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Development of novel and functional gluten-free cracker formulas by using diverse cereal, pseudo-cereal and legume flours

Entwicklung neuartiger und funktioneller glutenfreier Knabbergebäck-Rezepturen unter Verwendung verschiedener Getreide-, Pseudogetreide- und Hülsenfruchtmehle

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Summary

This study aims to develop novel and nutritious crackers, especially for celiac patients (CP). For this purpose, 10 different gluten-free flours were separately used as wheat flour (WF) substitutes. Physical, chemical, textural, color and sensory properties of trial cracker samples (TCS) were determined. Various gluten-free flours affected the cracker characteristics significantly. The protein quantity and quality of TCS containing plant (various flour and flax and chia seeds) and animal-derived protein (egg) were relatively high. Diameter, thickness and spread ratio values of gluten-free cracker formulas were found to be superior when compared to the gluten-containing control samples. The crackers formulated with peanut derivatives had a relatively high score of around 70 out of 75 points among sensory panelists. TCS, except for corn semolina cracker, had an acceptable quality. Therefore, if a similar dough recipe is used in cracker production, the gluten-free flours can be successfully substituted for WF. TCS which had a nutritious composition and potential to skip meals could be used as healthy bakery products in the nutrition of CP and children. In conclusion, novel, more nutritious and functional crackers were developed.

Keywords: gluten-free cracker, celiac patients, cracker characteristics, novel functional cracker, food quality

Abbreviations
CP: celiac patients; TCS: trial cracker samples; WF: wheat flour; RF: rice flour; CF: corn flour; CPF: chickpea flour; CS: corn semolina; BF: buckwheat flour; QF: quinoa flour; LF: lentil flour; AF: almond flour; PF: peanut flour; PS: peanut sesame

Introduction

In the modern age, consumers have started to pay more attention to consuming healthy food and they require new products to be introduced into the market since they prefer nutritionally enriched foods to good/pleasant taste (Sedej et al., 2011; Ahmed and Abozed, 2015). In the snack food industry, products such as cakes, biscuits, crackers, snacks, wafers, potatoes, and corn chips expanded the market considerably and have accelerated the introduction of new products into the industry almost every day (Millar et al., 2017; Dizlek, 2019). Snack foods, high in carbohydrates and fats, are consumed alongside hot or cold beverages or alone, which may cause skipping meals (Dizlek, 2020). Their main ingredients are usually wheat flour (WF), sugar, oil, and chocolate. Among these snack foods, the demand for crackers increased because they have many advantages such as their variety, long-term preservation, and easy access (Ahmed and Abozed, 2015; Faccioli et al., 2021; Wesley et al., 2021). Crackers are thin and brittle products made from low in sugar, leavened, or unleavened dough. Crackers have a structure that can be formulated with diverse food components (Polat et al., 2020). Consumers, particularly children, highly appreciate crackers because of their crispy texture and characteristic delicious flavor (Dizlek, 2019, 2020).

A significant part of the crackers produced in the world is readily manufactured using WF (Dizlek, 2019). WF contains gluten proteins (gliadin and glutenin). Gluten proteins have been implicated as a cause of food intolerance (Celiac). Celiac is a type of disease associated with the immune system-induced intestinal disorder and it is a malabsorption syndrome that appears in susceptible individuals after the intake of gluten, including foods (Holtmeier and Caspary, 2006; Queiroz et al., 2022). Nowadays, food production for patient groups suffering from diseases such as Celiac, Diabetes, Phenylketonuria, Beriberi, and Pellagra is among the most critical topics for the food industry and food scientists (Dizlek, 2019). While celiac patients (CP) cannot consume many foods made from WF such as bread, pasta, biscuit, cracker, they can easily consume gluten protein-free rice flour (RF), corn flour (CF), buckwheat flour (BF), lentil flour (LF), chickpea flour (CPF) and foods made from them (Dizlek and Özer, 2016). It has been revealed that biscuits and crackers are an essential part of the diet of CP, compared to bread (Valitutti et al., 2017). To meet the nutritional needs of CP, there are various alternative products available in the market. However, because of their high prices, access difficulties, lack of flavor, poor mouth feel, CP who consume these products and especially live in rural areas experience nutritional problems (Gallagher et al., 2004; Turabi et al., 2008; Jnawali et al., 2016; Pestorić et al., 2017; Queiroz et al., 2022).

The diets of people with celiac disease are at a higher risk of being unbalanced as it needs to be gluten-free and there are limited food choices for gluten-free foods (Jnawali et al., 2016; Vici et al., 2016; Naqash et al., 2017). Considering the increase in the number of individuals with gluten intolerance, this study aims to develop more nutritionally beneficial products primarily for CP, but also for all consumers and the food industry. Crackers, which have an important place in daily life as a snack food and whose consumption is increasing day by day, were chosen as the application area of this research.

To the best of our knowledge, limited studies have been conducted on the development of gluten-free crackers and limited number of components were used (Han et al., 2010 [CPF, LF, yellow pea, pinto and navy bean flours]; Sedej et al., 2011 [refined and wholegrain BF]; Acharya et al., 2020 [RF + soya flour + sesame seed]; Dick et al., 2020 [clado-de flour and cactus mucilage]). In this study, 11 different cracker types were produced. We aimed to produce new cracker formula using food ingredients that have diverse functional properties such as RF, CF, corn semolina (CS), BF, quinoa flour (QF), LF, CPF, almond flour (AF), peanut flour (PF), and peanut sesame (PS) as the substitute for WF. The focus on developing gluten-free products that are acceptable in terms of sensory quality increases the importance of the study and reinforces its purpose. In addition, it is believed that since this research is the first attempt for many poor/developing countries' cracker industry, the obtained results are expected to provide important tips to researchers and potential industrial food producers working on developing healthy new products in this field. Further, as is known, the main factor affecting the quality of bakery products is flour. Another goal of the study is to examine the variations in product quality by substituting WF with other flour derivatives on the formulated cracker. Briefly, this study explored the development of a novel, nutritious and functional gluten-free cracker formulas which contain functional food components such as flax and chia seeds and nutritious food items such as egg and olive oil.

Materials and methods

Materials

WF (refined flour with a flour yield of 69%), RF, CF, CS, BF, QF, yellow LF, CPF, AF, PF, PS, flaxseed, chia seed, baking powder, olive oil, egg, salt, and water were used as materials in cracker production. WF and its substitutes were purchased from Turkey's market. Flaxseed, chia seed, baking powder, olive oil, egg, salt were bought from local supermarkets in Gaziantep, Turkey. PF and PS, which are by-products of the peanut processing industry, with a particle size of 0–1 mm and 3–5 mm, respectively, were used.

Cracker formula and production method

In the main trials, the type and amount of other ingredients were tested practically in the cracker dough sample prepared with WF to determine the appropriate dough formula to be used in cracker production. Therefore, preliminary trials were made using different amounts of each ingredient in the dough recipe and the appropriate dough formula was optimized. Analytical measurements were not applied to the dough and cracker samples, and the ideal cracker formula was selected according to subjective data. This formula was used in the main cracker trials. In the preliminary trials of cracker production, the amount of water to be added was determined separately for each formula considering the dough coming together to form a solid mass (single piece) and can be kneaded. We also tried to determine the appropriate time and tem-

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peratures to be used in cooking the cracker samples. The WF sample, the control group, was taken as a reference; applications of 150, 160 °C temperature, 25, 30 and 35 min time were tested. Again, considering the subjective data, the most suitable baking requirements were determined under trial conditions. These requirements were applied (kept constant) in all cracker production trials.

Cracker dough was prepared by using the ingredients given in Table 1 in the amounts specified. Flour varieties were used as a variable in the formula, and the amount of water was changed accordingly to obtain the proper dough consistency.

In the preparation of crackers, firstly, all dry ingredients in the formula were mixed well. Then, liquid components other than water (egg, olive oil) were added, and the dough was kneaded for 4 min. Finally, water was added. Briefly, the dough was optimally kneaded until dough development. The dough preparation process took 6 min in total. The obtained dough was kept in a closed container for 10 min at room temperature. With the help of a roller, rested dough was laminated 5–6 times and placed between two greaseproof papers and two boards of 4.0 mm thickness. With the fixed thickness, it was cut with a 45 mm diameter cutting mold. Circled dough pieces were placed on the original tray of the oven by placing greaseproof paper (Protex brand) at specific intervals to prevent sticking, and they were baked. Baking was carried out in the Arçelik brand "8315 S" model oven (İstanbul, Turkey) at 150 °C for 35 min in the third rack of the five-rack oven from the top. Crackers were removed from the oven after cooking, cooled on a tray for 5 min and put on a wire rack for 55 min, at room temperature.

TABLE 1: *Cracker dough formula used in the study.*

Ingredients	Weight (g)
Wheat flour or its substitutes[a,b]	[c]
Water[b]	[d]
Egg	57
Chia seed	25
Flaxseed	20
Olive oil	15
Salt	1.5
Baking powder	1

[a]Weighing of flour samples, which is the main component in the cracker dough formula, was made on a 14 % moisture basis of 150 g. [b]Variable ingredients. Flour varieties are used as a variable in the formula and the amount of water has been changed accordingly to obtain the proper dough consistency. [c]146.04 g for WF, 141.3 g for RF, 144.19 g for CF, 146.8 g for CS, 145.02 g for BF, 147.19 g for QF, 136.97 g for LF, 137.98 g for CPF, 133.94 g for AF, 135.26 g for PF, 133.49 g for PS. [d]0 g for AF and PF, PS; 25 g for CF and QF; 28 g for BF, 30 g for WF and RF, 50 g for CS, 55 g for LF, 135 g for CPF.

Analysis

Chemical (proximate) analysis

Moisture, ash, crude protein, crude fat (AACCI Method 44-19.01, 08-01.01, 39-25.01, 30-25.01, respectively; [AACC, 2010]), carbohydrate, and energy (Karaağaoğlu et al., 2008) contents of various flour samples and trial cracker samples (TCS) were analyzed. The proximate carbohydrate and energy contents of flours and TCS were calculated according to Eq. 1 and Eq. 2, respectively. pH values of TCS were also determined (AACCI Method 02-52.01; AACC, 2010).

$$\text{Carbohydrate Amount (\%)} = 100 - (\%\ \text{moisture} + \%\ \text{ash} + \%\ \text{protein} + \%\ \text{fat}) \quad (1)$$

$$\text{Energy Value (kcal)} = [(9\times\%\ \text{fat}) + (4\times\%\ \text{protein}) + (4\times\%\ \text{carbohydrate})] \quad (2)$$

Physical analysis

Densities of cracker doughs were analyzed by dividing the weight of the dough by the volume of water determined using a known container (Dizlek, 2015). Diameters and thicknesses of the TCS were measured using a manual caliper (Somet Inox, Poland). The spread ratio was calculated by dividing the diameter of crackers by the thickness value (AACCI Method 10-54.01; AACC, 2010). The baking losses of the TCS were determined according to Dizlek (2015), and their volumes were determined by the displacement method with mustard seeds (AACCI Method 10-05.01; AACC, 2010).

Color and texture analysis

Color analysis of TCS was done using the Hunterlab Color flex (Model No. 45/0, Reston, Virginia, USA) color measurement device with standard methods, measuring L*, a*, b* color values. The texture properties of TCS were analyzed using TA.TX2 model texture analyzer (Stable Micro Systems Ltd., Godalming, Surrey, UK). Fracture ability and hardness values of crackers were determined by applying a three-point break test according to Adeola and Ohizua (2018) with some modifications. Analysis was performed with HDP/3BP three-point bend ring blade set using test speed 3 mm/s, pre-test speed 1 mm/s, post-test speed 10 mm/s, trigger load 50 g and distance 5 mm.

Sensory analysis

Hedonic sensory evaluation of the crackers was conducted by a panel consisting of 16 non-celiac, untrained panelists (8 women and 8 men aged 18–56 years, non-smokers, and healthy) in the sensory booth where heat, light, smell, and sound conditions were controlled. All the panelists agreed to taste the TCS before the sensory evaluation tests were carried out and stated that they consumed crackers and had no allergies or intolerances to any of the ingredients present in the samples and were informed that they were trying control and gluten-free crackers. Panelists were asked to evaluate the TCS in terms of surface appearance properties (brightness-opaqueness, color, surface smoothness), cross-sectional features (cross-sectional structure and color), tasting properties (bite, chewing, and swallowing), and affordability properties using a five-point hedonic scale (1: bad, 2: not enough, 3: acceptable, 4: good, 5: very good). Water, at room temperature, was provided to the panelists to clean their palate after eating each sample. Samples were coded with three-digit numbers and served to the panelists at random. The Research Ethics Committee of the Gaziantep University (Turkey) approved this study, and all the participants signed an informed consent form prior to enrolling in the study.

Chemical and physical analyses of TCS were measured 1 and 2 h after they had been removed from the oven, respectively. Other analyses were conducted 1 day after baking.

Statistical analysis

Experiments and analysis were carried out in two and three replicates, respectively. Experimental data were expressed with mean±standard deviation (means±SD). Variance analysis (ANOVA) Statistical Package for Social Science program (SPSS, version 18.0 for Windows, SPSS Inc., Chicago, IL, USA) was applied to the data obtained regarding the measured properties of crackers. Values that were found significant were subjected to Duncan's multiple comparison tests to determine the differences among the mean values ($P < 0.05$).

Results and discussion

Basic characteristics of various flour samples

Basic chemical compositions of 11 different flour/semolina samples are shown in Table 2. The moisture content of the samples in the legume category, was lower than that of cereal-based and pseudo-cereal derivatives. Probably due to the main component of cereals and pseudo-cereals, which is carbohydrates. Still, in LF and CPF in the legume category, both carbohydrate and protein content were high, and AF and peanut-based samples (PF, PS) had a high content of fat and protein, respectively. In contrast to the moisture content, the ash content of the samples varied in a more limited range. Expectedly, the samples with the lowest ash content are cereal-based; the ash content of other samples varied within the range of 2–3%. Peanut-based samples had the highest protein content among the different flour samples. This was followed by AF, leguminous flours, pseudo-cereal flours, and cereal flours, respectively. As expected, the fat contents of the three different oilseed derivatives (AF, PF and PS) used in the study were significantly higher than the other samples ($P < 0.05$). It has been observed that the fat content of the samples in question constitutes more than half of their chemical composition. Based on the literature, RF has the highest carbohydrate content followed by corn-based products, WF and pseudo-cereals, probably due to their high content of starch, a storage carbohydrate in plants, which is the major component of cereals and cereal flours. The carbohydrate content of legume-based products was also relatively high and constituted about two-thirds of their chemical composition. The high fat and protein content of the oilseed samples was effective on their low carbohydrate content. The data presented in Table 2 coincided with the properties of the raw materials. In this regard, expected differences were observed between the samples, which is quite possible. The energy values of legume, pseudo-cereal and cereal-based samples were found to be 40-45% lower than the energy value of oilseed samples (Table 2).

Chemical properties of crackers

The overall view of TCS is presented in Figure 1. The chemical composition, energy, and pH values of the TCS are given in Table 2. Moisture contents of the TCS ranged values from 0.3% to 6%. The product must have low moisture content and a crispy-crunchy structure for the crackers to have desired textural properties (Dizlek, 2019). Based on this definition, it can be said that the basic characteristics expected from crackers by the consumers exist in the TCS. In the research, although the crackers baking norms are kept constant, the variation in the moisture content of the crackers occurred in tandem with the variation of the flour type used in dough formulation (due to differences in the initial moisture content and the water holding capacities of the flour samples). The amount of water used in the dough formula was a significant factor in this variation.

The moisture content of the TCS was like what has been reported in the literature (Polat et al., 2020). In addition, some crackers (AF, PF and PS) had an inverse proportion

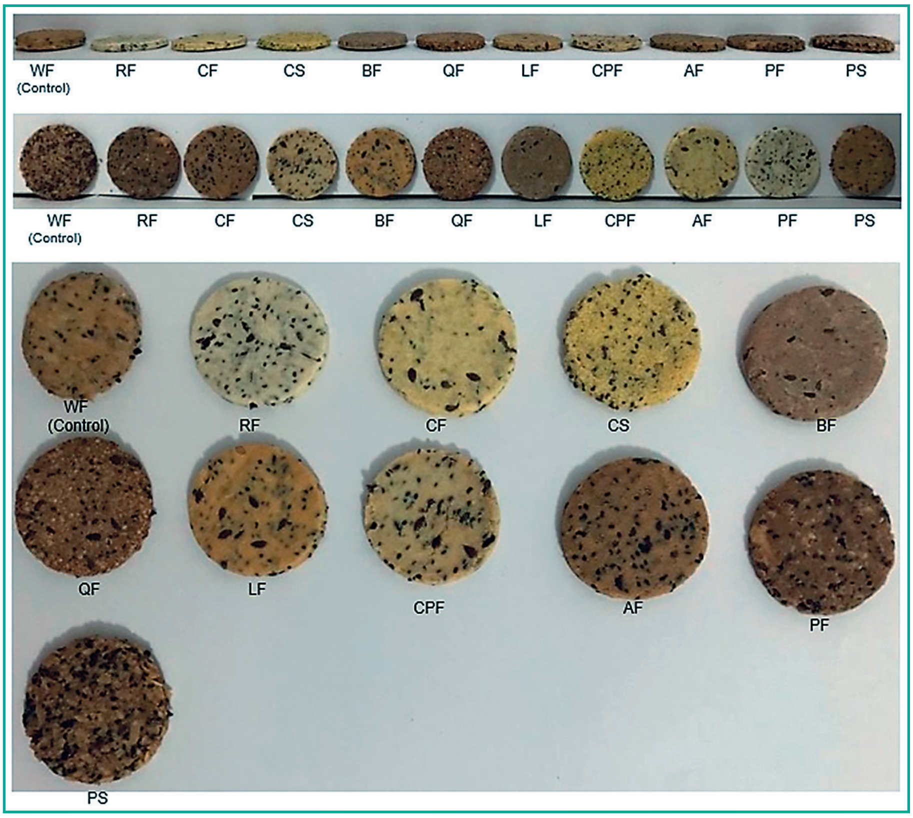

FIGURE 1: *Views of the trial cracker samples from different angles (WF: wheat flour; RF: rice flour; CF: corn flour; CPF: chickpea flour; CS: corn semolina; BF: buckwheat flour; QF: quinoa flour; LF: lentil flour; AF: almond flour; PF: peanut flour; PS: peanut sesame).*

TABLE 2: *Chemical compositions of various flour samples and crackers produced using various flour samples*.*

Flour and Cracker Type	Flour samples: Moisture Content (%)	Ash Content (%)	Protein Content (%)	Fat Content (%)	Carbohydrate Content (%)	Energy Value (kcal/100 g)	Cracker samples: Moisture Content (%)	Ash Content (%)	Protein Content (%)	Fat Content (%)	Carbohydrate Content (%)	Energy Value (kcal/100 g)	pH Value
Wheat flour	$11.7^{b}\pm0.3$	$0.64^{fg}\pm0.01$	$11.6^{e}\pm0.6$	$2.3^{fg}\pm0.2$	$73.8^{c}\pm0.7$	$362.3^{h}\pm2.1$	$3.25^{c}\pm0.35$	$2.50^{g}\pm0.14$	$18.8^{f}\pm0.6$	$10.2^{g}\pm0.1$	$65.2^{c}\pm0.2$	$427.3^{g}\pm2.0$	$7.72^{c}\pm0.01$
Rice flour	$8.7^{e}\pm0.1$	$0.53^{g}\pm0.01$	$7.2^{f}\pm0.0$	$0.7^{h}\pm0.1$	$82.9^{a}\pm0.1$	$366.4^{fgh}\pm0.1$	$0.95^{fg}\pm0.07$	$2.80^{ef}\pm0.00$	$14.8^{h}\pm0.6$	$11.3^{g}\pm1.3$	$70.2^{a}\pm0.1$	$441.6^{ef}\pm3.7$	$7.80^{b}\pm0.03$
Corn flour	$10.5^{d}\pm0.1$	$0.74^{f}\pm0.06$	$7.8^{f}\pm0.3$	$2.7^{ef}\pm0.1$	$78.3^{b}\pm0.2$	$368.3^{efg}\pm0.3$	$1.25^{e}\pm0.07$	$2.85^{de}\pm007$	$16.2^{g}\pm0.3$	$11.5^{fg}\pm0.7$	$68.2^{b}\pm0.9$	$441.4^{ef}\pm3.1$	$7.63^{d}\pm0.01$
Corn semolina	$12.1^{a}\pm0.1$	$0.35^{h}\pm0.01$	$7.6^{f}\pm0.6$	$0.4^{h}\pm0.0$	$79.6^{b}\pm0.6$	$352.0^{i}\pm0.5$	$1.15^{ef}\pm0.07$	$1.60^{h}\pm0.14$	$16.0^{g}\pm0.6$	$14.4^{de}\pm1.0$	$66.8^{bc}\pm1.7$	$461.3^{c}\pm6.4$	$7.74^{c}\pm0.03$
Buckwheat flour	$11.1^{c}\pm0.0$	$2.06^{e}\pm0.04$	$12.2^{e}\pm0.3$	$3.7^{e}\pm0.2$	$71.1^{d}\pm0.5$	$365.8^{gh}\pm0.8$	$2.60^{d}\pm0.00$	$2.60^{fg}\pm0.00$	$20.1^{e}\pm0.3$	$14.5^{de}\pm1.0$	$60.1^{d}\pm1.6$	$451.7^{d}\pm6.4$	$7.60^{d}\pm0.01$
Quinoa flour	$12.4^{a}\pm0.1$	$2.38^{c}\pm0.04$	$14.0^{d}\pm0.6$	$6.3^{d}\pm0.2$	$65.0^{f}\pm0.4$	$372.4^{e}\pm1.0$	$3.90^{b}\pm0.00$	$2.90^{de}\pm0.00$	$21.1^{e}\pm0.6$	$16.8^{c}\pm0.4$	$55.3^{e}\pm0.8$	$456.6^{cd}\pm1.1$	$7.26^{g}\pm0.03$
Lentil flour	$5.8^{g}\pm0.1$	$3.01^{a}\pm0.13$	$26.7^{b}\pm0.6$	$1.3^{gh}\pm0.3$	$63.1^{g}\pm0.3$	$371.3^{ef}\pm1.9$	$1.00^{fg}\pm0.14$	$2.95^{de}\pm0.07$	$34.7^{b}\pm0.6$	$13.0^{ef}\pm0.3$	$48.3^{f}\pm0.2$	$449.2^{de}\pm3.7$	$7.51^{e}\pm0.01$
Chickpea flour	$6.5^{f}\pm0.1$	$2.62^{b}\pm0.11$	$16.2^{c}\pm0.3$	$7.4^{c}\pm0.3$	$67.3^{e}\pm0.2$	$400.4^{d}\pm0.7$	$6.00^{a}\pm0.00$	$4.40^{a}\pm0.57$	$23.5^{d}\pm0.6$	$15.8^{cd}\pm0.5$	$49.9^{f}\pm1.1$	$435.7^{f}\pm3.8$	$7.91^{a}\pm0.00$
Almond flour	$3.7^{i}\pm0.0$	$3.01^{a}\pm0.04$	$25.9^{b}\pm0.6$	$53.9^{a}\pm1.2$	$13.4^{h}\pm1.8$	$642.9^{a}\pm5.6$	$0.85^{g}\pm0.21$	$4.30^{b}\pm0.14$	$32.3^{c}\pm0.6$	$55.2^{a}\pm0.1$	$7.4^{h}\pm0.3$	$655.3^{a}\pm1.7$	$7.52^{e}\pm0.03$
Peanut flour	$4.6^{h}\pm0.0$	$2.22^{d}\pm0.03$	$29.1^{a}\pm0.6$	$50.5^{b}\pm0.6$	$13.6^{h}\pm1.1$	$624.9^{c}\pm3.4$	$1.00^{fg}\pm0.00$	$3.55^{c}\pm0.07$	$36.5^{a}\pm0.3$	$50.7^{b}\pm0.4$	$8.2^{gh}\pm0.8$	$635.4^{b}\pm2.0$	$7.31^{f}\pm0.01$
Peanut sesame	$3.4^{j}\pm0.0$	$2.32^{cd}\pm0.04$	$28.7^{a}\pm0.0$	$50.6^{b}\pm0.4$	$15.0^{h}\pm0.5$	$630.2^{b}\pm1.9$	$0.30^{h}\pm0.00$	$3.05^{d}\pm0.07$	$35.9^{a}\pm0.0$	$50.6^{b}\pm0.3$	$10.1^{g}\pm0.5$	$640.0^{b}\pm1.7$	$7.32^{f}\pm0.02$

*The differences between the values shown in the table with the same superscript letters in the same column are insignificant according to the 0.05 confidence limit ($P > 0.05$).

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between fat and moisture content. This can be explained by the fact that fat particles surround protein and starch, preventing protein hydration (reduces protein's ability to hold water). There was a significant difference (P < 0.05) between the ash and moisture content of the TCS. The ash content of crackers produced using CPF, AF, PF, and PS was high due to the high level of minerals found in these flours. This finding is consistent with Rybicka and Gliszczyńska-Świgło (2017). They reported that the mineral content of gluten-free products made with buckwheat, chickpea, millet, oat, amaranth, and quinoa was generally higher than those made with rice, potatoes, corn, and gluten-free wheat starch. As most of the used alternatives (e.g., buckwheat, chickpea, amaranth, quinoa) to WF are not as refined as typically used WF, information presented in the previous sentence doesn't stand when compared to wholegrain WF.

The ash content of each cracker sample was higher than the ash content of the flour sample used in its production. Probably it attributed to the flax, chia seeds and salt in the dough formula since the three components contain higher levels of minerals than trial flour samples. Conclusively, gluten-free crackers contain higher ash and are essentially more nutritious than the control sample, except CS (Table 2). Consistent with the findings of our study, Polat et al. (2020) found the ash content of the cracker samples between 1.66 and 2.38%, and Ahmed and Abozed (2015) between 2.41 and 3.38%.

Expectedly, crackers produced with peanut derivatives containing high protein levels had the highest protein content, while crackers made with RF with lower protein level compared to other samples had the lowest protein content. However, the TCS contained high levels of protein. It was further observed that even the crackers formulated with RF, contained 15% protein, and this value has increased to 35–37% in crackers produced with LF and peanuts. The protein content of the control cracker (18.8%) was higher than the cracker samples produced with corn derivatives and RF (14.8–16.2%), but lower than the cracker samples produced with other raw materials (20.1–36.5%, P < 0.05). Each type of cracker included a higher level of protein than the flour used in its production. It can be attributed to the reduction in the water content of the crackers while baking and the use of egg as a fixed ingredient in the dough formula.

The protein levels of crackers containing protein of plant (various flour, flax and chia seeds) and animal origin (egg) were found to be high, and the biological value of the protein was higher than the foods containing only plant protein. Because the TCS contains eggs that can enter the status of perfect quality protein after breast milk (Ogechi and Irene, 2013). Crackers made with peanut derivatives contain higher protein than crackers made with legumes (LF and CPF) – which are prominent in terms of high protein content –. These findings contain prominent clues that TCS can be used successfully and beneficially, particularly in children's daily diets and in adults' nutrition, particularly in terms of protein quantity and quality.

Crackers made from fat-rich flours such as almond, peanut and PS have been found to have a very high-fat content; they contain five times as much fat than the control sample. Except for crackers made with oilseed material, the other TCS contains higher levels of fat than the fat content of raw materials given in Table 2. The factors that impact this are olive oil, flax and chia seeds, which contain substantial levels of fat in the dough formula and the low moisture content of TCS. High energy values of the crackers presented in Table 2 were directly affected by the relatively high-fat content of crackers (10–17%; crackers not produced with oilseed material, 50–55%; crackers produced with oilseed material [AF, PF and PS]). In this regard, TCS with high nutritional value are recommended but have a high-calorie content; therefore, they should be used in limited amounts. Particular attention should be paid to the consumption margin of cracker samples produced with oilseed derivatives, which have the potential to be tastier, especially in terms of their high-fat content.

The carbohydrate content of TCS varies between two values, one of which is 10 times more than the other (RF and AF). The flour component has a dominant effect on the carbohydrates amount of the crackers. The order from the highest to the lowest in terms of carbohydrate contents was expectedly cereal, pseudo-cereal, legume, and oilseed flours crackers. Peanuts and AF-based crackers with the highest amount of fat and protein were found to have the lowest carbohydrate content.

The lowest value in terms of energy content belonged to the control group cracker. This situation can be explained by the fact that WF has the lowest fat content. Among the TCS, the highest energy value belongs to the AF cracker with 655.3 kcal/100 g. AF cracker is followed by crackers produced with PS (640 kcal/100 g) and PF (635.4 kcal/100 g). Since the types of flour used in the production of bakery products have different fat contents and oil holding capacities, the fat content and, therefore, energy content of products may also differ (Baljeet et al., 2010; Kaur et al., 2015). As expected, the energy values of crackers were increased in parallel with the increase in fat content. Baked goods, like biscuits, crackers, and wafers with very low moisture content, also have high energy values directly related to the high dry matter content. At this point, the TCS have a nutritious and rich content. Ahmed and Abozed (2015) found the energy content of the cracker samples between 397 and 421 kcal/100 g. These findings are lower than the energy values of crackers obtained from our study (427–655 kcal/100 g) because of variability and different quantity of ingredients used in the cracker formulas. The pH values of crackers were generally close to neutral and to each other. Foods with neutral pH (about 7.0) such as water and bread are called carrier foods because they are easily consumed plain and facilitate the uptake of other foodstuffs into the body. The fact that the baking powders in the content of samples such as cakes, biscuits and crackers contain acid and alkali components in a way to balance (neutralize) each other according to the neutralization value (Dizlek and Altan, 2015) was effective in the pH value of the crackers to be close to neutral (Table 2).

Physical properties of crackers

The physical properties of TCS are shown in Table 3. The dough density of the control sample was higher than the other samples (P < 0.05). Cracker dough prepared with peanut derivatives have the lowest dough density. The control cracker sample, which has a dense consistency, is low in diameter and high in thickness. This is due to the high viscosity of the dough of the control sample compared to other samples.

The dough prepared with the samples of oilseeds with high fat (liquid phase) content had a softer and looser structure, and therefore the dough density values in these samples are low. The gluten protein matrix is thought to be contributing factor in increasing the dough density of the control sample. Because gluten brings dough compo-

TABLE 3: *Physical, color and textural properties of crackers produced using various flour samples*.*

Cracker Type	Dough Density (g/mL)	Diameter (mm)	Thickness (mm)	Spread Ratio	Volume (cm^3)	Baking Loss (%)	Color Values			Textural Properties	
							L*	a*	b*	Hardness (N)	Fractur ability (mm)
Wheat flour	$1.23^{a}\pm0.01$	$37.93^{g}\pm0.61$	$7.23^{a}\pm0.21$	$5.24^{g}\pm0.22$	$9.6^{a}\pm0.7$	$28.6^{de}\pm0.7$	$63.76^{f}\pm0.05$	$7.62^{f}\pm0.03$	$27.54^{d}\pm0.05$	$97.96^{a}\pm3.96$	$23.8^{a}\pm0.5$
Rice flour	$1.12^{b}\pm0.01$	$41.10^{de}\pm0.56$	$4.12^{f}\pm0.15$	$9.99^{bc}\pm0.48$	$7.3^{b}\pm1.6$	$28.9^{d}\pm0.6$	$72.73^{a}\pm0.12$	$2.57^{k}\pm0.03$	$19.23^{i}\pm0.12$	$13.62^{d}\pm7.49$	$20.7^{de}\pm0.6$
Corn flour	$0.96^{g}\pm0.01$	$41.74^{bc}\pm0.12$	$4.01^{f}\pm0.06$	$10.41^{a}\pm0.13$	$4.1^{f}\pm0.7$	$27.0^{f}\pm0.5$	$71.05^{b}\pm0.05$	$4.42^{i}\pm0.02$	$28.83^{bc}\pm0.13$	$21.37^{cd}\pm3.39$	$20.0^{e}\pm0.1$
Corn semolina	$1.01^{f}\pm0.01$	$40.14^{f}\pm0.06$	$4.30^{e}\pm0.10$	$9.35^{d}\pm0.24$	$3.4^{fg}\pm0.1$	$31.2^{c}\pm0.2$	$65.56^{d}\pm0.09$	$6.21^{h}\pm0.03$	$32.98^{a}\pm0.16$	could not be measured	could not be measured
Buckwheat flour	$1.09^{c}\pm0.01$	$41.94^{b}\pm0.33$	$5.03^{b}\pm0.10$	$8.34^{f}\pm0.19$	$6.0^{d}\pm0.4$	$28.4^{de}\pm0.8$	$60.85^{g}\pm0.16$	$7.91^{e}\pm0.04$	$22.46^{h}\pm0.10$	$46.01^{b}\pm1.10$	$21.4^{bcd}\pm0.1$
Quinoa flour	$1.03^{e}\pm0.01$	$41.03^{e}\pm0.12$	$4.50^{d}\pm0.24$	$9.14^{de}\pm0.51$	$6.3^{cd}\pm0.6$	$27.9^{e}\pm1.0$	$50.57^{h}\pm0.08$	$11.90^{b}\pm0.04$	$26.45^{f}\pm0.14$	$20.73^{cd}\pm7.53$	$21.4^{bcd}\pm0.4$
Lentil flour	$1.06^{d}\pm0.00$	$40.16^{f}\pm0.23$	$4.12^{f}\pm0.10$	$9.76^{c}\pm0.26$	$3.1^{g}\pm0.3$	$33.3^{b}\pm1.0$	$64.61^{e}\pm0.04$	$7.05^{g}\pm0.04$	$28.88^{b}\pm0.11$	$40.01^{bc}\pm1.68$	$20.6^{de}\pm0.2$
Chickpea flour	$1.01^{f}\pm0.00$	$40.76^{e}\pm0.10$	$4.03^{f}\pm0.02$	$10.11^{ab}\pm0.06$	$5.0^{e}\pm0.2$	$44.9^{a}\pm0.6$	$67.14^{c}\pm0.10$	$3.75^{j}\pm0.05$	$24.81^{g}\pm0.11$	$7.02^{d}\pm2.41$	$20.8^{cde}\pm1.2$
Almond flour	$0.94^{h}\pm0.01$	$41.69^{bc}\pm0.17$	$4.95^{b}\pm0.05$	$8.42^{f}\pm0.11$	$7.1^{bc}\pm0.3$	$19.1^{g}\pm0.2$	$44.23^{j}\pm0.42$	$12.23^{a}\pm0.11$	$28.65^{c}\pm0.18$	$20.13^{cd}\pm4.39$	$21.6^{bc}\pm0.4$
Peanut flour	$0.92^{i}\pm0.00$	$41.43^{cd}\pm0.07$	$4.92^{b}\pm0.06$	$8.42^{f}\pm0.11$	$6.4^{bcd}\pm0.4$	$19.5^{g}\pm0.9$	$41.23^{k}\pm0.05$	$11.72^{c}\pm0.06$	$26.84^{e}\pm0.04$	$14.61^{d}\pm2.96$	$22.0^{b}\pm0.3$
Peanut sesame	$0.92^{i}\pm0.00$	$42.69^{a}\pm0.12$	$4.76^{c}\pm0.06$	$8.97^{e}\pm0.09$	$7.2^{bc}\pm0.5$	$19.2^{g}\pm0.3$	$46.04^{i}\pm0.36$	$10.78^{d}\pm0.05$	$26.58^{f}\pm0.29$	$15.08^{d}\pm2.75$	$21.3^{bcd}\pm0.1$

*The differences between the values shown in the table with the same superscript letters in the same column are insignificant according to the 0.05 confidence limit ($P > 0.05$).

nents together and establishes dough elasticity, extensibility, and viscoelastic structure (Costa et al., 2013; Dizlek and Özer, 2016; Ma et al., 2019). Also, Delcour and Hoseney (2010) reported that higher viscosity structures produced by a denser gluten network slow gas diffusion and maintain structure. Although the dough density values of other samples except crackers produced with control and oilseed derivatives (PF, PS, and AF) changed in a relatively limited range, a statistically significant difference was observed between them ($P < 0.05$).

It is desirable to have a high diameter value, which is one of the parameters used in determining the quality of biscuits-crackers (Rogers et al., 1993). The protein amount of flour used in biscuit-cracker production is used to estimate the diameter value of samples (Labuschagne et al., 1996). There is a negative relationship between the amount of protein contained in flour and the diameter of biscuits-crackers (Singh et al., 1993).

By examining the diameters of the TCS (Table 3), the control sample had the lowest cracker diameter, while the crackers produced with other flours that did not contain gluten in their composition had runnier, splayed, and softer dough characteristics, which caused their diameter values to be higher. A statistically significant difference ($P < 0.05$) was observed between the diameter values of the samples except for the control group. Runny, splay, and soft dough are desired features in the production of biscuits-crackers. In this sense, gluten-free crackers had a higher diameter than the control sample. The thickness values of crackers except for the control sample varied relatively narrowly (between 4.03–5.02 mm). The thickness of the control sample (7.23 mm) was significantly more than the other samples (Fig. 1). The control sample volume, whose thickness value is much higher than other samples, was also expectedly high. A thick structure is not desired in biscuits and crackers. At this point, the crackers made with legumes and other cereal flours (RF and CF) had a better property. In terms of spread ratio, crackers produced with CF and CPF have the highest characteristics, whereas the control sample has the lowest quality. Studies have shown that the rate of spread decreased with increasing biscuit/cookie protein content (Claughton and Pearce, 1989; Bajaj et al., 1991; Singh et al., 1993; Singh and Mohamed, 2007). Kissell and Yamazaki (1975) reported that the spread ratio of biscuits made with flour with high protein content did not improve during cooking. These findings are consistent with our study results.

Biscuits, cookies, and crackers should have a large surface area (high diameter value) and a thin height (a non-thick structure) (AACCI Method 10-50.05; AACC, 2010; Dizlek, 2020). These properties are the main criteria to produce crackers of the desired characteristic and superior quality (crispy and crunchy). Based on these definitions, crackers produced with CF and subsequently CPF have the lowest thickness and highest spread ratio and therefore have the highest qualities, while the control sample has the lowest quality. Gluten-free cracker formulas were superior in terms of diameter, consistency and spread ratio when compared to the control sample. Cracker samples with the highest thickness value and, therefore, the lowest spread ratio belong to the control group. In addition, the thickness of the samples except the control group was close to each other. Since the samples other than the control group did not contain gluten complex, no swelling occurred in these crackers, and similar values were obtained. Crackers obtained from gluten-free flours were found to have higher spreading ratios than crackers made from WF.

The volume of the control sample was found to be the highest among the TCS (Table 3). It was observed that the diameter and thickness values of the crackers were compatible with the volume values. There was a variation between TCS in terms of volume values; accordingly, crackers with greater thickness have higher volumes. The surface area (diameter) and thickness of the cracker are effective on the cracker volume. According to the findings obtained in the study, it is concluded that the cracker thickness is more determinant on cracker volume than on cracker diameter. The control sample had worse physical properties than the other samples by examining the other data together except for baking loss presented in Table 3. This situation revealed that if the dough recipe used in the research or a similar recipe is used, the gluten-free flours used in the trial can be successfully substituted (increasing the cracker quality) for WF.

As the amount of water entering the dough formula increased, the baking loss increased (Table 3). As can be expected, the cracker dough prepared with CPF, which has a higher water content than other samples, lost more water during cooking, and therefore, the cracker prepared with the sample in question has the highest baking loss value. The baking loss of the crackers produced with oilseed derivatives was lower than other samples. In general, high baking loss values were caused by the low amount of cracker dough put in the tray, their high surface area and low thickness. The oven heat penetrates more easily and quickly to the samples with a large and thin surface area (Dizlek and Özer, 2017), which leads to increased baking loss for crackers. In a study on gluten-free pasta, it was reported that the starch polymers are poorly retained since the pasta structure does not contain gluten proteins, and therefore, the baking loss in the final product is quite high (Marti et al., 2010). There were significant variations between the TCS regarding the primary criteria used in determining the quality of crackers presented in Table 3. It is believed that desired quality crackers are produced physically (structurally) for CP.

Color and textural properties of crackers

The color of the product is one of the important factors that affect consumers' food selection. Many factors affect the color of the product, from the raw materials used in the production of the product to the processing methods. Color is one of the important quality criteria in cracker production.

Crackers produced with RF and subsequently CF have the brightest structure among the TCS, whereas crackers produced with oilseed products have the most matte structure (Table 3). Brightness is a desired feature in crackers; crackers produced with cereal and legume flours have a brighter structure than those produced with pseudo-cereal and oilseed products. Crackers produced with oilseed derivatives and QF were found to have higher red color intensity. The fact that the fat content of the samples is relatively high, and this fat that contributes to the appearance of an attractive brown-reddish color during cooking may be a contributing factor in increasing the desired red color index in crackers. RF, which has an entirely white color structure, has the lowest a* value. This sample has the lowest yellowness value among the 11 crackers produced in the study. Cracker produced with CS had the most yellowish color. Wheat/corn varieties with dense carotenoid/xanthophyll color pigment are preferred in wheat semolina and CS production, because one of the most important quality criteria of semolina is color, and the yellowish color is selected (preferred).

Hardness is the force required to provide a certain deformation in the cracker structure in Newton, while the fracture ability is defined as the expression of the deformation value in mm caused by the force required to crack the cracker (Bourne, 2002). Hardness is an essential parameter for crackers due to its contribution to product quality, and it was observed that the hardness values of the TCS varied between 7.02–97.96 N (Table 3). The force required to achieve a certain deformation in the structure of crackers prepared with WF is significantly higher ($P < 0.05$) than the crackers prepared with other flours. The fact that gluten proteins provide a tight and elastic structure to the dough is considered effective in this situation (Ktenioudaki et al., 2011; Dizlek and Özer, 2016). The fact that the dough sample of the cracker produced with CS is challenging to form and therefore disintegrates very quickly has prevented the textural measurements for this sample. There is a limited difference between the fracture ability values of the crackers, and the values range between 20.0 and 23.8 mm. The control sample had the highest value in terms of fracture ability as well as the hardness, and there was no significant difference among the other samples (Table 3).

Sensory properties of crackers

One of the main steps in the development of novel food products is the determination of sensory attributes (Zay and Gere, 2019). A lower sensory quality characterizes gluten-free baked goods than their gluten-containing counterparts (Drabińska et al., 2016). Mazzeo et al. (2014) evaluated some gluten-free biscuits' visual and taste preferences. They showed that the gluten-free biscuits did not fully satisfy the taste of children with celiac disease. The use of gluten-free raw materials may cause the biscuits to have unacceptable sensory quality.

There was a significant difference ($P < 0.05$) between 11 different TCS with varying flour types in terms of sensory qualities (Table 4). The distinctive brownish color of BF is thought to have a negative effect on the brightness of the crackers. The surface smoothness and color are some of the most critical biscuits parameters in consumer acceptability (Torbica et al., 2012). The internal structure should not be tight in a good cracker. The lowest tightness value belongs to QF crackers, and the highest value belongs to crackers made of AF and PF. The crackers produced with LF, together with crackers produced with RF and oilseed derivatives, have the highest surface appearance properties (brightness-opaqueness, color, and surface smoothness). Similarly, Polat et al. (2020) reported that germinated lentil extract enriched crackers might be consumed as functional food without changing sensorial aspects. Cracker produced with QF had low quality in terms of its cross-sectional characteristics; in addition, the tasting characteristics and affordability of the sample in question are quite low. In conclusion, the panelists moderately accepted the control sample; they preferred some features but not hardness-crispness. Crackers produced with oilseed derivatives have a brittle structure in terms of crispness, an important quality criterion of crackers. In contrast, the brittleness of the crackers produced with CF, QF and WF was not suitable. Crackers made with oilseed derivatives and RF, CF, and LF have superior properties in terms of easy dispersion in the mouth and flavor characteristics. The crackers that are easily dispersed in the mouth are desired, and the sample made with PS had a high average score of 4.88 out of 5 points in this criterion. Crackers produced with oilseed derivatives are in the first place in terms of affordability, followed by crackers produced with RF, CF and LF. Crackers made using BF, QF and CPF, especially CS; had low purchase potential and the control sample received a value between these two groups. All TCS had acceptable quality except for CS cracker. This shows that CS could not be successfully adapted to the trial cracker formula and lacks consumer appreciation (Table 4).

TABLE 4: *Average measurement results of the sensory properties[a] of crackers produced using various flour samples*.*

Cracker Type	Surface Appearance Properties			Cross-Section Properties					Tasting Properties							
	Brightness Opaqueness	Color	Surface Smoothness	Tight Structure	Pore Distribution	Crust Thinness	Inner Color	Crust Inner Color Difference	Hardness	Crispness	Not being Sandy/Dry	Dispersion in Mouth	Dissolve ability	Flavor	Affordability	Total (0-75 Point)
Wheat flour	3.38^{d}±0.5	4.25^{a}±0.7	3.94^{bc}±1.1	3.75^{c}±0.7	4.38^{ab}±0.7	4.13^{abc}±1.4	4.13^{bcd}±0.8	4.50^{abc}±0.7	2.50^{ef}±1.2	3.13^{efg}±1.0	4.06^{abc}±1.3	3.75^{de}±1.1	3.50^{de}±0.7	3.75^{cd}±1.4	3.50^{bc}±1.2	56.63^{c}±8.9
Rice flour	4.13^{abc}±0.6	4.25^{a}±0.4	4.50^{ab}±0.5	4.25^{abc}±0.7	4.50^{a}±0.7	4.63^{ab}±0.7	4.63^{ab}±0.5	4.75^{a}±0.4	4.06^{bc}±1.1	4.25^{bcd}±0.7	4.25^{abc}±0.9	4.38^{abcd}±0.9	4.19^{abcd}±0.8	4.00^{bcd}±1.0	4.13^{ab}±1.0	64.88^{b}±6.5
Corn flour	3.63^{bcd}±0.9	4.00^{ab}±0.5	4.25^{ab}±0.7	4.25^{abc}±0.4	4.63^{a}±0.5	4.63^{ab}±0.5	4.63^{ab}±0.5	4.63^{ab}±0.5	4.50^{ab}±0.7	4.38^{abcd}±0.9	4.13^{abc}±0.8	4.00^{cde}±0.9	4.00^{bcd}±0.9	4.25^{abc}±1.0	4.19^{ab}±0.8	64.06^{b}±5.1
Corn semolina	2.63^{e}±1.0	2.44^{c}±0.7	2.75^{d}±0.7	3.00^{d}±1.0	3.63^{c}±1.0	3.63^{c}±1.3	3.69^{d}±1.1	3.63^{d}±1.3	2.75^{ef}±1.1	2.75^{g}±1.1	2.88^{e}±1.2	3.00^{f}±1.0	3.00^{e}±1.0	2.38^{f}±0.9	2.25^{d}±0.9	44.38^{e}±9.5
Buckwheat flour	3.25^{de}±1.0	3.50^{b}±1.2	3.13^{d}±1.1	4.00^{bc}±0.9	3.88^{bc}±1.0	3.75^{c}±1.1	3.88^{cd}±1.5	4.00^{bcd}±1.3	3.19^{de}±1.5	4.00^{cd}±1.5	3.94^{bc}±1.4	3.75^{de}±1.2	3.88^{cd}±1.3	3.38^{de}±1.3	2.88^{cd}±1.1	54.38^{cd}±11.4
Quinoa flour	3.63^{bcd}±0.7	3.63^{ab}±0.9	3.38^{cd}±0.9	2.88^{d}±1.0	3.50^{c}±0.9	3.69^{c}±1.3	3.88^{cd}±1.2	3.88^{cd}±1.2	2.38^{f}±0.7	3.00^{fg}±1.2	3.00^{de}±1.4	3.31^{ef}±0.9	3.56^{de}±1.0	2.75^{ef}±1.2	2.88^{cd}±1.6	49.31^{de}±9.2
Lentil flour	4.56^{a}±0.5	4.25^{a}±0.7	4.75^{a}±0.4	4.13^{abc}±1.1	4.50^{a}±0.5	4.38^{abc}±0.7	4.63^{ab}±0.7	4.44^{abc}±0.9	3.69^{cd}±1.3	3.81^{de}±1.0	3.75^{cd}±1.2	4.13^{bcd}±1.1	4.13^{abcd}±1.1	4.25^{abc}±0.9	4.13^{ab}±1.0	63.50^{b}±7.7
Chickpea flour	3.50^{cd}±1.4	3.63^{ab}±1.0	3.13^{d}±1.1	4.13^{abc}±1.0	3.88^{bc}±1.2	4.00^{bc}±1.2	4.38^{abc}±0.9	4.25^{abcd}±1.1	4.13^{bc}±0.8	3.69^{def}±1.1	3.75^{cd}±1.2	3.88^{cde}±1.1	3.63^{de}±1.0	3.00^{ef}±1.0	3.00^{cd}±1.6	55.94^{c}±9.7
Almond flour	3.88^{abcd}±1.0	4.00^{ab}±1.2	4.25^{ab}±1.0	4.75^{a}±0.4	4.81^{a}±0.4	4.63^{ab}±0.7	4.63^{ab}±0.7	4.63^{ab}±0.7	4.75^{ab}±0.4	4.63^{abc}±0.5	4.50^{abc}±0.5	4.50^{abc}±0.7	4.50^{abc}±0.7	4.63^{ab}±0.5	4.75^{a}±0.4	67.81^{ab}±6.0
Peanut flour	3.88^{abcd}±1.3	4.13^{ab}±1.1	4.50^{ab}±0.7	4.63^{ab}±0.5	4.63^{a}±0.5	4.63^{ab}±0.5	4.63^{ab}±0.5	4.63^{ab}±0.5	4.75^{ab}±0.4	4.88^{ab}±0.3	4.63^{ab}±0.5	4.75^{ab}±0.4	4.69^{ab}±0.5	4.63^{ab}±0.5	4.75^{a}±0.4	68.69^{ab}±5.0
Peanut sesame	4.25^{ab}±0.9	4.25^{a}±0.9	4.13^{ab}±1.0	4.75^{a}±0.6	4.75^{a}±0.4	4.88^{a}±0.3	4.88^{a}±0.3	4.88^{a}±0.3	5.00^{a}±0.0	5.00^{a}±0.0	4.88^{a}±0.3	4.88^{a}±0.3	4.81^{a}±0.4	4.88^{a}±0.3	4.75^{a}±0.4	70.94^{a}±3.0

[a]Each sensory trait was evaluated on 5 full-point hedonic scale (1: bad, 2: not enough, 3: acceptable, 4: good, 5: very good). *The differences between the values shown in the table with the same superscript letters in the same column are insignificant according to the 0.05 confidence limit ($P > 0.05$).

The crackers produced by oilseed derivatives received a very high score of about 70 over 75 points by evaluating the sum of fifteen different criteria of sensory properties by panelists, followed by crackers produced with RF, CF, and LF, after that WF, CPF, and BF crackers. The samples produced with CS and QF were found to have the most negative properties in terms of sensory evaluation. Crackers made with AF, and peanut derivatives scored higher than other samples in terms of two important sensory qualities; flavor and affordability, and almost all the criteria discussed in Table 4. This situation indicates that the appeal of crackers produced with CS, QF and CPF, which scored low, can be increased by adding the oilseed derivatives at certain levels to their formula. Flax and chia seeds, which consumers recently prefer in terms of being nutritious and functional foods, have been used in the cracker prescription as fixed components in the research. The seeds in question added flavor to the crackers, were found suitable in terms of taste, provided the formation of new product profiles, and enriched the nutritive value of the crackers. The mentioned ingredients were used in the trial dough recipe with success because of all these favorable properties.

Dick et al. (2020) reported that, the production of gluten-free crackers might encounter technical difficulties because the gluten absence provokes a lack of suitable flow-mechanical properties for the processing of flour doughs due to the absence of the viscoelastic structure characterized by gluten formation after hydration and kneading. Contrary to literature information (Hooda and Jood, 2005; Sedej et al., 2011; Tiwari et al., 2011; Zucco et al., 2011; Kaur et al., 2015), in this study, many gluten-free crackers (RF, CF, LF, AF, PF, and PS crackers) had higher sensory quality compared to their gluten-containing counterpart (Table 4). It is thought that the appropriate selection of the cracker dough formula used in the experiment has a great effect on this. For example, cracker made with PS, which is the most preferred by panelists and has superior sensory qualities in this sense, has a significant point difference of 25% from control cracker (PS cracker 70.94 points, control cracker 56.63 points). Consistent with findings from our study, Wesley et al. (2021) have recently shown that the rice and beans biscuits characterized in their study proved to be an innovative gluten-free food product. Similarly, Faccioli et al. (2021) reported an innovation in cracker development with olive leaf flour for those seeking differentiated and nutritious products.

The benefits and potential drawbacks of different cracker formulations can be listed as follows: relatively high protein content versus high fat and energy content, acceptable sensory quality versus high nutritional value, and good spread ratio value versus high baking loss. On the other hand, in the study, the benefits and potential drawbacks of control cracker can be summarized as follows: low fat and energy content versus relatively bad physical characteristics, acceptable sensory quality versus relatively high baking loss, good chemical composition and color scores versus poor textural characteristics. Briefly, as can be seen from the matters mentioned above, TCS had both strengths and weaknesses.

Developing new products is very important for food industry. Because of people don't want to consume same foods every time. In this sense, it is important to develop novel, nutritious and healthy food products and bring them to the food market and gastronomy. Based on this fact, in this study, 11 different crackers were produced particularly for a disadvantaged group, Celiac. It is thought that gluten-free crackers with oilseed derivatives, which are appreciated by panelists in sensory analysis, will create product variety in kitchens and menus.

In the study, novel, more nutritious and functional crackers especially for CP, generally for all consumers and food industry were developed. The obtained results are expected to provide important tips to potential producers who will be working on developing new products in this field.

Conclusions

TCS with high nutritional value is recommended, but because of its high-calorie content, it should be consumed moderately in our diets. Various gluten-free flours affected the cracker characteristics significantly; crackers other than the ones produced with CS contained higher ash and were more nutritious than the control sample. They were found to have healthy and rich content and have the potential to skip meals. In this respect, it is thought that they have a strong potential to provide a practical solution, especially for lunch and afternoon meals for individuals with an active lifestyle.

Gluten-free cracker formulas are superior to the gluten-containing control sample in terms of diameter, thickness, and spread ratio values, which are the most important quality criteria for crackers. The control sample had significantly worse physical properties, except for the baking loss, than other samples. This situation revealed that if the dough recipe used in the research or a similar recipe is used, the gluten-free flours can be successfully substituted (increasing the cracker quality) for WF. Therefore, these crackers are good alternatives to the products which consumed by CP even though they do not like them.

Finally, it can be concluded that crackers formulated with peanut derivatives and AF had better sensory characteristics due to its different flavors, good/pleasant tastes, and improved appearances. These formulations produced in the scope of the study, proved to be the overall most recommendable crackers. On the other hand, CS cracker had an unacceptable quality. In conclusion, novel, more nutritious and functional crackers were developed. TCS contains functional food components such as flax and chia seeds, and nutritious food items such as egg and olive oil can be successfully used as a health-friendly nutrient in the daily diets of CP and children.

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Conflict of interest

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