Contents list available http://www.kinnaird.edu.pk/

Journal of Natural and Applied Sciences Pakistan

Journal homepage: http://jnasp.kinnaird.edu.pk/

NUTRITIONAL, RHEOLOGICAL AND SENSORY CHARACTERIZATION OF WHOLE WHEAT-LOTUS RHIZOME (NELUMBO NUCIFERA) COMPOSITE FLOUR

Mohsina Nasim[1]*, Dr. Rabia Naz[2], Dr. Sara Fatima[3], Dr. Nadia Akram[4], Dr. Mahnaz Nasir Khan[5]
[1*]Department of Nutrition & Dietetics, School of Health Sciences, University of Management and Technology, Pakistan
[2]Department of Food Sciences and Human Nutrition, Kinnaird College for Women, Pakistan [3]Geological Survey of Pakistan, Lahore
[3]Department of Clinical Sciences, School of Health Sciences, University of Management and Technology, Pakistan
[4]Department of Food Sciences and Human Nutrition, Kinnaird College for Women, Pakistan
[5]Department of Food Sciences and Human Nutrition, Kinnaird College for Women, Pakistan

Article Info

*Corresponding Author
Email: mohsina.nasim@umt.edu.pk

Keywords

Functional Ingredient, Lotus Rhizome Powder, Staple food fortification, Chapatti Quality, Rheology, Wheat Composite Flour, Malnutrition

Abstract

The rising rates of under nutrition call for low cost enrichment of staple food items. Current study intended to develop composite wheat flour using indigenous lotus rhizome powder in order to improve the quality of staple food (chapatti- an unleavened flatbread made from wheat flour) used in Pakistan. The composite flour can further be utilized for other recipes based on its quality and nutritional characterization. Five variants of sample containing different substitution levels of lotus rhizome powder in whole wheat flour were prepared, analyzed for nutritional composition, dough rheology and sensory attributes of chapatti prepared from it and compared with the wheat control. Nutritionally, wheat-lotus rhizome composite flour was found to be rich in fiber, low in fat content and provided an adequate amount of protein. Mineral composition indicated that lotus rhizome was rich in calcium (108mg), potassium (365mg) but low in sodium (20mg) and phosphorous (73mg) content. Rheological evaluation of the dough showed marked improvements in functional properties at higher substitution levels. Specifically, the formulation with 50% lotus root powder exhibited optimal water absorption (66.8%), enhanced dough stability (16 minutes), and a suitable dough development time (6.34 minutes), indicating improved dough handling and processing characteristics. Evaluating the overall quality of chapattis, it is clearly seen that the mean score for all the samples was 7 or above 7 which signifies that sensory attributes of all chapattis were acceptable wherein sample with 30% substitution of lotus root flour produced highly acceptable chapattis with mean score of 8.7 indicating excellent acceptability in terms of taste, texture, appearance, and aroma. In conclusion, the study demonstrates that the incorporation of lotus rhizome powder into whole wheat flour not only enhances the nutritional value of chapattis but also maintains desirable sensory and rheological qualities. This composite flour holds promise for the development of innovative, nutritionally enriched food products that can contribute to improved dietary quality, particularly in regions vulnerable to malnutrition

1. Introduction

The rising burden of malnutrition especially in developing countries like Pakistan, necessitate that nutritionally adequate, local food products be developed. Although food fortification and enhancement is a whole industry working to cater the needs of undernourished, enhancing staple food items with local but under recognized products with known functional properties. Whole wheat flat bread (chapatti) is a staple in Pakistan but nutritional adequacy of wheat flour in terms of protein and mineral content is questionable. Enhancing the nutritional properties of whole wheat flour with a locally available item may provide a cost effective and far reaching strategy for combating malnutrition. Lotus (*Nelumbo nucifera*) is a medicinally versatile edible plant which is often used as an essential raw material in Ayurveda and folk medicine (Bharathi Priya, Huang, Hu, Balasubramanian, & Baskaran, 2021). Different parts of lotus plant including flowers, leaves, seeds and rhizomes have been reported to be used in medical therapy for different diseases (Bhardwaj & Modi, 2016). The root of lotus plant (rhizome) is usually consumed by Asian people as one of the most nutritional and delicious aquatic vegetable (Yi *et al*., 2016). In Pakistan specifically in Sindh and in Southern Punjab, it is commonly known as "Beh". It is widely used to make stir-fried foods, pickled vegetables, salads and confections because of its distinctive taste, aroma, crispy and hard texture. Lotus root possess several pharmacological benefits like antioxidant activities (Yi *et al*., 2016), anti-obesity (Tsuruta *et al*., 2012; You, Lee, Kim, Kim, & Chang, 2014), hypoglycemic (Mukherjee, Saha, Pal, & Saha, 1997), anti-diabetic (You *et al*., 2014), anti-diarrheal and anti-microbial (Bhardwaj & Modi, 2016) properties. Since it is a "Root" vegetable therefore it is richly packed with vitamins and minerals (Mishra, Raigond, Thakur, Dutt, & Singh, 2020). Moreover, nutritional composition indicated that lotus root contains high level of bioactive ingredients such as polyphenols and it is abundant in amino acids, proteins, dietary fiber, potassium, calcium, vitamin A, vitamin B_6 and vitamin C (Bharathi Priya *et al*., 2021). In addition, lotus root contains good amount of starches which gives characteristic binding property and swelling power to dough therefore it can also be used in bread preparation or other bakery items. When wheat composite flour is prepared, gluten content is reduced and this causes challenges during mixing and kneading dough of chapatti formulations. The replacement of gluten in cereal-based products especially chapatti remains a challenge for food scientists, because of its distinctive role in formation of stable network, that helps to entrap air bubble. When gluten is removed from flour, starch is the key component left which helps in gelling, adhesion, thickening, stabilizing, moisture-retention and texturizing the dough. Source of starch helps in predicting the rheological properties of dough. Thus, starch plays an essential role during preparation of bakery items and have an even more significant role in low-gluten or gluten-free products like composite chapattis (Horstmann, Lynch, & Arendt, 2017). Yet, to our knowledge there is no available research or study on using lotus root powder in the development of any bakery items such as chapattis. Therefore, wheat-composite flour containing powdered lotus root can be considered as an appropriate functional ingredient for chapattis to improve the nutritional value. Thus, the objectives of the present investigation were to study how the rheological and sensory attributes of wheat flour were affected by composite flours prepared from lotus root.

2. Materials and Methods

The objectives of current study were to formulate and develop composite flour using whole wheat and lotus rhizome flour, to study the nutritional and rheological properties of dough made from this composite flour, and to develop and evaluate sensory attributes of unleavened flatbread (*chapati*) made from this flour. The materials and methods section has been split into sub headings in accordance with the sequence of events which occurred during this research project.

2.1 Procurement of raw material for composite flour

The whole Wheat Flour (WF) was purchased from a local market in Lahore, Pakistan. Lotus Rhizome (LR) were collected first handedly by the researchers from Chenab river belt, Southern Punjab, Pakistan. The roots were washed, thoroughly peeled and sliced into thin flakes (56 mm thickness), blanched in simmering water containing sodium metabisulphite for three minutes. The blanched roots were cooled and then dried until crisp in the convection microwave oven. The dried material was grounded into fine powder using an electric grinder and passed through a 0.150 µm sieve. The fine Lotus Rhizome Flour (LRF) was stored in airtight bottles at 4 degree celsius.

2.2 Formulation of Composite Flour (CF)

Composite flour (CF) was formulated using various concentrations of WF and LRF. The 100% WF [CF-0] and 100% LRF [CF-6] were used as controls while varying concentrations of LRF (10% [CF-1], 20% [CF-2], 30% [CF-3], 40% [CF-4], 50% [CF-5] (w/w) were added in WF to make composite flours.

2.3 Evaluation of Dough Rheological Characteristics

Dough was made from all the CF samples. The dough rheological characteristics were studied using the Farinograph Method (AACC, 1999). The parameters studied were water absorption, dough development time, stability, maximum consistency, and weakening.

2.4 Nutritional composition of the CF dough

Nutritional composition was studied using proximate analysis and mineral content analysis. Proximate analysis for moisture, ash, crude protein, crude fat and total fiber was performed using AOAC standards. Moisture content was analyzed using oven drying method (AOAC 925.10), ash/dry matter was analyzed using combustion method (AOAC 923.03), crude fiber by gravimetric method (AOAC 978.10), fat content (AOAC 2003.05) by Soxhlet method, and protein content by Kjeldahl method (AOAC 960.52). Sodium, potassium, and calcium were determined using flame photometric method (AOAC 977.29) while phosphorous was estimated through atomic absorption spectrophotometer. After evaluating dough properties chapati was made from the composite flour.

2.5 Preparation of Chapati (unleavened flatbread)

All the six versions of CF dough were used to make the final food product i.e. Chapati. The dough was allowed to rest for 30 minutes and then divided into small circular portions, rolled and molded (thickness 0.25 cm, diameter 10.5 cm). The flatbread was then cooked for 2-2.5 minutes on both sides on a non-stick, flat metal plate (locally called *tawa*) over flame (180 to 200ºC).

2.6 Sensory evaluation of Chapati

Lastly, the flat breads made from all versions of CF were subjected to a double blinded sensory evaluation by a semi-trained panel selected from the nutrition and food science faculty members (n=8). The sensory attributes including taste, color, aroma, tearing ability, hardness, chewiness, fold ability, and overall-acceptability were rated on a nine point hedonic scale (1 = extremely dislike to 9 = extremely like). A mean value of >5 points on sensory evaluation was treated as an acceptable quality (Boukid, 2022).

2.7 Statistical analysis All the chemical and rheological analyses were performed in triplicate and were expressed as average (M±SD). The data was analyzed for descriptive statistics and Analysis of Variance (ANOVA, pair wise) using Statistical Analysis for Social Sciences (SPSS) Version 18.0 and Statistix Version 9.0. The data was expressed in tabular as well as graphical form using MS Excel.

3. Results and Discussion

3.1 Rheological Properties of Wheat-Lotus Root Composite Flour

The effects of adding lotus root powder on rheological properties of composite flour is shown in Table 1. Results indicated that CF-3 produced stronger dough as compared to wheat control (CF-0). Addition of lotus root more than 30% adversely affected rheological properties of flour dough. Furthermore, the water absorption capacity improved from 61.80 to 66.8 % with subsequent increase in lotus root flour content. This might be due to high starch and fiber content of the flour as previously reported that flour which contains higher fiber content usually have higher water absorption capacity (Zarzycki *et al.*, 2022). This relationship between water absorption and fiber content has been shown in Figure 1. Similarly, previous researches showed dietary fibers from orange, cocoa pea, coffee and wheat had noticeable effects on dough

Table 1. Rheological properties of various blends of Composite Flour

Composite flour blends	Water Absorption (%)	Dough development Time (min)	Stability (min)	Maximum Consistency C_{MAX*} (UF)	Weakening (UF)
CF-0	61.80±1.55^{c}	3±0.08^{b}	7±0.08^{f}	660±16.50^{b}	40±1.00^{a}
CF-1	63.5±1.59^{bc}	3±0.08^{b}	11.50±0.29^{d}	576±14.41^{c}	40±1.00^{a}
CF-2	64±1.60^{abc}	3±0.08^{b}	17±0.42^{b}	573.64±14.34^{c}	31±0.78^{c}
CF-3	63.60±1.59^{bc}	3±0.08^{b}	18.50±0.46^{a}	648.18±16.20^{b}	41±1.03^{a}
CF-4	65.30±1.63^{ab}	3±0.08^{b}	10.50±0.26^{e}	649.55±16.24^{b}	35±0.88^{b}
CF-5	66.80±1.67^{a}	6.5±0.16^{a}	16±0.4^{c}	691±17.28^{a}	0±0.00^{d}

- Mean values within the same row with "abc" superscript letters differs significantly (P< 0.05).
- Values are represented as mean ± standard deviation (n=3).

rheological behavior yielding higher water absorption as compared to without fiber addition (Arslan, Rakha, Xiaobo, & Mahmood, 2019). Dough development time (DDT) and stability values are indicator of the flour strength, where dough with higher values indicating stronger dough. Results pertaining to stability of the dough indicated that CF-3 got the highest stability time i.e. 18.50 minutes whereas CF-0 has only 7 mins of stability time. Addition of lotus root powder above a dose of 3% relatively decreased stability in CF-4 and CF-5 (10% and 20% respectively). DDT remained constant (3 minutes) as compared to control and then suddenly increased in CF-5 to 6.5 minutes. This fact is explainable because good quality flour must have a certain amount of protein content to form a uniform and stable network in flour dough. Since composite flour has low protein or wet gluten content that will influence rheological properties, producing less elastic and sticky dough at the end of the mixing stage with a weak consistency. This is true of the gluten free products because less gluten negatively affects the dough quality (Khan *et al*., 2021). However, when gluten is removed from flour, starch is the key component left which helps in maintain the rheology of dough. Source of starch helps in predicting the rheological properties of dough. Thus, starch plays an essential role during preparation of bakery items and have an even more significant role in low-gluten or gluten-free products like composite chapattis (Horstmann, Lynch, & Arendt, 2017). Moreover, DDT is also influenced by water absorption and mineral content. A direct significant correlation has been found previously between water absorption and parameters ash content and development time (Codină, Istrate, Gontariu, & Mironeasa, 2019). Maximum consistency during kneading also improved from CF-1 (576 UF) to CF-5 (691 UF) with the subsequent addition of lotus root whereas wheat control having consistency of 660 UF. Weakening of dough was also improved in CF-5 (0UF) as compared to wheat control (40UF). These results could be best explained by the interactions between gluten and fiber, as suggested by Cheng & Bhat (2015). Lotus root addition reduces the wheat flour gluten network formation rate. Similar results on the effects of adding of dietary fibers on the rheological properties of whole wheat flour were reported by (Packkia-Doss, Chevallier, Pare, & Le-Bail, 2019).

3.2 Nutritional Composition of Wheat Control and Lotus Rhizome Flour

Proximate analysis of wheat-lotus root composite showed in Table 2 indicated that wheat control (CF-0) was low in fiber (2.70%) and moisture (8.12%) but high in fat content (3.3%) as compared to lotus root powder CF-6 (11.73%, 13.18%, and 0.73% respectively). As the substitution level of LRF was increased from 10 to 50%, moisture and fiber content was increased (3.90%-7.00%) and fat content was reduced (2.95%-1.30%) as compared to wheat control. This relatively low fat content and high fiber content of CF is desirably demanded by health-conscious consumers. Moreover, CF provides adequate amount of protein (12.76-10.99%) and ash (1.89%-1.72%) as compared to wheat flour (12.98% and 1.94% respectively). Similar results were reported by Ham *et al*. (2017), where ash, protein or moisture content had no significant (p>0.05) impact while lotus Rhizome powder increased crude fiber content but significantly ($p < 0.05$) reduced fat content of sausage. Results of this study were in accordance with previous researches where whole wheat chapattis in comparison to composite chapattis showed significantly low fiber (2.5-2.8%) and moisture content (15.29-16.40%) as reported by (Khan, Mahesh, Semwal, & Sharma, 2015). As the amount of crude fiber increased (rising levels of LR), the water absorption capacity also increased as shown in Figure 1.

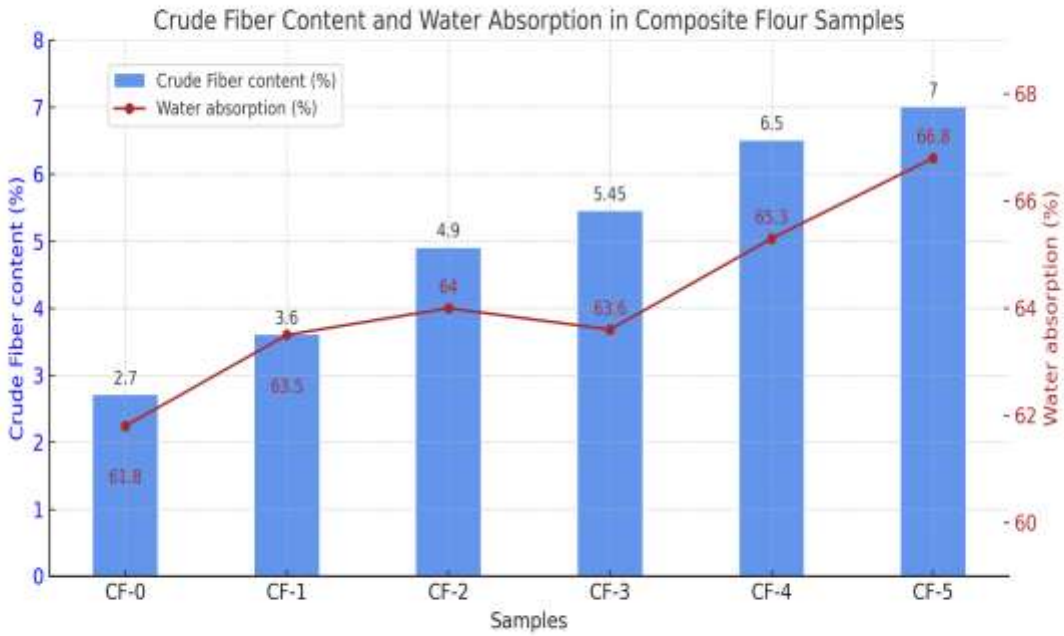

Figure 1: Effect of crude fiber content on water absorption capacity of wheat-lotus Rhizome composite flour

Table 2: Nutritional composition of various blends of Composite Flour (100g flour)

Composite flour blends	Crude Protein (%)	Moisture (%)	Crude Fibre (%)	Fat (%)	Ash (%)
CF-0	12.98 ± 0.32^{a}	8.12 ± 0.20^{d}	2.70 ± 0.07^{g}	3.10 ± 0.16^{a}	1.94 ± 0.05^{a}
CF-1	12.76 ± 0.32^{a}	9.36 ± 0.23^{c}	3.90 ± 0.07^{f}	2. 95 ± 0.09^{a}	1.89 ± 0.09^{ab}
CF-2	11.46 ± 0.34^{b}	9.53 ± 0.24^{c}	4.90 ± 0.15^{e}	2.50 ± 0.07^{b}	1.85 ± 0.01^{bc}
CF-3	11.38 ± 0.36^{b}	9.75 ± 0.24^{c}	5.45 ± 0.16^{d}	2.00 ± 0.05^{c}	1.81 ± 0.04^{cd}
CF-4	11.16 ± 0.36^{bc}	10.29 ± 0.26^{b}	6.50 ± 0.16^{c}	1.75 ± 0.04^{c}	1.76 ± 0.02^{de}
CF-5	10.99 ± 0.38^{c}	10.66 ± 0.26^{b}	7.00 ± 0.17^{b}	1.30 ± 0.03^{d}	1.72 ± 0.01^{e}
CF-6	9.03 ± 0.36^{d}	13.18± 0.26^{a}	11.73± 0.16^{a}	0.73± 0.03^{e}	1.50 ± 0.01^{f}

- Mean values within the same row with "abc" superscript letters differs significantly (P< 0.05).
- Values are represented as mean ± standard deviation (n=3).

Table 3: Mineral analysis of wheat-lotus rhizome composite flour (100 g flour)

Composite flour blends	Sodium (mg)	Potassium (mg)	Calcium (mg)	Phosphorous (mg)
CF-0	45±0.60[a]	183±0.11[g]	42±0.11[g]	327±0.27[a]
CF-1	42.5±0.30[b]	201.2±0.24[f]	48.6±0.10[f]	301.6±0.28[b]
CF-2	40±0.70[c]	219.4±0.22[e]	55.2±0.20[e]	276.2±0.25[c]
CF-3	38±0.30[d]	237.6±0.28[d]	61.8±0.02[d]	250.8±0.22[d]
CF-4	35±0.70[e]	255.8±0.27[c]	68.4±0.70[c]	225±0.21[e]
CF-5	31.5±0.30[f]	274±0.26[b]	75±0.08[b]	200±0.20[f]
CF-6	20.3±0.30[g]	365±0.24[a]	108±0.23[a]	73±0.11[g]

- Mean values within the same row with "abc" superscript letters differs significantly (P< 0.05).
- Values are represented as mean ± standard deviation (n=3).

Mineral composition of wheat-lotus Rhizome composite flour represented in Table 3 indicated that lotus root was low in sodium (20mg) and high in potassium (365mg) and has the optimum 1:4 ratio of sodium and potassium content. Diuretic and anti-hypertensive properties of lotus root are well-explained by this mineral ratio. Rich mineral content of lotus root is explainable by the fact that root vegetables draw water and minerals directly from the soil. The end results of this study are similar with the findings of Khan, Mahesh, Semwal, & Sharma (2015) who observed increased potassium content (695.33mg) in gluten free ready to serve whole wheat product. While results for calcium content indicated that CF-6 has maximum calcium level (108mg) indicating lotus root rich calcium source as compared to control (CF-0) which contains only 42mg of calcium. Wheat control has 327mg of phosphorous and with subsequent addition of lotus root it improved from CF-1 to CF-5 (301mg to 200mg respectively). The increase in the nutritive value of flour by supplementation of other vegetables has been reported by several investigators (Bhat & binti Yahya, 2014; Cheng & Bhat, 2015; M. Khan *et al*., 2015).

3.3 Sensory Profile and Physical characteristics of CF unleavened flatbread (Chapattis)

Mean scores of sensory profile of wheat-lotus Rhizome chapattis demonstrated in Table 4 indicated that the mean scores within the same row with "abc" superscript letters differs significantly (P< 0.05). For taste and aroma CF-2 had the highest mean score (8.5 and 8.7 respectively) while CF-5 had least scores (7.0 and 7.3 respectively). This could be possibly explained by their wholesome sweetish aftertaste while CF-4 and CF-5 comparatively scored lower because of their slightly less sweet taste caused by high mineral content present in lotus root. Change in taste upon addition of lotus has been reported previously (Beya, Netzel, Sultanbawa, Smyth, & Hoffman, 2021). Mean score of color/appearance decreased from 8.5 to 7.2 with subsequent increase in lotus root powder indicating that chapatti prepared from 10% lotus root flour had more appealing wheatish-brown color with uniform dark brown spots. On the other hand, color of chapattis made from 40 and 50% of lotus root were relatively darker. Chapattis made from 20 and 30% were not as dark as the latter two varieties. This variation in color might be due to the direct influence of original lotus rhizome color and enzymatic browning of lotus root. Assessment of the tearing capacity of chapattis showed that 40 and 50% scored very low this is probably because of decreasing protein/gluten content with subsequent addition of lotus root powder. So, on the basis of sensory quality, it was observed that we could go up to 30% substitution of lotus root powder with chapatti without adversely affecting quality

attributes. It was found that at 50% of lotus root flour substitution, all the sensory parameters were adversely affected as compared to the control wheat chapattis. Effect of protein content on tearing capacity has been illustrated in Figure 2 results indicated that protein plays important role in giving chapatti structural stability and gives optimum resistance to tearing. Cheng & Bhat (2015) stated that good quality chapattis should give minimum resistance to tearing. However, unlike in bread, where softer bread generally gets higher score, it is not very easy to evaluate the required tearing strength in a highly acceptable chapatti. It is desired that chapatti should not be too fragile with easy to tear properties, but it should offer some resistance to tearing as well as chewing. That is why chapatti with 30% lotus root was overall more acceptable giving moderate resistance to tearing strength. Ma *et al*. (2016) reported that bread prepared from high protein flour were chewier with high tearing resistance and vice versa. Moreover, it has previously been explained that higher water absorption capacity of flour renders chapattis soft and pliable (Moradi, Khaneghah, Fallah, & Akbarirad, 2016). Results of sensory evaluation of chapattis with respect to their eating quality properties i.e. chewiness and hardness indicated that

Table 4. Effect of adding lotus root powder on sensory attributes of chapattis (n-6)

Sensory Attributes	Samples					
	CF-0	CF-1	CF-2	CF-3	CF-4	CF-5
Taste	7.6 ± 0.5^{bc}	8.0 ± 0.5^{b}	8.2 ± 0.3^{ab}	8.5 ± 0.2^{a}	7.8 ± 0.4^{bc}	7.0 ± 0.5^{c}
Aroma	7.8 ± 0.5^{bc}	8.2 ± 0.2^{ab}	8.0 ± 0.5^{b}	8.7 ± 0.4^{a}	7.6 ± 0.5^{c}	7.3 ± 0.6^{c}
Appearance/Colour	8.5 ± 0.2^{a}	8.4 ± 0.2^{a}	7.8 ± 0.3^{b}	7.5 ± 00.5^{bc}	7.3 ± 0.2^{c}	7.2 ± 0.5^{c}
Tearing Capacity	8.7 ± 0.5^{a}	8.5 ± 0.4^{ab}	8.0 ± 0.6^{b}	7.5 ± 0.2^{c}	7.1 ± 0.5^{d}	7.0 ± 0.1^{d}
Fold ability	7.3 ± 0.5^{cd}	7.5 ± 0.2^{c}	7.7 ± 0.3^{b}	8.0 ± 0.1^{a}	7.1 ± 0.5^{cd}	7.0 ± 0.1^{d}
Hardness	8.0 ± 0.4^{b}	8.1 ± 0.5^{b}	8.5 ± 0.1^{ab}	8.7 ± 0.3^{a}	7.6 ± 0.2^{c}	7.3 ± 0.2^{d}
Chewiness	8.1 ± 0.1^{bc}	7.6 ± 0.4^{c}	8.0 ± 0.5^{b}	8.5 ± 0.1^{a}	7.1 ± 0.4^{d}	7.0 ± 0.3^{d}
Overall Acceptability	7.7 ± 0.5^{bc}	8.0 ± 0.2^{a}	8.3 ± 0.5^{ab}	8.7 ± 0.4^{a}	7.6 ± 0.5^{c}	7.3 ± 0.6^{c}

- Mean values within the same row with "abc" superscript letters differs significantly ($P < 0.05$).
- Values are represented as mean ± standard deviation (n=3).

samples with 20 and 30% lotus root powder showed relatively higher scores. These chapattis were neither tough nor hard to chew. They were not weak as like CF-1 offering less resistance to chewing but had optimum chewing properties. This might be because of high starch and fiber content in lotus root. The results of this study were in accordance with previous researches where more than 15% of lotus root powder additive increased hardness and reduced adhesiveness, cohesiveness, and springiness of dried noodles (Kim, Kim, Kim, Tan, & Shim, 2021).

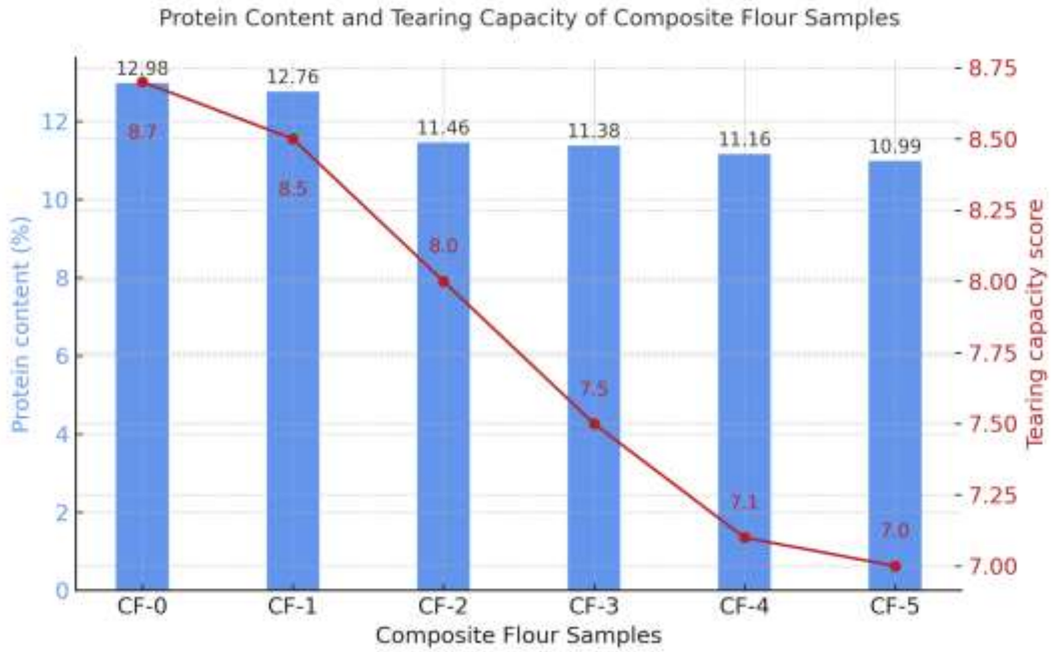

Figure 2: Effect of protein content tearing capacity of wheat-lotus Rhizome composite Chapattis

4. Conclusion

In conclusion, the wheat–lotus rhizome composite flour demonstrated a notable enhancement in dietary fiber, a reduction in fat content, and an adequate protein profile, collectively offering multiple potential health benefits. Mineral analysis demonstrated that lotus rhizome is particularly rich in calcium, potassium, contains moderate levels of phosphorus and low levels of sodium, indicating its potential for enhancing the micronutrient content of staple foods. The dough possesses appreciable rheological properties providing good stability, water absorption and dough development time making it suitable for flat breads (chapattis). Organoleptic evaluation revealed that chapatti prepared with a 30% substitution of wheat flour with lotus rhizome powder achieved the highest sensory scores among all tested formulations suggesting that such a formulation not only retains the desirable qualities of traditional wheat chapatti but also enhances its overall sensory appeal, including taste, texture, aroma, and appearance. Hence, lotus root can be utilized in developing novel food products providing good nutritional value as well as appreciable sensory and rheological properties.

References

American Association of Cereal Chemists. (1999). *Approved methods of the AACC* (10th ed.).

Method 54-21: Farinograph method for flour. St. Paul, MN: AACC International.

AOAC (1990) Official methods of analysis. (15th edition) Association of Official Analytical Chemists, Washington DC.

AOAC (2005) Official Methods of Analysis. (18th edition) Association of Official Analytical Chemists International, Maryland, USA.

AOAC (2005) Solids (Total) and Moisture in Flour, Method 925.10. In: Official Methods of Analysis, 18th Edition, AOAC International, Gaithersburg

Arslan, M., Rakha, A., Xiaobo, Z., & Mahmood, M. A. (2019). Complimenting gluten free bakery products with dietary fiber: Opportunities and constraints. *Trends in food science & technology, 83*, 194-202.

Beya, M. M., Netzel, M. E., Sultanbawa, Y., Smyth, H., & Hoffman, L. C. (2021). Plant-based phenolic molecules as natural preservatives in comminuted meats: A review. *Antioxidants, 10*(2), 263.

Bharathi Priya, L., Huang, C. Y., Hu, R. M., Balasubramanian, B., & Baskaran, R. (2021). An updated review on pharmacological properties of neferine—A bisbenzylisoquinoline alkaloid from Nelumbo nucifera. *Journal of Food Biochemistry*, *45*(12), e13986.

Bhardwaj, A., & Modi, K. (2016). A review on therapeutic potential of Nelumbo nucifera (GAERTN): the sacred lotus. *Int J Pharm Sci Res, 7*, 42-54.

Bhat, R., & binti Yahya, N. (2014). Evaluating belinjau (Gnetum gnemon L.) seed flour quality as a base for development of novel food products and food formulations. *Food chemistry, 156*, 42-49.

Boukid, F. (2022). Flatbread-a canvas for innovation: A review. *Applied Food Research*, 100071.

Cheng, Y., & Bhat, R. (2015). Physicochemical and sensory quality evaluation of chapati (Indian flat bread) produced by utilizing underutilized jering (Pithecellobium jiringa Jack.) legume and wheat composite flours. *International Food Research Journal, 22*(6).

Codină, G. G., Istrate, A. M., Gontariu, I., & Mironeasa, S. (2019). Rheological properties of wheat–flaxseed composite flours assessed by mixolab and their relation to quality features. *Foods, 8*(8), 333.

Ham, Y.-K., Hwang, K.-E., Song, D.-H., Kim, Y.-J., Shin, D.-J., Kim, K.-I., . . . Kim, C.-J. (2017). Lotus (Nelumbo nucifera) rhizome as an antioxidant dietary fiber in cooked sausage: effects on physicochemical and sensory characteristics. *Korean journal for food science of animal resources, 37*(2), 219.

Horstmann, S. W., Lynch, K. M., & Arendt, E. K. (2017). Starch characteristics linked to gluten-free products. *Foods, 6*(4), 29.

Khan, M., Mahesh, C., Semwal, A. D., & Sharma, G. (2015). Effect of spinach powder on physico-chemical, rheological, nutritional and sensory characteristics of chapati premixes. *Journal of food science and technology, 52*, 2359-2365.

Khan, R., Shehzadi, K., Bacha, U., Afzal, M. N., Tanweer, A., Nasim, M., & Khan, S. (2021). Physico-Functional, Nutritional and Sensorial Features of Psyllium Husk Enriched Gluten-Free Oat Cookies. *Nurture, 15*(1), 1-8.

Kim, J.-H., Kim, J.-E., Kim, W.-H., Tan, K. V., & Shim, S.-M. (2021). Plant based protein products: Characterization and functionality of dried tofu noodles containing lotus root powder. *Food Bioscience, 43*, 101342.

Ma, S., Li, L., Wang, X.-x., Zheng, X.-l., Bian, K., & Bao, Q.-d. (2016). Effect of mechanically damaged starch from wheat flour on the quality of frozen dough and steamed bread. *Food Chemistry, 202*, 120-124.

Mishra, T., Raigond, P., Thakur, N., Dutt, S., & Singh, B. (2020). Recent updates on healthy phytoconstituents in potato: a nutritional depository. *Potato Research, 63*, 323-343.

Moradi, V., Khaneghah, A. M., Fallah, A., & Akbarirad, H. (2016). Rheological properties of wheat flour with different extraction rate. *International Food Research Journal, 23*(3), 1056.

Mukherjee, P. K., Saha, K., Pal, M., & Saha, B. (1997). Effect of Nelumbo nucifera rhizome extract on blood sugar level in rats. *Journal of ethnopharmacology, 58*(3), 207-213.

Packkia-Doss, P. P., Chevallier, S., Pare, A., & Le-Bail, A. (2019). Effect of supplementation of wheat bran on dough aeration and final bread volume. *Journal of Food Engineering, 252*, 28-35.

Tsuruta, Y., Nagao, K., Shirouchi, B., Nomura, S., Tsuge, K., Koganemaru, K., & Yanagita, T. (2012). Effects of lotus root (the edible rhizome of Nelumbo nucifera) on the deveolopment of non-alcoholic fatty liver disease in obese diabetic db/db mice. *Bioscience, biotechnology, and biochemistry*, 1203012817-1203012817.

Yi, Y., Sun, J., Xie, J., Min, T., Wang, L.-M., & Wang, H.-X. (2016). Phenolic profiles and antioxidant activity of lotus root varieties. *Molecules, 21*(7), 863.

You, J. S., Lee, Y. J., Kim, K. S., Kim, S. H., & Chang, K. J. (2014). Ethanol extract of lotus (Nelumbo nucifera) root exhibits an anti-adipogenic effect in human pre-adipocytes and anti-obesity and anti-oxidant effects in rats fed a high-fat diet. *Nutrition research, 34*(3), 258-267.

Zarzycki, P., Wirkijowska, A., Nawrocka, A., Kozłowicz, K., Krajewska, M., Kłosok, K., & Krawęcka, A. (2022). Effect of Moldavian dragonhead seed residue on the baking properties of wheat flour and bread quality. *LWT, 155*, 112967.