



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

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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

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. The purpose of this study was to prepare gluten-free cookies using sorghum flour, sweet potato powder, and chickpea powder, while also assessing their physicochemical and sensory qualities.

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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, S3-70% sorghum flour + 10% sweet potato and 20% chickpea powder, S4-60% 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 powder 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 powder 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 up to 20% chickpea and 10% sweet potato powder was the most acceptable for the sensory characteristics of the gluten-free cookies.

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 [1]. The food industry has faced significant challenges in developing gluten-free products to cater to the needs of individuals with celiac disease [2].

Sorghum (*Sorghum bicolor* L. Moench) is recognized as the fifth most important cereal crop globally [3]. This remarkable grain offers a diverse nutritional profile, encompassing carbohydrates, protein, polyunsaturated fatty acids (PUFA), fibers, resistant starch, and essential minerals such as potassium, phosphorus, magnesium, and zinc. These components contribute to the bioactive properties of sorghum [4]. Notably, sorghum is an exceptional choice for individuals with celiac disease, as it lacks gluten proteins and imparts a delightful flavor to gluten-free baking [5].

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 [6]. Chickpea proteins are regarded as a suitable source of dietary protein due to their excellent balance of essential amino acids [7].

Sweet potato (*Ipomoea batatas* L.) is a highly nutritious food enjoyed by people all over the world. While it may be low in fat and protein, it is abundant in carbohydrates. Additionally, it boasts an impressive array of vitamins, including vitamin C and vitamin A in the case of orange-fleshed sweet potatoes. This versatile root vegetable is a valuable source of energy, fiber, vitamin B5 (pantothenic acid), vitamin B6 (pyridoxine), and potassium. Moreover, colored-fleshed sweet potatoes contain bioactive compounds that contribute to maintaining the health of consumers [8].

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 life at ambient temperatures, and affordable prices. They are easy to handle during production and distribution [1].

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

2. MATERIALS 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, Egypt. 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

2.2.1 Preparation of raw materials

2.2.1.1 Preparation method for sweet potato powder

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 60°C 24 hours in a drying oven. The dried slices were ground and then sieved through a 60-mesh screen (250 mm). The powder samples were packed in polyethylene bags and stored at ambient temperature prior use according to methods described by Ukwuru and Adama [9].

2.2.1.2 Preparation method for sweet chickpea powder

Sweet chickpeas were ground using a grinder, to obtain a fine powder that passed through a 60-mesh sieve (250 mm). All powders obtained were kept in an airtight polyethylene bag as described by Saker and Hussien [10].

2.2.1.3 Preparation method for sorghum flour

Sorghum samples were carefully cleaned from impurities, and then washed with tap water. Sorghum grains were soaked in tap water for 12h 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 (250 mm).

All powders obtained were kept in an airtight polyethylene bag as described by Ibrahim [11].

2.2.2 Cookie preparation

Cookies were prepared according to Singh et al. [12] 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.

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 [13]. 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 digester (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 [14]. Three replicates were measured for each sample.

2.2.4 Determination of Total-carotenoids

Total carotenoids were determined in raw materials and cookies using the method outlined by Santra et al. [15]. 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 rotronic Hygro Lab EA10-SCS Switzerland) aw meter. The measurements were performed in triplicate.

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				

2.2.6 Physical characteristics of cookies

Cookies were evaluated for weight (g), thickness (mm), diameter (mm), density (g/cm³) and spread ratio as described by Gaines [16]. 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 [17] 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

Cookies were organoleptically evaluated for their sensory characteristics. Biscuit samples were served on white, odorless and disposable plates, and water was provided for rinsing between samples for ten panelists. Samples were scored for color, flavor, crispiness, texture and overall acceptability according to the method of Larmond [18].

2.2.9 Statistical analysis

The data from this study were statistically analyzed for means and standard deviations using Costat statistical software [19]. 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 flour and the obtained results are presented in Table 2.

The analysis results indicate that chickpea flour has the highest protein content of 25.00 g/100 g followed by sorghum flour 9.09 g/100 g and the

lowest was sweet potato powder with a content of 3.77 g/100 g. The same is true for fat content were chickpea powder has a content of 6.75 g/100 g followed by sorghum flour 2 g/100 g and finally sweet potato powder with a content of 0.79 g/100 g. As for crude fiber, the values are in close range between 2.37 and 2.75 g/100 g. While ash content was the highest in sweet potato flour 4.03 g/100 g; followed by chickpea powder 3.10 g/100 g and finally sorghum flour 1.30 g/100 g. Notably, sweet potato powder displayed a significantly higher carotene content of 32.61 mg/kg compared to chickpea powder and sorghum flour. These findings align with the research conducted by Sakr and Hussien [10]; Ibrahim [11] and Omran and Hussien [20].

Water holding capacity (WHC) was presented in Table 2. Notably, sweet potato flour exhibited the highest WHC at 240.15%, followed by sorghum flour at 160 g/100 g, and finally chickpea powder at 132.95 g/100 g. These results are consistent with the findings reported by Saker and Hussien [10], who observed a water holding capacity of 131.60 g/100 g for chickpea powder, and Omran and Hussien [20], who reported a water holding capacity of 243.13 g/100 g for sweet potato powder. Uthumporn et al. [21] 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.

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 powder led to a significant 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. [22].

The moisture content of the cookies exhibited a slight decrease with the increase in concentration of chickpea powder. This can be attributed to the lower water-binding capacity of chickpea flour compared with sweet potato powder, resulting in lower moisture retention in the final products. As the level of chickpea powder 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 powder. These findings align with the research conducted by Soni et al. [23].

The incorporation of 10% sweet potato powder resulted in an increase in total carotenoids to

20.32mg/kg compared with 13mg/kg for control. These findings are consistent with the results obtained by Samuel et al. [24]. While the inclusion of chickpea powder 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.

Table 2. Physico-chemical properties of raw materials

Sample	Sweet Potato Powder	Chickpea Powder	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

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

S1- 90% sorghum flour and 10% sweet potato, S2-80% sorghum flour + 10% sweet potato and 10% chickpea powder, S3-70% sorghum flour + 10% sweet potato and 20% chickpea powder, S4-60% sorghum flour + 10% sweet potato and 30% chickpea powder. 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

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±0.05 ^{b^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

S1- 90% sorghum flour and 10% sweet potato, S2-80% sorghum flour + 10% sweet potato and 10% chickpea powder, S3-70% sorghum flour + 10% sweet potato and 20% chickpea powder, S4-60% sorghum flour + 10% sweet potato and 30% chickpea powder. 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

Table 5. 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

S1- 90% sorghum flour and 10% sweet potato, S2-80% sorghum flour + 10% sweet potato and 10% chickpea powder, S3-70% sorghum flour + 10% sweet potato and 20% chickpea powder, S4-60% sorghum flour + 10% sweet potato and 30% chickpea powder. 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

Data in Table 4 show an increase in all minerals analyzed, except phosphorous and sodium, as a result of substituting sorghum with sweet potato powder. This may be due to the high mineral content in sweet potato powder. 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 [25].

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 powder, for several physical characteristics.

Cookies prepared with a combination of sorghum and 10% sweet potato powder 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 with 10% sweet potato powder. The results agree with work by Omeran and Hussien [20]. They explained that the cookies spread is strongly correlated to the water absorption capacities 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 of sweet potato powder is presumed to be higher than sorghum flour. Hence, one can deduce that the inclusion of sweet potato powder restricts the spread of cookies.

Furthermore, the addition of different levels of chickpea powder 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. The control cookies exhibited the maximum diameter and thickness of 6.14 and 0.95cm, while the cookies with the highest chickpea powder content (S4) had the minimum diameter and thickness of 5.47 and 0.83cm. It is evident that the increase in chickpea powder levels resulted in decreased diameter and thickness of the cookies. These results are consistent with the findings of El-Dreny and El-Hadidy [26]. 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 powder 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 [11] showed that the spread ratio 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 powder are summarized in Fig 1. A notable reduction in hardness was observed in S1 sample, with the substitution with sweet potato powder. This decrease in hardness can be attributed to the substitution of sorghum flour with sweet potato powder, which are known to be hydrophilic in nature, and thereby, absorbed excessive moisture and affected the hardness [20].

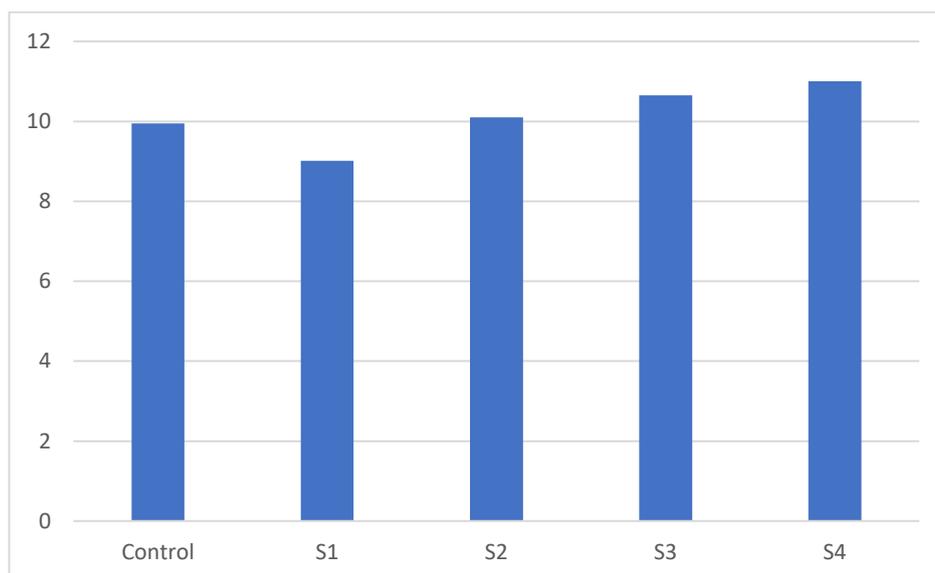


Fig. 1. Hardness (N) of gluten free cookies

(S1- 90% sorghum flour and 10% sweet potato, S2-80% sorghum flour + 10% sweet potato and 10% chickpea powder, S3-70% sorghum flour + 10% sweet potato and 20% chickpea powder, S4-60% sorghum flour + 10% sweet potato and 30% chickpea powder)

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}

S1- 90% sorghum flour and 10% sweet potato, S2-80% sorghum flour + 10% sweet potato and 10% chickpea powder, S3-70% sorghum flour + 10% sweet potato and 20% chickpea powder, S4-60% sorghum flour + 10% sweet potato and 30% chickpea powder. Values are means of ten replicates ±SD, numbers in the same column followed by the same letter are not significantly different at 0.05 level

Furthermore, with substitution with chickpeas hardness increased. These results are consistent with the work conducted by Elzoghby et al. [22]. This increase could be attributed to high protein

content of chickpeas. Ibrahim [11] stated that hardness of biscuits increases with increase in protein content of biscuits [27-30].

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 powder 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 powders above 20% had a negative impact on the sensory characteristics of the cookies [30-33].

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 powder. 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 powder into cookies up to

a level of 20% does not have an adverse effect on their sensory qualities.

4. CONCLUSION

This study concluded that it is possible to produce gluten-free cookies using varying combinations of sorghum flour, chickpea, and sweet potato powders. The resulting cookies displayed enhanced levels of crude protein, crude fiber, and fat compared to traditional cookies. Additionally, these cookies were rich in carotene and essential minerals like calcium, iron, and zinc.

Importantly, the sensory qualities of these cookies surpassed those made solely with sorghum flour. This suggests that the inclusion of chickpea and sweet potato flour not only enhances nutritional value but also improves taste and texture.

These cookies represent a promising option for individuals with celiac disease, as they are gluten-free and offer a valuable source of essential nutrients.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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