.009 ± 0.001 ^{bc})	(0.011 ± 0.005 ^{ab})	(0.036 ± 0.007 ^a)
Vanillic acid	–	–	0.024 ± 0.001	–
(bound)	(0.016 ± 0.001 ^a)	(0.017 ± 0.004 ^a)	–	–
Caffeic acid	0.218 ± 0.00 ^a	0.218 ± 0.002 ^a	0.221 ± 0.002 ^a	0.219 ± 0.003 ^a
(bound)	(0.219 ± 0.004 ^a)	(0.218 ± 0.002 ^b)	–	–
Syringic acid	0.102 ± 0.001 ^a	0.098 ± 0.000 ^a	0.101 ± 0.003 ^a	0.099 ± 0.005 ^a
(bound)	(0.104 ± 0.005 ^a)	(0.104 ± 0.009 ^a)	(0.106 ± 0.003 ^a)	(0.109 ± 0.002 ^a)
<i>p</i> -Coumaric acid	0.118 ± 0.001 ^c	0.118 ± 0.001 ^{bc}	0.124 ± 0.001 ^{ab}	0.129 ± 0.001 ^a
(bound)	(0.125 ± 0.004 ^a)	(0.125 ± 0.001 ^a)	(0.131 ± 0.006 ^a)	(0.133 ± 0.002 ^a)
Sinapic acid	–	–	–	–
(bound)	(0.047 ± 0.003 ^a)	(0.046 ± 0.00 ^b)	–	–
<i>tr</i> -Ferulic acid	3.168 ± 0.095 ^a	2.461 ± 0.035 ^b	–	–
(bound)	(2.038 ± 0.035 ^a)	(2.012 ± 0.043 ^a)	(1.039 ± 0.000 ^a)	(1.887 ± 0.082 ^a)
<i>tr</i> -2-Hydroxycinnamic acid	0.733 ± 0.035 ^a	0.616 ± 0.040 ^a	0.668 ± 0.029 ^a	0.656 ± 0.002 ^a
(bound)	(0.136 ± 0.006 ^c)	(0.137 ± 0.000 ^{bc})	(0.159 ± 0.000 ^{ab})	(0.159 ± 0.006 ^a)

CTC control cracker, WFC wheat fiber cracker, OFC orange seed fiber cracker, GFC grapefruit seed fiber cracker

* Means in the same row followed by different superscript letters were significantly different ($P < 0.05$)

Amounts of Na, K, Ca, and Mg were higher, and the other minerals were even less than 1.0 mg/100 g sample. In one study (Yilmaz et al. 2014), six minerals in rice bran added crackers were reported. Zn, Fe and Ca contents were higher in our samples, whereas the higher content of Na and K was reported in their study. In another study (Ahmed and Abozed 2015), crackers prepared with hibiscus by-products were analyzed for K, Ca, Mg, Mn, Fe and Zn minerals. As the added hibiscus by-product increased, the mineral contents also increased. Compared to our results, we had higher mineral amounts than theirs. The results in Table 3 indicate that addition of different dietary fibers have not

created any large difference for the measured minerals compared with the control sample.

Consumer preference

The four cracker samples were evaluated for their sensory quality by hedonic scale with 140 consumers for appearance, hardness, taste/flavor and aroma attributes using a 5-point scale (Table 4). The appearance scores were not significantly different. Sensory hardness value of the control sample (CTC) was significantly higher than the others. Hence, addition of fibers decreased the sensory hardness

Table 3 Mineral compositions of the crackers

Mineral (mg/100 g)	CTC	WFC	OFC	GFC
Na	676.83 ± 4.35 ^{a*}	631.62 ± 7.68 ^b	518.1 ± 18.5 ^d	599.22 ± 4.91 ^c
Ca	84.61 ± 2.70 ^b	84.39 ± 3.21 ^b	103.01 ± 6.40 ^{ab}	111.75 ± 1.77 ^a
K	131.08 ± 3.68 ^a	130.33 ± 0.55 ^a	110.07 ± 3.40 ^b	126.55 ± 0.61 ^a
Mg	33.37 ± 0.17 ^{ab}	32.79 ± 0.64 ^{ab}	29.89 ± 1.33 ^b	33.96 ± 0.26 ^a
Fe	2.56 ± 0.02 ^b	2.97 ± 0.16 ^b	2.98 ± 0.24 ^b	5.34 ± 0.44 ^a
Mn	2 ± 0.01 ^{ab}	2 ± 0.01 ^{ab}	1.86 ± 0.02 ^b	1.93 ± 0.002 ^a
Zn	3.23 ± 0.24 ^b	3.93 ± 0.27 ^{ab}	3.84 ± 0.25 ^{ab}	6.05 ± 1.08 ^a
Ba	0.33 ± 0.01 ^b	0.31 ± 0.01 ^b	0.68 ± 0.13 ^a	0.31 ± 0.02 ^b
B	1.30 ± 0.04 ^a	0.95 ± 0.01 ^b	1.29 ± 0.02 ^{ab}	1.08 ± 0.06 ^c
Cr	0.04 ± 0.00 ^a	0.04 ± 0.00 ^a	0.05 ± 0.01 ^a	0.03 ± 0.00 ^a

CTC control cracker, WFC wheat fiber cracker, OFC orange seed fiber cracker, GFC grapefruit seed fiber cracker

* Means in the same row followed by different superscript letters were significantly different ($P < 0.05$)

Table 4 Consumer preferences of the crackers

Sensory property	CTC	WFC	OFC	GFC
Appearance	3.59 ± 0.08 ^a	3.48 ± 0.08 ^a	3.45 ± 0.08 ^a	3.31 ± 0.08 ^a
Hardness	3.23 ± 0.09 ^a	1.93 ± 0.09 ^c	2.65 ± 0.09 ^b	2.49 ± 0.11 ^b
Taste/Flavor	3.62 ± 0.09 ^a	3.12 ± 0.09 ^b	2.00 ± 0.09 ^c	1.74 ± 0.09 ^c
Aroma	3.60 ± 0.07 ^a	3.44 ± 0.07 ^a	3.09 ± 0.08 ^b	3.06 ± 0.08 ^b

CTC control cracker, WFC wheat fiber cracker, OFC orange seed fiber cracker, GFC grapefruit seed fiber cracker

* Means in the same row followed by different superscript letters were significantly different ($P < 0.05$, $n = 140$)

perceived by the consumers. This finding contradicts with the instrumentally measured hardness values (Table 1), where the lowest value was in the CTC sample. The taste/flavor scores of the samples show that the control sample is regarded as the best followed by WFC, OFC and GFC. Obviously, OFC and GFC samples were not liked by the consumers for their taste/flavor. In fact, this is expected, since citrus seed fibers had a distinct bitter taste, and this taste was evident in the cracker samples. As can be clearly observed from Table 2, the OFC and GFC samples had 8.76 and 12.93 mg/g sample of total phenolic compounds (flavonoids and phenolic acids), respectively. Although CTC and WFC samples had that total amount as 10.39 and 8.99 mg/g samples, respectively, their taste scores were better, since both samples did not contain any flavonoids. It is well known (Russo et al. 2014) that flavonoids are very bitter tasting compounds. More research is needed to improve the taste property of citrus seed fibers. Combination of these fibers with other neutral tasting fibers could improve product taste scores. Although citrus seed fibers are quite rich in bioactive flavonoid and phenolic compounds (Table 2) and have higher contents of insoluble fiber (Table 1), their bitter taste may limit food

applications. Howard et al. (2009) showed that cheddar-cheese flavored peanut flour crackers were liked best by consumers. Appearance, texture, flavor, taste and preference rank of the rice bran added crackers were evaluated (Yilmaz et al. 2014), and it was found that up to 5% bran addition enhanced the scores. In another study (Fradinho et al. 2015), color, flavor, texture and overall acceptability of Psyllium fibre enriched biscuits showed higher acceptance at 6% fiber addition level. Similarly earlier research on hibiscus by-product added crackers (Ahmed and Abozed 2015) indicated that up to 2.5% addition level, the scores of color, taste, crispness, odor, appearance and overall acceptability enhanced, and then decreased as addition level increased up to 5.0%. Clearly, fiber addition to cracker formulations could be accepted by consumers up to some level, but much higher additions may create sensory problems.

Storage stability of cracker texture

To assess the storage textural stability of the crackers, samples were produced in the same way and placed in zippered storage bags and stored at room temperature under dark for

90 days. Instrumental color, fracturability, hardness, and water activity values were measured at every 15th days during the storage period. The total color difference (ΔE) values indicate the significance of color change in a sample under two different conditions. Thus, the ΔE can yield information about the color stability of the samples. It was stated that if ΔE is less than 1.0, the difference is not significant, if equal or higher than 1.0, the color difference is significant (Pomeranz and Meloan 1994). Clearly, some color differences occurred during the storage period in the CTC and OFC samples. The ranges of L values for CTC, WFC, OFC and GFC samples were 62.36–69.15, 64–69–71.06, 61.49–65.69, and 60.52–68.55, respectively. Likewise, a^* values ranged as 6.38–8.15, 5.37–7.08, 5.38–7.63, and 5.74–7.75 for the CTC, WFC, OFC and GFC samples, respectively. In the same manner, values of 29.39–32.95, 28.75–32.81, 25.10–32.32, and 26.17–31.22 for the b^* values were measured. Although there were some total color differences observed for the CTC and OFC samples, the color values of all samples were alike.

The fracturability values of the crackers during the storage period are given in Fig. 1a. Comparisons of the four samples were done at every 15th day of storage. Clearly, in almost all measurement days, the highest score was in the WFC sample. During storage some small fluctuations occurred for all samples, but fracturabilities of the samples at

Fig. 1 Fracturability (a) and hardness (b) values of the crackers during storage. CTC control cracker, WFC wheat fiber cracker, OFC orange seed fiber cracker, GFC grapefruit seed fiber cracker

the beginning and at the end of 90 days storage period were not significantly different. Hence, it could be claimed that the crackers were stable enough under the defined storage conditions for their fracturability properties. Similarly, the hardness values were monitored during the storage period (Fig. 1b). All fiber added samples were harder than the control sample. Most importantly, during the 90 days storage the hardness values did not decrease in any sample. In fact, there were some little enhancements in the hardness of the fiber added crackers after 60 days of storage. Generally, it can be said that during storage the textural properties of the samples did not change significantly, and the crackers kept their fragile and crunchy structures. This result could be considered good for such snack type products.

Lastly, the water activity values of the samples during the storage period were measured and presented in Fig. 2. After cooking, the fresh crackers had water activity values at around 0.10–0.15, but during storage up to first 15 days, the values increased to around 0.40–0.50 water activity. Then, the water activities of all samples decreased gradually to around 0.15–0.20 in 90 days. It would be possible that at the beginning of storage, the very dry crackers absorbed some water from the surrounding package atmosphere, but over the time of storage, they reached a balance value. In fact, all measured water activity values are quite low, and acceptable for low moisture foods to be stable. In these types of foods, water activity would be very important both in terms of microbial growth and loss of crispness. For cracker and cookie type dry foods, water activity no more than 0.3 is suggested for product stability (Tarancón et al. 2013). Hence, these crackers could be accepted as quite stable even after 90 days storage. In one study (Fradinho et al. 2015), Psyllium fiber added biscuits were shown to have 0.2–0.7 water activity values. Our results concur with Tarancón et al. (2013) and Fradinho et al. (2015) for the ranges of measured water activity values of the crackers.

Fig. 2 Water activity values of the crackers during storage. CTC control cracker, WFC wheat fiber cracker, OFC orange seed fiber cracker, GFC grapefruit seed fiber cracker

Conclusion

Crackers as common and preferred snacks could be a very valuable source of dietary fibers in human diet. There are many different kinds of fibers with variable ratios of soluble and insoluble fractions. This study reports the applications of orange seed fiber and grapefruit seed fiber in cracker preparation. For most physicochemical properties, there were no differences between fiber added and control samples. At 2.9% addition levels, the orange seed and grapefruit seed fibers yielded more soluble and insoluble fibers than that of the control sample, but they were lower than that of the wheat fiber added sample. Both new fibers added crackers showed higher antioxidant capacity values, mostly due to their phenolic compositions. Both orange seed fiber cracker (OFC) and grapefruit seed fiber cracker (GFC) sample had significant amounts of flavonoids and phenolic acids. These compounds are bioactive molecules and may aid some health promoting activities in humans. More studies are needed in this respect. Mineral composition analysis showed that these crackers could be good sources of Ca, K and Mg. Consumer sensory scores indicated that the OFC and GFC samples were not accepted in terms of their taste/flavor attributes. In fact, these two samples had some bitterness, and this problem is better ought to be solved. We suggest blending of citrus seed fibers with neutral tasting fibers. Storage stability study indicated that these new crackers are fairly stable in terms of their color, textural properties (fracturability and hardness) and moisture content. During the 90 days storage, the crackers were well stable. In conclusion, this study proved that crackers with bioactive molecules and dietary fibers can be produced with the very new fiber sources, namely orange seed and grapefruit seed fibers. The bitter taste of these new fibers should be resolved either during their extraction procedure by applying degradation enzymes or blending the fiber with neutral tasting fibers. The functional and health effects of the bioactive components of these new fibers may lead to new research topics.

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