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# Gluten-Free Crackers Preparation

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***Authors' contributions***

*This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.*

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## ABSTRACT

Gluten free crackers enriched with rice flour ,lentil flour and quinoa flour is an innovative and highly nutritious snacks product. The current study was carried out to make gluten free crackers of high quality for celiac disease patients. The chemical analyzed included as minerals and amino acids of broken rice, lentil and quinoa flour and its blends was determined. Also, chemical composition for gluten free crackers blends was determined and the results showed that ash, protein, ether extract and fiber contents were higher in all blends prepared using rice flour, quinoa flour and lentil flour than that blend prepared using rice flour. All sensory properties of free gluten crackers blends B2, B3, B4 and B5 prepared using rice flour, lentil flour, and quinoa flour were somewhat higher than crackers prepared from rice flour B1. Hardness decreased from 74.97 newton in blend (1) made from 100% rice flour to 35.19 newton in blend (5) made from 50% rice flour, 25% lentil flour and 25% quinoa flour. Finally, it could prepare some bakery products using raw materials free of gluten such rice flour, lentil flour and quinoa flour with high quality that are proper for celiac disease patients.

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## 1. INTRODUCTION

As a result of urbanization and modernization, consumption of snack food has increased. However, most snacks have high levels of fat, sugar, and salt, as well as low levels of dietary fiber, which can lead to health problems [1]. Therefore, consumer demands for nutritious snacks is growing. As a result of their outstanding eating quality and superior nutritional properties, snack crackers are one of the most desirable snacks.

Crackers are a type of biscuit with flaky inner layers. Crackers have a low sugar content, a moderate fat content, and a low salt content [2]. A gluten-free food should be primarily based on certainly gluten-free diets with a high-quality of micro and micronutrients: milk and dairy products, nuts, rice , legumes, fruits, vegetables, potatoes, and corn are all proper components of such a food. If commercially prepared, gluten-free products are replaced by enriched or fortified minerals with and vitamins are preferable. Some minor cereals are healthy alternative to these ready products and have high nutritional and biological value. Furthermore, it contents protein of higher nutritional value than those of wheat and in greater amounts. An increasing demand of gluten free foods is cause by a rising total of diagnosed celiac patients and allergenic proteins consumers from the food. Driven by the speedily increasing sell, wide-ranging of gluten free goods are necessary. The main principle of this investigation study is to concisely present an overview of various approaches to improve sensory properties and physicochemical qualities of gluten free ,crackers, bread, cake and pasta goods.A growing demand of gluten free products is cause by a growing total of diagnosed celiac patients and allergenic proteins consumers from the diet. Driven by the speedily growing sell, wide-ranging of gluten free goods are essential. The main principle of this research study is to concisely current an overview of various approaches to enhance physicochemical and sensory qualities of gluten free crackers, bread, cake and pasta products [3]. Dietary fiber has gained a lot of attention as one of these additional components. According to Valencia et al., there is a growing need for high fiber food products to help people overcome health problems like hypertension, diabetes, and colon cancer[4].

Lentil (*Lens culinaris Medik*.) is a very significant legume crop that is widely cultivated and consumed. The plants are farmed for their lens-shaped edible seeds, which are high in protein (35-40%) and carbohydrates, as well as calcium, phosphorus, iron, and vitamins B-complex [5]. It is one of the earliest known food crops utilized only for human use. It's also abundant in lysine, making it a wonderful complement to cereal grains' amino acid content [6].

Wheat flour is the most common flour used in bread goods. Prolamins (ethanol soluble) and glutenin are the two types of proteins found in grain flour (ethanol insoluble). When these proteins are hydrated, they form a gluten-like protein complex. Gluten is responsible for the dough's viscoelastic qualities, which are required for making many varieties of wheat flour breads.

Some people are allergic to gluten, and as a result, they develop celiac disease. This is an autoimmune disorder caused by a combination of environmental, genetic, and immunological factors. Due to the harmful effect of the alcohol soluble portion of gluten, the prolamins, Celiac disease is associated with decreased digestion and absorption of nutrients, vitamins, and minerals in the gastrointestinal tract. This protein causes inflammatory bowel disease as well as a variety of other side effects. Other cereals, such as barley, rye and oats, have similar effects to wheat and are hence classed as gluten-containing cereals [7].

Which disease is treated with a gluten-free diet. Rice (*Oryza sativa*) and corn (*Zea mays*) are gluten-free, have a high number of easily digestible carbohydrates, and their flour is utilized to make gluten-free foods.

Quinoa is classified as a pseudo-cereal since it is a starchy dicotyledonous seed, rather than a cereal [8]. It's gluten-free, therefore it's suitable for both CD sufferers and wheat allergy sufferers. Quinoa seeds are high in protein, fats, carbohydrates, minerals, and vitamins such as vitamin B [9].This work aimed to study the use of rice, lentil and quinoa flour for the enhancement of gluten-free crackers for people suffering from celiac disease patients.

## 2. MATERIALS AND METHODS

### 2.1 Materials

Lentil flour(*Lens culinaris Medik*.) whole seeds, broken rice flour (*Oryza sativa*) and quinoa flour (*Chenopodium quinoa* Willd.) were obtained from Agriculture Research Center, Giza, Egypt. Sugar (sucrose), salt (sodium chloride), cumin, curcuma, red pepper, vegetable oil, baking powder and plastic bags were purchased from the local market, Cairo, Egypt. All chemicals and reagents used in this study were of analytical grade and Sigma Company.

### 2.2 Crackers Preparation

Crackers formula is shown in Table 1. The dry ingredients including lentil flour, rice flour and quinoa flour, salt(Sodium chloride), cumin, curcuma, red pepper and baking powder except sucrose were placed in the bowl of mixing for 30 s according to the method described by Han, et al. [2]. Then mix wet ingredients alone (sucrose, water and oil) for 30 s, then all the ingredients were mixed. Until acquired dough, and then rest for 10 min at room temperature before cutting into a circular shape. The crackers were then baked for 4 minutes at 175°C in an electric oven, then cooled for 30 min, packed in plastic bags, and stored at room temperature.

### 2.3 Chemical Analysis

Crude ash (method 08-01), crude protein (method 46012), and crude fat (method 30-25) were performed using AACC procedures [10].

The total carbohydrates were determined using Equation Vaz et al., [11] and the results of related nutrients were given on dry weight basis (DWB) as mean value of three measurements:

carbohydrate (%) = 100% – (protein% +Crude fiber%+ fat% +ash %).

Calorie value (kcal/100g) = (%carbohydrate × 4.1) + (% protein×4.1) + (% fat× 9.1).

were performed using AACC procedures [10].

**Table 1. Crackers formula**

| Components | B1 | B2 | B3 | B4 | B5 |
|---|---|---|---|---|---|
| **Rice flour (g)** | 1000 | 500 | 500 | 500 | 500 |
| **Lentil flour(g)** | --- | 100 | 150 | 200 | 250 |
| **Quinoa flour(g)** | --- | 400 | 350 | 300 | 250 |
| **Oil(g)** | 100 | 100 | 100 | 100 | 100 |
| **Salt(g)** | 40 | 40 | 40 | 40 | 40 |
| **Sucrose (g)** | 30 | 30 | 30 | 30 | 30 |
| **Cumin(g)** | 10 | 10 | 10 | 10 | 10 |
| **Curcuma(g)** | 20 | 20 | 20 | 20 | 20 |
| **Red pepper(g)** | 05 | 05 | 05 | 05 | 05 |
| **Baking powder((g))** | 20 | 20 | 20 | 20 | 20 |

*B1= 1000 g Rice flour; B2= 500 g Rice flour+100g Lentil flour +400g Quinoa flour; B3= 500g Rice flour+200g Lentil flour +300g Quinoa flour; B4= 500g Rice flour+300g Lentil flour +200g Quinoa flour; B5= 500g Rice flour+400g Lentil flour +100g Quinoa flour*

## 2.4 Determination of Minerals

Minerals including Calcium, Potassium, Magnesium, phosphorus, Sodium, manganese, Iron, and Zinc were measured in ash solution using ICP-OES Agilent 5100 VDV according to the US EPA [12].

## 2.5 Determination of Amino acids Composition

Amino acids composition of blends of crackers prepared from rice flour, lentils flour and quinoa flour were performed in National Research Center, Cairo, Egypt ,using amino acid analyzer (Beckman amino acid analyzer, Model 119CL) according to the method described before [13].

## 2.6 Estimation of Tryptophan

Tryptophan content of samples was determined calorimetrically according to the method described before [14].

## 2.7 Sensory Evaluation of Crackers

Appearance, color, odor, taste, crispiness, and overall acceptability of all the crackers products prepared from different ratios of rice flour, lentils flour and quinoa flour were assessed using 20 staff members of Bread and Pastry Department, Food Technology Research Institute, Egypt. According to [15], the panelists were asked to score the above characteristics on a standard hedonic rating scale ranging from 9 (like extremely) to 1 (dislike extremely).

## 2.8 Texture Profile Analysis of Crackers

Texture profile analysis was conducted by Brookfiled CT3 Texture Analyzer No. M08-372-C0113 (version2.1, 1000gram unit). Hardness of samples were automatically recorded by computer software (TA-CT-PRO software).According to A.A.C.C. [16] the samples were compressed twice to 40% deformation trigger load 5 N, and test speed-2 mm/s. The experiments were conducted under ambient conditions.

## 2.9 Determination of Water Activity ($a_w$)

Water activity (aw) was measured at 25°C using a Decagon A qualab Meter Series 3TE (Pullman, WA, USA). All samples of storage crackers were broken into small pieces immediately before water activity measurement [17].

## 2.10 Statistical Analysis

Duncan's multiple range tests were used for mean comparison in the statistical analysis, which was done using SPSS software (version 16).

# 3. RESULTS

## 3.1 Chemical Composition of Rice Flour, Lentil Flour and Quinoa Flour (On Dry Weight Basis)

Table 2 shows the chemical analysis of rice flour, lentil flour and quinoa flour on dry weight basis. Results showed that rice flour contained 0.846% ash; 7.781% crude protein; 0.681% ether extract; 0.336% crude fiber; 90.418% available carbohydrates and 408.243kcal/100g Caloric value. These results agree with El-Dreny and El-Hadidy [18] reported that rice flour contains 7.95% crude protein, 0.67% fat; 0.93% ash, 0.32% crude fiber and 90.13% total carbohydrates.

For lentil flour, results revealed 25.547% crude protein, 2.656% ether extract, 3.415% ash, 20.472% crude fiber, 47.881% available carbohydrates and 325.343 kcal/100g Caloric values. The data were harmony with the reported work stated that lentil flour had 2.20% fat, 21.70% crude fiber, 2.77% ash, 25.63% proteins, and 48.70% total carbohydrates [19].\

Results of Quinoa flour analysis showed that crude protein was 14.574%; ether extract reached 6.176%, while crude fiber was 6.510 %, ash was 4.449%, available carbohydrates were 68.290% and 395.948 kcal/100g Caloric value. The data are accorded to the study of El-Hadidy et al. which indicated that quinoa flour had 13.13% crude protein, 6.52% crude ether extract, 4.65% ash, 75.70% total carbohydrates, and 414 kcal/100g Caloric value [9].

## 3.2 Proximate Chemical Composition of Crackers (on Dry Weight)

The chemical composition of crackers made from rice, lentils and quinoa flour shows in Table 3. Data revealed that moisture content of the crackers were 3.061%, 7.352%, 6.335%, 6.091% and 5.996%, for blends (1, 2, 3, 4 and 5),

**Table 2. chemical composition of rice, lentil and quinoa flour (on dry weight)**

| | Raw materials | | |
|---|---|---|---|
| | **Rice flour** | **Lentil flour** | **Quinoa flour** |
| **Moisture content%** | 9.550± 0.190[b] | 10.552± 0.150[a] | 7.333± 0.130[c] |
| **Crude protein%** | 7.781 ± 0.140[c] | 25.574 ± 0.893[a] | 14.574 ± 0.738[b] |
| **Crude ether extract%** | 0.618 ± 0.093[c] | 2.656 ± 0.720[b] | 6.176 ± 0.846[a] |
| **Crude fiber%** | 0.336 ± 0.059[c] | 20.472 ± 0.957[a] | 6.510 ± 0.893[b] |
| **Ash%** | 0.846 ± 0.079[c] | 3.415 ± 0.532[b] | 4.449 ± 0.665[a] |
| **Available carbohydrates%** | 90.418 ± 0.253[a] | 47.881 ± 0.309[c] | 68.290 ± 0.313[b] |
| **Caloric value (kcal/100 g)** | 408.243 ± 0.381[a] | 325.343 ± 0.251[c] | 395.948 ± 0.219[b] |

*- a, b, c , d different superscript letters in the same rows are significantly different at LSD at (p ≤ 0.05).*
*-Each value was an average of three determinations ± standard deviation.*
*[*]Available carbohydrates = 100 – (crude protein + ash + ether extract + crude fiber)*

**Table 3. chemical composition of crackers (on dry weight basis)**

| | Chemical composition of crackers (g /100 g) | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Moisture content** | **Crude protein** | **Crude ether extract** | **Crude fiber** | **Ash** | **carbohydrates** | **Caloric value (kcal/100 g)** |
| **Blend (1)** | 3.061 ± 0.010[c] | 6.436 ±0.016[e] | 8.686 ± .028[e] | 0.290 ± 0.028[e] | 0.713 ±0.017[e] | 83.874 ± 0.055[a] | 449.316 ± 0.080[a] |
| **Blend (2)** | 7.352 ± 0.054[a] | 10.058 ±0.119[d] | 10.668 ±0.030[a] | 4.013 ± 0.156[d] | 2.039 ±0.022[a] | 73.077 ± 0.296[b] | 437.936 ± 0.797[b] |
| **Blend (3)** | 6.335 ± 0.063[b] | 10.410 ±0.176[c] | 10.505 ±0.041[b] | 4.506 ± 0.029[c] | 1.993 ±0.020[b] | 72.485 ± 0.117[c] | 435.876 ± 0.208[c] |
| **Blend (4)** | 6.091 ± 0.126[b] | 10.964 ±0.119[b] | 10.370 ±0.028[c] | 5.070 ± 0.026[b] | 1.984 ±0.018[c] | 71.659 ± 0.071[d] | 433.124 ± 0.011[d] |
| **Blend (5)** | 5.996 ± 0.044[b] | 11.414 ±0.040[a] | 10.220 ±0.027[d] | 5.633 ± 0.024[a] | 1.903 ±0.017[d] | 70.829 ± 0.069[e] | 430.202 ± 0.075[e] |

*- a, b, c d different superscript letters in the same columns are significantly different at LSD at (p ≤ 0.05).*
*-Each value was an average of three determinations ± standard deviation.*
*B1= 1000 g Rice flour; B2= 500 g Rice flour+100g Lentil flour +400g Quinoa flour; B3= 500g Rice flour+200g Lentil flour +300g Quinoa flour; B4= 500g Rice flour+300g Lentil flour +200g Quinoa flour; B5= 500g Rice flour+400g Lentil flour +100g Quinoa flour*

respectively. Blend (5) recorded the highest value of protein 11.414% compared to blends (1, 2, 3 and 4) were 6.436%, 10.058%, 10.410% and 10.964%, respectively (on dry basis).Table 3 show that, blend (5) have the highest value of crude fiber and crude ether extract followed by blend (4), blend (3), blend (2) and blend (1) which contained (5.633% and 10.220%), (5.070% and 10.370%), (4.506% and 10.505%), (4.013% and 10.668%) and (0.290% and 8.686%), respectively (on dry basis).On the other hand, Blend (5) the lowest values of total carbohydrates , energy 70.829% and 430.202 kcal/100g respectively, compared to blends 1, 2, 3, and 4 were (83.874%, 73.077%, 72.485% and 71.659%) and (44.316, 437,936, 435,876 and 433.124 kcal/100g samples), respectively. These results agree with earlier work of Elhadidy et al., that showed addition of quinoa flour to rice flour increase crude protein in bakery products [9].

## 3.3 Mineral Content of Crackers Blends (on Dry Weight)

Table 4 show mineral content of crackers. Most minerals in calcium, potassium, magnesium, phosphorus and sodium as a macro elements and zinc, iron and manganese as a micro elements content of crackers. The results indicate that blend (2) contains high amounts of calcium, potassium, magnesium, iron and manganese were 66.466, 857.301, 291.167, 5.946 and 3.289 mg /100g samples, respectively compared to blend (1) crackers. Also, blend (5) contains high amount P, Na and Zn compared to blend (1).

**Table 4. Influence of addition lentil and quinoa flour to rice flour to make crackers on mineral contents (on dry weight basis)**

| | Macro elements (mg /100g) | | | | | Micro elements (mg /100g) | | |
|---|---|---|---|---|---|---|---|---|
| | **Ca** | **K** | **Mg** | **P** | **Na** | **Zn** | **Fe** | **Mn** |
| **Blend (1)** | 16.00 ±1.000$^{b}$ | 361.667 ±7.637$^{e}$ | 140.00 ±10.01$^{e}$ | 126.00 ±1.010$^{e}$ | 6.501 ±0.500$^{e}$ | 1.080 ±0.045$^{e}$ | 1.986 ±0.047$^{e}$ | 2.493 ±0.031$^{e}$ |
| **Blend (2)** | 66.466 ±2.250$^{a}$ | 857.301 ±7.660$^{a}$ | 291.167 ±4.817$^{a}$ | 278.667 ±1.069$^{d}$ | 30.217 ±0.501$^{d}$ | 2.420 ±0.036$^{d}$ | 5.946 ±0.009$^{a}$ | 3.289 ±0.041$^{a}$ |
| **Blend (3)** | 65.683 ±1.875$^{a}$ | 832.613 ±7.667$^{b}$ | 271.750 ±4.953$^{b}$ | 281.416 ±0.833$^{c}$ | 31.201 ±0.377$^{c}$ | 2.481 ±0.033$^{bc}$ | 5.795 ±0.013$^{b}$ | 3.183 ±0.044$^{b}$ |
| **Blend (4)** | 64.933 ±1.501$^{a}$ | 627.401 ±3.774$^{d}$ | 249.00 ±2.946$^{c}$ | 284.167 ±0.651$^{b}$ | 32.183 ±0.256$^{b}$ | 2.548 ±0.039$^{ab}$ | 5.645 ±0.021$^{c}$ | 3.078 ±0.047$^{c}$ |
| **Blend (5)** | 64.166 ±1.127$^{a}$ | 783.250 ±7.697$^{c}$ | 232.916 ±5.257$^{d}$ | 286.916 ±0.577$^{a}$ | 33.167 ±0.144$^{a}$ | 2.614 ±0.045$^{a}$ | 5.494 ±0.028$^{d}$ | 2.983 ±0.065$^{d}$ |

*- a, b, c , d different superscript letters in the same columns are significantly different at LSD at ($p \leq 0.05$).*
*-Each value was an average of three determinations ± standard deviation*

### 3.4 Amino Acids Content of Crackers

Data in Table 5 show essential amino acids and non-essential amino acids. In a decreasing order the total essential amino acids were in blend (5), blend (4), blend (3) and blend (2) compared with blend (1). on the other hand, the blend (2), blend (3), blend (4) and blend (5) had a higher percentage of protein and lysine than blend (1) crackers made from 100% rice flour. The results show the differences in crackers for amino acids and the ratios of lysine in blend (5), blend (4), blend (3) and blend (2) were 5.475, 5.460, 5.445 and 5.430 g /100g samples, respectively compared with blend (1) was 3.800 g /100g samples. Generally, it can be concluded that, results of all blends showed high values of protein, fat, fiber and lysine amino acid.

**Table 5. amino acids in blends crackers made from lentil and quinoa flour to rice flour (g /100g Protein)**

| | **Blend (1)** | **Blend (2)** | **Blend (3)** | **Blend (4)** | **Blend (5)** |
|---|---|---|---|---|---|
| Lysine | 3.800 | 5.430 | 5.445 | 5.460 | 5.475 |
| Iso_leucine | 4.300 | 4.410 | 4.365 | 4.320 | 4.275 |
| Leucine | 8.500 | 8.430 | 8.395 | 8.360 | 8.325 |
| Phenyl alanine | 8.300 | 7.200 | 7.100 | 7.000 | 6.900 |
| Tyrosine | 5.340 | 4.120 | 4.145 | 4.170 | 4.195 |
| Histidin | 2.900 | 3.100 | 3.050 | 3.000 | 2.950 |
| Valine | 4.470 | 4.445 | 4.450 | 4.455 | 4.460 |
| Thereonine | 4.760 | 4.280 | 4.230 | 4.180 | 4.130 |
| Methionine | 2.800 | 3.000 | 2.850 | 2.700 | 2.550 |
| Tryptophan | 1.500 | 1.322 | 1.326 | 1.329 | 1.333 |
| Cysteine | N.D. | 0.070 | 0.105 | 0.140 | 0.175 |
| Total (EAA) | 37.370 | 45.807 | 45.461 | 45.114 | 44.768 |
| Aspartic acid | 9.800 | 8.037 | 7.730 | 7.560 | 7.118 |
| Glutamic acid | 17.500 | 14.165 | 13.623 | 13.296 | 12.537 |
| Serine | 5.200 | 4.770 | 4.718 | 5.015 | 4.613 |
| Proline | 0.850 | 2.515 | 2.560 | 3.095 | 2.650 |
| Glycine | 4.470 | 6.195 | 5.925 | 6.015 | 5.385 |
| Alanine | 4.600 | 4.770 | 4.755 | 5.210 | 4.725 |
| Arginine | 7.300 | 5.130 | 5.420 | 5.710 | 6.000 |
| Total (NEAA) | 49.670 | 45.582 | 44.731 | 45.605 | 43.028 |

*Total (EAA) = Total Essential Amino Acids Total (NEAA) = Total Non-Essential Amino Acids*

### 3.5 Hedonic Sensory Evaluation and Overall Acceptability of Crackers

The sensory qualities appearance, color, odor, crispiness, taste and overall acceptability of crackers prepared from rice flour, lentil flour and quinoa flour of different extents and crackers prepared from 100% of rice flour were measured by twenty panelists. The results were statistically studied and recorded in Table 6. From the data presented in Table 6. It could be observed that appearance, color, odor, crispiness and overall acceptability in blend (2) and blend (3) had higher score than blend (1). Blends (4) and (5) sensorial attributes of gluten free crackers contained rice flour; lentil flour and quinoa flour were nearly similar in sensorial attribute with those of blend (3). it could be observed that crispiness of blend (1) have lower scores than other blends B2, B3, B4, B5. *El-Hadidy et al*., stated that adding quinoa flour to make high nutritional value biscuits improve the color, taste, appearance and odor [9]. Sensory evaluation is seen to be a useful approach for resolving issues with food acceptability. It can be used to improve products, maintain quality and more importantly develop new products.

### 3.6 Hardness and Water Activity of Crackers

Data in Fig. 1 presented the hardness of gluten free crackers blends. A decrease in hardness from 74.97 newton in blend (1) made from 100% rice flour to 35.19 newton in blend (5) made from 50% rice flour, 25% lentil flour and 25% quinoa flour. These results due to increasing lentil flour ratio in crackers blend (5). It is well acknowledged that texture has a significant role in customer acceptance. Due to its tight link with human perception of freshness, Karaolu and Kotancilar stated that hardness is the most important factor in assessing baked products [20].

On the other hand, Fig. 2 show that tracking water activity in different blends were 0.329, 0.389, 0.412, 0.385 and 0.395 in blends (1), (2), (3), (4) and (5), respectively.

## 4. DISCUSSIONS

This work confirms that there is a great interest for organic and inorganic compounds due to the different applications for these compounds in different fields [21-29].

The texture properties of many cereal snack items, such as cellular, brittle, and crisp, contribute to their widespread popularity. For many cereal-based foods, texture is significant sensory property. Crispness is linked to a pleasant textural experience as well as freshness and quality, and its loss is a leading cause of customer rejection. Breakfast cereals, wafers, biscuits, and snacks are examples of low moisture baked and extruded products that have a crispy feel. If the moisture content of these foods increases as a result of water sorption from the atmosphere or mass transit from neighbouring components, a soggy, soft texture [30]. Water is a food constituent that influences the stability, quality, and physical attributes of the food. The ratio of the vapour partial pressure of water in food to the vapour partial pressure of pure water at the same temperature and total pressure is described as water activity – $a_w$ [31]. A measure defining 'water availability' in materials. In both the liquid and solid states, water has an impact on the rheological properties of food. Water has an effect on the responsiveness of solid foods to force. Plasticizing or anti-plasticizing effects might occur when the water content is increased [32] .Deformation is facilitated by the plasticization of polymer chains, and brittle material becomes more soft and flowable while losing crispness.

**Table 6.Hedonic sensory evaluation and overall acceptability of crackers**

| Blends | Appearance (9) | Color (9) | Odor (9) | Taste (9) | Crispiness (9) | Over all acceptability (9) |
|---|---|---|---|---|---|---|
| Blend (1) | 7.80±0.13$^{ab}$ | 8.00±0.00$^{a}$ | 8.6±0.16$^{a}$ | 7.15±0.07$^{c}$ | 6.10±0.23$^{b}$ | 7.36±0.10$^{c}$ |
| Blend (2) | 7.89±0.15$^{ab}$ | 7.93±0.27$^{a}$ | 8.6±0.22$^{a}$ | 8.21±0.10$^{a}$ | 7.33±0.15$^{a}$ | 7.99±0.13$^{a}$ |
| Blend (3) | 7.94±0.12$^{a}$ | 7.93±0.27$^{a}$ | 8.6±0.22$^{a}$ | 8.21±0.41$^{a}$ | 7.45±0.13$^{a}$ | 8.03±0.13$^{a}$ |
| Blend (4) | 8.25±0.23$^{a}$ | 8.05±0.029$^{a}$ | 8.6±0.12$^{a}$ | 8.45±0.13$^{a}$ | 7.45±0.13$^{a}$ | 8.16±0.18$^{a}$ |
| Blend (5) | 7.75±0.21$^{ab}$ | 7.75±0.21$^{ab}$ | 8.6±0.17$^{a}$ | 8.15±0.07$^{ab}$ | 7.25±0.24$^{a}$ | 7.90±0.16$^{ab}$ |

*- a, b, c , d different superscript letters in the same columns are significantly different at LSD at ($p \leq 0.05$).*
*-Each value was an average of twenty determinations ± standard deviation*

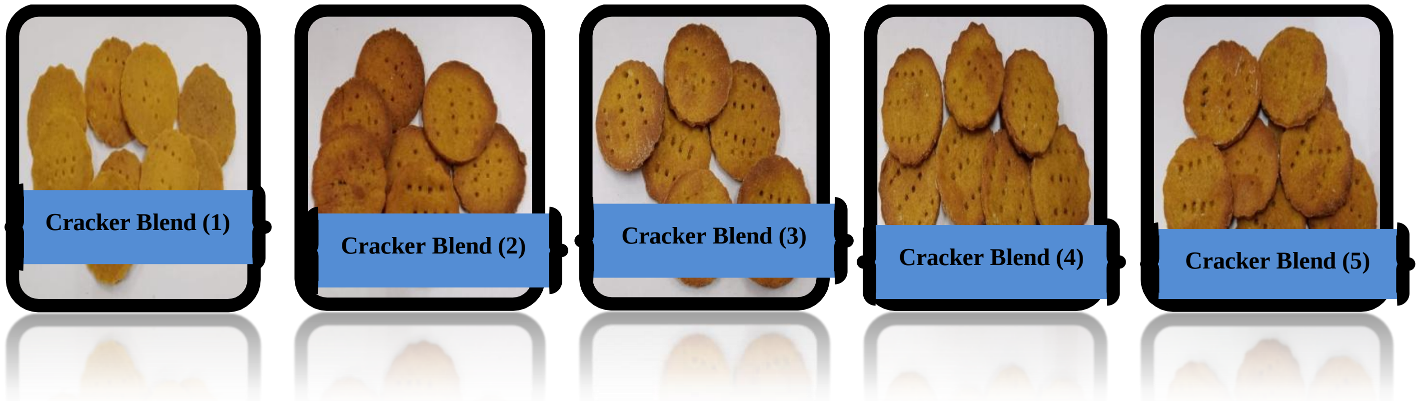


**Photo 1. Different blends of crackers**

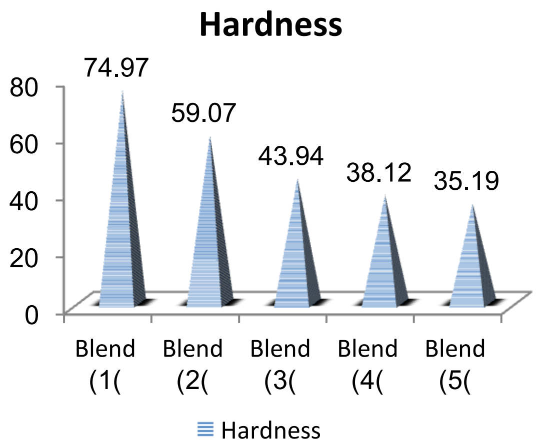


**Fig. 1. Hardness of crackers**

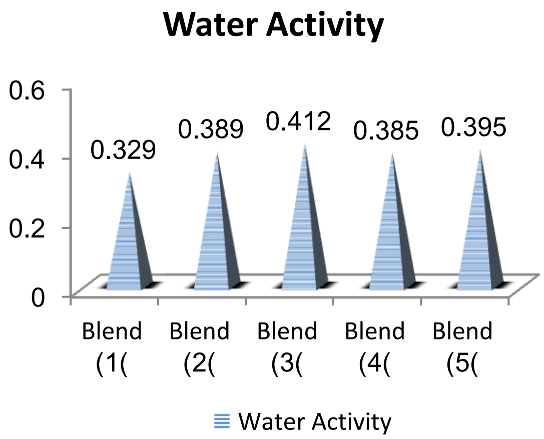


**Fig. 2. Water activity of crackers**

Until date, the antiplasticizing impact has been a mystery. The texture of snack products like crackers and chips has been described as a result of water activity by [33]. They reported that when water activity exceeded 0.35 to 0.50, baked saltine crackers, popcorn, and fried potato chips lost their crispness. At $a_w \leq 0.5$, the crispness of breakfast cereal decreased slightly. After that, a rapid loss of crispness was seen until aw = 0.8, at which point the product fully lost its brittleness [34]. For crackers with various water activity values ($a_w$ = 0.14-0.80), force-deformation curves for a uniaxial compression test were recorded [35]. With increased water activity, the curves got smoother and the maximum force decreased. The compression test was earlier studied [36] to investigate the textural qualities of crispy bread as a function of water content. They detected plasticizing effects of water between 3 and 9 percent, followed by apparent hardness of the material up to 11 percent. The perceived stiffness modules reduced after 11 percent water content, and the softening effect of water became dominant. The anti-plasticizing effect has been seen in several circumstances. Adsorbed water gives the material more strength and makes it less brittle. According to [37] failure stress of flat wheat and rye bread increased as moisture was absorbed, reaching at an aw range of 0.5 to 0.6. Cooking causes the majority of crystalline structures in native starch to disappear, hence baked and extruded cereal products are often glassy. Above their glass transition temperature, products suffer modifications that present themselves in a variety of ways, including changes in mechanical properties. The tensile characteristics of cellular products can increase as they densify [38]. The force-deformation correlations of brittle and crunchy foods are known to be very irregular and irreproducible [39].

## 5. CONCLUSION

The obtained results in this work revealed that crackers were prepared from rice flour, lentil flour and quinoa flour at different ratios. The final products were rich of crude protein, crude fiber, ash and ether extract. These products were a rich source of indispensable amino acids especially lysine and minerals especially potassium, calcium, magnesium and iron. The sensorial properties of prepared crackers from rice flour, lentil flour and quinoa flour were nearly similar of products prepared using rice flour. These products were free of gluten therefore; they are very appropriate for celiac disease patients. Finally, it could prepare some bakery products using raw materials free of gluten such rice flour, lentil flour and quinoa flour with high quality that are proper for celiac disease patients.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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