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Research paper

Formulation of Diabetes-Targeted Product with Flaxseed and Chirayita for Optimised Glycemic Control

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ABSTRACT

The rising demand for functional foods has driven the incorporation of bioactive ingredients into bakery products. This study developed a functional bread using wheat flour, chickpea flour, roasted flaxseed powder and chirayita, to enhance nutritional quality and therapeutic value. Compared with conventional wheat bread, the enriched formulation showed higher crude fiber (22.35 ± 0.33 g/100 g vs. 15.67 ± 0.21 g/100 g) and reduced carbohydrate content (40.54 ± 0.30 g/100 g vs. 64.17 ± 0.30 g/100 g). Gluten quality was markedly lower, with wet gluten (8.74%) and dry gluten (3.1%) well below control values (31.2% and 10.46%), reflecting the impact of fiber enrichment on gluten structure. Anti-nutrient analysis indicated a decline in phytic acid (4.2 mg/100 g vs. 5.5 mg/100 g), suggesting improved mineral bioavailability. Although the glycemic load of the sample bread (121.44) was slightly higher than the control (101.41), the presence of resistant starch, soluble fiber, and bioactive compounds contributed to slower starch digestion and moderated glycemic response. Functional evaluation showed stronger α-amylase inhibition (76.8 ± 2.28 U/L vs. 71.99 ± 3.11 U/L), while sugar and starch levels remained within acceptable ranges compared to market bread. Sensory analysis confirmed consumer acceptability at optimized chirayita levels. The enriched bread exhibited increased fiber content, reduced gluten levels, notable enzyme inhibitory activity, and promising anti-diabetic potential, underscoring its value as a functional food for dietary management.

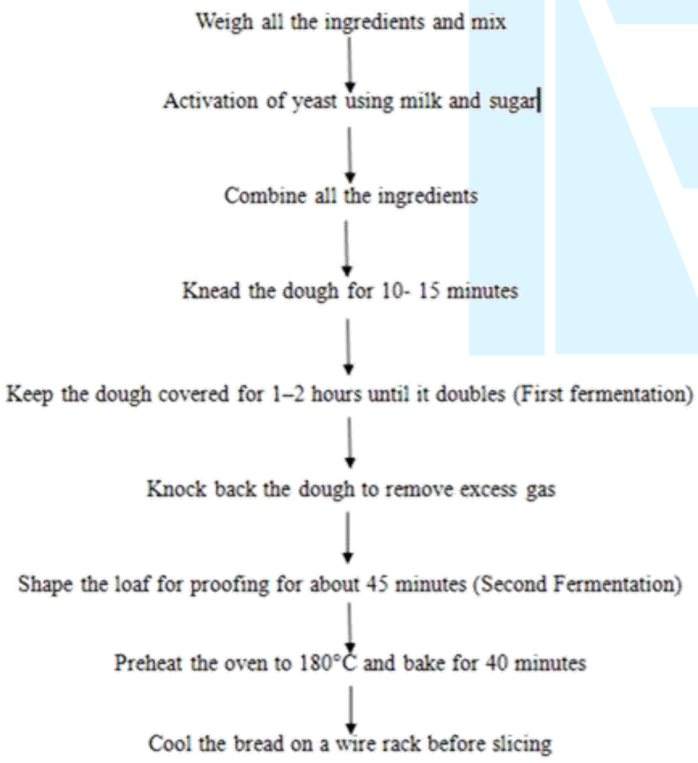
1. Introduction

The increasing demand for functional foods has led to the development of value-added bakery products enriched with bioactive ingredients. In this study, a novel bread formulation was prepared using wheat flour, besan (chickpea powder), roasted flaxseed powder, yeast and chirayita, aiming to enhance the nutritional and therapeutic profile of traditional wheat bread. Chickpea can reduce postprandial blood sugar levels & regular consumption of chickpea has been linked to improved glycemic control and reduced risk of type 2 diabetes. (Taylor *et al.,* 2016). Flaxseed, known for its high content of omega-3 fatty acids, lignans, and soluble fiber, has shown potential in improving insulin sensitivity and lowering blood glucose levels (Shams *et al.,* 2022). Chirayita, a traditional medicinal herb, possesses anti-diabetic and antioxidant properties, further contributing to the formulation's therapeutic value (Swati *et al.,* 2023). The prepared bread was subjected to proximate and biochemical analysis and compared with standard wheat bread to assess improvements in nutritional quality. This study not only highlights the health-promoting potential of flaxseed but also demonstrates the feasibility of integrating medicinal herbs and high-fiber flours in conventional baking processes to produce nutritionally superior alternatives. The results provide insights into the application of plant-based functional ingredients in bakery products for improved dietary interventions.

2. Materials and Methods

2.1 Procurement of raw materials

The bread was prepared using a combination of whole wheat flour, chickpea flour (besan), roasted flaxseed powder, chirayita powder, milk, unsalted butter, active dry yeast, salt, sugar, and flavoring ingredients such as fresh garlic, dried oregano, and chilli flakes. The ingredients were sourced from D-Mart supermarkets located in Bengaluru, India, while chirayita powder was obtained separately from the Patanjali Ayurvedic outlet. Roasted flaxseed powder was obtained by dry roasting whole flaxseeds for 5 minutes and grinding them into a fine powder using a mixer grinder.



Flowchart 1 Steps involved in the preparation of bread

2.2 Preparation of Bread

2.2.1 Formulations

Various bread trials were prepared, including a control (NB) using only wheat flour, and two experimental trials incorporating chickpea flour, flaxseed powder, and chirayita (SB1 and SB2), as presented in Table 1. The measured quantities of wheat flour, chickpea flour, flaxseed powder, chirayita, salt, oregano, and chili flakes were first combined and mixed uniformly. For leavening, 6 g of active dry yeast was activated in 50 mL lukewarm milk with 1 teaspoon of sugar and left for 10 minutes. The wet ingredients lukewarm milk, melted butter, minced garlic, sugar, activated yeast and water were gradually added to the dry mixture. The dough was kneaded for 10–12 minutes until smooth and elastic, placed in a greased bowl, covered, and proofed for one hour until doubled in size. After the first proofing, the dough was deflated, shaped into a loaf, and subjected to a second proofing for 45 minutes. Baking was carried out at 180 °C for 40 minutes until a golden-brown crust developed. Once cooled, the loaves were dried in a hot air oven and packed in airtight wraps for subsequent nutritional analysis.

Table 1 Formulations of the developed product

Ingredients	NB*	SB1*	SB2*
Whole Wheat Flour (g)	200	180	180
Chickpea powder (g)	-	20	20
Flaxseed powder (g)	-	20	20
Chirayita (g)	-	0.4	0.5
Milk (ml)	100	100	100
Butter (g)	15	15	15
Yeast (g)	6	6	6
Salt (g)	3	3	3
Garlic (g)	6	6	6
Oregano (g)	3	3	3
Chilli flakes (g)	3	3	3
Sugar (g)	5	5	5

*NB- Normal bread; *SB1- Sample bread 1; *SB2- Sample bread

2.3 Sensory Evaluation

A sensory evaluation was conducted to determine the acceptability of fiber-rich bread using a nine-point hedonic scale. The assessment was carried out by 20 semi-trained panellists at Padmashree Institute of Management & Sciences, who evaluated key attributes such as appearance, color, texture, taste, flavor, odor, and overall acceptability. (Mohan and Gupta, 2015).

2.4 Nutritional Analysis

The nutritional composition of chirayita and the developed product was evaluated using standard methods. Moisture was determined by the evaporation method (AOAC 930.04), protein by the Kjeldahl method (AOAC 978.04), fat by the Soxhlet extraction (AOAC 930.09), crude fiber (AOAC 930.10) and ash using a muffle furnace (AOAC 930.05), and carbohydrates were calculated by the difference method (Wijaya and Romulo, 2021). Energy content was estimated by the calculation method (Food energy- methods of analysis and conversion factors: 2003). The estimation of total sugars and starch was performed using the Lane-Eynon titration method (Zerban *et al.,* 1946). Ascorbic acid was measured using the iodometric technique described (Bhavya *et* *al.* 2023), and iron content was determined via the ammonium thiocyanate method (Goswami and Kalita, 1988). Calcium was measured via EDTA complexometric titration (Bird *et al.,* 1961).

2.5 Qualitative tests for Phytochemicals and Carcinogen precursors

2.5.1 Phenols

To detect phenolic compounds, 1 mL of the extract was treated with three drops of ferric chloride, followed by 1 mL of potassium ferricyanide solution. The appearance of a greenish-blue coloration indicated a positive result (Sileshi et al., 2023).

2.5.2 Tannins

About 200 mg of the extract was warmed in 10 mL of distilled water, followed by the addition of a 0.1% ferric chloride solution. The development of a blue-black coloration was taken as evidence for the presence of tannins (Sileshi et al., 2023).

2.5.3 Asparagine

1 ml of the test solution was placed in a test tube, followed by the addition of a few drops of 2% ninhydrin reagent. The tube was placed in a water bath for 5 minutes of heating and then allowed to cool down to room temperature. The appearance of a brown coloration confirmed the presence of asparagine (Dhrumi et al., 2022).

2.6 Total phenol and Amylase activity

Total phenolic content, indicative of antioxidant capacity, was assessed using the Folin-Ciocalteu reagent method (Tambe and Bhambar, 2014). The anti-nutrients, including phytic acid were estimated using the Wade reagent method (Gai *et al.,* 2007) and tannins by the Folin-Ciocalteu (FC) method (Tambe and Bhambar, 2014), respectively. Amylase activity inhibition (Bhutkar and Bhise, 2012) was also assessed for both chirayita and the developed product.

2.7 Determination of Gluten Content

To determine gluten content, 25 g of flour was mixed with 15 ml water to form a dough, which was hydrated for one hour. The dough was then washed under running water over a fine sieve to remove starch, confirmed by a negative iodine test. The remaining cohesive mass was collected as wet gluten, pressed, and weighed. It was then dried in a hot air oven at 130–133 °C for two hours. Once cooled in a desiccator, the dried gluten was weighed to determine its content. (Mohan and Gupta, 2015)

2.8 Glycemic Index and Glycemic Load

The glycemic index (GI) of carbohydrate-containing foods indicates the rate at which they are digested and absorbed, influencing the rise in blood glucose levels. Glycemic load (GL) is determined by multiplying the GI value with the amount of available carbohydrates present in a given serving. (Augustin *et al.,* 2015)

2.9 Statistical analysis

The data were reported as means ± standard deviation (SD) and statistical analysis primarily utilized graphs and calculations, using Microsoft Excel for tabulation. A Student's t-test was conducted to determine P-value to check its significance (*P ≥0.05). The results were presented in tables, accompanied by discussion.

3. Results and Discussion

For bread development, flaxseeds were first roasted on low heat for 5 minutes and then ground into a fine powder before incorporation into the dough. The mixing process facilitated flour hydration and initiated gluten formation, while the addition of salt strengthened the gluten network and helped regulate yeast activity. Kneading enhances gluten development, improving dough elasticity and its capacity to retain air. During fermentation, yeast metabolized available sugars to produce carbon dioxide and ethanol, which leavened the dough and contributed to flavor through the formation of organic acids. Subsequent shaping and proofing allowed redistribution of gases and further expansion. Baking induced starch gelatinization and gluten coagulation, which stabilized the bread's internal structure, while Maillard reactions and caramelization generated the crust's characteristic color, aroma, and flavor. Finally, cooling stabilized the loaf as starch retrogradation began, a natural process associated with staling (Mesta *et al.,* 2024).

3.1 Sensory evaluation

The sensory evaluation of the normal and sample breads of variations (0.4 and 0.5) as shown in Table 6. The normal bread was overall acceptable (7.35). The overall acceptability of sample breads of variations 0.4 and 0.5 was (6.95 and 6.35). Compounds such as chiratin and ophelic acid present in chirayita are primarily responsible for imparting its characteristic bitterness (Swati *et al.,* 2023), which influenced the sensory properties of the bread. The incorporation of chirayita at 0.4 g and 0.5 g levels slightly reduced overall acceptability, with the 0.4 g variation being comparatively more acceptable to the panelists.

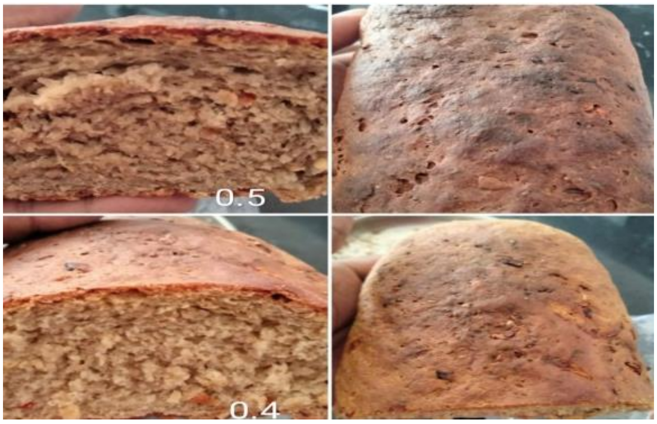
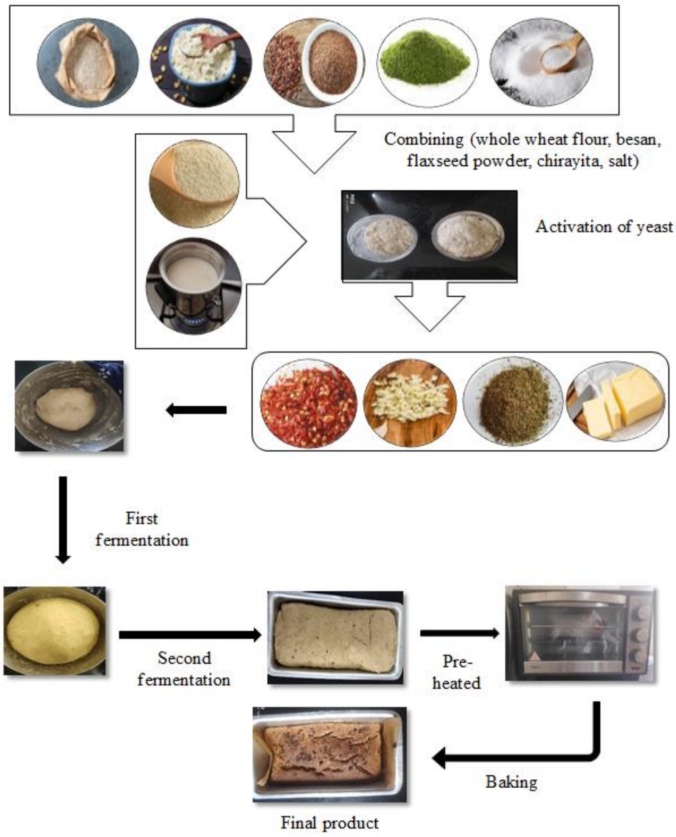


Fig. 1 Developed product



Flowchart 2 Preparation of bread

3.2 Nutritional Analysis

Chirayita is a medicinal plant that is helpful for the management of diabetes. The powdered form of the chirayita was used in the preparation of bread. The nutritional analysis of chirayita found to have protein content (20.93 ±3.98 g/100g), fat (1.77±0.81 g/100g), crude fiber (5.77±0.21 g/100g), ash (15±0.42 g/100g), carbohydrate (56.03±5.5 g/100g), moisture (0.45±0.007 g/100g) and energy (323.85±1.20 kcal/100g) was determined as depicted in Table 2. The ascorbic acid was found to be (0.023±0.00 g/100g), iron content (26.16±3.06 mg/100g), calcium (400±0.00 mg/100g) and functional components such as total phenol content of chirayita was found to be (3.4 ±0.28 mg GAE/100g). *Swertia chirayita* exhibits strong antidiabetic activity due to compounds like swerchirin, mangiferin, swertiamarin, amarogentin, and gentianine, which enhance insulin secretion, inhibit carbohydrate-digesting enzymes, and reduce oxidative stress (Dey *et al.,* 2020). Hence roasted flaxseeds, chickpea powder, and chirayita were incorporated into the developed product due to their rich nutritional profile and well documented antidiabetic properties, which contribute to the development of a functional and health-promoting food. The nutritional content was determined for the developed product, wherein protein was significantly higher (P = 0.06) in SB (17.5 ±0 g/100g) when compared with NB (11.25±1.76 g/100g). The crude fat content of was relatively higher in sample bread (14.97±0.45 g/100g) than that of normal bread (3.55±1.62 g/100g). Crude fiber content in the sample bread (22.35±0.33 g/100g) was higher than that of normal bread (15.67±0.21 g/100g). The moisture content of the sample bread (0.58±0.00%) was significantly (P= 0.05) lower than normal bread (0.9±0.07%). The changes also observed in (Musa *et al.,* 2016) which was between wheat bran flour bread (WB) and chickpea bran incorporated wheat bread (CPB), where the moisture content of WB (7.8%) was higher than CPB (7.2%) and crude fiber of CPB (28.5%) was higher than WB (9.6%). The carbohydrate content in the sample bread (40.54±0.30 g/100g) was significantly lower when compared to that of the normal bread (64.17±0.30 g/100g) (P= 0.05). The ash content was lower in sample bread (4.05±0.49 g/100g) compared to normal bread (4.45±0.21 g/100g) (P= 0.14). The energy in the sample bread (366.17±3.5 kcal/100g) is relatively higher than the normal bread (195.45±7.4 kcal/100g). There were no changes observed in the ascorbic acid content of both normal bread (0.011±0.00 g/100g) and sample bread (0.011±0.00 g/100g). The iron content of sample bread (32.5±3.53 mg/100g) was significantly (P= 0.18) higher than normal bread (27.65±7.99 mg/100g). The calcium in the sample bread (440±0.00 mg/100g) was higher when compared with the normal bread (200±0.00 mg/100g). Flaxseed is considered a promising functional food because it contains valuable nutrients, including lignans, soluble fiber, phenolic compounds, alpha-linolenic acid (ALA), and high-quality proteins (Pramanik *et al.,* 2023). Studies shown that chickpeas help lower postprandial blood sugar levels, and regular intake of chickpeas has been associated with improved glycemic control and a reduced risk of type 2 diabetes (Taylor et al., 2016).

Fig. 2 Estimation of Phenols

3.3 Phytochemicals and Carcinogen Precursors

The presence of total phenols, tannins and asparagine was determined using the qualitative tests for tannins and phenols the absence of them are shown in Table 4. The results were found to be negative where there was no presence of phenols, tannins and asparagine in both normal and sample bread. Free asparagine in bread dough plays a pivotal role in the formation of acrylamide during baking, as it reacts with reducing sugars via the Maillard reaction, leading to the generation of acrylamide (Cankaya *et al.,* 2025).

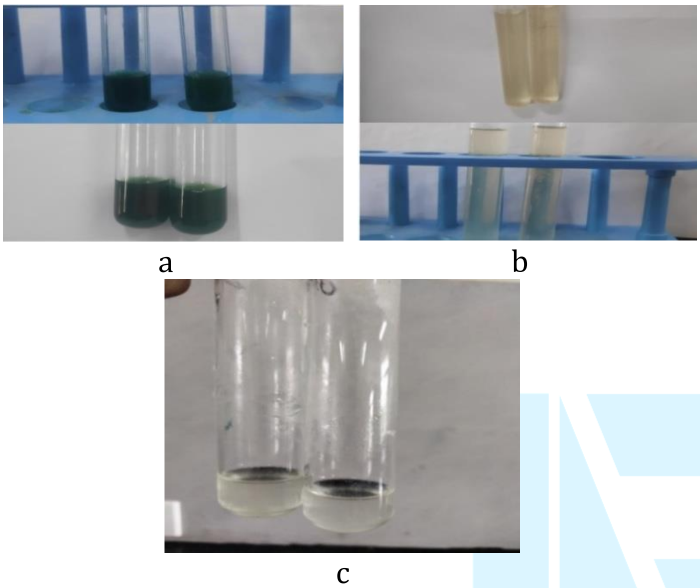


Fig. 3 Qualitative Tests for; a- Phenols; b- Tannins; c- Asparagine

3.4 Anti-nutrients

The anti-nutrient such as phytic acid and tannin contents of chirayita was (9.3 ±0.00 mg/100g) and (1.2 ±0.10 mg GAE/100g). The phytic acid decreased in the sample bread (4.2±0.00 mg/100g) when compared to normal bread (5.5±0.00 mg/100g). Phytic acid is heat-labile, and exposure to roasting or other dry-heat treatments can break down its molecular structure or reduce its stability, leading to a noticeable decrease in its levels (Pandey and Awasthi, 2013). According to (Longin *et al.,* 2023), phytic acid reduction in bread is mainly achieved through long fermentation, which enhances phytase activity and hydrolyzes phytate.

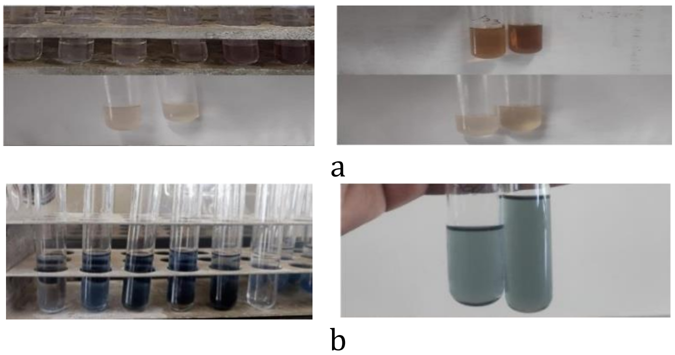


Fig. 4 Estimation of a- Phytic acid; b- Tannins

3.5 Amylase activity inhibition

The α-amylase inhibition test is used to assess how much a food slows the breakdown of starch into sugars, which is crucial for diabetic-friendly products because inhibiting this enzyme delays glucose release and reduces post-meal blood sugar spikes (Tundis *et al.,* 2010). The α-amylase activity inhibition of chirayita was found to be (60.75±2.28 U/L) and it was highly inhibited in sample bread (76.8±2.28 U/L) when compared to normal bread (71.99±3.11 U/L). Whole wheat flour contributes fiber and resistant starch, which physically restricts enzyme access to starch, thereby slowing enzymatic hydrolysis (fiber forms a physical barrier, slowing hydrolysis in whole grain and wholemeal; resistant starch is markedly higher in whole grain wheat versus refined flour) (Snow and O'Dea, 1981). An experimental study, where chirayita extract was injected to streptozotocin induced diabetic albino rats have showed significant blood glucose reduction (from 250.62 ± 2.35 mg/dl to 86.5 ± 2.85 mg/dl by day 21) along with improved lipid profile and organ protection, highlighting its potential as a natural therapy for diabetes management (Dey *et al.,* 2020).

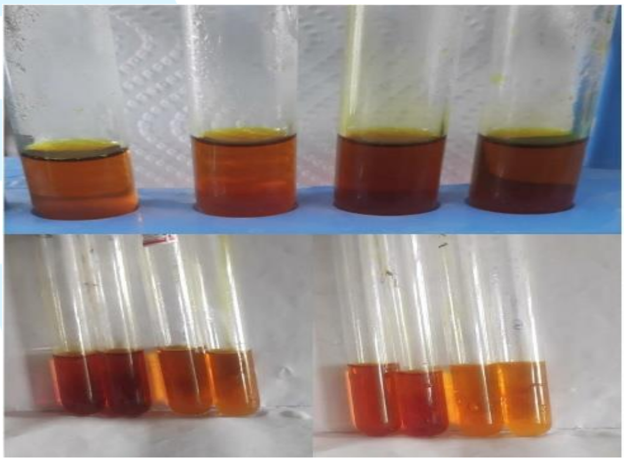


Fig. 5 Estimation of Amylase Activity Inhibition

3.6 Total sugars and Starch content

The total sugar content in the sample bread (14.1 ± 0.14%) was higher than in normal bread (10.05 ± 0.07%) but remained below that of market bread (16.45 ± 1.06%). The starch content followed a similar trend, with the sample bread (26.25 ± 0.00%) exceeding normal bread (19.6 ± 0.14%) yet slightly lower than market bread (27.75 ± 0.00%). Processing techniques such as roasting and baking can help increase the resistant starch content (Vaidya and Sheth, 2011). Resistant starch reduces the proportion of rapidly digestible starch, resulting in a slower release of glucose. Upon reaching the colon, it undergoes fermentation to produce short-chain fatty acids, which play a role in improving insulin sensitivity and supporting glucose regulation in the liver. (Trunckle *et al.,* 2024).

Fig. 6 Determination of Total sugars and Starch content

3.7 Glycemic index and Glycemic load

Glycemic index and Glycemic load of normal bread and sample bread were determined by using the calculative method and the results are shown in the Table 9. The overall glycemic load of the sample bread (121.44) was slightly higher than normal bread (101.41). A similar study conducted (Goni and Carmen 2003) demonstrated that the incorporation of chickpea flour into wheat spaghetti significantly reduced its glycemic index, lowering it from 73 ± 5 in regular wheat spaghetti to 58 ± 6 in the chickpea flour–enriched version. Research suggests that the inclusion of chickpea flour may help reduce postprandial blood glucose levels in individuals with diabetes, attributed to its low-glycemic-index carbohydrates, resistant starch, and bioactive compounds that delay starch digestion and glucose absorption. (Nam *et al.,* 2023).

3.8 Gluten

Gluten is a protein complex primarily composed of gliadin and glutenin, and both its amount and quality vary depending on factors such as wheat variety, growing conditions, and milling process. These variations determine the suitability of wheat flour for different products in terms of texture, structure, and application (Mohan & Gupta, 2015). In the present study, the wet gluten content of the sample bread (8.74%) was notably lower than that of normal bread (31.2%), while its dry gluten content (3.1%) was also reduced compared to normal bread (10.46%). This reduction can be attributed to the higher fiber content, as increasing fiber in bread formulations is known to decrease gluten levels (Mohan & Gupta, 2015). Furthermore, a pilot study in adolescents newly diagnosed with type 1 diabetes (without celiac disease) found that adherence to a low- or gluten-free diet improved glycemic control, with HbA1c levels dropping from 7.8% to 5.8–6.0% and fasting glucose remaining stable without insulintherapy for up to 20 months post-diagnosis (Antvorskov et al., 2014).

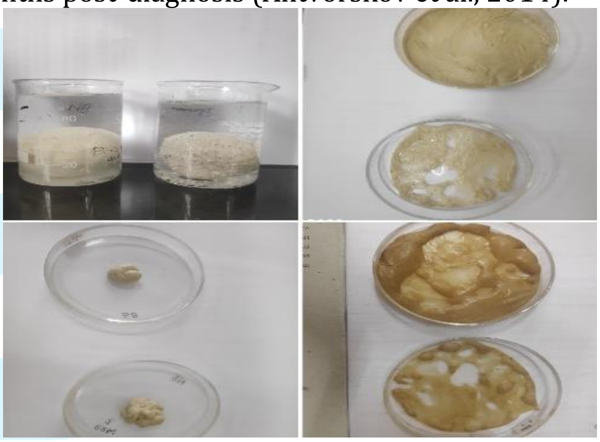


Fig. 7 Determination of Gluten content

Table 2 Sensory Evaluation of Bread

Trail	Appearance	Taste	Texture	Aroma	Overall acceptability
NB*	7.6±1.14	7±0.79	6.9±0.91	7.4±0.75	7.35±0.81
SB1	6.9±1.16	6.9±1.29	6.8±1.15	6.55±1.31	6.95±1.27
SB 2	6.45±0.99	5.9±1.37	6.45±0.99	6.65±1.08	6.35±1.08

*NB- Normal Bread; *SB1- Sample bread 1; *SB2- Sample bread 2

Table 3 Nutritional Composition of the developed products

Nutrient	CH	NB	SB
Energy (kcal)	323.85±1.20	195.45±7.4	366.17±3.5
Moisture (%)	0.45±0.007	0.9±0.07	0.58±0*
Carbohydrates (g)	56.03±5.5	64.17±0.30	40.54±0.30*
Protein (g)	20.93±3.98	11.25±1.76	17.5±0*
Fat (g)	1.77±0.81	3.55±1.62	14.97±0.45
Crude Fiber (g)	5.77±0.21	15.67±0.21	22.35±0.33
Ash (g)	15±0.42	4.45±0.21	4.05±0.49*
Ascorbic acid (g)	0.023±0	0.011±0	0.011±0
Iron (mg)	26.16±3.06	27.65±7.99	32.5±3.53*
Calcium (mg)	400±0	200±0	440±0

*CH- Chirayita; *NB- Normal Bread; *SB- Sample Bread;
Values are means ± standard deviations; n=2; *P ≥ 0.05 (significance)

Table 4 Phytochemical and Carcinogen precursor analysis of the developed product

Phytochemicals and carcinogenic precursor	NB*	SB*
Phenols (mg)	-	-
Tannins (mg)	-	-
Asparagine (mg)	-	-

(-ve) -negative; *NB- Normal Bread; *SB- Sample Bread

Table 5 Anti- Nutrients Composition of the developed product

Anti- Nutrient	CH (mg/100g)	NB* (mg/100g)	SB*(mg/100g)
Tannins (mg)	1.2±0.10	-	-
Phytic acid (mg)	9.3±0	5.5±0	4.2±0

CH- Chirayita; *NB- Normal Bread; *SB- Sample Bread;
Values are means ± standard deviations; n=2; *P ≥ 0.05 (significance)

Table 6 Amylase Inhibition of the developed product

α- Amylase inhibition	CH* (mg/100g)	NB* (mg/100g)	SB*(mg/100g)
α- Amylase inhibition (U/L)	60.75±2.28	71.99±3.11	76.8±2.28

CH- Chirayita; *NB- Normal Bread; *SB- Sample Bread;
Values are means ± standard deviations; n=2; *P ≥ 0.05 (significance)

Table 7 Study on the diabetic profile of the developed product

Nutrients	NB	SB	MB
Carbohydrates (g)	64.17±0.30	40.54±0.30*	44.2±1.06
Starch (%)	19.6±0.14	26.25±0	27.75±0
Total sugar (%)	10.05±0.07	14.1±0.14*	16.45±1.06

(n=2); *NB- Normal Bread; *SB- Sample Bread; *MB- Market Bread;
values are means ± standard deviations; *P ≥ 0.05 (significance)

Table 8 Glycemic index and Glycemic load of sample bread

Bread variations	Glycemic index	Glycemic load
NB*	145	101.41
SB*	208	121.44

*NB- Normal Bread; *SB- Sample Bread

Table 9 Determination of Gluten content in developed product

Bread variations	Wet gluten	Dry gluten
NB* (%)	31.2	10.46
SB* (%)	8.74	3.1

*NB- Normal Bread; *SB- Sample Bread

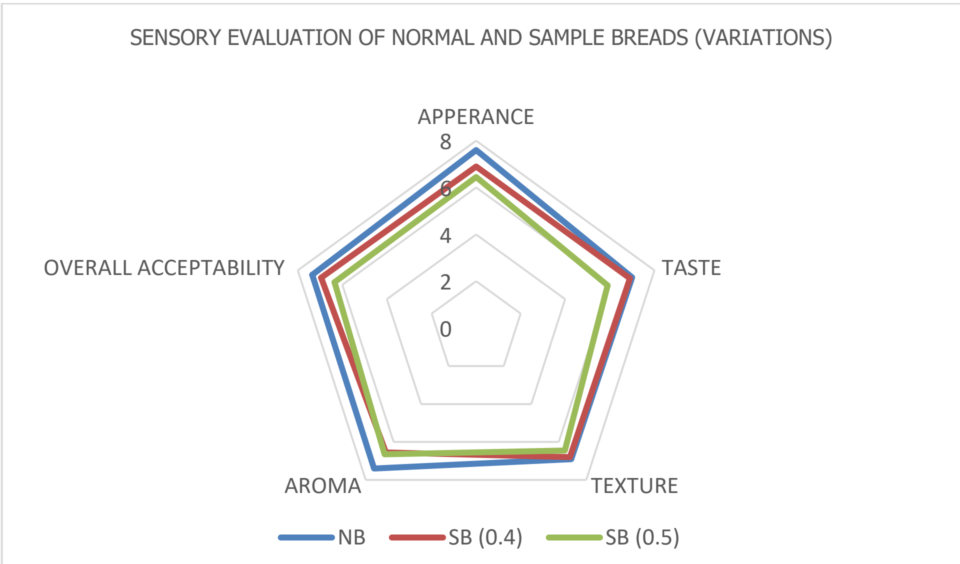


Fig. 8 Sensory Evaluation of bread

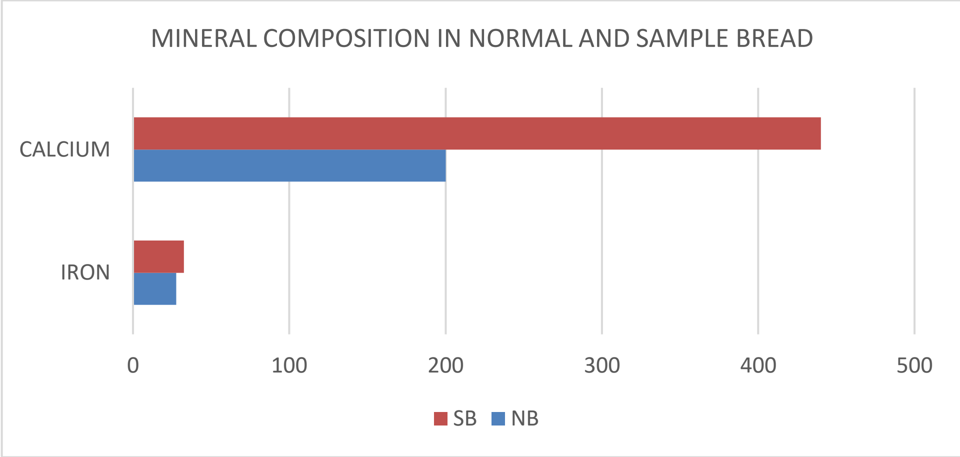


Fig. 9 Mineral composition of Normal and Sample bread

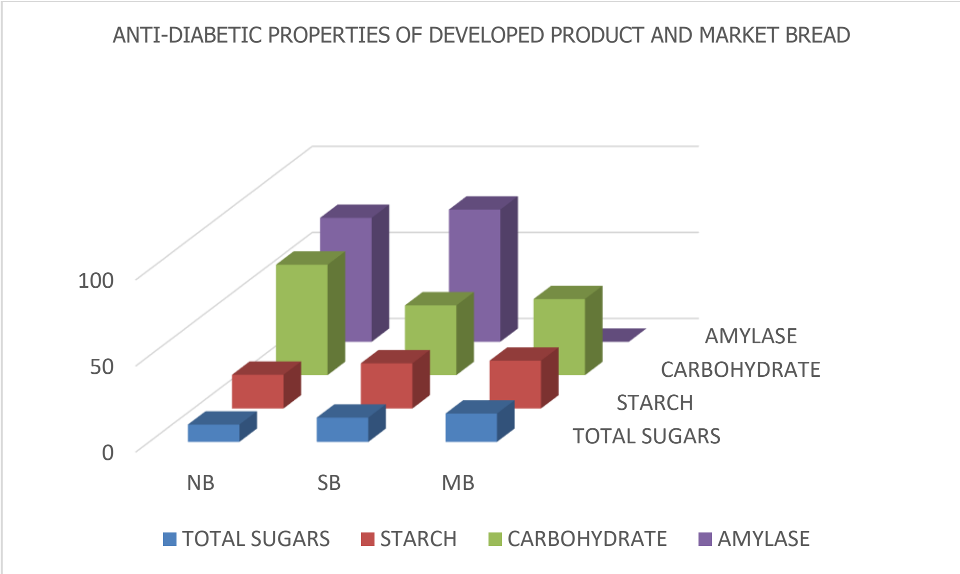


Fig. 10 Anti-diabetic properties of developed product and market bread

4. Conclusion

The present study focused on formulating a functional bread enriched with chickpea flour, roasted flaxseed powder, and chirayita, to enhance the nutritional and therapeutic profile of conventional wheat bread. Chickpea flour contributed soluble fiber and bioactive compounds that help regulate glycemia and reduce postprandial glucose spikes, while roasted flaxseed supplied omega-3 fatty acids, lignans, and mucilaginous fiber, which improve insulin sensitivity and slow carbohydrate absorption. Chirayita, a traditional medicinal herb with well-documented antioxidant and anti-diabetic properties, further strengthened the therapeutic potential of the formulation. The developed bread exhibited reduced gluten content, increased dietary fiber, and notable α-amylase inhibitory activity, collectively supporting blood glucose regulation. Although its glycemic index was slightly higher than that of control bread, the synergistic effects of chickpea and flaxseed promoted a gradual release of glucose, making the product beneficial for individuals with diabetes. Additionally, lower phytic acid levels improved mineral bioavailability, while the absence of harmful compounds such as asparagine confirmed product safety. Sensory evaluation revealed that bread enriched with 0.4 g of chirayita offered an optimal balance of health benefits and consumer acceptability. Overall, the findings demonstrate the potential of incorporating functional flours and medicinal herbs into staple foods, thereby contributing to the development of plant-based bakery products aligned with preventive nutrition. Future investigations should emphasize animal and human clinical studies, as well as shelf-life assessments, to validate therapeutic efficacy and ensure product stability for broader application.

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Conflict of Interest

The author(s) declare that they have no known financial or personal relationships that could have appeared to influence the work reported in this paper. The research was conducted independently without any conflict of interest.

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