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Research Article

Effect of Incorporating Foxnut (*Euryale ferox*) Powder on Physico-Chemical Attributes and Amino Acid Composition of Cookies

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Abstract

Background: The main goal in recent years has been to fortify bakery items with components high in phenolic compounds, antioxidant activity, proteins, vitamins, and minerals. Foxnut (*Euryale ferox*), popularly known as Makhana, is an important aquatic crop belonging to the family, Nymphaeaceae. It is considered to be a native of South-East Asia and China, but is distributed in almost every part of the world. In India, it is cultivated in Bihar, Assam, North Bengal and other North Eastern states.

Material and Methods: Good quality puffed foxnut, refined wheat flour, butter, sugar were procured from the local market of Ludhiana. Puffed foxnuts were oven-dried for 2 hours at 40°C. The popped foxnut was ground into a fine powder, and then blended with refined wheat flour in various proportions (0:100, 15:85, 20:80, 25:75) of popped foxnut and refined wheat flour respectively. Organoleptically accepted cookies were nutritionally evaluated and compared with control samples.

Results: The study concluded that the developed products showed a significant increase in nutrient content in term of crude protein, fiber, total ash and minerals and a significant decrease in fat content. Total phenols and flavonoid content also increased with the incorporation of foxnut powder. An increase in antioxidant potential in terms of DPPH, reducing power, metal chelating and ABTS was also observed in foxnut cookies.

Conclusion: It is inferred from the results that the incorporation of foxnut powder in bakery products may serve as a useful alternative for developing bakery products possessing better functional and nutritional properties to meet the consumers' demand for healthier food choices without compromising palatability.

Keywords: *Euryale ferox*; FTIR; Antioxidant Potential; Consumer Acceptance; *Nymphaeaceae*

Abbreviations

µg: Microgram; AAE: Ascorbic Acid Equivalent; ABTS: Azino-Bis-3ethylbenzthiazoline-6-Sulphonic Acid; AOAC: Association of Official Analytical Chemists; C: Control; CE: Catechin Equivalents; DPPH: 2,2-Diphenyl-1-Picrylhydrazyl; EDTA: Ethylene Diamine Tetra Acetic Acid; FTIR: Fourier-Transform Infrared Spectroscopy; GAE: Gallic Acid Equivalent; HPLC: High Performance Liquid Chromatography; ICP-AES: Inductively Coupled Plasma Atomic Emission Spectrometer; MCA: Metal Chelating Activity; mg: Milligram, ml: Milliliter; QE: Quercetin; RPA: Reducing Power Activity; rpm: Revolutions Per Minute; SD: Standard Deviation; SOD: Superoxide Dismutase; TPA: Texture Profile Analysis

Introduction

Cookies are ready-to-eat and quick-to-prepare delicacies. Traditionally, they are made with flour, eggs, and sugar and are rather simple to make. Apart from that, the major ingredients utilized in the formulation are frequently used to categorize cookies, such as nut cookies, fruit cookies, and chocolate cookies. Cookies are typically characterized by their preparation process, such as drop, moulded, pressed, refrigerated, bar, or rolled [1]. Food enrichment has been a useful tool for managing or preventing certain nutritional deficiencies, as well as promoting a general sense of well-being in many groups and possibly preventing some chronic diseases [2]. The main goal in recent years has been to fortify bakery items with components high in phenolic compounds, antioxidant activity, proteins, vitamins, and minerals. Cookies have been fortified with various nutrients in recent years to make them a complete food with all essential nutrients [3].

The foxnut (*Euryale ferox*), also known as Makhana, is an aquatic crop in the Nymphaeaceae family. It is widely sold in China, Japan, and Korea, but it is mostly grown in Uttar Pradesh, Bihar, West Bengal, Madhya Pradesh, Assam, and Tripura in India [4]. The foxnut is most typically consumed in popped form, and the creation of that popped form (known as black diamond) from the seed is done by mechanically smacking roasted foxnut seeds into a light and voluminous white diamond [5]. The white perisperm inside the seed is the most delicious part of the foxnut, and it's usually eaten popped as snacks or desserts [6]. Due to its high carbohydrate (80% starch), ash, protein and low-fat content, foxnut is a highly healthy organic non-cereal food that is used as a dry fruit [7-10]. It is regarded as a superfood because of its numerous health advantages, including cardioprotective, anti-diabetic, antioxidant, and anti-fatigue properties [11]. Currently, it is being utilized for the preparations of various foods especially sweets and healthy foods [10]. Despite efforts to cultivate new varieties and analyse nutritional content, limited research has been done to use foxnut's potential to produce value-added products. This research aims to uncover ways for foxnut to be more accepted not only as a traditional processed food but also as a value-added product by looking at the possibility of improving foxnut use as an important food. As a result, the goal of this study was to see how incorporating foxnut flour into cookies affected their proximate, physical properties, mineral, amino acid content, and bioactive properties. The findings of this study will help to expand the usage of foxnut in baked products and demonstrate its economic potential.

Material and Methods

Materials

Good quality puffed foxnut, refined wheat flour, butter, sugar were procured from the local market of Ludhiana. Puffed foxnuts were oven-dried for 2 hours at 40°C (Figure 1). The popped foxnut was ground into a fine powder, and then blended with refined wheat flour in various proportions (0:100, 15:85, 20:80, 25:75) of popped foxnut and refined wheat flour respectively.

Formulation of cookies

Composite flour with different proportion of refined wheat flour and foxnut powder was prepared, with 100% refined wheat flour served as control (Table 2). The flours were weighed and mixed using a digital weighing balance and a food mixer, respectively.

Preparation of cookies

The oven was first preheated at 190°C. In a food mixer, creaming of butter and sugar was done together. After that, a composite flour sample was added to the mix. The material was then blended and kneaded until it formed dough. The dough was formed into small sized flattened balls, placed on a greased baking sheet, and baked for 15 minutes, or until golden brown. They were allowed to cool

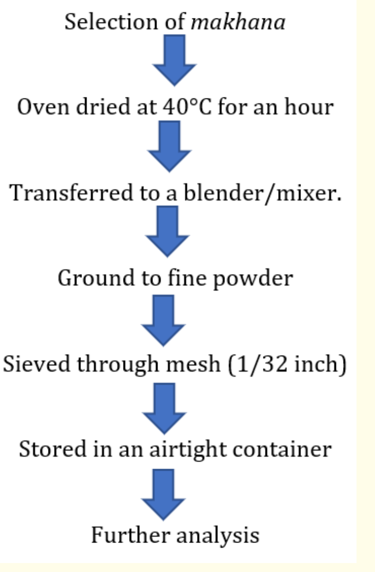

Figure 1: Flowsheet for the preparation of foxnut powder.

before being sealed in a plastic bag and stored in a cool, dry place. The four formulations were tested for cookie preparation. The final product was chosen and kept for future investigation based on sensory scores.

Consumer acceptance

A total number of 75 people from PAU, Ludhiana, evaluated the prepared products organoleptically. All the preparations were served with one control sample and three testing samples. Foxnut powder was utilized in test samples in varying amounts for various recipes, while control samples were made using ingredients from the standardized recipes. On white disposable plastic plates, samples of cookies were placed, and water was offered for rinsing the mouth. To avoid any prejudiced judgement, the samples were coded. A sensory assessment form was also provided to the consumers to evaluate the products. Consumers were asked to rate the sample on color, flavour, taste, appearance, texture and overall acceptability. The average score was obtained after each product was tested on the Likert scale.

Physical properties

Colour measurement

The colour of samples was assessed by measuring L*, a*, and b* values with the Colour Flex metre (Hunter Lab Colour Flex, 150 Hunter Associates Inc., USA), where L* = lightness, a* = redness, b* = yellowness.

Texture

Using a Texture Analyzer TA-XT2i, a texture profile analysis (TPA) was performed to determine the texture of the cookies (Stable Micro Systems, Surrey, UK). The sample was compressed twice, with a 50-second gap between compressions, using a plunger with a 1.0 cm diameter. Assessments were made of the qualities of hardness, chewiness, springiness, gumminess and cohesion.

Proximate analysis

Using the AOAC methodology, moisture, crude protein, crude fat, crude fibre, and total ash, were determined [12].

Mineral content

The mineral profiles of samples were determined using AOAC methods [12]. In a nutshell, after the samples were digested with HNO_3/H_2O_2, the extract was redissolved in double-distilled water, and the data were then analysed using ICP-MS. The standard curve was used to determine the content of each element, which was then expressed as mg/100 g dry matter.

Determination of bioactive compounds

Total phenolic content

The Folin-Ciocalteu (F-C) colorimetric method was used to determine total phenolic content (TPC), with gallic acid acting as the standard [13]. In that order, 0.5 mL of methanolic extract and 5 mL of 10% (v/v) F-C reagent were added to the test tube. It was held for 5 minutes before adding 4 mL of saturated sodium carbonate. After 15 minutes in the dark, the absorbance was measured using a spectrophotometer calibrated to 765 nm (Spectronic 20, Bausch and Lomb, USA). The gallic acid equivalent (GAE) mg/100g db was used to calculate the results.

Total flavonoid content

To estimate the total flavonoid content, 1 ml of the methanol extract, 1.5 ml of pure methanol, 0.1 ml of 10% aluminium chloride, 0.1 ml of potassium acetate solution, and 2.8 ml of distilled water were carefully mixed together. The absorbance of the combination was measured at 415 nm. The flavonoids were given in mg/100g db quercetin equivalent (QE) quantities [14].

Determination of antioxidant activity

DPPH (2,2-diphenyl-1-picryl hydrazyl) antioxidant activity

The DPPH free radical scavenging capacity of the samples was evaluated [13]. The extract (1ml) was mixed with tris buffer in a test tube (1ml). This mixture received 2 ml of DPPH, which was added, and was allowed to sit at room temperature in the dark for 30 minutes. At 517 nm, the absorbance was measured using methanol as a standard. To express the results, TROLOX EQUAL (TE) mol/L was employed.

Reducing Power

The ability of extracts to reduce ferric ions (Fe^{+3}) was investigated [14]. One millilitre of methanol extract was combined with 2.5 millilitres of phosphate buffer and 2.5 millilitres of 1% potassium ferricyanide and incubated at 50°C for 20 minutes. After that, it was centrifuged at 3000 rpm with 10% trichloroacetic acid (2.5 ml). Finally, the absorbance at 700 nm was measured using 2.5 ml of the supernatant solution, 2.5 ml of water, and 0.1 percent ferric chloride (0.5 ml). The results were expressed in milligrammes of ascorbic acid equivalent (AAE) per 100 g of dry matter.

Metal chelating activity

The Naithani et al (2011) method was used to determine the chelating of ferrous ions [15]. One ml of the sample was added to 2 mM of ferric chloride. By adding 0.2 ml of a 5 mM ferrozine solution to the mixture, the reaction was started. After a thorough blending, the mixture was left to stand at room temperature for 10 minutes. At 562 nm, the solution's absorbance was determined. The results are expressed as mg ethylene diamine tetra acetic acid equivalent (EDTA)/mmol/L db.

ABTS

The Kim *et al* (2003) method was used to estimate ABTS activity of the samples [16]. Potassium persulfate (2.45m mol/L) solution with a pH of 7.4 and ABTS (1m mol/L) were combined. In a test tube, one ml of the sample was added to 3 ml of ABTS solution. For 40 minutes, the mixture was kept in the incubator at 30°C. After being brought to room temperature, at 734 nm, the solution's absorbance was determined.

Amino acid profile

The acid hydrolysis method was used to determine the amino acid content. 6 N HCl was used to hydrolyze 1 g of sample at 110°C for 24 hours. After that, dilution was done by adding 6 N NaOH to get the pH level 2.2. Derivatization was carried out by placing the extract in a 200 ml injection vial filled with borate buffer and briefly vortexing. The AccQ Tag Ultra reagent was added, vortexed for some time, and then incubated for 10 minutes at 55°C in a water bath. For the purpose of determining the amino acid profile, the sample was sent to high-performance liquid chromatography (Agilent Technologies, Inc., USA, 1,200 series).

$$\text{Concentration (mg/100g)} = \frac{\text{Concentration of standard} \times \text{Area of sample} \times \text{Dilution factor}}{\text{Area of standard} \times \text{Weight of sample}}$$

FTIR analysis

Using an Agilent Cary 630 FTIR spectrometer, the developed products were examined for FTIR spectra. The spectra were gathered in the 4000-400cm wave number range, and all of the samples were examined at room temperature.

Statistical analysis

All the determinations were carried out in triplicate. Several statistical tools, including mean and standard error, were used to analyze the data. Chi-square, two-tail t-test and critical difference were used with the SPSS 16 software to determine the significant difference between the control and experimental samples.

Results and Discussion

Physico-chemical properties of raw material

The raw materials' physicochemical properties, such as moisture, protein, ash, fibre, and fat, were determined and are shown in table 1. The table revealed that the physicochemical parameters of raw materials differed significantly ($p < 0.05$). The moisture content, which is important in determining shelf life, ranged from 5.43 to 7.55. The moisture, protein, fiber and ash content of foxnut powder was observed to be higher than the refined flour, whereas, fat content of refined flour was greater than the foxnut powder. Similar results for foxnut were observed in various studies ranging from 8.7-11.03, 0.3-0.5, 0.2-0.4 and 0.3-0.4 per cent for crude protein, fat, fiber and ash respectively [10,17,18]. The raw materials were subjected to the color determination parameter that included L (lightness), a* (redness-greenness), and b* (yellowness-blueness). The foxnut powder's L*, a*, and b* coordinates were 93.85, -0.03 and 8.29, respectively whereas, the same parameters were seen to be 81.60, 2.51 and 11.94 for refined flour. These findings agreed with those of Devi *et al* (2020), who reported the corresponding color values for L*, a*, and b* as 83.21, 1.26 and 6.92 of popped foxnut [7]. Total phenolic, flavonoid content, antioxidant activity were assessed in the raw materials, which are depicted in table 1. The foxnut powder contained 84.86 mg GAE/100g of total phenols, whereas the flavonoid content was evaluated to be 3.39mg QE/g, which were significantly higher ($p < 0.05$) than the phenolic and flavonoid content of refined flour. Similar results for the flavonoid content of foxnut were reported by Liaquat., *et al.* [19], whereas, total phenolic content of popped foxnut was observed to be 1.12 mg GAE/g [7]. The present study observed antioxidant activity as 42.97 per cent inhibition (DPPH), 33.73 mg AAE/100g (RPA), 0.932 EDTA mmol/L (MCA) and 72.19 per cent inhibition (ABTS). Studies revealed that roasting improved DPPH from 48.54 to 79.13 per cent inhibition, FRAP from 662.46 to 957.14µmol $FeSO_4$/g, total phenolics from 346.02 to 470.62mg GAE/100g, and total flavonoids from 4.15mg to 4.43mg CE/g, of *E. ferox* [19].

Parameters	Foxnut powder	Refined flour	t-value
Moisture (%)	7.55 ± 0.04	5.43 ± 0.03	93.62**
Protein (%)	9.6 ± 0.02	5.91 ± 0.03	181.20**
Fat (%)	0.27 ± 0.01	2.12 ± 0.02	122.82**
Fiber (%)	0.87 ± 0.50	0.21 ± 0.10	9.90*
Mineral (%)	0.77 ± 0.01	0.05 ± 0.05	47.76**
Total phenolic content	84.86 ± 0.20	59.12 ± 0.03	110.32**
Total flavonoid content	1.39 ± 0.25	0.28 ± 0.12	6.76*
DPPH	42.97 ± 0.02	36.70 ± 0.20	37.61**
RPA	33.73 ± 0.01	13.01 ± 0.30	15.52**
MCA	0.93 ± 0.3	0.749 ± 0.02	6.51*
ABTS	72.19 ± 0.01	46.22 ± 0.02	147.20**
L*	93.85 ± 0.21	81.60 ± 0.72	87.54**
a*	-0.03 ± 0.03	2.51 ± 0.19	22.03**
b*	8.29 ± 0.01	11.94 ± 0.02	23.30**

Table 1: Physico-chemical properties of raw material.

Values are expressed as Mean of duplicate samples, each analyzed in triplicates (n = 6) ±SD.

** Significant at 1% level of significance ($p < 0.01$).

* Significant at 5% level of significance ($p < 0.05$).

Ingredients	Quantity (g)			
	B	BT1	BT2	BT3
Refined flour	100	85	80	75
Foxnut powder	-	15	20	25
Sugar	50	50	50	50
Fat	60	60	60	60
Baking powder (tsp)	1/2	1/2	½	½
Baking soda (tsp)	1/2	1/2	½	½
Water (ml)	5	5	5	5

Table 2 Formulation of cookies.

- B- Control
- BT1- 15% Foxnut powder
- BT2- 20% Foxnut powder
- BT3- 25% Foxnut powder.

Consumer acceptance

Consumer test results revealed that there is a significant difference in terms of appearance, colour, texture, flavour and overall acceptability in all the prepared cookies (Table 3). Cookies incorporated with 25 per cent foxnut powder received highest scores against all other samples for all sensory characteristics and was deemed to be most acceptable with overall acceptability 4.66. The scores were even observed to be higher than control sample of cookies. Therefore, cookies containing 25 per cent foxnut powder was further assessed for physico-chemical, bioactive compounds and antioxidant parameters, along with the control cookies prepared from refined flour only.

Physical parameters of cookies

The mean values of the physical properties of control an foxnut cookies prepared are depicted in table 4. The amount of pro-

Table 3: Consumer acceptance scores for cookies

	Colour	Appear-ance	Texture	Taste	Flavour	Overall accept-ability
B	3.60±0.56	3.60±0.63	3.90±0.51	3.60±0.51	3.93±0.70	3.96±0.61
BT1	3.90±0.65	3.70±0.65	3.90±0.65	3.80±0.67	3.83±0.59	3.89±0.50
BT2	4.13±0.54	4.10±0.60	4.01±0.66	4.10±0.80	4.30±0.80	4.10±0.57
BT3	4.30±0.51	4.60±0.51	4.60±0.50	4.73±0.45	4.66±0.48	4.66±0.44
χ^2	132.9**	151.0**	145.8**	146.6**	152.8**	143.0**

Values are expressed as Mean±SD (n=75)

** Significant at 1% level of significance (p<0.01)

* Significant at 5% level of significance (p<0.05)

B – Control

BT1 – 15% foxnut powder

BT2 – 20% foxnut powder

BT3 – 25% foxnut powder

	Control cookies	Foxnut cookies	t-value
Color			
L*	73.84 ± 0.09	66.88 ± 0.21	51.19**
a*	5.85 ± 0.04	4.72 ± 0.02	76.92**
b*	30.84 ± 0.01	29.67 ± 0.02	78.48**
Texture			
Hardness	86.94 ± 0.04	100.67 ± 0.03	472.25**
Cohesiveness	0.11 ± 0.10	0.10 ± 0.09	0.12NS
Chewiness	0.1 ± 0.08	0.11 ± 0.10	0.21NS
Gumminess	0.11 ± 0.10	0.09 ± 0.09	0.25NS

Table 4: Physical properties of prepared cookies.

Values are expressed as Mean of duplicate samples, each analyzed in triplicates (n = 6) ±SD

** Significant at 1% level of significance (p < 0.01)

* Significant at 5% level of significance (p < 0.05).

tein in the mixture of wheat flour and foxnut powder was altered by the addition of foxnut powder, which also had an impact on the consistency and textural qualities of the cake, cookies, bread and doughnuts. The hardness of the cookies incorporated with 25 per cent was determined to be the highest i.e., 100.67. This could be as a result of foxnut cookies being thicker than the control ones. Sandeep *et al* had also noted an increase in hardness, in his study where makhana flour was added to cookies in varied proportions compared to wheat cookies [20]. A decreasing trend was observed in case of cohesiveness, when foxnut flour was added to the products. The decrease in cohesiveness shows that there has been a decrease in the amount of food that can be deformed before breaking. The elasticity of the food product, which was reduced by the inclusion of foxnut powder, is connected to the springiness. However, the inclusion of foxnut powder resulted in a considerably (p < 0.05) higher score for gumminess, chewiness and stringiness. According to the definition of gumminess, which is the outcome of hardness and cohesiveness, bakery products with a high value for hardness has more gumminess. A greater chewiness suggested that more effort could be needed to masticate the food. Hardness and stringiness have a direct impact on how chewy a product is [21]. Color is an important product characteristic. The colour qualities that are distinctive to many types of food products have a strong correlation with the final product's consumer acceptability [22]. The color of cookies varied significantly with the addition of foxnut powder. The lightness (L*), redness (a*) and yellowness (b*) of prepared cookies were determined as presented in table 4. The L* value, indicates the brightness of the samples that was found higher in control cookies than the foxnut cookies. The a* value indicates the redness and greenness of developed products, whereas, b* coordinates indicate the yellowness and blueness of the color. Highest b* value was found in the control sample i.e., 30.84, whereas foxnut cookies had the lower value i.e., 29.67.

Proximates, mineral profile and bioactive compounds of cookies

Table 5 shows the results of the physicochemical examination of made cookies. The control cookies' mean moisture content was found to be lower than that of the foxnut cookies. The control sample's protein, fiber, ash level was much lower than foxnut cookies with the values 6.75, 1.14 and 1.76 per cent for protein, fiber and ash respectively, whereas a decreasing trend in fat content in foxnut cookies was observed. The carbohydrate and energy content of foxnut cookies were found to be 61.52 per cent and 542.75 Kcal respectively. As a result, foxnut powder improved the nutritious value of cookies when compared to cookies made exclusively from refined flour. The calcium, potassium, iron, magnesium content of foxnut cookies was significantly greater than the calcium content of the control sample. Additionally, it was discovered that the sodium content of foxnut cookies was found to be significantly lower than the control sample, whereas phosphorus content of test sample was found to be significantly greater than the phosphorus content of control cookies. The prepared cookies were also analysed for the bioactive compounds and antioxidant activity (Table 5). The major bioactive compounds majorly present in foxnut are phenols, which are well known for their medicinal value [23]. The total phenols in control cookies was 32.74 mg GAE/100g, which further increased to 52.05 mg GAE/100g in foxnut cookies. It was observed that phenols present in foxnut had better retention of phenolic activity after baking. Seetal studied the effect of baking on the concentration of phenolic compounds in baked products [24]. The type of phenolic compounds, baking recipe and heating conditions had an impact on the retention of phenolic compounds during baking. The bound phenolic acids decreased while the free phenolic acid increased in baked products which may be due to the

	Control cookies	Foxnut cookies	t-value
	Amount (%)		
Moisture	0.43 ± 0.04	0.73 ± 0.04	7.86*
Crude protein	4.69 ± 0.02	6.75 ± 0.03	3.96*
Crude fat	29.52 ± 0.04	28.61 ± 0.03	31.54**
Crude fiber	0.60 ± 0.01	1.14 ± 0.04	25.65**
Ash	1.53 ± 0.03	1.76 ± 0.01	9.43*
Carbohydrates	63.53	61.52	-
Energy (kcal)	547.05	542.75	-
Minerals	Amount (mg/100g)		
Calcium	28.71 ± 0.06	35.07 ± 0.06	22.60**
Potassium	18.39 ± 0.01	24.63 ± 0.03	27.71**
Iron	0.97 ± 0.02	1.73 ± 0.05	26.09**
Magnesium	7.83 ± 0.03	14.84 ± 0.25	40.78**
Sodium	45.89 ± 0.02	41.10 ± 0.02	19.80**
Phosphorus	22.92 ± 0.02	40.08 ± 0.07	105.08**
Bioactive compounds			
Total phenols (mg GAE/100g)	32.74 ± 0.02	52.05 ± 0.05	585.18**
Flavonoids (mg QE/100g)	26.52 ± 0.03	39.55 ± 0.24	66.22**
Antioxidant potential			
DPPH (% inhibition)	33.45 ± 0.02	41.43 ± 0.02	410.91**
Reducing power assay (mg AAE/100g)	27.03 ± 0.03	33.01 ± 0.01	303.24**
Metal chelating activity (EDTA mmol/L)	0.73 ± 0.04	0.87 ± 0.05	3.193*
ABTS (% inhibition)	41.98 ± 0.09	58.64 ± 0.02	102.02**

Table 5: Proximates, mineral profile and bioactives parameters of prepared cookies.

Values are expressed as Mean of duplicate samples, each analyzed in triplicates (n = 6) ±SD

**Significant at 1% level of significance ($p < 0.01$)

*Significant at 5% level of significance ($p < 0.05$).

heat stress that causes degradation of the conjugated polyphenolic compound. Therefore, baking may be a useful method for increasing bioavailability of bound phenolic acids [25]. Foxnut cookies contained 39.55 mg/100g of flavonoids. The values enhanced due to incorporation of foxnut powder, in comparison to control cookies with the value 26.53 mg/100 g. Yang *et al* studied the effect of baking on flavonoid content, in which it was concluded that the baking temperature and time conditions did not impact the concentrations of flavonoids [26]. The antioxidant activity significantly ($p < 0.05$) increased by addition of foxnut powder. The presence of polyphenols in a product has a close relationship to its antioxidant properties. All the treated samples were found to have high per cent inhibition (DPPH). Control cookies showed 33.45 per cent inhibition, which was enhanced with the incorporation of foxnut powder, therefore the per cent inhibition in foxnut cookies 41.43 per cent. Liaquat *et al* concluded that popped foxnut had 48.54 per cent inhibition of DPPH [19]. Jan *et al* reported that processing techniques like baking and microwave roasting increases antioxidant activity [27]. This could be explained by the formation of brown pigment melanoidins that are produced during baking as a result of the non-enzymatic browning reaction known as the maillard reaction. Reducing power, metal chelating, ABTS activity of cookies improved by incorporating foxnut powder from 27.03mg AAE/100g, 0.73 EDTA nmol/L, 41.98 per cent inhibition to 33.01 mg AAE/100g, 0.87 EDTA nmol/L and 58.64 per cent inhibition respectively.

Amino acid profile of prepared cookies

Although cereal grains are significant dietary staples around the world, they typically lack the amino acids lysine and threonine, methionine. When compared to control cookies, cookies containing foxnut powder had significantly higher levels of threonine, methionine, and valine (p 0.05). Compared to the control cookies, the foxnut powder-infused cookies had a threonine content of 9.74 mg per gramme as opposed to 3.33 mg per gramme. In foxnut-infused cookies, lysine (4.20 mg/g), glutamic acid (13.20 mg/g), and histidine (52.62 mg/g) content levels were significantly higher than in the control sample (Table 6). Almost all amino acids showed a significant increase overall, with the exception of valine (3.22mg/g). Foxnut is extremely rich in all of the essential amino acids, which makes it very appealing from a nutritional standpoint. It can be used for fortification to make up for the lack of lysine, methionine, and histidine, which are typically present in very small amounts in cereals and bakery goods made with cereal as a base.

Amino acids (mg/g)	Control cookies	Developed cookies	t-value
Leucine	6.18 ± 0.11	6.85 ± 0.09	5.14*
Lysine	3.35 ± 0.31	4.20 ± 0.33	6.15**
Valine	3.02 ± 0.11	3.22 ± 0.21	2.61NS
Methionine	1.12 ± 0.08	1.80 ± 0.12	6.40**
Proline	3.51 ± 0.16	6.50 ± 0.21	12.23**
Histidine	2.12 ± 0.09	52.62 ± 0.29	84.96**
Cysteine	1.22 ± 1.12	1.47 ± 0.08	4.15*
Glutamic Acid	11.81 ± 0.11	13.20 ± 0.08	10.97**
Glycine	3.36 ± 0.13	15.34 ± 0.07	45.38**
Threonine	3.33 ± 0.11	9.74 ± 0.12	29.32**
Serine	3.63 ± 0.10	8.76 ± 0.07	25.42**
Aspartic Acid	6.63 ± 0.20	7.87 ± 0.05	6.09**

Table 6: Amino acid profile of prepared cookies.

Values are expressed as Mean of duplicate samples, each analyzed in triplicates (n = 6) ±SD

** Significant at 1% level of significance ($p < 0.01$)

* Significant at 5% level of significance ($p < 0.05$).

FTIR analysis

In present study, FTIR was used to identify functional groups and other fingerprint groups that were present in cookies with foxnut incorporation as compared to control cookies (Figure 2). The spectra between 2978 and 2817.9 cm-1 has very faint peaks and exhibits C-H stretching, both of which point to the existence of alkanes [28]. Carbohydrates can be found in the peak between 2920 and 2924 cm^{-1} (aliphatic C-H stretch), whereas alkynes can be seen in the spectrum between 2319.3-2159.5 cm^{-1}, which reflects C ≡ C stretching. The bands between 1770.8-1702.9 cm^{-1} and 1457.8-1338.8 cm^{-1} show C-H bending, corresponding to aromatic compounds and alkanes, respectively. The absorption between 952.8-816.5 cm^{-1} and 1649.9-1591.4 cm^{-1} shows C=C stretching, medium bending of C = C, respectively. Both type of peaks represents the presence of alkenes in the product [29]. The stretching CH_3 asymmetrically and symmetrically (1379-1396 cm^{-1}), C-O-C asymmetrically (1242-1247 cm^{-1}) and CH-CH, C-CH and C-OH (1027-1052 cm^{-1}) revealed the existence of phenolic compounds, organic compounds- sugars, alcohols, glucose and organic acids can be found in the peaks between 800-1500 cm^{-1}. The stretches of C-Cl and C-Br in the bands between 781.5 and 656.0 cm-1 range indicate the presence of aliphatic chloro and bromo groups [30].

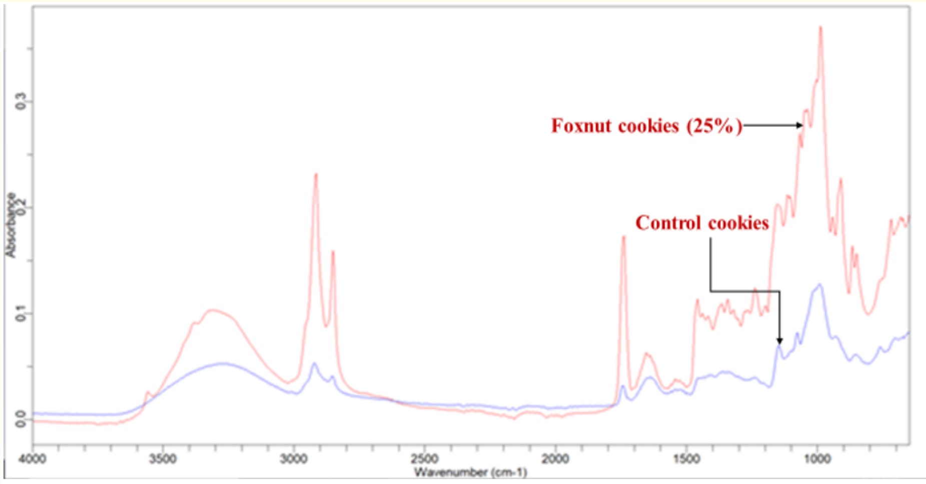

Figure 2: FTIR Spectra (cm^{-1}) of the developed cookies.

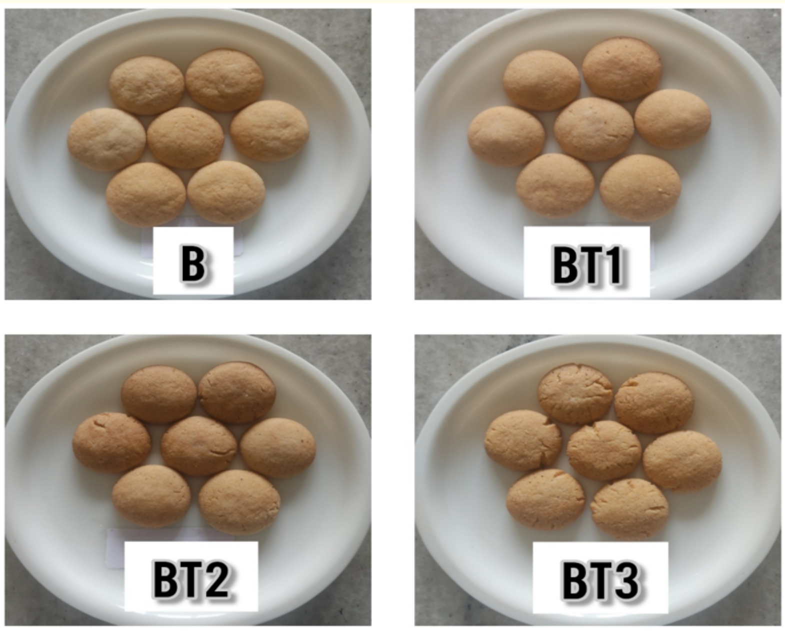

Figure 3: B-Control
BT1-15% foxnut powder, BT2-20% foxnut powder
BT3-25% foxnut powder
Plate 1: Foxnut incorporated cookies.

Conclusion

Based on the results obtained, it was concluded that cookies with high acceptability can be prepared by incorporating foxnut powder. Foxnut powder provide extra nutritional value to the baked products. The findings revealed that foxnut cookies provided substantial amount of protein, fiber and bioactive compounds. The incorporation of foxnut powder in cookies also resulted in an increase in antioxidant potential in terms of DPPH, reducing power, metal chelating and ABTS. Hence, it is inferred from the results that the incorporation of foxnut powder in cookies may serve as a useful alternative for developing bakery products possessing better functional and nutritional properties to meet the consumers' demand for healthier food choices without compromising palatability.

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Conflict of Interest

The authors declare that they have no conflict of interest.

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