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Production of Gluten-Free Biscuits for Celiac Patients Using Yellow Corn Flour, Sweet Lupine and Sweet Potato Powders

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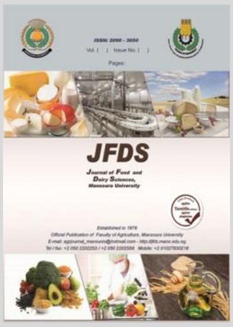

ABSTRACT

Gluten-free corn biscuits were prepared from yellow corn flour and partially replaced by various levels (10, 20 and 30%) of sweet lupine and sweet potato powders. The proximate composition, minerals content, physical and sensory attributes of the prepared gluten-free biscuits was evaluated. The obtained data observed that, the water absorption and dough stability of yellow corn flour was gradually increased as the percentage of replacement with sweet lupine and sweet potato powders increased. On contrast, dough weakening was gradually decreased as the substitution level increased. Also, the blends of sweet potato and yellow corn flour had the most significant set-back values. On contrast, sweet lupine powder had the lower set-back values. The replacement of yellow corn flour with sweet lupine powder caused gradually increase in both of biscuits moisture, ash, protein, lipids, crude fibers and minerals levels as the level of replacement increased. Meanwhile, total carbohydrates content was gradually decreased as the level of replacement increased. Gradual increase in both of biscuits weight and spread ratio and gradual decrease in biscuits specific volume were observed by raising the proportion of replacement with sweet lupine and sweet potato powders in compare to control sample. Sensory results showed the levels of substitution with 20% sweet lupine and 10% sweet potato powders were the most preferable. Due to the lack of gluten, these studied biscuits can be suitable for celiac disease patients.

Keywords: Gluten-free biscuits - Yellow corn flour - Sweet lupine powder - Sweet potato powder.

INTRODUCTION

Gluten is the major protein in wheat flour which structure-forming and the absence of gluten results in problems during preparation the dough since gluten is accountable for the protein-starch interaction giving viscoelastic qualities in dough (Yildirim *et al.*, 2018).

Celiac disorder is an enduring small intestine disease which results from gluten intake in people who are genetically susceptible to it. It is distinguished by an extreme immunological reaction against specific amino acid sequences that exist in wheat, barley and rye prolamin fractions. Once celiac patients consume or eat products involving gluten their immune system reacts by damaging intestinal villi resulting in failure of nutrients absorption and negatively impacting all corporal systems completely (Cardo *et al.*, 2021).

Although adhering to a gluten-free diet may appear easy, it is not. It not only entails avoiding gluten-containing cereals as well as goods that include them, which necessitates continual monitoring, but there additionally a feeling of isolation from society and stress that comes with the system (Itzlinger *et al.*, 2018). "Gluten free" is an optional concept that refers to food involving less than twenty ppm of gluten (Demirkesen and Ozkaya, 2022).

Maize (*Zea mays*) is a good-energy sustenance with greatly digestible carbohydrate, fairly good quality protein for one's health and an adequate amount of elements. Also, maize is abundant in vitamins-B and the yellow grain is useful supplier for the beta-carotene that is known to restrict blindness (Samtiya *et al.*, 2020 and Mandha *et al.*, 2021).

Maize flour is a common component in both home kitchen and several manufactured goods. Maize additionally is mainly used to produce starch, syrup, oil and cornflakes (Qamar *et al.*, 2017).

Among legume seeds, lupine (*Lupineus albus*) is one of the greatest and most plentiful supports of protein and fibers as well as many nutritional compounds such as vitamin E, phytosterols, polyphenols and Antioxidants (Plustea *et al.*, 2022).

Lupine components like lupine powder or protein concentrates, are utilized as additives or functional ingredients (Vollmannova *et al.*, 2021). Lupine powder used as a base in gluten-free bakery products due to its unique physical and chemical properties compared with rice and corn flour (Mohammed *et al.*, 2018).

Sweet potato (*Ipomoea batatas* L.) is one of the world's major commodities. It is recognized as an origin of β-carotene in addition to antioxidants, carbohydrates, minerals, fibers and vitamins (C, E, B1, B2 and B3) (Van Toan and Anh, 2018). Sweet potato, one of the favored tubers because of its significant content of dry matter for human intake where the main component is starch that can be applied as a major raw material in some dietary purposes (Jemziya and Mehendran, 2017). Sweet potato powder is often applied to bettering sensory attributes of food products. Besides, it is characterized by large amounts of carbohydrates, dietary fibers and elements (Dereje *et al.*, 2020).

The purpose of this research is to produce high quality and high nutritious gluten-free biscuits for celiac patients using

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yellow corn flour partially substituted with different levels from sweet lupine and sweet potato powders.

MATERIALS AND METHODS

Materials:

Yellow corn flour (*Zea mays*), Margarine, Baking powder and Vanilin: were obtained from Fathalla market, EL-Mansoura city, EL-Dakahlia Governorate, Egypt.

Sweet potato tubers (*Ipomoea batatas* L.), whole eggs and sugar: were obtained from local market, EL-Mansoura city, EL-Dakahlia Governorate, Egypt.

Sweet Lupine powder (*Lupineus albus*) was obtained from local market, Cairo, Egypt.

All chemicals used in this study for analysis were of analytical grade and obtained from El Gomhouria Pharmacentical Company, EL-Mansoura city, EL-Dakahlia Governorate, Egypt.

Methods:

Preparation of sweet potato powder:

Sweet potato powder was prepared according to the method described by (Julianti *et al.*, 2017) as follows: Sweet potato tubers were washed, peeled and cut into thin slices, spread in a tray, dried at 50-60°C for 10 hours in an air-dryer oven (model of Garbuio, made in Italy) at department of food Industries, faculty of agriculture, Mansoura university and was milled into powder. The sweet potato powder was screened through an 80 mesh sieve and then collected in polyethylene bags and stored at room temperature (25±2˚C) until further use.

Analytical methods:

Proximate chemical analysis of raw materials and studied biscuits samples:

Moisture, ash, lipids, crude fibers and nitrogen contents were determined according to the method described in A.O.A.C. (2019) at Central laboratory, faculty of Agriculture, Mansoura University, Dakahlia, Egypt.

The protein content was calculated by multiplying total nitrogen percentage by 6.25. Lipids were extracted in Soxhlet apparatus using N-hexane as a solvent.

Total carbohydrates were calculated by difference according to the following equation:

Total carbohydrates = 100 – (% protein + % lipids + % crude fibers + % ash).

Determination of minerals contents of raw materials and studied biscuits samples:

The samples were wet acid-digested, using a nitric acid and perchloric acid mixture (HNO_3: $HClO_4$, 5:1 w/v) according to the method described by Chapman and Pratt, (1979). Then the total amounts of Potassium, Sodium, Calcium, Magnesium, Iron, Zinc and Manganese in the digested samples were determined by atomic absorption spectrophotometry (model of varian spector AA.20, Australia). Whereas phosphorus was determined by spectrophotometer according to the method of Astm, (1975). Minerals content was determined at Delta fertilizers and chemical industries company, Talkha city, Dakahlia Governorate, Egypt.

Determination of dietary fibers of raw materials and studied biscuits samples:

Total dietary fibers were determined according to the method described by A.O.A.C. (2019). Soluble and insoluble dietary fibers were determined according to method described by Prosky *et al.,* (1988). Dietary fibers were determined at Food Technology Research Institute Laboratories, EL-Dokky, Giza, Egypt.

Determination of total beta carotene content of raw materials and studied biscuits samples:

β-carotene content was determined according to the method described in (A.A.C.C. 2010) at Food Technology Research Institute Laboratories, EL-Dokky, Giza, Egypt.

Preparation of yellow corn flour blends:

Different flour samples were prepared by, partially substituting of yellow corn flour by different ratios of sweet lupine and sweet potato powder's, to prepare different flour samples which used in preparation of experimental samples of gluten-free biscuits as presented in the following Table (A).

Table A. Blends of yellow corn flour substituted with sweet lupine and sweet potato powders:

No. of blends	Yellow corn flour	Sweet potato powder	Sweet Lupine powder
Control	100	-	-
Blend (1)	90	10	-
Blend (2)	80	20	-
Blend (3)	70	30	-
Blend (4)	90	-	10
Blend (5)	80	-	20
Blend (6)	70	-	30

Preparation of gluten-free biscuits:

Gluten-free biscuits were formulated and baked according to the methods of Fenster, (2004) and Adeyemo *et al.,* (2022). The gluten-free biscuits dough formula consisted of yellow corn flour or composite flour is given in Table (B) (Gambuś *et al.*, 2009).

Table B. Ingredients used in making of gluten-free biscuits (control sample)

Ingredients	Weight (g)
Yellow corn flour	100
Sucrose	46.15
Margarine	57.69
Fresh Egg	17.30
Salt (sodium chloride)	0.38
Baking powder	5
Vanillin	0.76
Water	As Required

Rheological Properties of studied mixtures dough:

Dough rheological investigations were performed by Mixolab Chemitec International Co., 6th October City, Giza, Egypt according to A.A.C.C. (2010).

Physical properties of gluten-free biscuits samples:

According to Sai-Manohar and Haridas-Rao, (1997) the diameter (D) and thickness (T) of six biscuits were measured in millimeter by placing them edge to edge and by stacking one above the other, respectively. To obtain the average, measurements were made by rearranging and restacking.

Spread factor of biscuits (SF) = diameter (mm)/ thickness (mm)

The weight of six biscuits was determined after cooling. The volume was measured by rape seed displaced by six biscuits.

Specific volume of biscuits = volume (cm^3) / weight (g).

Sensory evaluation of gluten-free biscuits samples:

The gluten-free biscuits samples and control sample were evaluated using a 15 member untrained panel selected from students and faculty members of the department of food Industries, faculty of Agriculture, Mansoura university. The biscuits samples were organoleptically evaluated after baking within one hour for appearance (10), color (15), taste (15), odor (15), thickness (15), crispiness (15), shrinkage (15) and overall acceptability (100) according to the method described by Smith, (1972).

Statistical analysis:

Data were analyzed by method as described by Sendecor and Cochran, (1997). Means were separated using Duncan's test at a degree of significance (P≤ 0.05). Statistical analyses were made using the producer of the SAS software system program (SAS, 1997).

RESULTES AND DISCUSSION

Chemical composition of yellow corn flour, sweet lupine and sweet potato powders:

From data presented in Table (1), yellow corn flour contained 11.92, 9.18, 1.96, 1.43, 1.87 and 85.56 % for moisture, crude protein, total lipids, ash, crude fibers and total carbohydrates, respectively. Our data were in accordance with Sharoba *et al.* (2014), they found that, yellow corn flour contained 7.91% protein, 2.0% fat, 1.50% ash, 1.20% crude fibers and 88.59% total carbohydrates.

At the same time, sweet lupine powder in the same table contained 8.71, 36.85, 9.35, 3.69, 6.42 and 43.69 % for moisture, crude protein, total lipids, ash, crude fibers and total carbohydrates respectively. Similar results were represented in previous study conducted by Monteiro *et al.* (2014) that sweet lupine powder gave 7.45% moisture, 36.30% protein, 8.37% fat, 2.84 ash and 35.93% total carbohydrates.

Concerning to the chemical composition of sweet potato powder, the obtained data indicates that sweet potato powder contained 5.86, 2.46, 0.90, 2.94, 3.26 and 90.44% for moisture, crude protein, total lipids, ash, crude fibers and total carbohydrates, respectively. These results approximately agree with Omran and Hussien (2015), they demonstrated that, sweet potato powder recorded 6.15% moisture, 3.77% protein, 0.79% fat, 4.03% ash and 91.41% carbohydrates.

Table 1. Proximate chemical composition of yellow corn flour, sweet lupine and sweet potato powders (g/100g on dry weight basis)

Chemical composition (%) Raw materials	Moisture	on dry weight basis				
		Crude protein	Total Lipids	Ash	Crude fibers	* Total carbohydrates
Yellow corn flour	11.92	9.18	1.96	1.43	1.87	85.56
Sweet lupine powder	8.71	36.85	9.35	3.69	6.42	43.69
Sweet potato powder	5.86	2.46	0.90	2.94	3.26	90.44

*** Calculated by difference.**

Minerals content of yellow corn flour, sweet lupine and sweet potato powders (mg/100g on dry weight basis):

The values of minerals in Table (2) exhibited that phosphorus was the highest major minerals in sweet lupine powder was 412.37 mg/100g, followed by calcium, potassium, magnesium and sodium were 195.38, 164.70, 122.65 and 85.88 mg/100g, respectively. Concerning to the values of trace minerals being 5.00, 4.32 and 2.03 mg/100g for manganese, iron and zinc, respectively. These results approximately agree with Mohammed (2017) who mentioned that, the content of elements in sweet lupine powder were (100.33 mg/100g) Mg, (5.43 mg/100g) Fe and (4.95 mg/100g) Zn. Also, the concentration of phosphorus was higher in yellow corn flour (208.50 mg/100g), followed by calcium, potassium, magnesium and sodium being 127.92, 118.65, 113.94 and 63.14 mg/100g, respectively. Trace minerals were 3.75, 1.18 and 0.89 mg/100g for manganese, iron and zinc, respectively. Our results were consistent with Tamimy (2018) who studied the minerals contents of yellow corn flour and he found that, yellow corn flour contained 122.37, 210.61, 2.18, and 0.97 mg/100g of magnesium, phosphorus, iron and zinc, respectively.

On the other hand, potassium was the highest major minerals in sweet potato powder (582.39 mg/100g), the rest of elements were 198.22, 142.96, 132.70, 123.58, 2.87, 2.15 and 0.46 mg/100g for phosphorus, sodium, calcium, magnesium, manganese, iron and zinc in sweet potato powder. Our data were in accordance with Cui and Zhu (2019), they mentioned that sweet potato powder contained 99, 89, 198, 111, 4.4, 1.1 and 2.7 mg/100g for Mg, Ca, P, Na, Mn, Zn and Fe, respectively.

Table 2. Minerals content of yellow corn flour, sweet lupine and sweet potato powders (mg/100g on dry weight basis)

Samples	Minerals (mg/100g)							
	Potassium (K)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Manganese (Mn)	Phosphorous (P)	Iron (Fe)	Zinc (Zn)
Yellow corn flour	118.65	127.92	113.94	63.14	3.75	208.50	1.18	0.89
Sweet lupine powder	164.70	195.38	122.65	85.88	5.00	412.37	4.32	2.03
Sweet potato powder	582.39	132.70	123.58	142.96	2.87	198.22	2.15	0.46

Total, soluble and insoluble dietary fibers of yellow corn flour, sweet lupine and sweet potato powders (g/100g on dry basis):

Data in Table (3) designate that, sweet lupine powder recorded highest dietary fibers content (35.46 and 30.55 g/100g dry weigh basis) for total and insoluble dietary fibers followed by, sweet potato powder (24.63 and 17.29 g/100g) and yellow corn flour (14.78 and 12.36 g/100g), respectively.

While, the highest soluble dietary fibers content was found in sweet potato powder (7.34 g/100g dry weigh basis) followed by sweet lupine powder (4.91 g/100g) and yellow corn flour (2.42 g/100g), respectively. The findings presented were in agreement with Tamimy, (2018) who found that, yellow corn flour contained 10.77% total dietary fibers, 8.64 insoluble dietary fibers and 2.13% (g/100 g) soluble dietary fibers. In addition, Ahmed, (2012) found that, sweet lupine powder contained 41.8 total dietary fibers and 30.55 (g/100g) insoluble dietary fibers.

Also Vitali *et al.,* (2010) reported that total dietary fibers in sweet potato powder range from 19.8 to 21.9 g/100 g, insoluble dietary fibers range from 10.31 to 14.45 g/100 g and soluble dietary fibers range from 8.56 to 9.50 g/100 g.

Table 3. Total, soluble and insoluble dietary fibers of yellow corn flour, sweet lupine and sweet potato powders (g/100g on dry basis)

Samples	Dietary fibers (g/100g on dry basis)		
	Total dietary fibers (TDF)	Soluble dietary fibers (SDF)	Insoluble dietary fibers (IDF)
Yellow corn flour	14.78	2.42	12.36
Sweet lupine powder	35.46	4.91	30.55
Sweet potato powder	24.63	7.34	17.29

Total beta-carotene content of yellow corn flour, sweet lupine and sweet potato powders (g/100g on dry basis):

Depending on the measured results in Table (4) sweet potato powder recorded highest beta-carotene content being 428.34 µg/100g followed by, sweet lupine powder 280.25 and yellow corn flour 227.96 (µg/100g dry weigh basis). Our observed outcomes were in accordance with those of Olapade and Ogunade (2014), they found that sweet potato powder contain 370 µg ß-carotene/100 g.

Table 4. Total beta-carotene content of yellow corn flour, sweet lupine and sweet potato powder (µg/100g on dry basis)

Samples	β-carotene (µg/100g dry basis)
Yellow corn flour	227.96
Sweet lupine powder	280.25
Sweet potato powder	428.34

Mixolab parameters of yellow corn flour dough with different levels of sweet lupine and sweet potato powders:

Regarding the data given in Table (5), it has been reported that the water absorption of yellow corn flour dough was gradually raised when the replacement ratio with sweet lupine and sweet potato powders raised, which reached to 59.8, 62.5 and 65.6% for blend (1), (2) and (3), respectively and 58.7, 60.4 and 62.3% for blend (4), (5) and (6), respectively in compare to 57.2% for yellow corn dough. The highest water absorption in blended samples with sweet lupine or sweet potato powder possibly owing to the higher starch, fibers and/or protein quantities of this sources than yellow corn flour.

Those data approximately agree with Adegunwa *et al.* (2017) who found that the high water absorption of plantain powder might be linked to flour's high starch and fibers content, Patil and Arya (2017) mentioned that, increasing protein, starch and fibers content rises water absorption and Al-Othman *et al.* (2022) indicated that the high water absorption ability of the corn flour combination after adding lupine powder could be tied to the high fibers and protein content in lupine powder that rivals the other dough components on water.

Also, dough development time (min) in blends that contain sweet lupine and sweet potato powders slightly increased to 2.57, 3.46 and 4.83 min for blend (1), (2) and (3), respectively and 2.35, 3.62 and 4.27 min for blend (4), (5) and (6), respectively. Nevertheless, dough growth time in control yellow corn dough arrived 1.28 min.

In the context of dough development, the dough development heightened across the blends from 1.065 (Nm) for control (100% yellow corn flour) to 1.143 and 1.148 (Nm) for blend (3) and (6), respectively. This information would be connected to an increase in rates of sweet lupine and sweet potato powders that take longer time for full hydration of flours and have been connected to the protein and starch properties and composition.

Such outcomes were related positively with the ones mentioned by Rodriguez-Sandoval *et al.* (2012), who found that quinoa flour raises the time taken for thorough hydration of dough that is possibly dependent on the starch composition and qualities, Sharma and Gujral (2019) stated that the low dough development time of millet flour compared to wheat flour could be associated to water absorption and protein features and Al-Othman *et al.* (2022) found that the dough development time increases since the content of lupine powder gets higher in the corn flour combination, which may be linked to the high protein content.

On the basis of the values presented in Table (5), dough stability (min) was gradually rising concomitant to rising in replacement rate of sweet lupine and sweet potato powders being 5.16, 7.04 and 8.98 min for blend (1), (2) and (3), respectively and 5.72, 8.30 and 9.83 min for blend (4), (5) and (6), respectively, as compared to 3.45 min for control (100% yellow corn flour). Those investigations may be correlated with starch structure and quality of the protein–starch network, as reported by Zi *et al.* (2019), they demonstrated that starch composition in six cultivars of wheat influences dough stability through altering water distribution in dough.

Concerning the value of dough breakdown, it was found that the dough weakening degree lowered with the replacement rate of sweet lupine and sweet potato powders increased from 0.914 (Nm) for control (100% yellow corn flour) to 0.492 and 0.348 (Nm) for blend (3) and (6), respectively, which may be due to the protein quality. Analogical results were represented in previous study conducted by Rodriguez-Sandoval *et al.* (2012) that simultaneous mechanical shear stress and temperature resulted in a minimum torque which has been associated to protein weakening. Besides, Matos and Rosell (2013) stated that the low values of dough weakening in gluten free dough might be attributed to the protein thermal properties.

Results in Table (5) indicate that starch behavior in the blends of sweet potato powder and yellow corn flour was distinguished by the highest gelling capacity that it was demonstrated by the starch gelatinization degree. In contrast, sweet lupine powder in tested dough samples caused a gradual decrease in starch gelatinization values. This suggests that the findings relate to a larger amount of starch and lower lipids and protein content in sweet potato and yellow corn blends. Similar results were obtained by Mir *et al.* (2017) who explained that the slightest protein and lipid content in one of corn starch cultivars is closely linked to increased peak viscosity. Also, partial replacement of starch by rapeseed protein isolate with values between 6 and 15% reduced the viscosity of gluten free dough's in pasting (Witczak *et al.*, 2021). Further, Çinar *et al.*, (20٢٣) observed that the partial replacement of rice flour with 10, 20, 30, 40, and 50% of tiger nut powder gradually decreased the viscosity values of gluten-free dough with increasing the level of substitution as the high content of fibers and lipids in tiger nut powder.

Table 5. Mixolab parameters of yellow corn flour dough with different levels of sweet lupine and sweet potato powders

Samples	Mixolab parameters									
	Mixing properties						Pasting ability behavior			
	Water absorption (%)	Development time (min)	Dough Stability (min)	Dough development (Nm)	Protein breakdown (Nm)	Protein weakening (Nm)	Starch gelatinization (Nm)	Amylase activity (Nm)	Starch gelling Or Final torque (Nm)	Set back torque (Nm)
*Control sample	57.2	1.28	3.45	1.065	0.151	0.914	2.127	1.842	1.699	0.428
Blend (1)	59.8	2.57	5.16	1.107	0.284	0.823	1.945	1.736	1.605	0.340
Blend (2)	62.5	3.46	7.04	1.125	0.460	0.665	1.706	1.687	1.388	0.318
Blend (3)	65.6	4.83	8.98	1.143	0.651	0.492	1.284	1.545	1.033	0.251
Blend (4)	58.7	2.35	5.72	1.116	0.336	0.780	2.463	1.938	1.914	0.549
Blend (5)	60.4	3.62	8.30	1.135	0.566	0.569	2.752	2.112	2.085	0.667
Blend (6)	62.3	4.27	9.83	1.148	0.800	0.348	2.914	2.327	2.179	0.735

*** 100 % yellow corn flour, Blend (1): substitution of 10%sweet lupine powder, Blend (2): substitution of 20%sweet lupine powder, Blend (3): substitution of 30%sweet lupine powder, Blend (4): substitution of 10% sweet potato powder, Blend (5): substitution of 20%sweet potato powder, Blend (6): substitution of 30%sweet potato powder.**

Regarding starch gelling and amylase activity, as shown in Table (5), amylase activity and starch gelling were decreased as the partial alternative of yellow corn flour with sweet lupine powder increased from 10 to 30% substitution, whereas it was 1.545 (Nm) for blend (3) for amylase activity and progressively decreased from 1.699 for yellow corn flour (control sample) to 1.033 (Nm) for starch gelling for blend (3). It has been reported that quinoa starch granules are not easily hydrolyzed by α-amylase because they are surrounded by a protein matrix (Repo-Carrasco-Valencia and Serna, 2011).

In terms of set-back viscosity that represented the rate of starch retrogradation, blend (4), (5) and (6) had the highest set-back values. On contrast, blend (1), (2) and (3) had the lower set-back values in Table (5). This may be related to composition of starch and presence of non-starch components, as reported by Srichuwong *et al.* (2017) they referred to the least starch retrogradation degree in quinoa and amaranth was due to the high amount of soluble dietary fibers and the short amylopectin branch chain. Similarly, Vamadevan and Bertoft (2018) mentioned that the starch retrogradation degree increase with higher amylose content or with long amylopectin branch chain.

Effect of composite flour on gluten-free biscuits characteristics:

Proximate chemical composition of produced gluten free biscuits samples:

The results presented in Table (6) demonstrate that the control sample containing 1.97% moisture, 9.97% crude protein, 25.53% lipids, 1.93% ash, 2.63% crude fibers and 59.94% total carbohydrates.

Table 6. Proximate chemical composition of produced gluten free biscuits samples (on dry weight basis)

Chemical Composition (%)	on dry weight basis					
Gluten free biscuits samples	Moisture	Crude protein	Total Lipids	Ash	Crude fibers	** Total carbohydrates
*Control sample	1.97	9.97	25.53	1.93	2.63	59.94
Blend (1)	2.64	12.74	26.27	2.16	3.08	55.75
Blend (2)	3.25	15.52	27.01	2.39	3.72	51.36
Blend (3)	3.98	18.26	27.75	2.62	4.36	47.01
Blend (4)	2.42	9.30	25.42	2.08	2.77	60.43
Blend (5)	2.95	8.63	25.31	2.23	3.12	60.71
Blend (6)	3.46	7.96	25.20	2.38	3.45	61.01

*** 100 % yellow corn flour, Blend (1): substitution of 10%sweet lupine powder, Blend (2): substitution of 20%sweet lupine powder, Blend (3): substitution of 30%sweet lupine powder, Blend (4): substitution of 10% sweet potato powder, Blend (5): substitution of 20%sweet potato powder, Blend (6): substitution of 30%sweet potato powder.**
**** Calculated by difference.**

The replacement partially of yellow corn flour with sweet lupine powder caused gradually increase in both of gluten free biscuits moisture, lipids, ash, crude protein and crude fibers contents by increasing the level of replacement (blend 1, 2 and 3), the increment in protein, lipids, ash and crude fibers of prepared gluten-free biscuits is presumably owing to the relatively rather large protein, lipids, ash and crude fibers content of sweet lupine powder. Meanwhile, Total carbohydrates content was gradually lowered by growing the rate of substitution. That is probably because of the lower content of this component in sweet lupine powder (43.69%), as shown in Table (1). These results approximately agree with El-Maasoud and Ghaly (2018) who discovered that substitution of wheat flour with 4, 8 and 12% of lupine powder caused gradual increase in moisture, crude protein, lipids, ash and crude fibers of biscuits whilst carbohydrates was gradually decreased when the quantity of substitution get higher.

Otherwise, substitution in amounts of yellow corn flour with sweet potato powder led a progressive rise in both of gluten free biscuits moisture, ash, crude fibers and carbohydrates contents when the substitution level increased (blend 4, 5 and 6), the increment in ash, crude fibers and carbohydrates of prepared gluten free biscuits probably caused by the relatively high carbohydrates, ash and crude fibers content of sweet potato powder. Meanwhile, crude protein and lipids contents were gradually decreased since percentage of replacement grew. This is may be a result of the reduced content of this component in sweet potato powder (2.46% and 0.90%, respectively) as shown in Table (1). These results were related positively to Srivastava *et al.*, (2012) who noticed the partial replacement of wheat flour with 10, 20, 30, 40 and 50% of sweet potato powder caused gradual increase in moisture, ash, crude fibers and carbohydrates of biscuits while crude protein and fat contents were gradually lowered as the substitution proportion grew.

Minerals content of produced gluten free biscuits samples (mg/100g on dry weight basis)

Based on the results given in Table (٧), the control gluten free biscuits contained 219.50 sodium, 132.40 potassium, 235.07 calcium, 127.36 magnesium, 12.68 manganese, 221.74 phosphorous, 1.56 iron and 0.98 zinc (mg/100g dry weight basis). The substitution partially of yellow corn flour with sweet lupine powder caused gradual increases in all investigated minerals contents of gluten-free biscuits samples with increasing the amount of replacement (blend 1, 2 and 3), the increment in minerals contents of studied biscuits probably regard to the relatively large amount of minerals in sweet lupine powder compared with yellow corn flour, as appeared in Table (2). Analogical investigations were obtained by Ibrahim *et al.* (2014) who found an increase in all elements content of biscuits after replacing portions of wheat flour with sweet lupine powder (5, 10 and 15%).

In contrast, replacing a portion of yellow corn flour with sweet potato powder caused gradual increases in both of gluten-free biscuits samples potassium, sodium and magnesium contents according to the amount of swapping grew (blend 4, 5 and 6). This seems to be owing to the raised concentration for this ingredient in sweet potato powder, as seen in Table (2). Its findings approximately agree with Adeola and Ohizua, (2018) who confirmed that, increased addition of sweet potato powder with 10, 21.67, 33.33, 45 and 80% resulted in a higher percentage of potassium, sodium and magnesium in biscuits made by a blend of pea, banana and sweet potato powders.

Table 7. Minerals content of produced gluten free biscuits samples (mg/100g on dry weight basis)

Gluten free biscuits samples	Minerals (mg/100g)							
	Potassium (K)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Manganese (Mn)	Phosphorous (P)	Iron (Fe)	Zinc (Zn)
Control sample	132.40	235.07	127.36	219.50	12.68	221.74	1.56	0.98
Blend (1)	137.15	241.82	128.24	221.78	12.80	242.13	1.87	1.09
Blend (2)	141.68	248.56	129.12	224.06	12.92	262.52	2.15	1.21
Blend (3)	146.24	255.34	130.00	226.34	13.04	282.91	2.49	1.32
Blend (4)	178.78	236.13	128.33	227.49	12.59	220.75	1.66	0.94
Blend (5)	225.14	237.26	129.44	235.28	12.50	219.68	1.74	0.90
Blend (6)	271.50	238.47	130.27	243.56	12.41	218.30	1.89	0.85

Total, soluble and insoluble dietary fibers of produced gluten free biscuits samples (g/100g dry basis)

From the obtained results in Table (8), the control gluten free biscuits sample preparing from 100% yellow corn flour contained 8.75% TDF, 1.95% SDF and 6.80% IDF. The partial replacement of yellow corn flour with sweet lupine and sweet potato powders caused gradual increases in both of total, soluble and insoluble dietary fibers contents as the level of sweet lupine and sweet potato powders increased (blend 1, 2 and 3) and (blend 4, 5 and 6).

Table 8. Total, soluble and insoluble dietary fibers of produced gluten free biscuits samples (g/100g dry basis)

Gluten free biscuits samples	Dietary fibers (g/100g dry basis)		
	Total dietary fibers (TDF)	Soluble dietary fibers (SDF)	Insoluble dietary fibers (IDF)
Control sample	8.75	1.95	6.80
Blend (1)	11.42	2.26	9.16
Blend (2)	14.09	2.54	11.55
Blend (3)	16.76	2.82	13.94
Blend (4)	10.34	2.49	7.85
Blend (5)	11.93	3.06	8.87
Blend (6)	13.52	3.67	9.85

The increment in the above mentioned components in prepared gluten free biscuits would be triggered to the high-level of these components in sweet lupine and sweet potato powders in comparison with yellow corn flour (control sample), as shown in Table (3). Saeed *et al.* (2012) reported similar findings regarding of an increase in dietary fibers content of cookies after adding sweet potato powder with various levels (5, 10, 15, 20 and 25%) to wheat flour. Also, Jayasena and Nasar-Abbas (2011) found a big rise in dietary fibers of wheat biscuits which substituted with 10, 20, 30, 40 and 50% of lupine powder.

Total beta-carotene content of gluten-free biscuits samples (µg/100g dry basis)

Findings in Table (9) showed that, beta-carotene content of control gluten-free biscuits sample was 241.38 µg/100g. Also, it could be noticed that, the partial replacement of yellow corn flour with sweet lupine and sweet potato powders caused gradual increases in total beta-carotene content as the level of sweet lupine or sweet potato powder increased (blend 1, 2 and 3) and (blend 4, 5 and 6).

Table 9. Total beta-carotene content of gluten-free biscuits samples (µg/100g dry basis)

Gluten free biscuits samples	β-carotene (µg/100g dry basis)
Control sample	241.38
Blend (1)	246.61
Blend (2)	251.86
Blend (3)	257.52
Blend (4)	261.43
Blend (5)	285.27
Blend (6)	304.68

The increment in total beta-carotene in prepared gluten-free biscuits is possible attributable to the increased content of sweet lupine and sweet potato powders in comparison with yellow corn flour (control sample) as shown in Table (4). Those findings were related positively to the results mentioned by Kindeya *et al.* (2021) who found an increase in beta-carotene content of biscuits after adding sweet potato powder by various percentages (5, 10, 15, 20 and 25%) to wheat flour combination.

Physical measurements of gluten free biscuits prepared by substituted of yellow corn flour by sweet lupine and sweet potato powders

From Table (10) It could be observed that, the control sample of gluten-free biscuits made from 100% yellow corn flour weighed 17.20 g and had a volume of 30.61 cm^3 giving a specific volume of 1.78 cm^3/g. The partial replacement of yellow corn flour with sweet lupine and sweet potato powders led to a progressive rise in gluten-free biscuit weight when the amount of substitution was increased (blend 1, 2 and 3) and (blend 4, 5 and 6). The increasing in gluten-free biscuits weight might be attributed to an elevated protein content as mentioned by Adeyemo *et al.* (2022) who found that the partial replacement of plantain flour with 5, 10 and 15% of shallot flour caused an increase in the biscuits weight by growing the level of replacement and indicated that the increase in weight of the shallot-enriched plantain biscuits could be owing to the significant protein content of shallot flour.

On the other side, the partial replacement of yellow corn flour with sweet lupine and sweet potato powders caused gradual decreases in gluten-free biscuits volume and specific volume after growing quantity of substitution in compare to control sample.

Concerning gluten-free biscuits samples thickness, the obtained findings illustrated that there was gradual decrease in gluten-free biscuits thickness by increasing level of replacement with sweet lupine and sweet potato powder in compare to control sample. In contrast, gradual increases in both of biscuits diameter and spread ratio were observed with increasing the level of replacement with sweet lupine and sweet potato powders in compare to control sample.

Table 10. Physical measurements of gluten free biscuits prepared by substituted of yellow corn flour by sweet lupine and sweet potato powders

Gluten free biscuits samples	Physical measurements					
	Weight (g)	Volume (cm^3)	Specific volume (cm^3/g)	Thickness "T" (cm)	Diameter "D" (cm)	Spread ratio (D/T)
Control sample	17.20	30.61	1.78	0.90	6.55	7.28
Blend (1)	18.75	30.18	1.61	0.87	6.56	7.54
Blend (2)	20.18	29.46	1.46	0.80	7.08	8.85
Blend (3)	21.98	28.62	1.30	0.77	7.43	9.65
Blend (4)	18.19	29.16	1.60	0.83	6.87	8.28
Blend (5)	18.66	27.63	1.48	0.80	7.18	8.98
Blend (6)	20.27	25.79	1.27	0.73	7.52	10.30

Sensory evaluation of gluten-free biscuits samples:

From statistics presented in Table (11) it was revealed that, there were no significant differences ($P\leq 0.05$) in appearance, color, crispiness, taste and odor of produced gluten-free biscuits between all prepared gluten-free biscuits samples.

Concerning the gluten-free biscuits appearance, it was a little decrease in biscuits samples contained sweet lupine (blend 1, 2 and 3) and sweet potato powders (blend 4, 5 and 6) with the substitution quantity growth.

For gluten-free biscuits color, no significant difference ($P\leq 0.05$) was recorded between control sample and other studied biscuits samples which ranged from 12.26 to 13.66. In a related vein, sensory results showed that substitution with sweet potato powder up to 25% did not affect significantly color score in wheat biscuits (Kindeya *et al.* 2021).

Furthermore, shrinkage scores were increased in gluten-free biscuits samples contained blend (2) and (3) which were 13.26 and 13.40, respectively but decreased in gluten-free biscuits samples contained blend (5) and (6) which were 12.46 and 12.33, respectively.

The scores for taste of gluten-free biscuits gradual decreased with increasing the level of substitution in the blends. Otherwise, gluten-free biscuits samples contained blend (4) had the highest taste score (13.46) in compare to control sample and biscuits samples evaluated.

Although the odor score of gluten-free biscuits samples contained blend (5) were not precisely low, it had the lowest score (11.73) among all the biscuits evaluated.

It was found that gluten-free biscuits samples which contained blend (2) and (4) expressed the highest score for overall acceptability.

Table 11. Sensory evaluation of gluten-free biscuits samples

Gluten free biscuits samples	Appearance (10)	Color (15)	Thickness (15)	Crispiness (15)	Shrinkage (15)	Taste (15)	Odor (15)	Overall acceptability (100)
Control sample	9.20^{a}	13.06^{a}	12.60^{a}	12.93^{a}	13.46^{a}	12.46^{ab}	13.00^{abc}	86.73^{ab}
Blend (1)	9.06^{ab}	13.20^{a}	13.13^{a}	12.93^{a}	12.60^{a}	12.86^{ab}	12.86^{abcd}	86.66^{ab}
Blend (2)	9.06^{ab}	13.66^{a}	13.00^{a}	13.20^{a}	13.26^{a}	12.66^{ab}	13.13^{ab}	88.00^{a}
Blend (3)	8.93^{ab}	12.80^{ab}	12.06^{a}	13.13^{a}	13.40^{a}	12.00^{ab}	12.06^{abcd}	84.40^{ab}
Blend (4)	8.86^{ab}	13.46^{a}	13.26^{a}	12.06^{a}	13.33^{a}	13.46^{a}	13.46^{a}	87.93^{a}
Blend (5)	8.60^{ab}	12.80^{ab}	12.60^{a}	11.46^{a}	12.46^{a}	12.06^{ab}	11.73^{abcd}	81.73^{ab}
Blend (6)	8.33^{ab}	12.26^{ab}	12.53^{a}	12.46^{a}	12.33^{a}	12.00^{ab}	12.13^{abcd}	82.06^{ab}

The same letter in each column are not significantly different at $P\leq 0.05$.

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انتاج بسكويت خالي من الجلوتين لمرضى حساسية الجلوتين باستخدام دقيق الذرة الصفراء ومسحوق كلا من الترمس الحلو والبطاطا الحلوة

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الملخص

تم تجهيز بسكويت خالي من الجلوتين باستخدام دقيق الذرة الصفراء (عينة كنترول) وتم تجهيز عينات من البسكويت الخالي من الجلوتين بإجراء استبدال جزئي لدقيق الذرة بمستويات ١٠، ٢٠ و ٣٠٪ من مسحوق كلا من الترمس الحلو والبطاطا الحلوة. تم تقدير كلا من التركيب الكيميائي، المحتوي من العناصر المعدنية، الخصائص الطبيعية والخواص الحسية لعينات البسكويت المنتجة. أوضحت النتائج المتحصل عليها حدوث زيادة تدريجية لكلا من معدل امتصاص الماء وثبات العجين بزيادة نسب الاستبدال لدقيق الذرة الصفراء بمسحوق كلا من الترمس الحلو والبطاطا الحلوة. بينما، لوحظ حدوث انخفاض تدريجي بالنسبة لدرجة ضعف العجين بزيادة مستويات الاستبدال. فيما يتعلق بقيم تراجع النشا لوحظ أن كلا من دقيق الذرة ومسحوق البطاطا الحلوة أعطي أعلي قيم ارتداد بالمقارنة بالعينات التي تحتوي علي مسحوق الترمس الحلو. أدي استبدال دقيق الذرة الصفراء بمستويات ١٠، ٢٠ و ٣٠٪ بمسحوق الترمس الحلو إلي حدوث زيادة تدريجية في محتوي عينات البسكويت المجهزة من الرطوبة، البروتين، الليبيدات، الرماد، الألياف الخام والعناصر المعدنية. بينما لوحظ حدوث انخفاض تدريجي في محتوي الكربوهيدرات الكلية بزيادة مستويات الاستبدال. وقد لوحظ حدوث زيادة تدريجية بالنسبة لوزن البسكويت ومعامل الافتراش وانخفاض تدريجي بالنسبة للحجم النوعي بزيادة نسب الاستبدال بمسحوق كلا من الترمس الحلو والبطاطا الحلوة مقارنة بالعينة الكنترول (١٠٠٪ دقيق ذرة صفراء). أظهرت النتائج الحسية أن مستويات الاستبدال بـ ٢٠% ترمس حلو و ١٠% مسحوق بطاطا حلوة كانت الأكثر تفضيلاً. ونظرًا لغياب الغلوتين، يمكن أن يكون هذا البسكويت الذي تمت دراسته مناسبًا لمرضى حساسية الجلوتين.