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Nutritional Properties of High Protein Pancakes Using Sorghum and Sweet Lupine

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ABSTRACT

Over the past ten years, legume flours have been the focus of ingredient innovation. Legume grains are suitable for a variety of consumer types, including those with celiac disease, due to their high protein and fiber content and lack of gluten. The purpose of the study is to investigate the effects of adding sweet lupine flour at 0.0, 2.5, 5, 7.5, 10, 12.5, 15, and 17.5% as a high protein source on the properties of gluten-free pancakes made with sorghum flour in terms of physicochemical, nutritional, and sensory properties. Mineral content was significantly higher in the gluten-free pancakes by substitution levels with sweet lupine flour compared with control pancakes. The moisture, ash, fat, crude fiber, and protein contents were significantly increased by increasing the level of sweet lupine flour. Substitution levels up to 15% lupine flour have significantly higher overall acceptability scores. The incorporation of sweet lupine flour into the pancakes led to an increase in all amino and chemical scores as compared with the control sample. The findings of the study suggested combining sorghum flour with sweet lupine flour to manufacture highly nutritious, gluten-free baked goods that are suitable for people with celiac disease.

1. Introduction

Sorghum (*Sorghum bicolor L. Moench*) holds the fifth position among major cereal crops worldwide, following wheat, maize, rice, and barley (FAO, 2018). Sorghum grains are high in starch, making up about 70% of their overall mass, with a 3:1 ratio of amylopectin to amylose. Furthermore, sorghum has a high content of phenolic compounds (Palavecino et al., 2016). The nutritional profile of sorghum includes minerals like potassium, phosphorus, magnesium, and zinc, protein, fibers, polyunsaturated fatty acids, resistant starch, and carbohydrates, which all contribute to its bioactivity (Khalid et al., 2022). Sorghum is a good option for those with celiac disease, as it does not contain gluten proteins and gives a delightful flavor to gluten-free baking (Curti et al., 2022). Sorghum flour has been traditionally applied in the preparation of various foods, including flatbreads, pancakes, beer, and porridges, throughout different cultures and countries (Spio-Kwofie 2023).

Legume seeds are an excellent source of proteins, minerals, vitamins, and sugars, making them very beneficial for human nutrition (Bojňanská et al., 2012). Lupine (Lupinus albus L.) has a starch content significantly lower than that of wheat flour, and it is also a significant source of dietary fiber. Particularly, its protein has an amino acid profile that is well balanced. (Wandersleben et al., 2018). Lupine contains a higher proportion of arginine among other amino acids and has a lower level of antinutrients like phytates and saponins compared with wheat grains (Kaczmarek et al., 2014 and Villarino et al., 2015). Cysteine, methionine, valine, tryptophan, lysine, isoleucine, leucine, phenylalanine, and tyrosine are among the essential amino acids found

In lupine grains (Štefániková et al., 2020).

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The mineral composition of lupine is similar to that of other legumes, with variations depending on the variety. Manganese, iron, and zinc are found in higher levels in lupine compared to other legumes (Trugo et al., 2003). Pancakes are thin, round, flat cakes that are usually served for breakfast or as a snack. Egg, butter or oil, milk and flour are mixed to make them. The batter rises and releases carbon dioxide when a leavening ingredient, such as baking soda or powder, is added, giving the dough a light, chewy consistency. (Incoronato et al., 2021).

The objective of this study is to investigate the effects of adding sweet lupine flour at 0.0, 2.5, 5, 7.5, 10, 12.5, 15, and 17.5% levels as a high protein source on the properties of gluten-free pancakes made of sorghum flour in terms of physicochemical, nutritional, and sensory properties.

2. Materials and Methods

Materials

White sorghum grains (*Sorghum bicolor L.*) Dorado variety were obtained from the Field Crops Research Institute, Agricultural Research Centre, Giza, Egypt; sweet lupine grains and other ingredients (sugar, baking powder, fresh whole egg, vanilla essence, raw milk, vegetable oil, and xanthan gum) were obtained from the local market. Chemicals and reagents utilized during this study were analytical grade and purchased from El-Gomhouria Co. for Chemical, Giza, Egypt.

Preparation of Sorghum and Lupine Flour

Sorghum grains were carefully cleaned and washed, then milled into whole grain flour using a laboratory hummer mill fitted with a 500-µm opening screen. lupine flour was produced after being ground in a lab hammer. The flours were stored at 4°C until analysis.

Methods

Chemical Analyses

According to (AOAC 2019), the following parameters were measured: moisture, crude protein, crude fiber, crude fat, and ash content. Protein (N x 6.25) (Kjeldahl method, AOAC method 978.04), fat (AOAC method 920.85), and ash were determined by incineration at 600 oC until a constant mass weight was achieved (AOAC method 923.03). Total carbohydrate content was calculated by difference on dry weight basis according to the following formula:

Total carbohydrate content % = (100 - ash% +fat% +crude protein% +crude fiber %)

Calcium (Ca), iron (Fe), zinc (Zn), phosphorus (P), and magnesium (Mg) contents were estimated by MPAES (Microwave Plasma-Atomic Emission Spectroscopy) (Agilent, Mulgrave, Victoria, Australia) as described by (Helal and Nassef 2021).

β-carotene was determined using the spectrophotometer (Spectronic 21D) method according to the method described by (Amaya, 2001).

Determination of the Amino Acid Profile of Pancakes

The amino acids of the investigated samples were carried out as described by the method of (AOAC 2010) using an amino acid analyzer (Biochrom 30). The chemical score of essential amino acids (EAA) was relatively calculated according to FAO/WHO (2007) using the following equation:

$$\text{Chemical Score } \left({}^{g}/_{100g}\right) = \frac{\text{EAA in crud protein sample}}{\text{EAA of FAO/WHO}} \times 100$$

Preparation of Pancakes

As shown in Table 1., pancakes were prepared according to method described by (Regina et al., 2022) with some modifications. For the pancake, 22 g of batter was cooked in a pan that was heated to 180–190 °C for 4 min before the pancake was flipped and cooked for another 2 min. The pancakes were cooled, packed in a low-density polyethylene bag, and kept in a plastic container for further analysis.

Sensory Evaluation

After baking, ten trained panelists from the Food Technology Research Institute assessed the pancakes based on their sensory qualities. On a hedonic scale ranging from one (strongly dislike) to nine (strongly like), the judges were asked to score for the method outlined by Gacula and for five sensory qualities (aroma, taste, color, textural, and overall acceptability were examined according to method described by Gacula and Rutenbeck (2006).

Table 1. Formula for pancake preparation

Ingredient	Control	2.5% Lupine Flour	5% Lupine Flour	7.5% Lupine Flour	10% Lupine Flour	12.5% Lupine Flour	15% Lupine Flour	17.5% Lupine Flour
Sorghum flour (g)	100	97.5	95	92.5	90	87.5	85	82.5
Lupine flour (g)	-	2.5	5	7.5	10	12.5	15	17.5
Fresh whole Egg	1	1	1	1	1	1	1	1
Vegetable Oil (ml)	15	15	15	15	15	15	15	15
Sugar(g)	20	20	20	20	20	20	20	20
Raw Milk (ml)	50	50	50	50	50	50	50	50
Water (ml)	As needed							
Xanthan gum (g)	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Baking powder (g)	5	5	5	5	5	5	5	5
Vanilla essence (g)	2	2	2	2	2	2	2	2

Texture Profile Analysis (TPA) of Pancakes

The Brookfield CT3 apparatus (Brookfield Engineering Laboratories, Inc., MA 02346-1031, USA) was used to examine the pancake texture profile in accordance with the AACC (2010) technique. TPA curves were used to compute the following parameters, which were measured: chewiness, springiness, and hardness (N). The test settings used were:

Target =40.0 % Trigger load = 3.00 N, test speed = 3.00 mm/s, return speed = 3 mm/s, and number of cycles = 2.0

Physical Characteristics of Pancakes

Pancakes were evaluated for their physical properties, weight (gm), volume (ml), thickness, and diameter (mm)). Parameters were measured according to (AACC 2010 and Bettge 2014). The volume and weight of the products were determined by measuring three pieces of pancakes. The diameter of each sample of pancakes was measured using a caliper by placing three pieces of pancakes next to each other without overlapping. The total diameter was measured, and the diameter of each formulation was calculated by dividing by 3. The thickness was measured by placing three pieces of pancake on top of each other and measuring the total height. The thickness of each sample was calculated by dividing by 3. Each sample's measurements were repeated three times.

Color Measurement

The color measurement was carried out in triplicate using a colorimeter (CR-400, Konica Minolta, Japan), according to McGurie (1992). The color values were recorded as: L* = lightness (0 = black, 100 = white), a* (-a* = greenness, +a* = redness), and b* (-b* = blueness, +b* = yellowness).

Determination of Water Activity (a_w)

Water activity was measured at 25±2°C using a Decagon Aqualab meter series 3TE (Pullman, WA, USA). All samples of pancakes were broken into small pieces immediately before water activity measurement (Shahidi et al., 2008).

Statistical Analysis

The collected data was analyzed using Costat statistical software version 6.400. The data were statistically analyzed for means and standard deviations in triplicate. The data were subjected to one-way analysis of variance (ANOVA) at $P \leq 0.05$, followed by Duncan's new multiple range tests, to assess differences between the sample means according to (Snedecor 1994).

3. Results and Discussion

Properties of the ingredients

Data presented in Table 2. showed the chemical composition and mineral of raw materials used in the preparation of pancakes. It could be demonstrated that lupine flour had higher protein, ash, fat, and fiber content (38.74, 2.95,2.95 ,7.87 and 8.45%) compared with sorghum flour (9.96, 1.17, 4.05 and 2.30%), but total carbohydrate contents were higher in sorghum flour (82.52) than sweet lupine flour (41.99). The results are in line with work by (Maray 2023), who found that the protein, ash, crude fiber, crude fat, and total carbohydrate contents of sweet lupine flour were 37.62, 3.40, 9.15, 9.15 ,8.43 and 41.40, respectively. (Awadelkareem et al., 2015) who found that protein content in sorghum (whole meal) ranged between 6.23 and 13.81, (Gebreyes, 2017) reported that the fat content in sorghum varieties varied from 2.60 and 4.63%; (Ullah et al., 2010) reported that crude fiber ranged between 0.80 and 2.32%; and (Serna-Saldivar and Espinosa-Ramírez 2019) reported that the ash content in different sorghum varieties ranged between 1.10 and 4.50%. Carotene content is lower in sorghum than in lupine flour. These results are in agreement with (Afify et al., 2012, and Algarni et al., 2019).

As for minerals, data in Table 2. show that sweet lupine flour contains the highest values of calcium (29.06 mg/100g), zinc (3.92 mg/100g), phosphorus (4.41 mg/100 g), and magnesium (129.06 mg/100g). These results are in line with those reported by (Plustea et al., 2022). Whereas iron (Fe) is higher in sorghum (5.23 mg/100 g) compared with sweet lupine flour. These results are in harmony with (Bhosale et al., 2021).

Table 2. Chemical composition of Sorghum and Sweet Lupine Flour (g/100g dry weight basis)

Components	Sorghum Flour	Sweet Lupine Flour
Moisture (%)	$8.00^{a}\pm0.04$	$7.85^{b}\pm0.12$
Crude Protein (%)	$9.96^{b}\pm0.07$	$38.74^{a}\pm0.10$
Crude Fat (%)	$4.05^{b}\pm0.03$	$7.87^{a}\pm0.04$
Ash (%)	$1.17^{b}\pm0.05$	$2.95^{a}\pm0.07$
Crude Fiber (%)	$2.30^{b}\pm0.02$	$8.45^{a}\pm0.15$
Total Carbohydrates (%)	$82.52^{a}\pm0.14$	$41.99^{b}\pm0.23$
β Carotene (mg/kg)	$0.70^{b}\pm0.04$	$3.07^{a}\pm0.10$
	Minerals (mg/100g)	
Ca	$19.49^{b}\pm0.07$	$29.06^{a}\pm0.20$
Fe	$5.23^{a}\pm0.03$	$2.33^{b}\pm0.15$
Zn	$2.51^{b}\pm0.04$	$3.92^{a}\pm0.19$
P	$2.86^{b}\pm0.10$	$4.41^{a}\pm0.07$
Mg	$23.30^{b}\pm0.12$	$129.06^{a}\pm0.04$

Data are presented as means ± SDM (n=3) & Means within a raw with different letters are significantly different at $P \leq 0.05$.

Proximate composition and mineral contents of the pancakes

The data in Table 3. show the proximate composition and mineral content for control and supplemented pancakes with lupine flour at levels 2.5, 5, 7.5, 10, 12.5, 15, and 17.5%. Moisture, ash, protein, lipid, and fiber content of pancakes were significantly increased by increasing the amount of lupine flour. The moisture content of pancake samples increased from 12.92% to 13.73% with a 17.5% substitution of sorghum flour for sweet lupine flour. (Hasmadi et al., 2020) reported that the moisture increase could be due to the presence of polar amino acids as well as the increase in fiber content. While protein increased from 13.60 to 16.17 and fat increased from 24.45 to 26.65 with the substitution of sorghum flour by sweet lupine flour, (Ahmed 2014) referred to the significant increase in protein content as attributed to the lupine flour, which contains about 40–45% protein. Also, ash increased from 0.98 to 3.06%, and fiber increased from 2.41 to 3.09%. The results agree with work by (Maghaydah et al., 2022). Also, the results in Table 3. showed that the mineral content increased with

with the increase in lupine flour. Calcium content significantly increased from 259.01 mg/100 g for pancakes with 17.5% lupine flour; this is due to the high content of calcium in lupine flour. Iron content non-significantly decreased from 2.55 (control) to 2.52 mg/100 g for pancakes with 17.5% lupine flour. Zinc significantly increased from 2.79 (control) to 5.85 mg/100 g for pancakes with 17.5% lupine flour; this is due to the high content of zinc in lupine flour. Phosphorous content follows the same trend as zinc. Magnesium, which is a mineral that plays an essential role in the optimal functioning of the body, increased from 40.20 (control) to 46.87 mg/100 g for pancakes with 17.5% lupine flour, which may be due to the high content of magnesium in lupine flour. Results are confirmed by the work of (Plustea et al., 2022).

Physical Properties of the Pancakes

Table 4. showed that the weight of pancakes slightly increased by increasing lupine flour substitution in blends; this may be due to the high water-holding capacity of lupine flour compared to sorghum. Results agree with work by (Liu et al., 2018). They observed that the addition of lupine resulted in an increase in bread weight. The same trend is true for thickness; an increase in thickness was found with the increase in lupine flour concentration. As for diameter, an opposite effect was noticed, which agrees with work by (Jayasena and Nasar-Abbas 2011), who referred to this decrease as being caused by shrinkage that occurs after baking as a result of the formation of an elastic network. The addition of lupine flour, which has a high dietary fiber content (29.1%), could act in a similar way to reduce the diameter of pancakes. According to (Cho et al., 2019), their study also emphasized that the pancake diameter was negatively correlated with the solvent retention capacity value, or, in other words, with the water holding capacity. As a result of this, the functional properties of lupine flour, especially water absorption capacity, could have a significant effect on pancake quality and its physical characteristics.

Pancake diameter was negatively correlated with the specific volume of pancake, which was highly correlated with the density of batter (Alecia et al., 2015).

The a_w values for lupine-enriched pancakes are significantly higher than those of the control pancakes. Results agree with work by (Mota et al., 2020). They reported that the water activity of lupine enriched cookies is significantly higher than that of the control. Furthermore, the a_w values of all the samples were found to be around 0.9., which means that all pancake formulations (with and without lupine flour) had a high percentage of free water for microbial growth, leading to a low-stability product.

Color Attributes of Pancakes

The appearance of food products is primarily defined by their color, making it a crucial quality characteristic. When consumers make purchasing decisions, color plays a significant role, as it is an easily assessable parameter that influences their choices prior to buying a product. Color values (L*, a*, and b*) of pancake samples containing different levels of lupine flour and control are presented in Table 5. Pancakes with 17.5% lupine had the highest L* value (62.64), which indicates a higher level of brightness, while 100% sorghum pancakes had the lowest L* (55.03) compared to other pancake samples. The addition of lupine flour increased yellowness; all pancakes have a* ranging from 0.99 to 2.25. Lupine contains large amounts of beta-carotene, zeaxanthin, and lutein, which are characterized by an intensely yellow color. The results agree with work by (Makowska et al., 2023), who reported that increasing the level of lupine caused an increase in the yellowness of bread samples. The redness of pancakes increased as the level of lupine flour increased; this could be due to the high b* value of lupine flour (21.33).

Table 3. Chemical composition and Mineral Content of the Pancakes

Components (g/100g)	Control (0% lupine Flour)	2.5% Lupine Flour	5% Lupine Flour	7.5% Lupine Flour	10% Lupine Flour	12.5% Lupine Flour	15% Lupine Flour	17.5% Lupine Flour
Moisture	12.92 ^{f} ±0.15	13.01 ^{e} ±0.11	13.11 ^{d} ±0.12	13.38 ^{c} ±0.10	13.44 ^{bc} ±0.14	13.50 ^{b} ±0.11	13.64 ^{ab} ±0.13	13.73 ^{a} ±0.15
Crude Protein	13.60 ^{h} ±0.09	14.03 ^{g} ±0.05	14.40 ^{f} ±0.09	14.76 ^{e} ±0.07	15.21 ^{d} ±0.09	15.59 ^{c} ±0.14	15.90 ^{b} ±0.11	16.17 ^{a} ±0.13
Crude Fat	24.45 ^{d} ±0.05	24.68 ^{d} ±0.06	25.14 ^{c} ±0.04	25.73 ^{c} ±0.03	26.00 ^{bc} ±0.02	26.38 ^{b} ±0.05	26.55 ^{a} ±0.07	26.65 ^{a} ±0.09
Ash	0.98 ^{f} ±0.05	1.75 ^{e} ±0.02	2.15 ^{d} ±0.03	2.45 ^{c} ±0.06	2.65 ^{b} ±0.04	2.83 ^{ab} ±0.07	3.01 ^{a} ±0.05	3.06 ^{a} ±0.03
Crude Fiber	2.41 ^{g} ±0.07	2.55 ^{f} ±0.05	2.63 ^{e} ±0.07	2.71 ^{d} ±0.04	2.80 ^{c} ±0.06	2.89 ^{b} ±0.02	3.05 ^{a} ±0.03	3.09 ^{a} ±0.05
Total Carbohydrate	58.56 ^{a} ±0.11	56.99 ^{b} ±0.14	55.68 ^{c} ±0.09	54.35 ^{d} ±0.06	53.34 ^{e} ±0.08	52.31 ^{f} ±0.05	51.49 ^{g} ±0.09	51.03 ^{h} ±0.07
Minerals (mg/100 g)								
Ca	259.01 ^{d} ±0.14	260.17 ^{cd} ±0.10	262.82 ^{c} ±0.12	265.46 ^{bc} ±0.14	268.11 ^{b} ±0.10	272.55 ^{ab} ±0.11	275.91 ^{a} ±0.13	279.91 ^{a} ±0.15
Fe	2.55 ^{a} ±0.05	2.55 ^{a} ±0.03	2.54 ^{a} ±0.04	2.54 ^{a} ±0.02	2.53 ^{a} ±0.06	2.53 ^{a} ±0.03	2.52 ^{a} ±0.04	2.52 ^{a} ±0.06
Zn	2.79 ^{g} ±0.04	3.55 ^{f} ±0.02	3.96 ^{e} ±0.03	4.50 ^{d} ±0.03	4.93 ^{c} ±0.02	5.35 ^{b} ±0.06	5.82 ^{a} ±0.02	5.85 ^{a} ±0.03
Ph	358.80 ^{e} ±0.11	360 ^{e} ±0.10	362.03 ^{d} ±0.02	364.00 ^{d} ±0.05	368.41 ^{c} ±0.12	371.83 ^{b} ±0.10	378.11 ^{a} ±0.11	380.01 ^{a} ±0.15
Mg	40.20 ^{d} ±0.10	41.32 ^{cd} ±0.14	42.32 ^{c} ±0.12	43.33 ^{bc} ±0.10	44.32 ^{b} ±0.12	45.40 ^{ab} ±0.14	46.47 ^{a} ±0.13	46.87 ^{a} ±0.11

Data are presented as means ± SD (n=3) & Means within a raw with different letters are significantly different at $P \leq 0.05$.

Table 4. Physical Properties of the Pancakes

Sample	Weight (gm)	Thickness (mm)	Diameter (mm)	Volume (mm^3)	Specific Volume (mm^3/g)	Water Activity (a_w)
Control (0% lupine Flour)	$43.7^{9}c \pm 0.09$	$0.60^{d} \pm 0.03$	$7.10^{a} \pm 0.06$	$90.00^{e} \pm 0.10$	$2.05^{c} \pm 0.18$	$0.897^{d} \pm 0.06$
2.5% Lupine Flour	$47.27^{bc} \pm 0.09$	$0.66^{cd} \pm 0.05$	$7.00^{ab} \pm 0.50$	$101.00^{de} \pm 0.06$	$2.14^{b} \pm 0.26$	$0.913^{c} \pm 0.03$
5% Lupine Flour	$51.67^{abc} \pm 0.05$	$0.69^{c} \pm 0.02$	$6.93^{ab} \pm 0.12$	$113.33^{cd} \pm 0.08$	$2.19^{b} \pm 0.20$	$0.917^{b} \pm 0.05$
7.5% Lupine Flour	$51.90^{abc} \pm 0.07$	$0.70^{c} \pm 0.06$	$6.67^{ab} \pm 0.15$	$117.33^{bc} \pm 0.02$	$2.26^{a} \pm 0.10$	$0.919^{b} \pm 0.07$
10% Lupine Flour	$53.96^{ab} \pm 0.02$	$0.73^{c} \pm 0.04$	$6.60^{ab} \pm 0.10$	$122.67^{abc} \pm 0.05$	$2.27^{a} \pm 0.20$	$0.920^{b} \pm 0.05$
12.5% Lupine Flour	$57.14^{a} \pm 0.21$	$0.84^{b} \pm 0.05$	$6.57^{b} \pm 0.05$	$130.00^{ab} \pm 0.04$	$2.28^{a} \pm 0.11$	$0.925^{a} \pm 0.03$
15% Lupine Flour	$58.32^{a} \pm 0.02$	$0.96^{a} \pm 0.04$	$6.53^{b} \pm 0.06$	$134.00^{a} \pm 0.07$	$2.30^{a} \pm 0.06$	$0.928^{a} \pm 0.04$
17.5% Lupine Flour	$59.90^{a} \pm 0.02$	$0.79^{b} \pm 0.04$	$6.00^{c} \pm 0.06$	$123.87^{abc} \pm 0.05$	$2.07^{c} \pm 0.20$	$0.930^{a} \pm 0.10$

Data are presented as means ± SD (n=3) & Means within a column with different letters are significantly different at $P \leq 0.05$.

Table 5. Color Parameters for Sorghum, Lupine Flour and the Pancakes

Samples	L*	a*	b*
Sorghum Flour	74.90±0.06	1.98±0.08	13.23±0.03
Lupine Flour	82.78±0.03	4.13±0.07	21.33±0.04
Pancakes			
Control (0% lupine Flour)	55.03^{d}±0.05	0.99^{f}±0.03	17.76^{e}±0.05
2.5% Lupine Flour	57.06^{c}±0.06	1.29^{e}±0.09	18.19^{de}±0.01
5% Lupine Flour	57.27^{c}±0.02	1.36^{de}±0.10	19.90^{cd}±0.05
7.5% Lupine Flour	59.28^{b}±0.06	1.49^{cd}±0.08	20.67^{bc}±0.17
10% Lupine Flour	59.97^{b}±0.07	1.64^{c}±0.07	20.83^{bc}±0.05
12.5% Lupine Flour	60.83^{ab}±0.16	1.93^{b}±0.02	22.50^{ab}±0.09
15% Lupine Flour	61.08^{ab}±0.13	2.13^{a}±0.15	23.37^{a} ±0.19
17.5% Lupine Flour	62.64^{a}±0.16	2.25^{a}±0.07	24.46^{a}±0.05

L* (lightness with L* = 100 for lightness, and L* = zero for darkness), a* [(chromaticity on a green (-) to red (+)], b* [(chromaticity on a blue (-) to yellow (+)], Data are presented as means ± SD (n=3) & Means within a column with different letters are significantly different at $P \leq 0.05$.

Texture Profile of Pancakes

Parameters of the texture profile of the pancakes are shown in Table 6. The applied additives modified the pancake texture. Significant differences were found in the hardness, springiness, and chewiness of lupine-enriched pancakes.

Hardness indicates the force required to compress food between the molars and is defined as the force necessary to attain a given deformation.

Table 6. Texture Profile Analysis for Pancakes

Sample	Hardness (N)	Springiness	Chewiness
Control (0% lupine Flour)	103.88^{a}±0.50	7.06^{c}±0.14	535.40^{a}±0.05
2.5% Lupine Flour	100.33^{ab}±0.42	7.80^{bc}±0.54	511.15^{ab}±0.03
5% Lupine Flour	97.53^{ab}±0.71	7.44^{bc}±0.61	455.20^{b}±0.03
7.5% Lupine Flour	91.01^{ab}±0.47	9.10^{b}±0.62	441.55^{b}±0.02
10% Lupine Flour	82.79^{b}±0.50	9.29^{b}±0.31	371.55^{c}±0.07
12.5% Lupine Flour	62.08^{c}±0.93	9.90^{ab}±0.10	237.10^{d}±0.05
15% Lupine Flour	56.58^{c}±0.40	10.03^{ab}±0.28	227.98^{d}±0.01
17.5% Lupine Flour	59.89^{c}±0.40	11.15^{a}±0.28	277.78^{e}±0.01

Data are presented as means ± SD (n=3) & Means within a column with different letters are significantly different at $P \leq 0.05$.

In the case of lupine flour addition, significant differences were noted. These changes in texture parameters are mainly caused by the increase in proteins and the large amount of dietary fiber characterized by high water absorption. These factors affect hardness as well as chewiness (understood as the energy required to chew a solid product) (Makowska et al., 2023).

The hardness of sorghum-lupine pancakes showed a decreasing trend with increasing lupine flour, and pancakes made with 17.5% lupine tended to be the least hard. The results agree with (Yemmireddy et al., 2013).

The springiness of pancakes showed a significant increase due to the percentage of lupine flour replacement. Chewiness followed the same trend as hardness. However, this disagrees with work by (Yemmireddy et al., 2013).

Sensory acceptability scores of pancakes

Table 7. represents the sensory acceptability scores of pancakes. It could be noticed that aroma, color, texture, taste, and overall acceptability scores were reported by the sensory analysis. According to sensory data on aroma (Table 7.), pancakes made with sweet lupine flour (17.5% lupine flour) received the lowest ratings, whereas the control pancake sample made with entirely 100% sorghum flour recorded the highest ratings for aroma and were non-significantly different from the composite pancakes produced. The results regarding color revealed a significant difference between the control group (100% sorghum flour) and the supplemented pancakes, with the control pancakes receiving lower scores. As the level of addition of lupine flour increased, the scores for texture significantly increased. The texture score showed that there were noticeable changes in the control, and pancakes with sweet lupine flour (15% lupine flour) received the highest ratings. Taste and acceptability follow the same trend. The data aligns with the findings of (Adonu et al., 2022), who concluded that substituting wheat flour partially with soybean flour at levels of up to 10% and 20% can result in the production of pancakes or pastry products that are deemed acceptable without compromising their sensory quality. Previous studies by (Nasar-Abbas and Jayasena 2012) on baked products, such as gluten-free cakes, reported that the incorporation of lupine flour up to 20% can produce bakery products with sensory and quality acceptability.

Table 7. Sensory acceptability scores for Pancakes

Samples	Aroma	Color	Texture	Taste	Overall Acceptability
Control 0% lupine flour	9.00^{a} ±0. 07	7.95^{c}±0.07	7.22^{b}±0.14	6.80^{b}±1.850	7.95^{c} ±0.06
2.5% lupine flour	8.88^{a} ±0.09	8.01^{bc}±0.08	7.37^{b}±0.20	7.10^{b}±0.06	8.00^{c} ±0.091
5% lupine flour	8.79^{a} ±0.01	8.14^{bc}5±0.09	7.62^{ab} ±0.06	7.25^{ab}±0.02	8.15^{c} ±0.03
7.5% lupine flour	8.73^{a} ±0.03	8.37^{abc}±0.02	7.83^{ab} ±0.09	7.48^{ab}±0.07	8.31^{bc} ±0.19
10% lupine flour	8.68^{a} ±0.06	8.49^{abc}±0.07	7.97^{ab} ±0.04	7.75^{ab}±0.08	8.75^{abc} ±0.05
12.5% lupine flour	8.61^{a} ±0.02	9.21^{ab}±0.05	8.37^{ab} ±0.09	8.00^{ab}±0.04	9.18^{ab} ±0.06
15% lupine flour	8.54^{a} ±0.08	9.35^{a} ±0.15	8.75^{a} ±0.05	8.66^{a}±0.13	9.49^{a}±0.08
17.5% lupine flour	8.50^{a} ±0.09	9.00^{ab}±0.08	8.30^{ab} ±0.20	7.68^{ab} ±0.06	7.97^{c} ±0.091

Data are presented as means ± SDM (n = 10, a 9-point hedonic scale: 1 (9= like extremely, 8= like very much, 7= like moderately, 6= like slightly, 5= neither like nor dislike, 4= dislike slightly, 3= dislike moderately, 2= dislike very much, 1= dislike extremely) & Means within a column with different letters are significantly different at $P \leq 0.05$.

Amino Acid Profile of Pancakes

Data in Table 8. included the amino acid composition and chemical score of the pancake samples (which contain 15% sweet lupine flour and were successful in sensory evaluation) as determined compared with the control.

Generally, the incorporation of sweet lupine flour into the pancakes led to an increase in all amino acids as compared with the control sample. Results agree with work by (Abd El-Maasoud and Ghay 2018). This increase may be due to the effect of lupine flour addition, which is high in amino acids, especially lysine, leucine, and isoleucine, as stated by (Maray 2023). Chemical scores reflect the amount requirements of the essential amino acids as reported by (FAO/WHO 2007). The chemical score of the lupine substituted sample was higher than that of the that of the sorghum control samples (Table 8). This may be due to the effect of the lupine flour addition.

Table 8. Amino Acid Content (g/100g protein) and Chemical Score of the Pancakes

	Control			15% L			FAO
Amino Acids	Amino acids (mg/100 g sample)	Amino acids (g/100 Protein)	Chemical Score %	Amino acids (mg/100 g sample)	Amino acids (g/100 Protein)	Chemical Score %	
Essential Amino Acids							
Threonine	0.245	1.82	53.40	0.461	2.90	85.20	3.4
Valine	0.379	2.81	80.29	0.550	3.46	98.89	3.5
Methionine	0.149	1.10	44.09	0.176	1.11	44.33	2.5
Isoleucine	0.313	2.32	82.83	0.478	3.01	107.34	2.8
Leucine	0.865	6.41	97.05	1.161	7.30	110.65	6.6
Phenylalanine	0.391	2.90	45.98	0.560	3.52	55.92	6.3
Lysine	0.316	2.34	40.41	0.530	3.34	57.52	5.8
Biological Value		60.39			69.21		
Non-Essential Amino Acids							
Aspartic*	0.488	3.62	-	1.067	6.71		
Serine*	0.314	2.32	-	0.618	3.89		
Glutamic acid*	1.742	12.90		2.843	17.88		
Proline*	0.628	4.65		0.895	5.63		
Glycine*	0.197	1.46		0.411	2.58		
Alanine*	0.529	3.92		0.627	3.95		
Arginine*	0.235	1.74		0.803	5.05		
Histidine	0.153	1.13		0.269	1.69		
Tyrosine	0.224	1.66		0.452	2.85		
Cystine	0.033	0.25		0.122	0.77		

4. Conclusion

From the current study, it could be concluded that gluten-free composite flour (sorghum and lupine flour) could be used to produce high-protein pancakes of good quality with acceptable sensory, physical, and nutritional values. This product could be used to improve the nutrition performance of children and celiac disease patients due to its high amount of protein, essential amino acids, calcium, iron, and zinc. Therefore, the utilization of lupine flour in sorghum pancakes improved the sensory characteristics and nutritional value and could be useful for the production of value-added bakery products targeted at specific health benefits.

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