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Use of cassava and quinoa flours to produce gluten-free coated chicken strips

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Abstract

The primary goal of this research was to produce gluten-free chicken strips in order to satisfy celiac patients' needs for gluten-free food with high nutritional value. The functional properties of wheat, cassava, quinoa, and a cassava-quinoa mixture were tested. Also, the effects of previous flour types on proximate analysis, physiochemical, chemical quality attributes, physical properties, texture, color, and sensory characteristics of battered chicken strips were evaluated. The control group was made with gluten-containing wheat flour. In terms of functional properties for flours, the results showed that cassava flour had the lowest water absorption capacity "WAC" among the flour samples that differed significantly (P≤0.05). In comparison, a mixture of cassava and quinoa flours had significantly higher (P≤0.05) oil absorption capacity "OAC" (1.95 g/g) than other flour examined, there was a significant difference (P≤0.05). There were not significant differences (P>0.05) between all tested flours in bulk density. Regarding nutritional value, there were significant differences between groups for all proximate composition parameters (P≤0.05), which could be attributed to differences in raw material chemical composition. The pH values varied slightly between samples, with no significant difference (P>0.05) between chicken strips coated with wheat or cassava flour. Furthermore, No significant difference (P>0.05) was found between chicken strips coated with quinoa and a mixture of quinoa and cassava flours. Thiobarbituric acid (TBA) and total volatile nitrogen (TVN) values were within acceptable limits for chemical quality attributes. Physical properties indicated that batter pick-up of coated chicken strips not affected by the types of flour meanwhile, oil uptake of chicken strips was significantly affected. Chicken strips coated with quinoa flour had the lowest oil uptake (226.73%). Furthermore, the lowest (P≤0.05) water holding capacity (highest value, 8.17cm^2/0.3g) was recorded for sample coated with cassava flour and the highest (P≤0.05) water holding capacity (lowest value, 3.74cm^2/0.3g) was recorded for sample coated with quinoa flour. Chicken strips coated with cassava flour had significantly higher (P≤0.05) cooking loss than other, while the lowest value was recorded for sample coated with quinoa flour. Texture analysis revealed that each treatment had a different effect on each parameter of texture profile. Color analysis and sensory evaluation revealed no significant differences (P>0.05) between all samples. This study demonstrated that all of the flours under consideration can be used to make gluten-free chicken strips without affecting the quality.

Keywords: Celiac disease, gluten-free, chicken strips, quinoa flour, cassava flour.

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1. Introduction

Celiac disease is a chronic inflammatory small intestine disease caused by an immune response to gluten present in wheat, barley, and rye in genetically susceptible individuals (Alaedini and Green, 2005). Chronic inflammation causes intestinal villi atrophy, resulting in malabsorption, malnutrition, and gastrointestinal symptoms. Systemic complications range from anaemia (iron deficiency), neuropathy, and osteoporosis to secondary autoimmunity and malignant tumours (cancer) (Nadhem *et al*., 2015). Celiac illness can only be treated with a gluten-free diet. Celiacs eat a wide variety of gluten-free foods. These products are divided into two categories: naturally occurring gluten-free foods (fruits, vegetables, and unprocessed meat, fish, and poultry) and gluten-free substitute foods (pasta, bread, cereals, crackers, and snack foods), in which wheat flour is replaced with gluten-free flour (Lee *et al*., 2007). Celiacs, on the other hand, should stay away from meats and poultry that have been processed into ready-to-cook or processed meat products that may contain gluten. In the batter system of coated items, wheat flour is required. It contains a large number of proteins (gluten), which are necessary for the formation of elasto-plastic batter (Amboon *et al*., 2012). Flour, salt, and water are the essential elements in traditional batter, with the amounts of the basic constituents variable. Wheat flour is the most widely used flour in batters because it includes a considerable number of proteins that are essential to create an elasto-plastic batter. Wheat flour is therefore suitable for a wide range of uses in meat, fish, and poultry products (Xue and Ngadi, 2006). Despite the fact that gluten allergy has been on the rise in the susceptible population in recent years, there has been little study into gluten-free meat products. Wheat-free chicken nuggets were made with rice starch and sorghum flour, according to Devatkal *et al.* (2011).

Cassava flour, also known as tapioca flour, can be substitute 100% wheat flour in meat products without altering processing yield or sensory characteristics. This formulation will meet the growing consumer demand for gluten-free meat products, helping to reduce the prevalence of celiac disease (Abiola and Ewebajo, 2009).

Quinoa (*Chenopodium quinoa Willd.*) flour is gluten-free and high-quality protein, making it a vital part of celiac disease and wheat allergy patients' diets (Doweidar and Kamel, 2011). The most recent study was carried out to evaluate the chemical quality and physical characteristics of gluten-free chicken strips prepared with different gluten-free flours (cassava, quinoa, and their combination) in order to develop healthier gluten-free ready-to-eat meat products for celiac patients who require gluten-free chicken meat products.

2. Materials and methods

2.1. Materials

All standards, chemicals, and solvents were purchased from Sigma-Aldrich in the U.S.A. Fresh skinless and boneless broiler chicken breast meat was provided by a local slaughterhouse in Giza, Egypt. Quinoa flour was obtained from the Al-Ahmadi Company for Agricultural Finance and Research in Giza, Egypt. Cassava flour was imported from Meannan Foods in Ghana. Sunflower oil, Wheat flour and all of spices were purchased at a local retail spice market in Giza, Egypt.

2.2. Preparation of chicken strips

Chicken breasts cuts parallel to the fiber direction by knife into chunks 20-25g, rectangular samples thickness ~1cm, width ~ 2 cm and length ~ 8 cm). The chicken strips divided to 4 industrial groups: chicken strips coated with wheat flour batter as control sample, chicken strips coated with cassava flour batter, chicken strips coated with quinoa flour batter and chicken strips coated with flour mixture batter (50% cassava flour and 50% quinoa flour). Generally, batters (liquid mixers) consists of 25% flour (individually into the corresponding batter), 2% mixture powder of spices (black pepper, white pepper, cloves, cardamom, cinnamon, ginger, nutmeg, rosemary), 1.5% garlic powder, 1.5% onion powder, 1% salt and 69% water. Every batter prepared individually and all ingredients were mixed manually without any conglomerate. Raw chicken strips were coated by dipping it on a particular batter (depends on type of flour used) for 20s and allowed to drip for 10s. Each group of chicken strips was deep frying separately in specific frying pan for 5 min in hot sunflower oil at 180°C.

2.3. Methods

2.3.1. Proximate composition

Moisture, ash, protein ($N \times 6.25$) and fat content were determined according to the methods described by the AOAC (2012). Carbohydrates were calculated by difference. The results were presented as wet weight basis (WW).

2.3.2. Evaluation of functional properties of flours

2.3.2.1. Water and oil absorption capacity (WAC and OAC)

The water and oil absorption capacities of flours have been determined using Sosulski et al. (1976) method. The flour samples (1g) were mixed with 10 ml distilled water or refined soybean oil and kept at ambient temperature for 30 min and then centrifuged for 10 min at 4000 rpm by a centrifuge (Sanyo Harrier 18/80 Refrigerator, UK). The WAC and OAC were expressed as grams of water or oil bound per gram of the sample on a dry basis. Triplicate determinations were carried out.

2.3.2.2. Bulk density

The flour samples were carefully poured into a previously prepared 10 ml graduated cylinder. After filling to the 10 ml mark, the bottom of the cylinder was gently tapped on a laboratory bench multiple times until there was no further drop of the sample level. For each sample, measurements were taken in triplicate. According to the method provided by, bulk density was estimated as the weight of the sample per unit volume of sample (g/ml) (Wang and Kinsella, 1976).

2.3.3. Physiochemical and Chemical quality attributes

The pH value was determined using a Jenway Automated pH- metre (Model 3510, UK) at 25±2°C after homogenate a 10 g of each sample in 100 ml distilled water for 30s as the method described by AOAC (2012). Winton and Winton's (1958) method was used to calculate total volatile nitrogen (TVN). (Kirk and Sawyer's, 1991) method was used to determine the thiobarbituric acid value (TBA). TBA concentrations were expressed as malonaldehyde/kg.

2.3.4. Texture Profile Analysis (TPA)

Chicken strips textural properties whether before and after cooking were evaluated using a textureometer, Brookfield model-CT3-10 kg, USA, equipped with fixture (TA-SBA). Texture profile analysis (Bourne, 1978) Samples were penetrated into the muscle to 90 % using a 2 mm diameter stainless steel cylindrical probe, measure their original thickness. The crosshead speed was set to 1.0 mm/s. The parameters listed below were determined: Hardness (N) = maximum force required to compress the sample (H); springiness (mm) = ability of the sample to return to its original shape after a deforming force has been removed (S); Cohesiveness = the extent to which a sample can be deformed before rupture (A2/A1, where A1 is the total energy required for the first compression and A2 is the total energy required for the second compression); Adhesiveness (Ns) is the amount of work required to pull the compressing plunger away from the sample; gumminess (N/mm2) is the amount of force required to disintegrate a semisolid sample for swallowing (H x cohesiveness); chewiness (N/mm) is the amount of work required to masticate the sample for swallowing (S x gumminess). The nugget was compressed to 35% of its original height using a 5-bladed Kramer Shear Cell. 3.0 mm/s was the test speed.

2.3.5. Instrumental color analysis

A Hunter Lab was used to measure the color. Color and color difference metre Model D25 (Hunter, 1985) The Hunter L*-, a*-, and b*- coordinates are used to make this colour assessment. L*-lightness and darkness, + a*-redness, + a*-greenness, + b*-yellowness, and – b*-blueness with white. Hunter Lab colour standard title: (L= 92.56, a= 0.87, and b= 0.15).

2.3.6. Physical analysis

The amount of batter that adheres to the chicken during immersion coating prior to frying is referred to as batter pick-up (Chen et al., 2008). The batter was allowed to drip for 10 seconds before the battered chicken was weighed.

Batter pick-up (%) = $\frac{B-S}{B} \times 100$

Where: B and S are the weights of battered and raw chicken samples, respectively.

The oil uptake (%) was calculated according to the following equation:

Oil uptake (%) = $\frac{O_f - O_r}{O_r} \times 100$

Where O_f is the oil content of fried chicken strips and O_r is the oil content of raw chicken strips expressed as dry matter.

The water holding capacity (WHC) of raw chicken breast meat and coated chicken strips samples was determined using Soloviev (1966) filter paper press process. The surface areas of two zones formed on the ashless filter papers were measured using a planimeter (Placom KP-90N, Japan) Water holding capacity was calculated as cm^2 /0.3g sample by subtracting the area of the internal zone from the area of the outer zone. While plasticity was expressed as the internal area zone (cm^2 /0.3g sample). Cooking loss was calculated as follows, according to Aleson-Carbonell et al (2005).

% Cooking loss = $\frac{\text{uncooked sample weight} - \text{cooked sample weight}}{\text{uncooked sample weight}} \times 100$

2.3.7. Sensory evaluation

Each group of coated chicken strips was deep-fried separately in a separate frying pan for 5 minutes in hot sunflower oil at 180°C. According to Mansour and Khalil (1999), the sensory properties of samples were tested by ten professional panelists from the meat and fish research technology department. Five sensory attributes (taste, odor, color, texture, and overall acceptability) were evaluated using a nine-point hedonic scale, where 9 = extremely like, 8 = very much like, 7 = moderately like, 6 = slightly like, 5 = neither like nor dislike, 4 = dislike slightly, 3 = dislike moderately, 2 = dislike very much and 1 = dislike extremely.

2.3.8. Statistical analysis

The results of this investigation are reported as mean values with standard deviations (SD). An analysis of variance (ANOVA) was performed using the Statistical Analysis System (SAS) software programme (SAS Institute 2004), followed by a statistically significant difference using tests (LSD) at P ≤0.05

3. Results and Discussion

3.1. Chemical composition, physiochemical, chemical quality attributes and physical properties of raw chicken breasts meat

Proximate composition, chemical, physical and physiochemical properties of raw chicken breast meat were shown in Table 1, it could be observed that, the moisture content, crude protein, crude fat, ash and carbohydrate of raw chicken breast meat were 74.74, 20.41, 3.80, 1.07 and 0.25%, respectively (74.74%, 20.41%, 3.80%, 1.07% and 0.25% respectively).

Table 1: Proximate composition, chemical, physical and physiochemical properties of raw chicken breast meat

Parameters	Raw chicken breasts meat
Moisture	74.74± 0.47
Crude protein	20.41± 0.20
Crude fat	3.80± 0.36
Total ash	1.07± 0.02
***Total carbohydrates**	0.25± 0.06
pH	6.10± 0.11
****TBA (mg malonaldhyde/kg)**	0.40± 0.02
*****TVN (mg N /100g)**	12.26± 0.44
******WHC(cm^2/0.3g)**	4.23±0.58
Plasticity(cm^2/0.3g)	2.23±0.23

*Mean ± SD: Mean of triplicate determinations ± standard division. * Total carbohydrates: calculated by differences.
** TBA: Thiobarbituric acid ***TVN: Total volatile nitrogen. ****WHC= Water holding capacity

These results consistent those of Thanatsang *et al.* (2020) provided information on gross chemical composition of broiler breast meat was 74.76% moisture content, 22.12% crude protein, 1.62% crude fat and 1.16% total ash, respectively.

Meanwhile, the mean pH value of raw chicken breast meat was 6.10, according to the initial evaluation of sample compositions. The findings showed that the meat pH value is good; according to (Prayitno and Suryanto, 2010) who reported that the optimal pH of broiler chicken meat without treatment varied from 6.11 to 6.25**.**

The data for thiobarbituric acid "TBA" an indicator of lipid oxidation, revealed a value of 0.40 mg malonaldhyde/kg. This result was below than the maximum limit for TBA (0.9 mg malonaldehyde/kg) which set by Egyptian Standards Specification (2005). The total volatile nitrogen content in raw chicken breast meat was 12.26 mg N/100g sample, which was less than the maximum limit for TVN (20 mg/100g) as mentioned by reported by Egyptian Standards Specification (2005). In the same Table 1, water holding capacity "WHC" and plasticity of raw chicken breast 4.23 cm^2/0.3g and 2.23 cm^2/0.3g, respectively.

3.2. Proximate composition and functional properties for wheat, quinoa, cassava and mixture of quinoa and cassava flours

Results of proximate composition and functional properties of wheat flour, cassava flour, quinoa flour and mixture of cassava and quinoa flours were tabulated in Table 2. There were significant differences (P≤0.05) between wheat flour and other types of flour in all proximate composition. The quinoa flour had significantly higher protein and fat contents (13.81 and 10.70%, respectively) than other types of flour. According to (Marco et al., 2019) reported that chemical composition of quinoa ranged from 8.0 to 22.0% protein, 2.0 to 11.0% oil content and 58.10 to 64.20% starch.

The functional properties of flours are critical in the production of a wide range of products. Food materials' ability to absorb water and oil are important functional properties because they improve mouthfeel and flavour retention. Among the flour samples, cassava flour showed the lowest WAC (1.72g water/g sample) which showed significant difference (P ≤ 0.05) when compared with other types of flour, whereas the highest WAC was found for quinoa (2.02 water/g sample) followed by (1.99 g water/g sample) without significant difference (P>0.05) between them. These findings are consistent with (El Sohaimy *et al.,* 2018) according to researchers, quinoa flour showed water absorption of 141.5± 0.54% that is significantly higher than that of wheat flour (76.3%). WAC refers to a product's ability to associate with water in settings where water is scarce (Singh, 2001). Variations in WAC among flours could be due to differences in protein structures and the presence of different hydrophilic carbohydrates. The lower WAC of cassava flour can be related to the presence of fewer hydrophilic components (Akubor and Badifu, 2004).

The oil absorption capacity "OAC" is crucial characteristic since it increases mouth feel and flavour retention (Kinsella, 1976). Mixture of cassava and quinoa flours showed higher OAC (1.95 g oil /g sample) with significant differences (P ≤ 0.05) in comparison to other tested flours. The lowest OAC was recorded for wheat flour (0.81 g oil / g sample). Variations in the presence of non-polar side chains, which might bind the hydrocarbon side chains of oil among the flours, might explain differences in the flours' oil binding capacity (Adebowale & Lawal, 2004). The bulk density of flour is the density that is measured without any compression. The present study revealed that there were not significant differences (P>0.05) between all tested flours in bulk density

Table 2: Proximate composition and functional properties for wheat, quinoa, cassava and mixture of quinoa and cassava flours

Parameters	**Wheat flour**	**Cassava flour**	**Quinoa flour**	**Mixture of 50% cassava and 50%quinoa flour coating**	**L.S.D at 0.05**
Moisture%	11.51^{a}±0.37	10.89^{b}±0.02	8.45^{c}±0.04	8.80^{c}±0.36	0.49
Crude protein%	10.49^{b}±0.12	2.30^{d}±0.11	13.81^{a}±0.37	8.41^{c}±0.35	0.51
Crude fat%	0.93^{c}±0.04	0.56^{c}±0.09	10.70^{a}±0.38	5.54^{b}±0.18	0.41
Total ash%	0.50^{d}±0.05	2.21^{b}±0.01	2.16^{c}±0.02	2.28^{a}±0.03	0.05
***Total carbohydrate%**	76.57^{b}±0.20	84.04^{a}±0.22	64.88^{d}±0.12	74.97^{c}±0.19	0.36
****WAC (g water/ g sample)**	1.86^{b}±0.06	1.72^{c}±0.03	2.02^{a}±0.05	1.99^{a}±0.01	0.08
*****OAC (g oil/ g sample)**	0.81^{d}±0.02	1.02^{c}±0.03	1.18^{b}±0.04	1.95^{a}±0.06	0.08
Bulk density (g/ ml)	13.25^{a}±2.17	14.46^{a}±0.54	12.73^{a}±0.59	13.36^{a}±0.41	2.21

Mean ± SD: Mean of triplicate determinations ± standard division.
Mean value the same raw with different letters are significantly different at p ≤ 0.05
* Total carbohydrates: calculated by differences
Where: **WAC= water absorption capacity; ***OAC= oil absorption capacity

3.3. Changes in proximate composition, chemical quality attributes, physiochemical and physical properties of coated chicken strips

From Table 3, it could be observed that there were notable differences for all proximate composition parameters among groups (P ≤ 0.05), this could be due to a difference in the chemical composition of the raw materials. The results of the same Table (3) showed that there were small variations between samples in pH values with no significant difference (P>0.05) between chicken strips coated with wheat and that coated with cassava flour. Also, there was no discernible difference (P>0.05) among chicken strips coated with quinoa and mixture of quinoa and cassava flours. Furthermore, the pH values for all treatments ranged between 5.40-5.62 and it's a suitable range for chicken products.

The thiobarbituric acid (TBA) test is used to assess oxidative rancidity (the formation of malonaldehyde) in meat. Furthermore, the TBA-test is a sensitive test for highly unsaturated fatty acid decomposition products that are not detected by peroxide determination (Melton, 1983). From the results in the same Table 3, it could be observed that TBA values of all coated chicken strips ranged from 0.51 to 0.64 mg malonaldehyde / kg sample, that showed non-significant differences between chicken strips coated with quinoa flour, wheat flour and mixture of cassava and quinoa flours, also between chicken strips coated with cassava flour and that coated with mixture of cassava and quinoa flours. On the contrary, there were significant differences in TBA between chicken strips coated with cassava flour and both of chicken strips coated with wheat flour and that coated with quinoa flour, this could be due to the variation of antioxidant effect between all types of flour which used in the study. Furthermore, according to Egyptian Standards Specification (2005), all samples had TBA values within the range of 0.9 mg malonaldehyd/kg.

According to Table 3, There were significant differences (P ≤ 0.05) in TVBN values among chicken strips coated with wheat flour and both of strips coated with cassava flour and that coated with mixture of cassava and quinoa flours, also between strips coated quinoa and that coated with cassava. The lowest TVN (13.71 mg N/100g) was recorded for chicken strips coated with cassava flour followed by strips coated with mixture of cassava and quinoa flours with no significant differences (P>0.05). On the contrary, the highest TVN (14.83 mg N/100g) was recorded for chicken strips coated with wheat flour followed by chicken strips coated with quinoa flour (14.41 mg N/100g) with no significant differences between them. The TVBN values in all treatments were within the acceptable level range reported by Egyptian Standards Specification (2005), which stated that the TVBN content should not exceed 20 mg/100 g.

Results in Table (3) showed that batter pick-up (%) of coated chicken strips not affected significantly by the types of flour meanwhile, oil uptake (%) of chicken strips significantly affected. Chicken strips coated with quinoa flour had the lowest oil uptake (226.73%) which showed significant differences (P≤ 0.05 when compared with chicken strips coated with cassava flour. In the coated food sector, coating pick-up is an important metric that normally varies from 30 to 50% (Loewe, 1993). Essentially, mechanisms that enable the formation of oil barrier films or increase the water holding capacity may reduce oil uptake (Dana nd Saguy, 2006). The proteins in batter provide structure and increase the consistency of raw batters and this is evidenced by a rise in viscosity, values of coating pick-up and final yield in fried items (Nasiri *et al*., 2012).

Table 3: Proximate composition, physical and physiochemical properties of coated chicken strips

	Treatments				
Parameters	**Wheat flour**	**Cassava flour**	**Quinoa flour**	**Mixture of 50%**	**L.S.D at**
Moisture%	71.34^{a}±0.82	72.19^{a}±0.17	69.38^{b}±0.38	71.69^{a}±0.82	1.16
Crud protein%	19.66^{b}±0.15	18.09^{d}±0.15	21.15^{a}±0.37	18.77^{c}±0.42	0.56
Crude fat%	3.85^{b}±0.11	4.20^{b}±0.09	5.29^{a}±0.19	5.08^{a}±0.56	0.58
Total ash%	1.67^{a}±0.02	1.51^{b}±0.01	1.45^{bc}±0.01	1.40^{c}±0.06	0.07
***Total carbohydrates%**	3.48^{ab}±0.71	4.01^{a}±0.38	2.73^{b}±0.17	3.06^{ab}±0.90	1.15
pH	5.40^{b}±0.02	5.44^{b}±0.04	5.62^{a}±0.03	5.56^{a}±0.05	0.07
****TBA mg malondhyde/kg**	0.62^{a}±0.04	0.51^{b}±0.07	0.64^{a}±0.04	0.59^{ab}±0.04	0.09
*****TVN mg N /100g**	14.83^{a}±0.09	13.71^{c}±0.20	14.42^{ab}±0.36	14.14^{bc}±0.22	0.45
Batter pick-up %	30.29^{a}±4.66	30.15^{a}±1.91	34.60^{a}±3.66	31.01^{a}±8.64	10.02
Oil uptake %	297.77^{b}±6.05	321.74^{a}±25.89	226.73^{b}±82.58	298.05^{ab}±12.08	82.46
******WHC(cm^2/0.3 g)**	5.06^{c}±0.11	8.17^{a}±1.09	3.74^{d}±0.25	6.37^{b}±0.75	1.27
Plasticity(cm^2/0.3 g)	2.57^{ab}±0.38	3.53^{a}±1.20	2.23^{b}±0.06	3.40^{ab}±0.34	1.23
Cooking loss	19.16^{bc}±1.14	21.23^{a}±0.75	18.24^{c}±0.05	20.15^{ab}±0.84	1.41

Mean ± SD: Mean of triplicate determinations tested ± standard division.
Mean value in the same row with different letters are significantly different at p ≤ 0.05
*Total carbohydrates: calculated by differences ** TBA: Thiobarbituric acid ***TVN: Total volatile nitrogen
****WHC= Water holding capacity

The ability to bind water to meat and meat products is referred to as water holding capacity (Pearce *et al.,* 2011). The variations of WHC were shown in Table 3. The lowest (P≤0.05) water holding capacity (highest value, 8.17 cm^2/0.3g) was recorded for Chicken strips coated with cassava flour and the highest (P≤0.05) water holding capacity (lowest value, 3.74 cm^2/0.3g) was recorded for sample Coated with quinoa flour. So, the lowest water holding capacity obtained when coating formulation was prepared with gluten free cassava flour and mixture of cassava and quinoa flours which might be due to lower protein content as shown in Table 2. These findings were consistent with previous research on chicken nuggets (Tasbas *et al*., 2016). For cooking loss values of coated chicken strips data revealed that the highest value (21.23%) was recorded for chicken strips coated with cassava flour followed by strips coated with mixture of cassava and quinoa flours with no significant differences (p>0.05). While, the lowest cooking loss (P≤0.05) was recorded for sample had quinoa flour coating. This observation can be attributed to the difference in protein content and water holding capacity.

3.4. Texture profile analysis (TPA)

Texture parameters of coated chicken strips prepared with Wheat**,** Cassava**,** Quinoa flours and mixture of cassava and quinoa flours coating before and after cooking were given in Table 4. The following are the key texture parameters: Hardness (N), Sprininess (mm), Cohesiveneses, Chewiness (kg.mm) and Gumminess. The findings revealed that the Hardness (N) for all coated chicken strips samples ranged between 9.44 to 17.54N. The lowest value (9.44 N) was recorded for chicken strips coated with mixture of cassava and quinoa flours. While the highest value was (17.54 N) for sample coated with cassava flour. The hardness of chicken strips is a sense to consumers and may be correlated with the dilation and cell structure of the product, independent of the moisture level in the product; these results are in agreement with (Demirok, 2014).

Table 4: Texture profile analysis of coated chicken strips before and after cooking process.

Treatments "before cooking"					
Parameters	**Wheat flour coating**	**Cassava flour coating**	**Quinoa flour coating**	**Mixture of 50% cassava and 50% quinoa flour coating**	**L.S.D at 0.05**
Hardness (N)	14.25^{b}±0.08	17.54^{a}±0.21	17.38^{a}±0.77	9.44^{c}±0.16	0.78
Sprininess (mm)	3.94^{b}±0.12	5.62^{a}±0.05	3.06^{c}±0.28	3.94^{b}±0.12	0.32
Cohesiveneses (kg.mm)	0.61^{ab}±0.03	0.66^{a}±0.02	0.48^{b}±0.11	0.63^{a}±0.09	0.14
Chewiness (kg.mm)	40.55^{b}±22.96	77.39^{a}±0.21	34.33^{c}±1.15	27.07^{d}±0.23	1.13
Gumminess	10.27^{b}±0.24	14.02^{a}±0.16	10.50^{b}±0.26	6.56^{c}±0.18	0.41
		Treatments "after cooking"			
Hardness (kg)	50.42^{c}±0.51	57.30^{b}±0.17	79.17^{a}±0.15	57.11^{b}±0.19	0.54
Sprininess (mm)	2.43^{b}±0.37	3.31^{a}±0.30	2.63^{ab}±0.60	2.13^{b}±0.15	0.74
Cohesiveneses	0.42^{d}±0.04	0.61^{c}±0.03	0.91^{a}±0.02	0.70^{b}±0.03	0.08
Chewiness (kg.mm)	80.61^{d}±0.53	131.2^{b}±0.34	209.2^{a}±0.35	95.10^{c}±0.17	0.68
Gumminess	30.10^{d}±0.10	39.34^{c}±0.29	77.51^{a}±0.46	45.29^{b}±0.35	0.62

Mean ± SD: Mean of triplicate determinations ± standard division.
Mean values in same row with different letters are significantly different at p ≤ 0.05

The values of Sprininess (mm), Chewiness (kg.mm) and gumminess significantly higher (P≤ 0.05) in coated chicken strips prepared from cassava flour than other samples. The cohesiveneses of coated chicken strips with cassava flour and mixture of cassava and quinoa flours similar to chicken strips coated with wheat flour (P>0.05). Also, the chewiness of coated chicken strips with quinoa flour and mixture of cassava and quinoa flours similar to that coated with wheat flour (P >0.05) but differed (P≤ 0.05) than coated with cassava flour. The treatments which had cassava flour shown high (P≤ 0.05) mean values for gumminess.

Moreover, the TPA analyses "after cooking' were presented in Table 4, coated chicken strips with quinoa flour had significantly (P≤ 0.05) higher hardness, cohesiveneses and gumminess values than other coated chicken strips. The treatments containing wheat, quinoa and mixture of cassava and quinoa flours presented similar (P >0.05) mean values for springiness. Also, the treatments which coated with quinoa flour shown high (P≤ 0.05) mean values for gumminess. These results are in agreement with (Gökçe *et al*., 2016).

3.5 Color analysis

Color analysis of food is an important field, always related strongly to market and consumers acceptability as it controls the first impression of any food product. L*, a* and b* values are how color is measured to describe the color differences between control and modified formulas, data of color values were presented in Table 5 The results of coated chicken strips samples showed after deep fat frying, there were no significant differences (p>0.05) in color (L*, a* and b* values) in all treatment groups. Table 5 shows that the L* values of the crusts battered chicken strips were ranged from 44.49 to 51.22. The crust color of fried chicken strips samples was varied slightly (p>0.05) depending on the type and content of flour. Coated chicken strips crust had lower redness, a*, and b* values than the L* values. The differences between L*, a* and b* values of chicken strips samples after frying could be due to the type and content of flour. In this context (Adedeji and Ngadi, 2011) who reported that the lightness value (L*) for the fried chicken nuggets coated with different batter formulation gradually increased by increasing substitution of wheat flour with long grain rice flour (high amylose rice flour).

Table 5: Color analysis of coated chicken strips after cooking process

Treatments					
Parameters	**Wheat flour coating**	**Cassava flour coating**	**Quinoa flour coating**	**Mixture of 50% cassava and 50% quinoa flour coating**	**L.S.D at 0.05**
L*	46.66^{a}±13.46	44.93^{a}±13.98	44.49^{a}±2.34	51.22^{a}±1.04	18.42
a*	11.20^{a}±7.49	6.02^{a}±5.99	6.84^{a}±2.06	6.57^{a}±1.44	9.28
b*	20.63^{a}±7.50	16.44^{a}±4.17	16.02^{a}±2.98	20.95^{a}±4.24	9.44

*Mean ± SD: Mean of triplicate determinations ± standard division.
Mean values in the same row with different letters are significantly different at p ≤ 0.05

3.6. Sensory properties of coated chicken strips

Sensory characteristics of any product influence the acceptability of products and the preference of the customer. The sensory properties of coated chicken strips were presented in Table 6, It could be noticed that there were no significant differences (P>0.05) for all sensory properties (odor, taste, color, texture and overall acceptability) between all treatments, regarding overall acceptability, all treatments received high overall acceptability scores ranging 8.22- 8.58 described as very much like by panelists. These results were in agreement with Tasbas *et al*. (2016), revealed that use of gluten-free wheat flour, cellulose, egg powder, whey powder and pectin had no significant effect on sensory properties of coated chicken nuggets compared to the control group.

Table 6: Sensory evaluation of coated chicken strips

Treatments					
Parameters	**Wheat flour coating**	**Cassava flour coating**	**Quinoa flour coating**	**Mixture of 50% cassava and 50% quinoa flour coating**	**L.S.D at 0.05**
Color	8.95^{a}±0.83	8.66^{a}±0.87	8.50^{a}±0.70	8.55^{a}±0.98	0.77
Taste	8.50^{a}±097	8.30^{a}±0.50	8.00^{a}±0.47	8.10^{a}±0.31	0.55
Odor	8.60^{a}±1.07	8.22^{a}±0.44	8.20^{a}±0.42	8.40^{a}±0.52	0.60
Texture	8.30^{a}±0.48	8.22^{a}±0.44	8.20^{a}±0.42	8.20^{a}±0.42	0.39
Overall acceptability	8.58^{a}±0.69	8.36^{a}±0.43	8.22^{a}±0.24	8.31^{a}±0.41	0.42

Mean ± SD: Mean of triplicate determinations ± standard division.
Mean values in in the same row with different letters are significantly different at p ≤ 0.05

4. Conclusions

We concluded that cassava, quinoa, and combinations of them can be utilized in the manufacturing of gluten-free chicken strips without compromising quality. Furthermore, it is a new product to meet the demands of celiac patients for gluten-free food with high nutritional value.

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