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Production and Evaluation of Gluten-free Crackers from Rice, Lentil, and Quinoa Flour for Celiac Disease Patients

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Abstract

The present work was carried out to prepare gluten free crackers of high quality for celiac ailment patients. Gluten free crackers prepared from rice flour, lentil flour and quinoa flour is an innovative and highly nutritious snacks produce. The chemical analyzed included as minerals and amino acids of broken rice, lentil and quinoa flour and its blends was estimated. Then, chemical composition for gluten free crackers blends was estimated and the results presented that ash, crude protein, fat 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 parameters of free gluten crackers samples 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 make some bakery products using raw materials free of gluten like rice flour, lentil flour and quinoa flour with high quality that are suitable for celiac ailment patients.

Keywords: celiac, rice, quinoa, lentil, crackers

1. Introduction

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 (Acharya et al., 2020). 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 (Williams et al., 2008). 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 (Han et al., 2010). 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 (Valencia et al., 2006).

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 (Giannakoula et al., 2012). 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 (Iqbal et al., 2006).

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 (Preichardt and Gularte, 2013).

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 (USDA U.S., 2005). 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 (El-Hadidy et al., 2020). 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., 2010). 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 ℃ in an electric oven, then cooled for 30 min, packed in plastic bags, and stored at room temperature.

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

2.3 Chemical Analysis

Crude ash (method 08-01), crude protein (method 46012), and crude fat (method 30-25) were performed using (AACC, 1990) procedures.

The total carbohydrates were determined using Equation (Vaz et al., 2011) 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 $\times$4.1) + (% protein$\times$4.1) + (% fat$\times$9.1).

were performed using (AACC,1990) procedures.

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, 1994).

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 (Duranti, and Cerletti, 1979).

2.6 Estimation of Tryptophan

Tryptophan content of samples was determined calorimetrically according to the method described before (Miller, 1967).

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 (Venkatachalam, and Nagarajan, 2017) 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 (AACC, 2000) 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 ℃ 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 (Nielsen et al., 2012).

2.10 Statistical Analysis

Data were tested statistically using the statistical software program SPSS, ver. 25. All values are expressed as Mean $\pm$SD. Statistical significance of the difference was analyzed using one way-ANOVA and post-hoc Duncan test for multiple group comparison.

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,2020) showed 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 (Fouad and Rehab, 2015).

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., 2020) 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.

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 ($p \leq 0.05$).

-Each value was an average of three determinations ± standard deviation.

[*]Available carbohydrates = 100 – (crude protein + ash + ether extract + crude fiber).

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), 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., 2020) that showed addition of quinoa flour to rice flour increase crude protein in bakery products.

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 ($p \leq 0.05$).

-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

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 crackers (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., 2020) stated that adding quinoa flour to make high nutritional value biscuits improve the color, taste, appearance and odor. 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.

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.

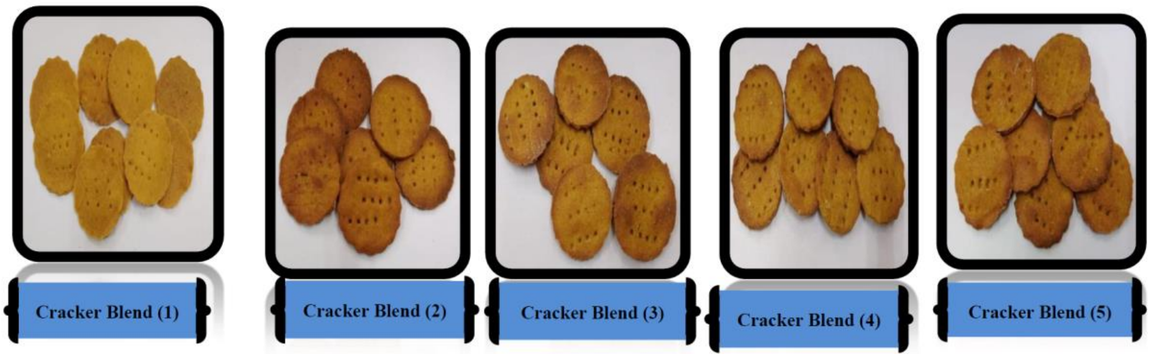

Figure 1. Different blends of crackers

3.6 Hardness and Water Activity of Crackers

Data in Fig. 2 presented the hardness of gluten free crackers blends. A decrease in hardness from 74.97 N in blend (1) made from 100% rice flour to 35.19 N 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, 2009) stated that hardness is the most important factor in assessing baked products.

On the other hand, Fig. 3 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.

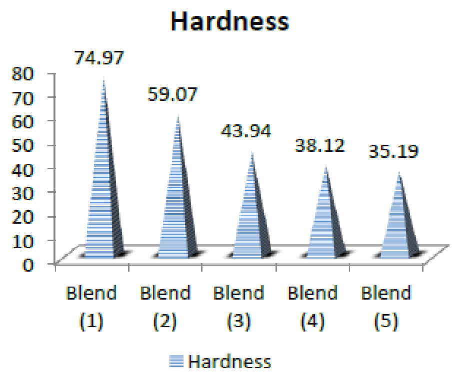

Figure 2. Hardness of crackers

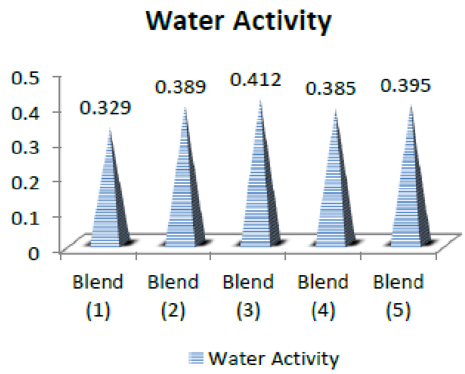

Figure 3. Water activity of crackers

4. Discussions

This work confirms that there is a great interest in functional foods and nutrition value due to the different applications for these bakery's products in different fields of nutrition (Elhadidy, 2009; El-Dreny and El-Hadidy, 2018; Elhadidy, 2014; El-Hadidy, 2020; El-Hadidy et al., 2020; El Hadidy and Rizk, 2020; El-Hadidy & El-Dreny, 2020).

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 (Nicholls, 1995). 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 (Scott 1957). 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 (Lewicki, 2004). Deformation is facilitated by the plasticization of polymer chains, and brittle material becomes more soft and flowable while losing crispness. 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 (Katz and Labuza, 1981). 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 (Sauvageot and Blond, 1991). For crackers with various water activity values (a_w = 0.14-0.80), force-deformation curves for a uniaxial compression test were recorded (Kohyama et al., 1997). With increased water activity, the curves got smoother and the maximum force decreased. The compression test was earlier studied (Roudaut et al., 1998) 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 (Marzec, 2002) 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 (Roudaut, 2003). The force-deformation correlations of brittle and crunchy foods are known to be very irregular and irreproducible (Peleg and Normand, 1992).

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.

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