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# Preparation of Gluten Free Cookie using Chestnut and Foxnut Flour Blend: Composition Optimization Through Response Surface Methodology

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## ABSTRACT

**Background:** Cookies are baked products that are consumed as a snack worldwide.Gluten, a commonly known protein found in wheat flour, contributes to the extensibility and elasticity of cookie dough. For an individual with aceliac disease, the consumption of gluten should be avoided. In addition, those who observe religious fasts abstain from wheat and wheat-derived items. This study developed gluten-free cookies and studied the impact of chestnut and foxnut flour on its physical, nutritional and sensory properties.
**Methods:** The experimental planning and analysis were performed using the Response Surface Methodology. Two independent variables (foxnut and chestnut flour) were selected and the Central Composite Design was applied. Altogether, thirteen experimental formulations were used for producing cookies. Along with sensory evaluation, the cookies' moisture, ash, fat and protein contents were examined. For general acceptance, 25-30 semi-trained panelistswere chosen to conduct the sensory analysis based on a numerical scoring test.
**Result:** The sample (S12; 60% chestnut and 5% foxnut flour) had the greatest overall acceptance score. The chemical components of S12, namely moisture, ash, fat and protein, were 3.84%, 3.51%, 18.52% and 6.92%, respectively. Compared to the control sample, S12 was preferredby the panelists.

**Key words:** Cookie formulation, Gluten free, Response surface methodology, Sensory evaluation.

## INTRODUCTION

The water chestnut refers to the plant found in water bodies, including lakes, ponds and rivers. This hydrophyte is considered a dependable food source for flood-prone areas due to its starch-producing nature. It is abundant in nutrients and minerals (Rajput and Singh, 2023). According to Ismail *et al.* (2008) water chestnut provides abundant fat, amino acids, sugar, minerals, water- and fat-soluble vitamins, fibers and antioxidants like flavonoids and phenols. Also, it is known for its antidiabetic, anti-inflammatory, suppressing pain and bactericidal properties and is used in bakery and sweets products (Parekh and Chanda, 2007; Kaur *et al.*, 2023).

Foxnut, also known as "makhana" in India, is a popped gorgon nut (*Euryale ferox*) kernel. Due to its gluten-free nature, it may be used effectively in food products consumed while fasting and in producing gluten-free products (Mishra *et al.*, 2014). It is an abundant source of carbohydrates, protein, fat and minerals (phosphorus, potassium, magnesium, calcium and sodium). The protein in foxnut seed has a unique amino acid composition high in essential amino acids (leucine, isoleucine, methionine and lysine). As a non-cereal cuisine, makhana is a perfect staple sustenance for devotees during their holy fast (Kumar *et al.*, 2016). The edible seeds of a legume are called "peanuts" or "groundnuts" in several regions of the world. Ground nuts have abundant protein, oil and fibers (Šoronja Simović *et al.*, 2017).

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Cookies are typically enjoyed as a snack item and are an energy source. With non-wheat flours including buckwheat, cassava, quinoa, *etc*., gluten-free cookies have been prepared previously by several researchers using different raw materials like quinoa flour, rice flour, coconut flour, sweet potato flour and cassava-based composite flour (De Lima Brito *et al*., 2014; Pãucean *et al*., 2016;

Susman *et al*., 2021). There is a need to create gluten-free cookies employing ingredients with functional properties to cater to those with gluten sensitivity while also providing extra health advantages (Giri andSakhale, 2021). Gluten content, which enables air cell expansion and provides stiffness after baking, enables it to carry out these duties (Suriya *et al*., 2017). Patients with celiac disease, however, must cut out gluten from their diets. Gül *et al*. (2018) report that 26 to 49% of children who come to tertiary care facilities in India with chronic diarrhea are later found to have celiac disease.

As per Cookies Market Forecast Report (2025) reports, the cookie sector will be worth 44.01 billion USD by 2025, with a CAGR of 5.3% and the Asian Pacific is projected to have the most spontaneous growth (6.8%). The main factors contributing to this growth include urbanization, a modern way of living and elevated incomes. Chestnut and foxnut flour play a critical role in delivering the nutritional benefits to the cookie. However, the scarcity of literature that delves into these flours' effects on sensory quality and consumer acceptability pushed the need for this study. This study aimed to assess the impact of chestnut and foxnut flour composition on the physical, nutritional and sensory properties of gluten-free cookies. The study utilized the Response Surface Methodology to choose the optimal blend of these flours to develop cookies with better consumer acceptability.

## MATERIALS AND METHODS

This study was conducted in the laboratories of the Food Technology Department, Raja Balwant Singh Engineering Technical Campus, Bichpuri, Agra, U.P., India between January and May 2023.

### Material

Foxnut (Tulsi Brand), water chestnut flour (Bansal Ji Spices), groundnut, sugar (Good Life refined sugar), cardamom, clove and baking powder (Ajanta) were procured from Agra, Uttar Pradesh, India's market. Sodium bicarbonate (Qualigens Fine Chemicals) was obtained from the Department of Food Technology at Raja Balwant Singh Engineering Technical Campus, Bichpuri, Agra, India. The xanthan gum (Sattvic Foods) was purchased online from Amazon.

### Preparation of foxnut powder and groundnut paste

The black spots on the foxnuts were first removed and then the foxnuts were broken into small pieces and dried in a tray dryer at a temperature of 80°C for 30 min to attain 6% moisture content. Following this, the foxnuts were cooled and ground to produce foxnut powder. For the paste,the groundnuts were cracked open and the red skin was removed. Then, the groundnuts were ground to paste by adding approximately 25 mL of Millipore water.

### Preparation of cookies

Cookie samples were prepared using the creamery method and the following ingredients as per Mishra *et al*. (2014) studies in the laboratory. Ingredients added were baking soda, baking powder, sugar and xanthan gum.The groundnutpaste (35 wt%) and sugar were combined in a dish and creamed. The sifting was done for the dry materials, such as the foxnut powder and water chestnut flour. Then, the prepared cream was combined with the major components (water chestnut and foxnut flour) and minor elements (leavening and binding agents) to create a dough that was given a rest for 30 min, then sheeted to a thickness of 7 mm and a round cookie cutter with a 5 cm diameter was used to cut it. Following it, the cookies were cooked in the ovenin three different steps: i) the bottom plate was heated to 100°C and the top plate to 80 for 15 min; ii) the bottom plate was heated to 80 and the top plate to 120 for 10 min; iii) the bottom and top plate temperatures were set to 70 for 7 min. The cookies were baked, cooled to room temperature and then stored in a moisture-proof container. Based on the amount of chestnut and foxnut utilized, a total of 13 cookie combinations were produced (as per the response surface methodology design) and all 13 combinations were cooked in the above-mentioned three different conditions (Table 1).

### Physio-chemical analysis of raw material and cookies

Official AOAC methods were followed to evaluate the samples' moisture, protein, ash and fat content (Latimar *et al*., 2023). Moisture and ash were assessed using a gravimetric method, while for protein and fat content, standard Kjeldahl and Mojonnier methods were followed, respectively. Meanwhile, weight, diameter and thickness were evaluated using the AACC method.

### Sensory analysis

Sensory analysis for appearance, flavour, chewability and overall acceptability was analysed using the numerical scoring test. Numerical scoring was performed: excellent: 9-10, good: 6-8, fair: 4-5 and poor: 1-3. Everypanelist was asked to evaluate the sample on a 10-point scale.

### Experimental design and analysis

To develop the design, Response Surface Methodology (RSM) was applied (Design Expert version 13, Stat-Ease 360). A three-factor design at five levels was adopted. Thirteen experiments were conducted as per the experimental design and the independent variables were water chestnut flour and foxnut powder. The dependent variables include sensory parameters, appearance, flavor and chewability. Statistical significance (at a 5% level) of every factor upon the response was evaluated using ANOVA. All the experiments were conducted in triplicate and values were reported as mean ± std deviation.

## RESULTS AND DISCUSSION

### Chemical composition of raw materials

The moisture, ash, fat and protein content of the flours are presented in Table 2. Notably, groundnut exhibited the highest protein content (22.70±0.73%) among the three flours, followed by foxnut (9.70±0.71%) and water chestnut flour (6.01±0.89%). The findings align with the protein content reported by Pawar and Singh for foxnut flour (Pawar and Singh, 2022). Our water chestnut flour's protein content values surpassed those reported by Shafi *et al*. (2016) (4.18%) but were lower than Ahmed *et al*. (2016) analysis (8.4%). The low protein content of the flour (6.01±0.89%) was likely due to the presence of non-protein constituents such as crude fiber, reducing and non-reducing sugars and starch.

The fat content was also significantly elevated in groundnut (43.20±0.86%) compared to foxnut (0.50 ±0.06%) and water chestnut (0.81±0.09%). Therefore, ground nuts present promising potential to produce high-nutrition cookies and may serve as a natural emulsifier. Shafi *et al*. (2016) and Bala *et al*. (2015) reported a fat content of approximately 0.52% for water chestnut flour. At the same time foxnut flour has around 0.4% fat (Pawar and Singh, 2022). Foxnut had the highest moisture content (12.80±0.91%), while both water chestnut and groundnut exhibited similar moisture levels (5.71± 0.37%). Regarding ash content, water chestnut flourhad the highest value (1.82±0.61%), followed by groundnut (1.72±0.20%) and foxnut (0.62±0.02%).

**Physical properties of cookies (weight, diameter and thickness)**

The weight of the cookies was in the range of 12.14 and 14.76 g (Table 3). Notably, the cookie sample S9 emerged as the heaviest and most voluminous. However, S2 weighs thelowest (12.14 g). The augmentation in weight can be attributed to the elevated incorporation of foxnut powder in the sample. Shafi *et al*. (2016) analysis demonstrated that foxnut flour hashigher bulk density than chestnut flour. Therefore, the substantial addition of foxnut flour exerts a pronounced influence on bulk density, consequently contributing to the increased weight of the cookies. Bulk density plays a pivotal role in assessing packaging requirements for any product, offering the opportunity for compact packaging by accommodating higher weight within a constant volume (Yellavila *et al*., 2015). Furthermore, this observation can be linked to the elevated moisture content and the moisture and oil absorption capacity inherent to foxnut powder. Similar observations were reported in the studies of Kumar *et al*. (2015) where substituting of popped makhana (foxnut) flour for wheat flour resulted in an increased weight of cookies. However, in the studies conducted by Shafi *et al*. (2016), the increased weight was ascribed to chestnut flour, which possessed a higher bulk density in comparison to wheat flour.

The diameter of the cookies displayed a reduction ranging from 56.1 to 49.0 mm for S10 and S9, respectively (Table 3). Kumar *et al*. (2015) also observed a decrease in the cookie diameter with the increased substitution of popped makhana flour in the blends. This phenomenon may be attributed to the enhanced water absorption capacity associated with the blend, which in turn leads to a reduction in the width of the cookie samples. A similar diminishing trend was observed in the thickness of the cookie samples, with values ranging from 7.8 to 9.6 mm (Table 3). S10 sample exhibited the maximum (9.6 mm) thickness. However, S11 had the least (7.8 mm) value. Notably, the thickness of the cookies experienced a significant decline with an increasing substitution level with foxnut powder. These findings, however, contradict those of Kumar *et al*. (2015).

**Table 1:** Formulation of cookies based on the chestnut and foxnut composition (as per the RSM design).

| Sample | Chestnut flour (%) | Foxnut flour (%) |
|---|---|---|
| Control | 0 | 0 |
| S1 | 55 | 10 |
| S2 | 47.9 | 10 |
| S3 | 55 | 10 |
| S4 | 50 | 15 |
| S5 | 55 | 10 |
| S6 | 50 | 5 |
| S7 | 55 | 10 |
| S8 | 62.1 | 10 |
| S9 | 60 | 15 |
| S10 | 55 | 2.9 |
| S11 | 55 | 17.1 |
| S12 | 60 | 5 |
| S13 | 55 | 10 |

**Table 2:** Summarization of the chemical attributes of the raw materials used for the cookie preparation.

| Components | Water chestnut flour (%) | Foxnut (%) | Groundnut (%) |
|---|---|---|---|
| Moisture | 5.71±0.22[a] | 12.80±0.91[b] | 5.71±0.37[a] |
| Ash | 1.82±0.61[a] | 0.62±0.02[b] | 1.72±0.20[a] |
| Fat | 0.81±0.09[a] | 0.50±0.06[a] | 43.20±0.86[b] |
| Protein | 6.01±0.89[a] | 9.70±0.71[b] | 22.70±0.73[c] |

**Table 3:** Summarization of the physical attributes (weight, diameter, thickness) of various cookie samples generated.

| Sample | Weight (g) | Diameter (mm) | Thickness (mm) |
|---|---|---|---|
| Control | 11.10±0.43 | 50.28±0.37 | 8.37±0.56 |
| S1 | 13.25±0.21 | 52.20±0.20 | 8.70±0.37 |
| S2 | 12.14±0.35 | 51.90±0.20 | 8.50±0.63 |
| S3 | 13.51±0.25 | 52.80±0.10 | 8.70±0.21 |
| S4 | 13.99±0.23 | 51.60±0.30 | 8.00±0.35 |
| S5 | 13.00±0.41 | 52.30±0.20 | 8.90±0.43 |
| S6 | 13.42±0.32 | 53.40±0.10 | 9.10±0.15 |
| S7 | 13.36±0.27 | 52.50±0.40 | 8.80±0.09 |
| S8 | 14.42±0.51 | 51.60±0.30 | 8.25±0.27 |
| S9 | 14.76±0.31 | 49.00±0.40 | 8.20±0.24 |
| S10 | 13.17±0.37 | 56.10±0.40 | 9.60±0.17 |
| S11 | 14.51±0.63 | 49.60±0.20 | 7.80±0.07 |
| S12 | 12.47±0.41 | 55.20±0.30 | 9.50±0.37 |
| S13 | 13.29±0.29 | 52.00±0.30 | 8.60±0.40 |

### Proximate composition of cookie (moisture, ash, fat and protein)

The variation in moisture, ash, fat and protein content of cookies with respect to the incorporation ratio of water chestnut flour and foxnut powder has been represented in Table 4. Moisture for the samples was between 3.50% and 3.84%, where the maximum value was obtained for S12 while the lowest was in the case of S11.

The findings were in correspondence with Pawar *et al*. (2023), where the moisture content of the cookies decreased with amaranth and foxnut flour substitution. The ash content of cookies ranged from 3.32% to 3.98%, with the highest content in S11 and the lowest in S10. It was observed that the ash content declined with increased foxnut powder content, which is attributed to the lowest ash content of the foxnut flour among all three flours used.

The fat of the samples was between 17.51% and 18.63%. Higher fat content can affect the shelf stability of the cookie by promoting lipid oxidation. The highest fat content was observed in S8 (18.63%), while the lowest was in S11 (17.51%). The findings were contrary to Kumar *et al*. (2015), where the foxnut powder addition boosted the fat content of the cookies. This might be because the relative fat content of the foxnut powder might be higher than the other ingredients used in their cookie formulation.

Protein is another essential component of cookies that assists in the growth of the human body. The protein of the samples was between 6.92% and 8.97%. The value for the fresh sample was highest (8.97%) for S9 and the lowest value (6.92%) was observed for S12. The findings corresponded with Kumar *et al*. that an increase in the popped makhana flour proportion increased the protein content of the cookies (Kumar *et al*., 2015).

### Sensory characteristics of cookies

The responses obtained at different ratios of chestnut and foxnut for the formulation of gluten-free cookies for fasting purposes are demonstrated in Table 5. The second-order polynomial equations were studied for the responses at different flour ratios. The models thus developed with coded variables are as follows:

$$Y_{Appearance} = 125.58 - 4.25A - 0.78B + 0.004AB + 0.04A^2 + 0.01B^2$$

$$Y_{Flavor} = 6.61 + 226.87A + 225.19B + 0.04AB + 160.75A^2 - 159.99B^2$$

$$Y_{Chewability} = 127.31 - 4.28A - 0.65B + 0.003AB + 0.04A^2 + 0.01B^2$$

In which, A stands for the chestnut and B stands for the foxnut flour.

The integrated influence of more than one variable was demonstrated through RSM (Fig 1, 2 and 3).

### Appearance

The maximum score observed for appearance was 7.9 and the minimum score was 2.5 (Table 5), with actual, predicted and adjusted $R^2$ values of 0.9177, 0.8996 and 0.9043, respectively. Both actual and predicted $R^2$ values were in agreement with the adjusted $R^2$. The developed model was significant at $p<0.05$; hence, both the variables (water chestnut and foxnut content) significantly influenced the appearance of the samples. With the progressive increase in foxnut content, a diminishing effect on the cookies' coloration was observed, imparting a slightly negative aspect to their appearance. The increased lightness can be attributed to the elevated moisture content found in foxnut flour (Correia *et al*., 2012). Kumar *et al*. (2015) also observed a decline in lightness value as the proportion of popped makhana flour in the blend of popped makhana and wheat flour increased. This underscores the role of foxnuts in influencing the cookies' visual appeal, with a discernible trend towards lighter coloration accompanying an escalating substitution level of foxnut flour. The optimal appearance of the cookies was achieved when incorporating a minimal amount of foxnuts (S10).

**Table 4:** Summarization of the chemical attributes of the raw materials used for the cookie preparation.

| Cookie samples | Moisture (%) | Ash (%) | Fat (%) | Protein (%) |
|---|---|---|---|---|
| Control | 4.16±0.35 | 1.84±0.33 | 26.5±0.25 | 5.20±0.17 |
| S1 | 3.70±0.27 | 3.72±0.30 | 17.92±0.67 | 8.41±0.23 |
| S2 | 3.81±0.29 | 3.65±0.27 | 17.83±0.78 | 7.50±0.42 |
| S3 | 3.67±0.39 | 3.76±0.07 | 17.92±0.71 | 8.50±0.32 |
| S4 | 3.61±0.31 | 3.93±0.78 | 17.66±0.33 | 8.83±0.49 |
| S5 | 3.73±0.41 | 3.74±0.35 | 17.95±0.52 | 8.45±0.32 |
| S6 | 3.78±0.47 | 3.54±0.46 | 18.20±0.11 | 7.13±0.24 |
| S7 | 3.69±0.25 | 3.73±0.34 | 17.97±0.83 | 8.39±0.64 |
| S8 | 3.56±0.13 | 3.87±0.62 | 18.63±0.21 | 8.94±0.34 |
| S9 | 3.52±0.06 | 3.90±0.31 | 18.46±0.43 | 8.97±0.36 |
| S10 | 3.83±0.09 | 3.32±0.29 | 18.28±0.38 | 7.20±0.58 |
| S11 | 3.50±0.29 | 3.98±0.81 | 17.51±0.13 | 7.01±0.58 |
| S12 | 3.84±0.40 | 3.51±0.45 | 18.52±0.09 | 6.92±0.23 |
| S13 | 3.68±0.43 | 3.72±0.56 | 18.05±0.77 | 8.41±0.51 |

**Table 5:** Summarization of the sensorial assessment of the developed cookie samples.

| Sample | Appearance | Flavor | Chewability | Overall acceptability |
|---|---|---|---|---|
| S1 | 4.2 | 6.5 | 5.5 | 5.4 |
| S2 | 6.2 | 7.9 | 6 | 6.7 |
| S3 | 4.1 | 6.6 | 5 | 5.2 |
| S4 | 2.7 | 5.7 | 4.5 | 4.3 |
| S5 | 4 | 6.8 | 5.2 | 5.3 |
| S6 | 6.4 | 8.7 | 7.7 | 7.6 |
| S7 | 4.2 | 6.5 | 5 | 5.2 |
| S8 | 7.1 | 6.3 | 7.5 | 6.9 |
| S9 | 3.2 | 6 | 4.7 | 4.6 |
| S10 | 7.9 | 6.5 | 7.8 | 7.4 |
| S11 | 2.5 | 5.1 | 4 | 3.9 |
| S12 | 6.5 | 8.9 | 7.6 | 7.8 |
| S13 | 4 | 6.5 | 5.1 | 5.2 |

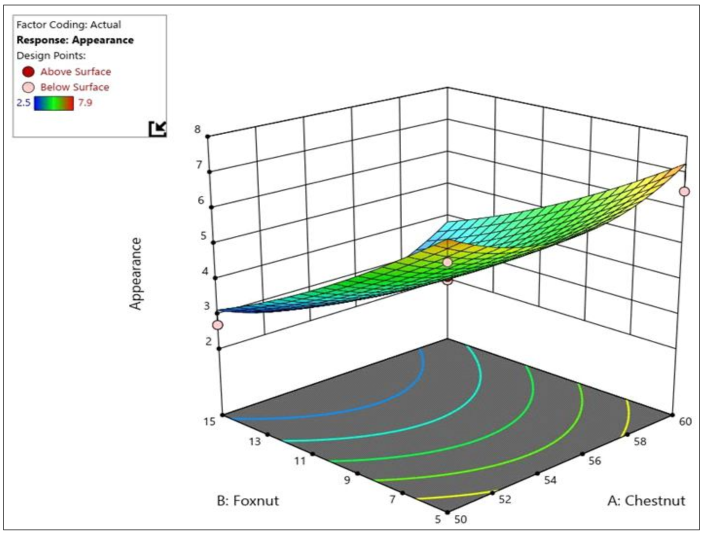


**Fig 1:** Response surface demonstrating the effect of foxnut and chestnuton appearance of cookie samples.

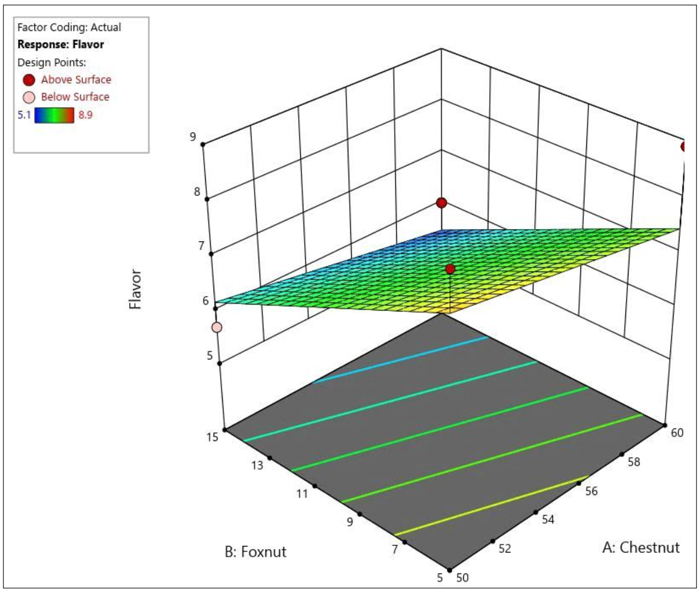


**Fig 2:** Response surface demonstrating the effect of foxnut and chestnut on flavor of cookie samples.

### Flavor

The maximum score observed for flavor was 8.9 and the minimum score was 5.1 (Table 5), with actual, predicted and adjusted $R^2$ values of 0.8981, 0.7942 and 0.8225, respectively. Both actual and predicted $R^2$ values were in agreement with the adjusted $R^2$. The developed model was significant at $p<0.05$; hence, both variables significantly influenced the flavor of the samples.

Notably, as the foxnut content ranged from 2.9% to 17.1%, the flavor of the cookies exhibited improvement, peaking at around 5% and subsequently declining as the foxnut content approached 17.1%. The most favorable flavor in the cookies was achieved in the case of the S12 sample (Fig 4). Pawar *et al*. (2023) observed the increased mean scores, particularly in terms of taste, that were notably pronounced up to 87-90% incorporation of amaranth flour and foxnut flour into the composite cookies. This reinforces the significance of foxnut's role in enhancing the overall flavor of baked goods, mirroring the findings observed in this study.

### Chewability

The maximum score observed for flavor was 7.8 and the minimum score was 4.0 (Table 5), with actual, predicted and adjusted $R^2$ values of 0.9769, 0.8989 and 0.9603, respectively. Both actual and predicted $R^2$ values were in agreement with the adjusted $R^2$. The developed model was significant at $p<0.05$; hence, both variables had a significant influence on the chewability of the samples. Notably, as the foxnut content increased, the cookies became progressively more challenging to chew. This trend

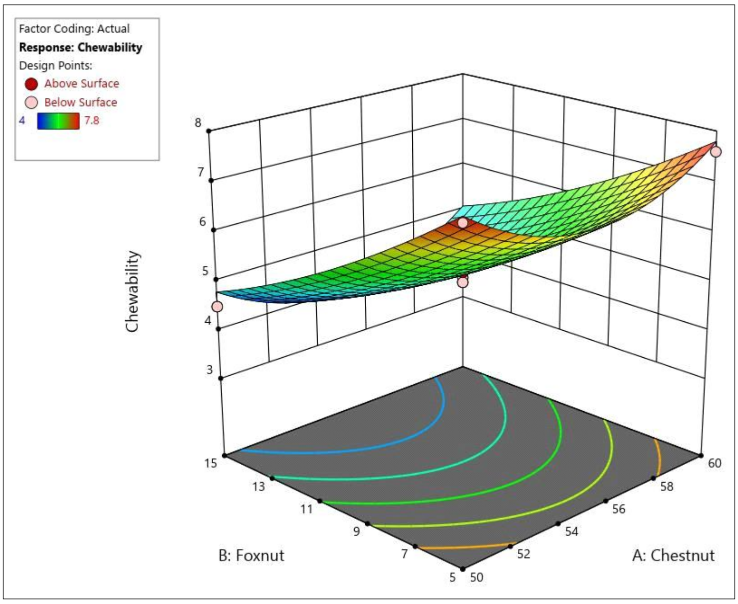


**Fig 3:** Response surface showing the effect of foxnut and chestnuton chewability of cookie samples.

**Fig 4:** Final cookies sample S12.

was corroborated by the increased hardness of the cookies, with the escalation in the substitution level of foxnut flour. The optimum chewability of the cookies was achieved with the lowest incorporation level of foxnut, specifically (S10). Mishra *et al*. (2014) reported that the biscuits developed using the Makhana powder had a rigid texture compared to those with a potato powder base. This might be due to the scarcity of gluten content in makhana powder, which, while absorbing water, imparts an elastic texture to the dough.

## CONCLUSION

The study demonstrated the feasibility of generating gluten-free cookies (with up-to-the-mark nutritive and sensory attributes) by completely replacing wheat flour with water chestnut and foxnut flour. Replacement of hydrogenated fat with groundnut paste during creaming controlled the excess oiliness in the baked cookies. It was observed that water chestnut flour could be incorporated up to 60% level in the cookies without affecting the flavor and texture of the cookies. Foxnut powder could be incorporated up to a 5% level as with an increase in the foxnut ratio of the cookie, the hardness of the cookies kept increasing. Groundnut paste was incorporated with up to 35% sugar during creaming without significantly affecting the texture and appearance. Further, nutritional assessments unveiled a substantial increase in protein by adding foxnut flour alongside water chestnut flour. Conversely, fat and moisture content significantly decreased and ash content elevated compared to the control. Totally, gluten-free cookies outperformed the control in terms of nutritional attributes. Sensory evaluation, encompassing parameters such as appearance, flavor and chewability, favored the gluten-free samples, with superior scores in terms of appearance and flavor. However, the control sample had a better scorefor chewability. Sample S12, developed using 60 parts water chestnut flour and 5 parts foxnut powder, garnered the highest overall acceptability score, underscoring its desirability.

### Declaration of competing interest

On behalf of all the authors, the corresponding author declares that there is no conflict of interest.

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