Original Research Article

Utilization of Sorghum,Sweet Potato and Chickpea for Production of High Nutritional Value Gluten Free Cookies

ABSTRACT

Aims: Gluten-free (GF) products are essential for individuals with celiac disease, as the only treatment currently available is adhering to a GF diet. Additionally, many people today are increasingly focused on healthy eating and seeking nutritious food options.
Methodology: Five gluten-free formulations were developed: control-100% sorghum flour as control, S1- 90% sorghum flour and 10% sweet potato, S2-80% sorghum flour + 10% sweet potato and 10% chickpea powder, S3-80% sorghum flour + 10% sweet potato and 20% chickpea powder,S4-80% sorghum flour + 10% sweet potato and 30% chickpea powder. The physicochemical properties and sensory evaluation of cookies were carried out.
Results: Results showed the inclusion of 10% sweet potato flour led to a significant increase in ash and fiber and carotenoids content in cookies furthermore, the increase of chickpea powder in cookies led to the increased proportion of crude fat, crude protein in cookies. Results also show an increase in mineral content with the increase in substitution with chickpea powder the addition of different levels of chickpea flour had a significant impact on the diameter and thickness of the cookies. As the chickpea powder level increased, there was a consistent decrease in cookie diameter and thickness.
Conclusion: These findings suggest that the replacement of sorghum flour with chickpea and sweet potato flour above 20% had a negative impact on the sensory characteristics of the cookies.

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Keywords: Gluten Free Cookies, Sorghum, Sweet Potato, Chickpea

1. INTRODUCTION

Celiac disease is a chronic enteropathy produced by gluten intolerance, more precisely to certain proteins. The primary treatment approach for individuals with celiac disease involves adhering to a gluten-free diet. This necessitates the elimination of not only wheat but also related grains such as rye and barley from the diet (**Hamdani *et al*., 2020**). The food industry has faced significant challenges in developing gluten-free products to cater to the needs of individuals with celiac disease (**Naqash*et al*., 2017**).

Protein fortification of bakery products is currently of great interest due to growing consumer awareness.Chickpeas (Cicer arietinum L) are abundantly rich in protein and predominantly composed of complex carbohydrates with a low glycemic index. They boast a wealth of vitamins and minerals while being relatively devoid of from anti-nutritional factors

(**Wood and Grusak, 2007**). Chickpea proteins are regarded as a suitable source of dietary protein due to their excellent balance of essential amino acids (**Zhang *et al*., 2007**).

The formation of a gluten network is not necessary for cookies, as their texture primarily relies on the gelatinization process of starch. Cookies have universal appeal and serve as important energy sources for all age groups. Their benefits include availability in diverse flavors and sizes, appealing sensory attributes, long shelf lives at ambient temperatures, and affordable prices.They are easy to handle during production and distribution (**Hamdani *et al*., 2020**).

The current study was designed to prepare cookies using sorghum flour with chickpea flour and sweet potato flour and to evaluate their physicochemical and sensorial properties.

2. MATERIAL AND METHODS

2.1 Materials

White sorghum (Dorado variety) grains were obtained from Field Crops Research Institute, Agricultural Research Center, Giza, Egypt. Wheat flour (72% extraction) was obtained from South Cairo Company of milling. Sweet potato, chickpea and baking ingredients (sugar, baking powder, butter and sodium chloride) were purchased from local market. All other chemicals were of the analytical reagent grade

2.2 Methods

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2.2.1 Preparation of Raw Materials

2.2.1. Preparation Method for Sweet Potato Flour

Raw sweet potato was washed in tap water, hand peeled then cut into thin slices and then blanched in hot water containing 0.1 % sodium meta-bisulphite for 3 minutes. The slices were then dried at 60º C 24 hours. The dried slices were ground and then sieved through a 60-mesh screen. The powder samples were packed in polyethylene bags and stored at ambient temperature prior use according to methods described by **Ukwuru and Adama, 2003**.

2.2.1.2 Preparation Method for Sweet Chickpea Flour

Sweet chickpeas were ground using a grinder, to obtain a fine powder that passed through a 60-mesh sieve. All powders obtained were kept in an airtight polyethylene bag as described by **Saker and Hussien, 2017**.

2.2.1.3 Preparation Method for Sorghum Flour

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Sorghum samples were carefully cleaned from impurities, and then washed with tap water. Sorghum grains were soaked in tap water for12h at room temperature (25˚ C). After that, water was drained off and sorghum grains were dried in drying oven at 45˚C ± 5˚C/18 h. Sorghum were ground using a grinder, to obtain a fine powder that passed through a 60-mesh sieve. All powders obtained were kept in an airtight polyethylene bag as described by **Ibrahim, 2017**.

2.2.2 Cookie Preparation

Cookies were prepared according to **Singh *et al.,* 2008** with some modification as shown in Table (1). The incorporation of 10% sweet potato flour was chosen to increase the total carotenoids level to cover apart of person's need per day.

Table 1. Formula of Cookies

Sample	Control	S1	S2	S3	S4
Sorghum	100	90	80	70	60
Sweet Potato	0	10	10	10	10
Chickpeas	0	0	10	20	30
Butter	35	35	35	35	35
Sugar	30	30	30	30	30
Sodium chloride	1	1	1	1	1
Baking Powder	1	1	1	1	1
Water			As needed		

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2.2.3 Proximate Composition of Raw Materials and Cookies:

Moisture, ash, protein, crude fiber and fat was determined according to the method of **AOAC, 2019.** Carbohydrate content was calculated on a dry weight basis by the difference: [Carbohydrates = 100 - (protein+fat+ash+crude fibers)].

The elemental analysis of sodium, potassium, magnesium, calcium, zinc, and iron, was conducted using, microwave digestor (Multiwave GO Plus 50 HZ) prior to spectrophotometric analysis of the samples by MPAES (Microwave Plasma -Atomic Emission Spectroscopy) (Agilent, Mulgrave, Victoria, Australia) as described by **Helal and Nassef, 2021**. Three replicates were measured for each sample.

2.2.4 Determination of Total-Carotenoids

Total carotenoids were determined in raw materialsand cookies using the method outlined by **Santra *et al.,* 2003**.A calibration curve was made from known quantities of β-carotene and was expressed as mg/kg on dry weight basis.

2.2.5 Water Activity of Cookies

Water activity (aw) was measured with a rotronicHygro Lab EA10-SCS Switzerland) aw meter. The measurements were performed in triplicate.

2.2.6 Physical Characteristics of Cookies

Cookies were evaluated for weight (g), thickness (mm), diameter (mm), density (g/cm3) and spread ratio asdescribed by **Gaines, 1991.** Six cookies were placed edge-to-edge for evaluation, and their average measurements were recorded. Diameter and thickness were measured using a Vernier caliper. The spread ratio was determined by dividing the diameter by the thickness, using the following equation: Spread ratio = Diameter / Thickness

2.2.7 Hardness of Cookies

Cookie hardness was measured using a Texture Profile Analyzer (TPA) following the **AACC, 2002** method. The measurement was conducted with a universal testing machine (Brookfield Engineering Lab. Inc., Middleboro, MA). A 25-mm diameter cylindrical probe was used in the TPA at a speed of 2 mm/s. Hardness was calculated from the TPA graph and expressed in Newtons (N).

2.2.8 Sensory Evaluation of Cookies

Cookieswere organoleptically evaluated fortheir sensory characteristics. Biscuit samples were servedon white, odorless and disposable plates, and water wasprovided for rinsing between samples for ten panelists.Samples were scored for color, flavor, crispiness, textureand overall acceptability according to the method of **Larmond, 1982**.

2.2.9 Statistical Analysis

The data from this study were statistically analyzed for means and standard deviations using Costat statistical software (**Steel *et al.*, 1997**). A one-way analysis of variance was conducted on the data.

3. RESULTS AND DISCUSSION

3.1 Physico-chemical Properties of Raw Materials

The mean values for proximate and minerals composition of sweet potato flour, chickpeas flour and sorghum flour were calculated in 100g of flours and the obtained results are presented in Table 2.

The analysis results for chickpea indicated a fat content of 6.75 g/100 g and a protein content of 25.00 g/100 g. The fiber content was measured at 2.75 g/100 g, while the ash content was 3.10 g/100 g, and carbohydrates accounted for 62.4g/100g. These findings align with the research conducted by **Sakr and Hussien, 2017**.

In the case of sorghum flour, the data showed a fat content of 2 g/100 g, a protein content of 9.09 g/100 g, a fiber content of 2.5 g/100 g, ash content of 1.30 g/100 g, and carbohydrates totaling 85.11 g/100 g. These results are consistent with the work of **Ibrahim, 2017.**

Sweet potato flour exhibited a protein content of 3.77 g/100 g, a fat content of 0.79 g/100 g, and a fiber content of 2.37 g/100 g. Notably, sweet potato flour displayed a significantly higher carotene content of 32.61 mg/kg compared to chickpea and rice flours. These results are consistent with the findings of **Omran and Hussien, 2015**.

Water holding capacity (WHC) was presented in Table 2. Notably, sweet potato flour exhibited the highest WHC at 240.15%, followed bysorghum flour at 160 g/100 g, and finally chickpea flour at 132.95 g/100 g. These results are consistent with the findings reported by **Saker and Hussien, 2017**, who observed a water holding capacity of 131.60 g/100 g for chickpea flour, and **Omran and Hussien, 2015**, who reported a water holding capacity of 243.13 g/100 g for sweet potato flour. **Uthumporn*et al.*, 2015**attributed the high water holding capacity of flour to the hydroxyl groups of cellulose in fiber, which have the ability to bind with free water molecules through hydrogen bonding, resulting in a greater water holding capacity.

Table 2. Physico-chemical Properties of Raw Materials

Sample	Sweet Potato Powder	Chickpea Flour	Sorghum Flour
Moisture	6.15±0.21	10.35±0.15	12.97±0.17
Protein	3.77±0.17	25.00±0.09	9.09±0.11
Fat	0.79±0.05	6.75±0.10	2.00±0.09
Crude Fiber	2.37±0.11	2.75±0.05	2.50±0.12
Ash	4.03±0.02	3.10±0.03	1.30±0.05
Total Carbohydrate	89.04±1.05	62.40±1.19	85.11±1.12
Carotene (mg/kg)	32.61±0.06	7.66±0.07	0.62±0.04
Ca (mg/100g)	6.37±0.03	114.50±0.06	10.49±0.09
P(mg/100g)	2.68±0.07	390.00±0.17	286.5±0.05
Fe (mg/100g)	1.537±0.03	6.08±0.05	8.25±0.09
Zn(mg/100g)	0.93±0.01	3.50±0.02	2.50±0.07
K(mg/100g)	43.30±0.07	519.0±1.21	287.40±0.03
WHC (g of water/g dry matter)	240.15±0.22	132.95±0.17	160.00±0.19

Values are means of three replicates ±SD, ***** *on dry weight basis*

3.2 Nutritional Evaluation of Gluten Free Cookies

Tables (3 and 4) present the nutritional analysis results for the produced cookies. The inclusion of 10% sweet potato flour led to asignificant increase in ash and fiber content, reaching 1.58 and 1.56 % respectively, as well as in carotene, reaching 20.32% compare with (1.39, 1.41 and 15% respectively) for control. This increase is a result of the elevated levels of ash and crude fiber found in sweet potatoes. These findings are consistent with the results obtained by **Elzoghby*et al.,* 2023.**

Table 3. Chemical Composition for Gluten-Free Cookies

Sample	Moisture	Protein	Fat	Ash	Crude Fiber	Total Carbohydrate	Carotenoids
Control	6.42±0.06^{C}	5.89±0.08^{d}	19.25±0.05^{d}	1.39±0.01^{e}	1.41±0.06^{e}	72.06±0.09^{a}	13.00±0.05^{c}
S1	6.69±0.09^{a}	5.53±0.05^{e}	19.00±0.02^{e}	1.58±0.07^{d}	1.56±0.04^{d}	72.33±0.06^{a}	20.32±0.07^{b}
S2	6.63±0.02^{ab}	6.18±0.04^{c}	19.28±0.07^{c}	1.67±0.03^{c}	2.50±0.09^{c}	70.37 ±0.05^{b}	20.72±0.04^{b}
S3	6.57±0.05^{b}	6.84±0.09^{b}	19.50±0.04^{b}	1.80±0.11^{b}	3.43±0.07^{b}	68.43 ±0.07^{c}	21.14±0.07^{a}
S4	6.43±0.02^{c}	7.43±0.07^{a}	20.47±0.09^{a}	2.05±0.08^{a}	4.35±0.05^{a}	65.70 ±0.08^{d}	21.52±0.06^{a}

Values are means of three replicates ±SD, numbers in the same column followed by the same letter are not significantly different at 0.05 level: ***** on dry weight basis; ****** Total carbohydrates were calculated by difference

The moisture content of the cookies exhibited a slight decrease with the increase in concentration of chickpea flour. This can be attributed to the lower water-binding capacity of chickpea flour compared with sweet potato flour, resulting in lower moisture retention in the final products. As the level of chickpea flour increased, protein and fat content increased, likely due to the high protein and fat content present in chickpea flour. Also, both ash and fiber contents increased with the addition of chickpea flour.These findings align with the research conducted by **Soni *et al*., 2018**.

The incorporation of 10% sweet potato flour resulted in an increase in total carotenoids to 20.32mg/kgcompared with 13mg/kg for control. These findings are consistent with the results obtained by **Samuel *et al.,* 2020.**While the inclusion of chickpea flour caused a rise in total carotenoids to 21.52 mg/kg for 30% chickpea flour. This increase can be attributed to the carotene levels present in sweet potatoes and chickpeas compared with sorghum.

Data in table (4) show an increase in all minerals analyzed, except phosphorous and sodium, as a result of substituting sorghum with sweet potato flour. This may be due to the high mineral content in sweet potato flours. Results agree with previous work by **Dako *et al.,* 2016.** Results also show an increase in mineral content with the increase in substitution with chickpea powder. Results are in line with previous work by **Ibrahim, 2022**.

Table (4): Mineral Content for Gluten-Free Cookies

Sample	Ca	Fe	Zn	P	K
Control	30.33±0.02^{e}	0.30±0.04^{e}	0.52±0.06^{e}	259.47±0.09^{a}	296.42±0.06^{c}
S1	44.55±0.04^{d}	1.24±0.06^{d}	1.59±0.03^{d}	233.52±0.07^{b}	265.84±0.02^{d}

S2	53.77±0.07[c]	1.47±0.09[c]	1.74±0.05[c]	231.61±0.03[b]	291.61±0.05[c]
S3	62.98±0.05[b]	1.70±0.04[b]	1.89±0.07[b]	229.83±0.05b[c]	317.46±0.09[b]
S4	72.21±0.09[a]	1.94±0.05[a]	2.03±0.03[a]	227.75±0.05[c]	342.78±0.07[a]

Values are means of three replicates ±SD, numbers in the same column followed by the same letter are not significantly different at 0.05 level: * on dry weight basis

3.3 Physical Properties of Cookies

Physical properties of cookies are important for both manufacturers and consumers. Table 5 shows the results of the evaluation of cookies prepared from mixture of sorghum flour, chickpea, and sweet potato flour, for several physical characteristics.

Table5. Physical Properties of Gluten-Free Cookies

Sample	Diameter (cm)	Thickness (cm)	Spread Ratio (D/T)
Control	6.14±0.07[a]	0.95±0.09[a]	6.46±0.07[c]
S1	5.87±0.03[b]	0.92±0.05[b]	6.38±0.02[d]
S2	5.79±0.06[c]	0.89±0.03[c]	6.51±0.06[b]
S3	5.65±0.03[d]	0.86±0.07[d]	6.57±0.03[ab]
S4	5.47±0.06[e]	0.83±0.05[e]	6.60±0.09[a]

Values are means of three replicates ±SD, numbers in the same column followed by the same letter are not significantly different at 0.05 level

Cookies prepared with a combination of sorghum and 10% sweet potato flour displayed a noticeable decrease in diameter and thickness compared to the control cookies made only from 100% sorghum flour. The results of spread ratio of cookies revealed a reduction from 6.46 (control) to 6.38 among cookies with10% sweet potato flour. The results agree with work by **Omran and Hussien 2015**.They explained that the cookies spread is strongly correlated to the water absorptioncapacities of the flour used. Since the water holding capacity of sweet potato flour is higher than that of sorghum flour, rapid partition of free water to hydrophilic sites ofsweet potato flour is presumed to be higher than sorghum flour. Hence, one can deduce that the inclusion of sweet potato flour restricts the spread of cookies.

Furthermore, the addition of different levels of chickpea flour had a significant impact on the diameter and thickness of the cookies. As the chickpea flour level increased, there was a consistent decrease in cookie diameter and thickness. The control cookies exhibited the maximum diameter and thickness of 6.14 and 0.95cm, while the cookies with the highest chickpea flour content (S4) had the minimum diameter and thickness of 5.47 and 0.83cm. It is evident that the increase in chickpea flour levels resulted in decreased diameter and thickness of the cookies. These results are consistent with the findings of **El-Dreny, and El-**

Hadidy, 2020. They stated that such differences in the physical properties could be attributed to properties in the raw materials. However, the spread ratio of these cookies increased. It is noticed that the spread ratio increases with adding of different levels of chickpea flour and as a result with the increase in the protein content of the cookies and it could have been affected by absence of gluten. These results are in agreement with **Ibrahim, 2017** showed that the spreadratio could have been affected by the competition of ingredients and other functional properties of proteins.

3.4 Textural Profile Analysis (TPA) of Gluten-Free Cookies

The significance of texture in gaining consumer acceptance is widely acknowledged. **Karaoğlu and Kotancilar, 2009** reported that hardness is the most important in evaluation of baked goods, because of its close association with human perception of freshness.

The texture characteristics of the control sample and the samples substituted with chickpea flour and sweet potato flour are summarized in Fig 1. A notable reduction in hardness was observed in S1 sample, with the substitution with sweet potato flour. This decrease in hardness can be attributed to the substitution of sorghum flour with sweet potato flour, which are known to be hydrophilic in nature, and thereby, absorbed excessivemoisture and affected the hardness. (**Omran and Hussien, 2015**)

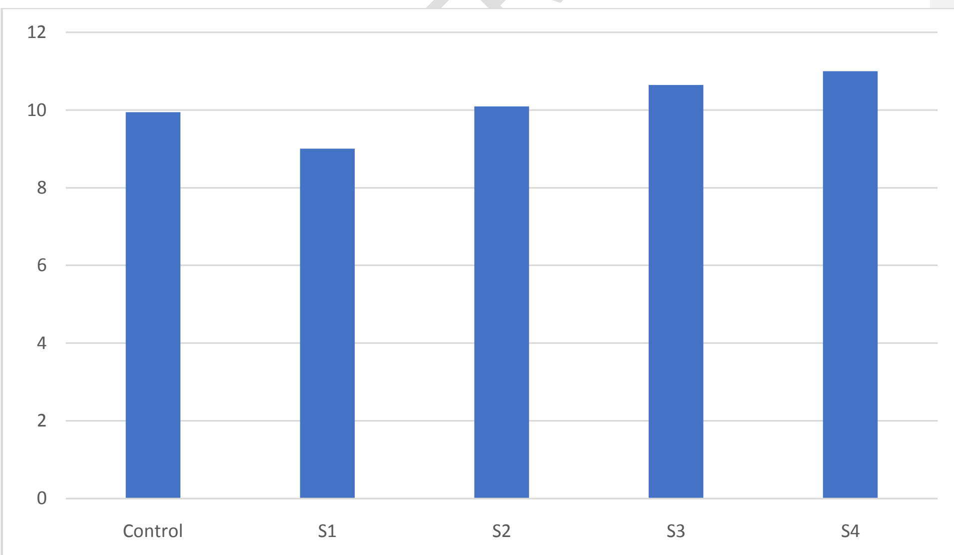

Fig 1.Textural Profile Analysis (TPA) of Gluten-Free Cookies.

Furthermore, with substitution with chickpeas hardness increased. These results are consistent with the work conducted by **Elzoghby*et al.,* 2023**. This increase could be attributed to high protein content of chickpeas. **Ibrahim, 2017** stated that hardness of biscuits increases with increase in protein content of biscuits.

3.5 Sensory Evaluation of Gluten-Free Cookies

The results of the sensory evaluation for the cookie samples are presented in the provided table. The scores obtained for each sample varied from 90.6 for the control sample to 94, 95.5, 97.4 and 94 for samples S1 to S4, respectively. Notably, sample S4, which contained both 10% sweet potato flour and 30% chickpea, received lower scores compared to the other samples. These findings suggest that the replacement of sorghum flour with chickpea and sweet potato flour above 20% had a negative impact on the sensory characteristics of the cookies.

Table 6. Sensory Evaluation of Gluten-Free Cookies

Sample	Color (20)	Taste (20)	Oder (20)	Texture (20)	Appearance (20)	Total score(100)
Control	18.5±0.11[c]	17.9±0.05[c]	18.5±0.01[b]	17.4±0.07[c]	18.3±0.06[c]	90.6±0.16[c]
S1	19.5±0.07[b]	18.5±0.09[b]	19.1±0.09[a]	18.0±0.06[b]	18.9±0.11[c]	94.0±0.02[bc]
S2	19.4±0.03[b]	19.0±0.12[a]	19.0±0.03[a]	18.5±0.13[b]	19.6±0.08[b]	95.5±0.09[b]
S3	20.0±0.05[a]	19.3±0.03[a]	19.1±0.07[a]	19.0±0.05[a]	20.0±0.07[a]	97.4±0.03[a]
S4	18.7±0.11[c]	18.7±0.09[b]	19.0±0.03[a]	18.2±0.13[b]	19.4±0.08[b]	94.0±0.06[bc]

Values in the same column followed by same letter is not significant difference at 0.05 probability.

Additionally, the results of the acceptance test indicated that the panelists displayed a preference for the light orange color observed in samples S1 and S2, which could be attributed to the presence of sweet potato flour. Conversely, the control sample received significantly lower scores for taste, texture, and appearance.

Regarding texture, the panelists favored samples S1 to S3 due to their soft and elastic nature, in contrast to the hard and less elastic texture of the control sample. Thus, it can be concluded that incorporating chickpea flour into cookies up to a level of 20% does not have an adverse effect on their sensory qualities.

4. CONCLUSION

The study involved the preparation of cookies using different proportions of sorghum flour, chickpea flour, and sweet potato flour. The cookies obtained from this experiment demonstrated elevated levels of crude protein, crude fiber, and fat, resulting in a high caloric content. Moreover, these cookies exhibited a notable abundance of carotene and essential minerals, such as calcium, iron, and zinc.

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Furthermore, when compared to cookies made exclusively with sorghum flour, the sensory characteristics of the cookies prepared in this study were superior. These cookies are a suitable choice for individuals with celiac disease, as they are gluten-free and cater to their specific dietary requirements.

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