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Development and characterization of protein-rich cookies fortified with red kidney beans: A nutritional approach to combat malnutrition

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Abstract

Malnutrition is a severe issue in developing countries due to the rapidly growing population, urbanization and industrialization, and a reduction in agricultural lands. It ultimately is an alarming situation for food security, thus, there is a need to look for alternate sources for food and nutrition security. This work aimed to enhance the compositional and functional properties of the cookies. In this study, different concentrations (0, 3, 6, 9, 12%) of red kidney beans were used to prepare cookies (T_0, T_1, T_2, T_3 and T_4). Nutritional, functional and sensorial attributes were assessed. Results showed that the inclusion of red kidney beans in cookies increased the protein and crude fiber contents by 1.75 and 1.40 times, respectively than the control sample. Functional properties of cookies such as water holding capacity and oil holding capacity were significantly increased (P<0.05). However, bulk density and water absorption capacity of cookies were significantly decreased (p<0.0%). Dietary fiber and mineral composition (iron, phosphorus, calcium and magnesium) in cookies significantly improved (p<0.05). Moreover, the sensorial attributes indicated that adding 9% red kidney beans to cookies was acceptable. In short, the addition of red kidney beans in cookies may help to mitigate malnutrition.

Keywords: Cookies, Physical, Red kidney beans, Sensory

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Introduction

Globally, the population is growing quickly, particularly in developing countries in Asia and Africa (Iqbal, 2018). The world population is predicted to reach 9.30 billion people by 2050 (Verstraete et al., 2016; Reihani et al., 2019). Feeding the planet in a balanced manner has become increasingly difficult due to the growing population (Noroz et al., 2021). The demand for meat and protein products is projected to increase by 50% and 102%, respectively, due to shifting dietary needs and lifestyles (Razzaq et al., 2022). Scientists have developed novel agronomic techniques, high-yield cultivars, and cutting-edge processing technologies to meet global food requirements. However, a severe gap persists between the supply and demand for food, along with widespread food shortages. Malnutrition arises from this imbalance, posing a serious threat to food security, especially in low-income nations (Mohibbe Azam et al., 2021). Unbalanced nutrient consumption leads to malnutrition, which manifests as stunted growth, wasting, decreased muscle mass, obesity, diabetes, overweight, and reduced stamina (Razzaq et al., 2020). Socioeconomic conditions, inadequate diet, energy imbalance, and vitamin deficiencies are among the factors contributing to malnutrition (Batool et al., 2015). Dietary-based strategies like nutrient enrichment and food fortification can address malnutrition-related issues (Gharibzahedi & Jafari, 2017). These approaches may unite people from all walks of life without requiring drastic dietary adjustments (Chadare et al., 2019). According to Dwyer et al. (2015), the primary benefits include easy nutrient distribution to large populations, diverse nutrient fortifications, standardized and optimized nutrient levels to prevent toxicity, cost-effective nutrient additions, and profitability for smallholder farmers.

Red kidney beans (*Phaseolus vulgaris* L.) are a rich source of nutrients, providing proteins (20–27%), minerals and vitamins (4–6%), fat (less than 2%), fiber (up to 28%), and carbohydrates (up to 60%) (Devi, 2021; Marquezi et al., 2017). The protein content in red kidney beans is 2–3 times higher than in cereals (Manonmani et al., 2014). They are also a good source of minerals such as calcium, magnesium, copper, iron, manganese, phosphorus, potassium, and molybdenum. Many researchers have reported the health benefits of red kidney beans, including cardiovascular protection (Sikand et al., 2015), antidiabetic effects (Sutedja et al., 2020), and anti-inflammatory properties (Winarsi et al., 2020).

Cookies are one of the most popular snack foods globally, consumed for their low cost, convenience, and long shelf life (Schouten et al., 2023). Most cookies are manufactured with wheat, which lacks essential amino acids and sufficient proteins. Developing cookies with improved organoleptic and functional qualities requires significant effort. Combining red kidney beans and grains could provide balanced protein due to their complementary nutritional profiles (Araro et al., 2020). The present study aims to prepare cookies by incorporating different concentrations of red kidney beans and to evaluate their effects on the nutritional, functional, and sensorial attributes of the cookies.

Materials and Methods

Procurement of raw materials

Raw materials such as wheat flour and additional supplies (baking powder, sugar, and butter) were procured from the supermarket of Faisalabad, Pakistan. On the other hand, red kidney beans were purchased from Ayub Agricultural Research Institute, Faisalabad. According to David et al. (2015), wheat flour had the following compositions: moisture (3.33%), crude fat (1.33%), crude fiber (0.51%), crude protein (10.23%), and carbs (83.60%). Similarly, according to Ibeabuchi et al. (2017), red kidney bean flour had the following contents: moisture (1.06%), fat (1.57%), fiber (4.00%), protein (20.31%), ash (5.00%), and carbs (68.03%). Analytical-grade chemicals and reagents (Merck, Germany) were utilized.

Preparation of sample

To get rid of pollutants, dirt particles, and damaged beans, red kidney beans were hand-cleaned. After that, the beans were ground into a powder in a hammer mill and sieved to produce a powder with a consistent size (less than 250 µm) and packed in polythene bags for further study.

Cookies preparation

Cookies were made with different concentrations of red kidney beans (Table 1). 380 g of flour mix, 225 g of sugar, 100 g of shortening, 21 g of beaten egg, 1.8 g of baking powder, and 3 g of salt were the ingredients of the basic cookie recipe. For three to five minutes, the dry ingredients were combined in a bowl after being weighed. After adding shortening, it was mixed until it was uniform. The dough was then kneaded in a mixer for five minutes after the addition of eggs. The dough was then cut out with a round biscuit cutter after being uniformly flattened out on the sheeting board. The dough cutout pieces were baked in a baking oven set to 160 °C for 15 minutes. After cooling to room temperature, the cookies were placed in polythene bags for further analysis (Arshad et al., 2007).

Table 1 Preparation of cookies with varying concentrations of red kidney beans

Treatments	Wheat Flour (%)	Red kidney beans (%)
T_0	100	0
T_1	97	3
T_2	94	6
T_3	91	9
T_4	88	12

Proximate analysis

The compositional (moisture, fat, protein, fiber, ash and carbohydrates) analysis of cookies was carried out according to the method of AOAC (2018) reported in the literature (Naqvi et al., 2022).

Physical analysis

The diameter and thickness of cookies were measured using Vernier caliper at various places of cookies and the average was calculated for each. Similarly, spread ratio of cookies was calculated using the formula: diameter of cookies divided by height of cookies (Chauhan et al., 2016).

Bulk density

The bulk density of cookies was determined using the suggested method described in the literature (Oguntoyinbo et al., 2021). In this method, a 100 mL cylinder containing 10g of cookies was tapped until a constant volume was reached. Following that, bulk density was computed using volume and weight.

Water holding capacity and water absorption capacity

Water holding capacity (WHC) and water absorption capacity (WAC) of cookies were measured using the recommended method, with minor modifications (Shah et al., 2017). After adding 10 mL of water to a test tube containing 1 g of powdered cookie sample, the mixture was allowed to remain at room temperature for 30 minutes before being centrifuged for 15 minutes at 3000 rpm. The reweighed evaporating dish was filled with the supernatant, which was then heated to 105°C in a hot air oven until the dry solids weight was consistent (Naw et al., 2019). The following formula was used to determine the water-holding capacity:

$$\text{WHC (\%)} = \frac{\text{Weight of wet sediments}}{\text{Weight ofdry solid}} \times 100$$

$$\text{WAC (\%)} = \frac{\text{Weight of dried solid in supernatant}}{\text{Weight of sample}} \times 100$$

Oil holding capacity and oil absorption capacity

Oil absorption capacity (OAC) and oil holding capacity (OHC) of cookies were assessed using the previously described methodology (Rapando et al., 2020). A test tube containing 1 g of powdered material and 10 mL of maize oil was left at room temperature for 30 minutes before being centrifuged for 15 minutes at 3000 rpm. A 10 mL graduated cylinder was used to measure the supernatant's volume:

$$\text{OHC}\ (\%) = \frac{\text{Weight of wet sediments}}{\text{Weight ofsample}} \times 100$$

$$\text{OAC}\ (\%) = \frac{\text{Initial volume of oil} - \text{Final volume of oil}}{\text{Weight of sample}} \times 100$$

Dietary fiber

The dietary fiber content of cookies was determined using the recommended methodology (AOAC, 2016). At room temperature, 1g of sample cookies was submerged in 40 mL of MES/TRIS buffer solution with a pH of 8.2. The sample was evenly mixed with the buffer solution using magnetic stirring. After adding 50 µL of alpha-amylase enzyme, the mixture was incubated in a water bath at 98–100°C for 30 minutes. The temperature was then lowered to 60°C. The mixture was then incubated for 30 minutes at 60°C with 200 µL of amyloglucosidase added. Afterwards, precipitation was done using 95% ethanol (1:4) that had been heated to 60°C. The resulting mixture was filtered, dried, and its protein and ash content were assessed. To examine the contribution of compounds to residue, a blank was also run.

$$\text{TDF}\ (\%) = \frac{\text{Residues weight} - \text{Protein} - \text{Ash} - \text{Blank}}{\text{Weight of sample}} \times 100$$

Color analysis

The color of the cookies was evaluated using a high-quality Colorimeter (ST-CP60, Stalwart, USA) (Khan et al., 2022). At different locations on the cookies, the L, a*, and b* values were recorded. Additionally, utilizing these fundamental characteristics, the following equations were used to calculate the change in color (ΔE), chroma (C*), and whiteness indexes (WI).

$$\Delta E = \sqrt{(L^* - L^*_{std})^2 + (a^* - a^*_{std})^2 + (b^* - b^*_{std})^2}$$

$$C^* = \sqrt{(a^*)^2 + (b^*)^2}$$

$$WI = 100 - \sqrt{(100 - L^*)^2 + (a^*)^2 + (b^*)^2}$$

Organoleptic properties

Organoleptic properties of cookies including color, texture, crispiness, taste, and overall acceptability were assessed by panelists using a 9-point hedonic scale. Twenty panelists, (ten men and ten women), with ages ranging from twenty to thirty, evaluated the cookies sensory qualities. Cookies were provided to the panelists at room temperature in white polystyrene plates. These cookies were labelled with a 3-digit code. Before each evaluation, the panelists were given water to rinse their mouths and wash away their taste buds (Khan et al., 2022; Asif et al., 2023; Asif et al., 2024).

Statistical analysis

All experiments were carried out in triplicate, and results are presented as the mean values along the standard deviation. The Tukey HSD test (α=0.05) was used to check the significance difference among treatments using Statistix 8.1 software.

Results and Discussion

Table 2 shows the proximate composition of cookies that were enriched with red kidney beans. The findings showed that the concentration of red kidney beans considerably ($P<0.05$) enhanced protein, fiber, and ash. In comparison to the control sample of cookies, the results showed that the protein content of cookies in T_1, T_2, T_3, and T_4 increased by 20, 37, 59.28, and 75%. Similarly, compared to the control sample, the fiber contents of enriched cookies rose 1.12, 1.24, 1.33, and 1.40 times in T_1, T_2, T_3, and T_4 ($P<0.05$). In contrast to the control sample, the ash content in T_4 rose by 63.75%. Red kidney beans, which are high in protein, fiber, and minerals, might be the cause of increase of fiber, protein and ash contents in cookies. As red kidney bean concentrations increased, cookies' carbohydrate content dramatically dropped (Singh et al., 2021). These results are consistent with the previous research reported in the literature (Cheng & Bhat, 2016).

Table 2 Proximate composition (%) of red kidney bean enriched cookies on dry basis

Treatments	Moisture	Fat	Protein	Fiber	Ash	Carbohydrates
T_0	5.40±0.27^{b}	23.00±1.15^{b}	14.00±0.70^{e}	1.10±0.05^{c}	0.80±0.04^{c}	55.70±2.78^{a}
T_1	5.90±0.29^{ab}	24.20±1.21^{ab}	16.80±0.84^{d}	1.23±0.06^{bc}	0.90±0.05^{c}	50.97±2.54^{ab}
T_2	6.30±0.31^{ab}	24.96±1.24^{ab}	19.20±0.96^{c}	1.37±0.07^{ab}	1.10±0.06^{b}	47.13±2.35^{bc}
T_3	6.50±0.33^{ab}	25.07±1.25^{ab}	22.30±1.11^{b}	1.47± 0.07^{a}	1.21±0.06^{ab}	43.42±2.17^{cd}
T_4	6.98±0.35^{a}	26.35±1.31^{a}	24.50±1.22^{a}	1.55±0.07^{a}	1.31±0.07^{a}	39.31±1.96^{d}

Physical analysis

The weight, diameter, thickness, and spread ratio of the cookies were determined, and the results are shown in Table 3. The addition of red kidney beans to the cookies increased their weight. T4 recorded the highest weight (9.02 g), which was 29.25%, 18.30%, 10.79%, and 7.38% higher than that of T_0, T_1, T_2, and T_3, respectively. This increase may be due to the high protein content added during cookie formation, which absorbed more water during dough preparation, thereby increasing the weight of the cookies (Bakara & Naibaho, 2024). These results align with previous findings (Aziah et al., 2012). Similarly, there was a noticeable decrease in the diameter of the cookies. The results showed that the diameter decreased as the amount of red kidney beans increased. T_4 had the maximum thickness (6.45 mm), which was 57.31% greater than that of the control sample. This effect may be due to the protein added to the cookies, which promoted stronger network formation among the ingredients, resulting in increased thickness (Yahya, 2004). These findings are consistent with prior research showing that cookies made with cassava/soybean/mango composite flour had a lower spread ratio and a thicker texture (Chinma & Gernah, 2007). As the concentration of red kidney beans increased, the spread ratio of the cookies decreased significantly ($p < 0.05$). This reduction could be attributed to the increased number of hydrophilic sites competing for the limited water available in the cookie dough (Kulthe et al., 2014). These results agree with a study that found that incorporating mixed composite flour containing legumes reduced the spread ratio (Vasanthakumari & Jaganmohan, 2018).

Table 3 Physical analysis of protein-fortified cookies

Treatments	Weight (g)	Diameter (mm)	Thickness (mm)	Spread ratio
T_0	8.07±0.40^{b}	46.0±0.23^{a}	4.10±0.20^{c}	11.21±0.56^{a}
T_1	8.81±0.44^{ab}	42.0±0.21^{ab}	4.50±0.22^{c}	9.33±0.46^{b}
T_2	8.86±0.45^{ab}	41.0±0.20^{ab}	5.25±0.26^{b}	7.80±0.39^{c}
T_3	8.89±0.45^{a}	40.0±0.20^{b}	6.25±0.31^{a}	6.40±0.31^{d}
T_4	9.02±0.46^{a}	39.0±0.19^{b}	6.45±0.32^{a}	6.04±0.28^{d}

Functional properties

Table 4 displays the functional characteristics of cookies that were measured. Supplementing cookies with red kidney beans resulted in a significant ($p<0.05$) drop in their bulk density. Moisture has an impact on cookies' bulk density (Ndife et al., 2014). Likewise, supplementation led to a considerable decrease in cookies' water-holding capacity (WHC). WHC rose 1.11 times when 3% red kidney beans were added in comparison to the control. Red kidney beans (12%) were added at a further rate, increasing the water-holding capacity by 1.80 times compared to the non-supplemented sample. It might be due to proteins which create a matrix that can hold a lot of water by arranging themselves into a three-dimensional network structure (Algarni et al., 2019). Furthermore, when compared to WHC, the oil holding capacity (OHC) of protein-enriched cookies showed the opposite behavior. The OHC was considerably reduced by increasing the red kidney bean concentrations. When 12% of red kidney beans were added to cookies, the OHC dropped by 51.93% from the control sample, which had the highest OHC. It might be due to the hydrophilic nature, mechanism of fat absorption, entrapment of oil and binding of fat to the polar chain of protein (Nawaz et al., 2019). The upsurge in water absorption capacity (WAC) of cookies dramatically dropped. The control group exhibited the highest capability for water absorption. In comparison to the control sample, the protein concentration in cookies dropped 0.96, 0.90, 0.80, and 0.77 times in T_1, T_2, T_3, and T_4. The protein concentration, protein characteristics, and degree of protein-water interaction can all be used to explain the WAC of red kidney bean flour and wheat flour. The WAC of cookies is also influenced by the relative surface distribution of hydrophilic and hydrophobic amino acids (Pauly et al., 2013). These results have been linked to earlier research (Dhankhar et al., 2021). Table 4 displays the oil absorption capacity (OAC) in cookies. It may be attributed that the addition of protein content and hydrophobic interaction of the protein with blended flour caused decreased OAC, which also serves to extend the shelf life and improve its palatability, particularly for baked goods like cakes, pancakes, and cookies (Chinma et al., 2009). These results are consistent with observations in the literature (Sibian & Riar, 2020).

Table 4 Functional properties of kidney beans supplemented cookies

Treatments	Bulk density (g/cm^3)	WHC (%)	WAC (%)	OHC (%)	OAC (%)
T_0	8.83±0.44^{a}	1.15±0.05^{d}	9.01±0.45^{a}	1.84±0.092^{c}	1.30±0.065^{d}
T_1	6.90±0.34^{b}	1.28±0.06^{cd}	8.68±0.43^{ab}	1.92±0.096^{c}	1.40±0.070^{cd}
T_2	6.62±0.33^{bc}	1.46± 0.07^{c}	8.17±0.40^{b}	2.38±0.119^{b}	1.50±0.075^{bc}
T_3	6.50±0.32^{bc}	1.68±0.084^{b}	7.28±0.36^{c}	2.50±0.125^{ab}	1.60±0.080^{ab}
T_4	6.01±0.30^{c}	2.08±0.104^{a}	7.00±0.35^{c}	2.78±0.137^{a}	1.70±0.085^{a}

Dietary fiber

Dietary fiber is an indigestible component of carbohydrates that has poor gastrointestinal tract digestibility. According to Maphosa and Jideani (2016), it offers numerous health advantages for the upkeep and wellness of the gastrointestinal system. Dietary fiber content in cookies was measured, and results are depicted in Fig. 1. The findings showed that there was a noticeable increase in dietary fiber in cookies. Dietary fiber increased to 4.0 g/100 g when red kidney beans (5%) were added to cookies. Higher dietary fiber content (5.11%) was the outcome of a 9% increase in red kidney bean concentration. The cookies with 12% red kidney beans had the highest dietary fiber level (Fig. 1). When compared to the control sample, the increase in dietary fiber was 2.52 times. The substitution of red kidney beans in cookies may upsurge the dietary fiber content in cookies. These results have been linked to previous research (Damat et al., 2019).

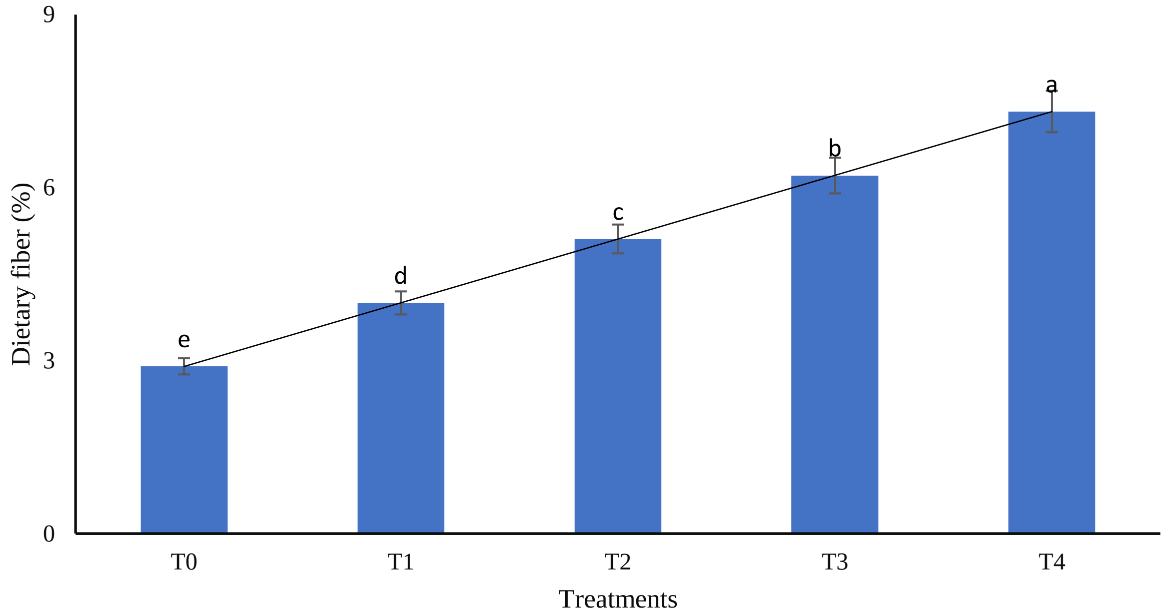

Fig. 1 Effect of varying concentrations of red kidney beans on dietary fiber content of cookies

Mineral contents

Table 5 lists the mineral contents of cookies that have been supplemented. The findings showed that the mineral content of cookies is significantly impacted by the addition of red kidney beans. In comparison to the non-supplemented sample, the iron content of cookies rose to 5.85, 14.63, 34.14, and 52.19% in T_1, T_2, T_3, and T_4. Similarly, adding 3, 6, 9, and 12% more red kidney beans to cookies raised their phosphorus level by 1.13, 1.26, 1.39, and 1.53 times compared to the control sample. Furthermore, compared to the control sample, the calcium content in T_1, T_2, T_3, and T_4 increased by 7.55, 16.83, 28.76, and 44.26% when the concentration of red kidney beans increased. In contrast, cookies supplemented with 3, 6, 9, and 12% red kidney beans had a magnesium level that was 1.02, 1.06, 1.11, and 1.13 times higher than that of a non-supplemented sample. The addition of red kidney beans, which are high in minerals, might be the cause. These results are consistent with the published research (Zhang et al., 2017; Noah & Banjo, 2020).

Table 5 Mineral composition in protein fortified cookies

Treatments	Iron (mg/100g)	Phosphorus (mg/100g)	Calcium (mg/100g)	Magnesium (mg/100g)
T_0	2.05±0.102^{d}	26.96±1.34^{d}	23.29±1.16^{d}	2.66±0.133^{c}
T_1	2.17±0.108^{cd}	30.49±1.52^{cd}	25.05±1.25^{cd}	2.73±0.136^{bc}
T_2	2.35± 0.117^{c}	34.03± 1.77^{bc}	27.21± 1.36^{bc}	2.84±0.142^{abc}
T_3	2.75±0.137^{b}	37.74±1.88^{ab}	29.99±1.49^{ab}	2.96±0.148^{ab}
T_4	3.12±0.156^{a}	41.45±2.07^{a}	33.60±1.68^{a}	3.03±0.152^{a}

Color analysis

One of the intricate quality factors that influence consumer acceptability before product consumption is color. Red kidney beans were added to wheat flour in varying amounts (0, 3, 6, 9, and 12%) to make the cookies shown in Fig. 2. Color, texture, taste, and general acceptability were among the various sensory evaluations of the enhanced cookies. The L*, a*, and b* were used to calculate the change in color, chroma, and whiteness index (Table 6). When compared to the control sample, the value of ΔE rose to 12.37, indicating a substantial shift. However, there was no discernible change in the chroma values. However, the whiteness index is considerably (P<0.05) impacted by increasing the percentage of red kidney beans in cookies, causing the hue to change from brown to dark brown. The cookies color during baking can be ascribed to both starch dextrinization and sugar caramelization, as well as non-enzymatic browning that occurs during baking between reducing sugars and amino acids (Gómez et al., 2008; Zucco et al., 2011). The results of earlier research relate to these findings (Bakar & Naibaho, 2024).

Table 6 ΔE, chroma and WI of fortified cookies

Treatments	L*	a*	b*	ΔE	Chroma	WI
T$_0$	65.33±3.3^{a}	8.52±0.4^{b}	30.61±1.5^{a}	0.00±0^{e}	31.77±1.58^{a}	52.97±2.64^{a}
T$_1$	58.93±2.9^{ab}	8.69±0.4^{b}	28.96±1.4^{ab}	6.61±0.3^{d}	30.23±1.51^{ab}	49.00±2.45^{ab}
T$_2$	57.77±2.9^{ab}	8.78±0.4^{b}	27.99±1.3^{b}	8.00±0.4^{c}	29.43±1.47^{ab}	48.58±2.42^{ab}
T$_3$	56.65±2.8^{b}	8.88±0.4^{b}	27.63±1.3^{b}	9.18±0.5^{b}	29.31±1.46^{ab}	47.83±2.39^{b}
T$_4$	53.11±2.6^{b}	10.4±0.5^{a}	27.45±1.4^{b}	12.37±0.6^{a}	29.01±1.45^{b}	44.67±2.23^{b}

ΔE = Total color difference; WI = Whiteness index; L*, a*, and b* denote the change in color

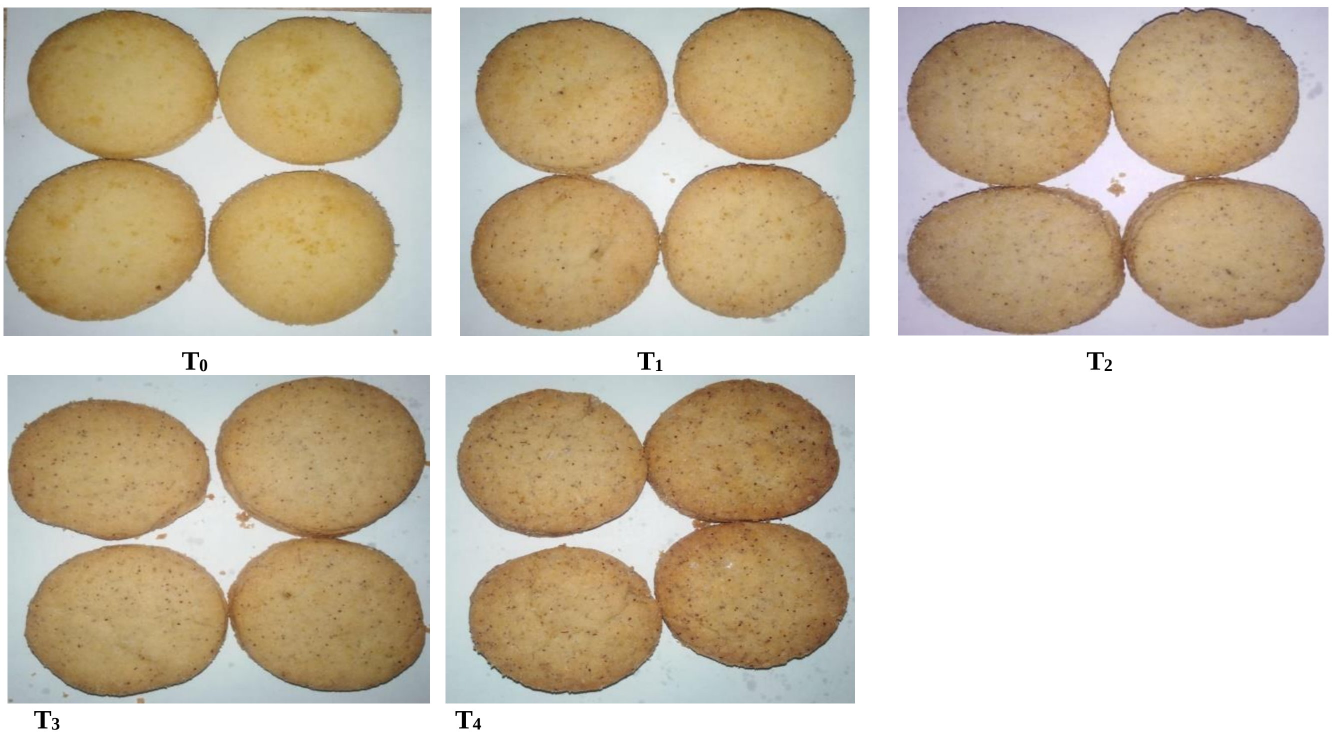

Fig. 2 Visual appearance of cookies fortified with increasing concentrations of red kidney bean flour: T0 (100% wheat flour, 0% red kidney beans), T1 (97: 3), T2 (94: 6), T3 (91: 9), and T4 (88: 12). A progressive darkening in cookie color is evident as the percentage of red kidney beans increases, shifting from light brown in T0 to dark brown in T4. This change corresponds with instrumental color analysis, which showed a significant rise in total color difference (ΔE) and a decrease in whiteness index (WI), while chroma remained relatively stable.

Sensory evaluation

The commercial and consumer acceptance of food products is determined by their sensory evaluation. In this context, a panel of unskilled workers assessed cookies on color, texture, crispiness, and general acceptance; the outcomes are shown in Fig. 3. The findings showed that adding red kidney beans to cookies had an impact on the sensory qualities and reduced the sensory score. The Maillard reaction between sugars and amino acids causes cookies to turn from brown to dark brown. These findings are consistent with those of published literature (Gani et al., 2015). Since more water is required for dough development, adding protein sources to cookies results in a harder texture. In a similar vein, cookies with over 9% red kidney beans score lower across the board. Accordingly, the results showed that adding red kidney beans to cookies was okay with up to 9% supplementation.

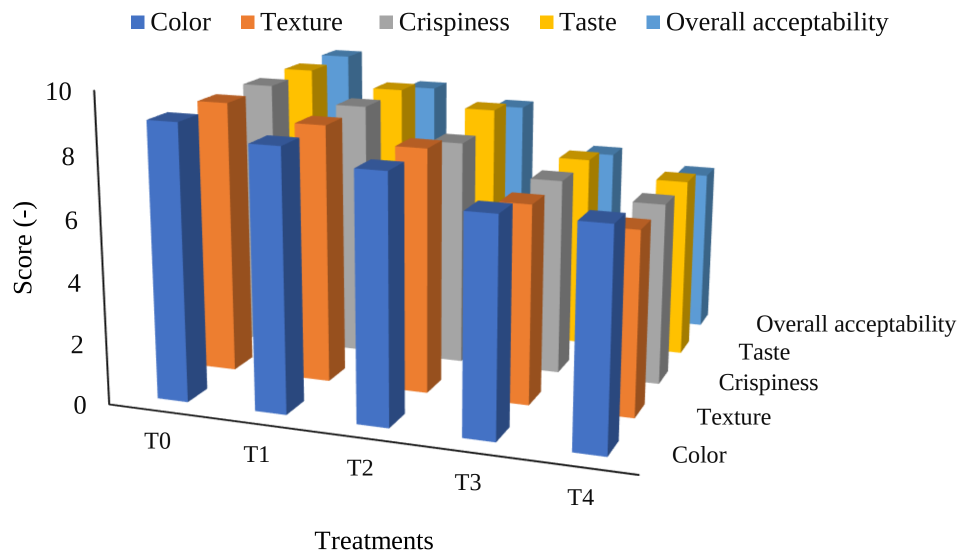

Fig. 3 Sensory attributes of cookies supplemented with red kidney beans

Conclusion

The aim of this study was the development of cookies by incorporating red kidney beans into wheat flour to increase the protein content of cookies. Results revealed that the incorporation of red kidney beans in cookies significantly increased the protein content (1.75), and dietary fiber (2.52) times as compared to the control. Likewise, the addition of red kidney beans in cookies significantly increased the weight and thickness of cookies. However, the diameter and spread ratio of cookies were significantly decreased. Moreover, the inclusion of red kidney beans significantly enhances the functional properties and mineral composition of cookies. Results of sensory evaluation showed that up to 9% (T_3) of red kidney beans in cookies were acceptable. Conclusively, the supplementation of different types of beans or pulses will help to reduce wheat import issues in the country and will also assist in the production of bakery food items with better nutritional profiles and sensorial acceptability.

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