Annals of Phytomedicine 13(1): 602-611, 2024

DOI: http://dx.doi.org/10.54085/ap.2024.13.1.62

Annals of Phytomedicine: An International Journal
http://www.ukaazpublications.com/publications/index.php

Print ISSN : 2278-9839 Online ISSN : 2393-9885

Original Article : Open Access

Nutritional quality of black wheat flatbread: A therapeutic alternative for diabetes management

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Article Info

Article history
Received 5 March 2024
Revised 22 April 2024
Accepted 23 April 2024
Published Online 30 June 2024

Keywords
Biofortified black wheat
Flatbread
Glycemic index
Enzyme inhibition
Nutrient adequacy
Sensory quality

Abstract

Flatbread is consumed all over the world and makes use of the majority of India's wheat crop. The present study aimed to utilize black wheat for the development of flatbread, and to analyze its nutritional quality, *viz*., nutrient composition, glycemic index, enzyme inhibition, nutrient adequacy, and index of nutritional quality, to pave the way for therapeutic management of diabetes mellitus. Ash, protein, fat, carbohydrate, and physiological energy value (PEV) content of black wheat flour (BWF) and yellow wheat flour (YWF) differed significantly. BWF had higher protein and lower carbohydrate content than YWF, which could lead to improved glucose response and insulin resistance. BWF was considered a superior source of dietary fiber due to its increased dietary fiber content compared to YWF. Gluten content of BWF was 15% lower than that of YWF, which may impact the strength, elasticity, and texture of the developed food product. Enzyme inhibitory activity of BWF and BWB was higher (50%) than YWF and its flatbread. In comparison to yellow wheat flatbread, one serving of black wheat flatbread could meet an adult Indian man's or woman's increased RDA requirements for protein up to 21% and dietary fiber up to 57%. Black wheat possessed therapeutic potential for the management of hyperglycemia because of its low GI (<55), better enzyme inhibitory activity, and improved nutritional quality (INQ>1). As such, it could be a good substitute for yellow wheat in the preparation of flatbread.

1. Introduction

Across the Indian subcontinent and portions of the Middle East, chapatti, a flatbread, is mostly made from wheat (*Triticum aestivum* L.) with little variations in ingredients and preparation technique (Gujral *et al*., 2004, 2008). About 90% of the wheat grown in India is utilized to make flatbread, with the remaining portion going toward making bread, biscuits, and cakes (Sharma and Gujral, 2014). In India, Pakistan, and some regions of Africa, flatbread is a staple food (Nandini and Salimath, 2001; Panghal *et al*., 2019) that is affordable, and a good source of calories and protein (Swaranjeet *et al*., 1982; Rehman *et al*., 2006). However, the quality of the wheat used to prepare flatbread determines its nutritional quality.

Owing to the antioxidant, anti-inflammatory activities of anthocyanin and other phytochemicals present in biofortified black wheat (BW) (Sharma *et al*., 2018), it could be a better ingredient for enhancing the nutritional quality of flatbread. Since flatbread is consumed by people of all ages, it would be advantageous for many communities' health to switch from standard yellow wheat to a pigmented wheat variety. Due to current awareness of changes in the glycemic index (GI), following the consumption of carbohydrate-rich food, the intake of pigmented cultivars, especially whole grains, has become more popular in recent years due to its health-beneficial effects (Mitra *et al*., 2021). This is especially true when it comes to preventing lifestyle diseases like cancer, type 2 diabetes, and cardiovascular disease, among others (Marquart, 2002; Fardet, 2010; Garg *et al*., 2016). According to Arvidsson-Lenner *et al*. (2004), GI may have an impact on one's health and is based on the blood glucose response following the consumption of 50 g of carbohydrates from food. GI of food can be determined by both *in vivo* and *in vitro* techniques. However, both techniques were strongly correlated for assessing starch digestion (Bohn *et al*., 2018).

Postprandial hyperglycemia can also be modulated therapeutically by targeting the α-amylase and α-glucosidase enzymes. These enzymes played a crucial role in hyperglycemia observed in diabetic patients after taking carbohydrate-rich foods due to the hydrolysis of carbohydrates by these enzymes into simpler monomeric units of glucose (Kim *et al*., 2005; Kwon *et al*., 2008). Hence, attenuation of these enzymes involved in the hydrolysis of starch could lower the postprandial increase in blood glucose after eating carbohydrate-rich food and this could be of importance in the management of type-II diabetes. Thus, GI and enzyme inhibitory activity could be regarded as the primary metrics for assessing the antidiabetic potential of the food.

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There has been considerable research relating to the development of pigmented wheat flatbread, its quality analysis in terms of organoleptic properties, and antioxidant activity (Kumari *et al*., 2020). Little or negligible work has been done to determine the nutrient adequacy and antidiabetic potential of pigmented wheat. Therefore, the present study focuses on utilizing black wheat for the development of black wheat flatbread (BWB) and aims to compare its nutritional quality, nutrient adequacy, and antidiabetic potential against yellow wheat flatbread (YWB).

2. Materials and Methods

2.1 Raw materials

Black wheat line (NABIMG-11-Black (BW/2* PBW621) (IC0620916; INGR17003), a wheat (*Triticum aestivum* L.) germplasm with black grain colour) and yellow wheat (conventional) (HD2967) were procured from the local market of Uchaiti village, Moradabad, Uttar Pradesh, India.

2.2 Cleaning and processing of grains

The grains were cleaned manually to remove any foreign substances such as damaged seeds, dust particles, stones, and metal and glass pieces. The samples were ground to make flour (Figure 1(b)) using a Flour Mill (1HP, Domestic Atta Chakki, Kalsi, Ludhiana) and sieved through British Standard Sieve No. 44 (355 microns) (Bassi *et al*., 2020). Wheat flour thus obtained was stored in air-tight containers till further analysis.

2.3 Preparation of flatbread

Flatbread was prepared using the method described by Cheng and Bhat (2015) with slight modifications (Figure 2).

(a) Black wheat **(b) Black wheat flour** **(c) Black wheat flatbread**

Figure 1: (a) Black wheat, (b) Black wheat flour, (c) Black wheat flatbread.

50 g of flour + salt (@ 1.5 per cent) was added

↓

Flour was sifted to mix salt uniformly

↓

Water was added (30 ml)

↓

Flour was kneaded manually to prepare dough (kneading time: 5 min)

↓

Covered with a damp muslin cloth, the dough was allowed to rest at room temperature (RT) (25 ± 1°C) for 30 min

↓

Dough was divided into balls of equal portions (avg. 40 g)

↓

Dough balls were rolled into round flat sheets (approx. diameter 14 cm, thickness 1.75 mm) using rolling pin on a flat surface

↓

Flatbreads were cooked for one minute on each side at 210°C on a hot induction plate, followed by 30 sec of flame-puffing

↓

Flatbreads (avg. 25 g) were cooled on wire rack (5 min) at RT and seal packed in LDPE pouches (50 microns) till further analysis

Figure 2: Flow chart for preparation of flatbread.

2.4 Nutritional analysis

The proximate composition of samples was analyzed using standard methods AOAC (2012) except for crude fiber, which was estimated using the AOAC (1995) method. The method outlined by Asp *et al.* (1983) was used to determine the content of soluble, insoluble, and total dietary fiber. Gluten content in flour was estimated using AACC (2000). The inhibitory activity of α-amylase and α-glucosidase was estimated by employing the technique described by Wongsa *et al.* (2019) and Wang *et al.* (2015). Using the *in vitro* approach described by Goni *et al.* (1997), the GI of flatbread was estimated and expressed as predicted glycemic index (pGI). Area under hydrolysis curves (AUC, 0 - 180 min) were computed using the trapezoid rule. The relationship between the AUC for the test food and the reference food (glucose), given as a percentage, was used to compute the hydrolysis index (HI).

$$AUC = \frac{1}{2} \times 0.5 \times \{(Y_0 + Y_{0.5}) + (Y_{0.5} + Y_{1.0}) + (Y_{1.0} + Y_{1.5}) + (Y_{1.5} + Y_{2.0}) + (Y_{2.0} + Y_{2.5}) + (Y_{2.5} + Y_{3.0})\}$$

(Y: concentration of glucose at different time intervals)

$$\text{Hydrolysis index (H)} = \frac{\text{Area under curve of test sample}}{\text{Area under curve of glucose}} \times 100$$

$$pGI = 39.7 + 0.548 \times HI$$

The approach of Sorenson and Henson (1975) was used to determine the index of nutritional quality (INQ) and nutrient adequacy (% RDA). It was calculated according to the following formula:

$$INQ = \frac{a \times b}{c \times d}$$

where,

a - amount of the tested component in 100 g of the product;

b - the standard value of energy demand depending on gender, physical activity, age, and body weight;

c - energy value per 100 g of the product;

d - the requirement for the tested component depending on age and gender.

2.5 Sensory evaluation of flatbread

Sensory evaluation was carried out at the Sensory Analysis Laboratory of the Department of Food Science and Nutrition, College of Home Science, G.B. Pant University of Agriculture and Technology, Pantnagar. Ten semi-trained panelists used a 9-point Hedonic scale (1 being extremely disliked to 9 being extremely liked) to rate samples (about one flatbread) based on sensory attributes such as color, texture, taste, flavor, and overall acceptability (Amerine *et al.*, 2013). The samples were labeled with random three-digit numbers.

2.6 Statistical analysis

Statistical analysis was done using WASP (Web Agri Stat Package)-2.0, ICAR Research Complex, Goa, India, and data was expressed in terms of mean ± standard deviation (SD). The experimental data for gluten content, GI, and sensory evaluation was analyzed for differences in mean using a paired t-test (p<0.05). Proximate and dietary fiber analysis data was analyzed for statistical significance using analysis of variance (ANOVA). The correlation between the hydrolysis index (HI) and the enzyme inhibitory activity of flatbread, was ascertained using the Pearson correlation coefficient. At p<0.05, differences were deemed statistically significant.

3. Results

3.1 Proximate and dietary fiber composition of flour and flatbread

Black wheat flour (BWF) and yellow wheat flour (YWF) differed significantly (p<0.05) for moisture, ash, protein, carbohydrate, and physiological energy value (PEV) (Table 1).

Table 1: Proximate and dietary fiber composition of flour and flatbread (dw)

Parameter	BWF	YWF	BWB	YWB
Moisture (%)	07.76 ± 0.13^d	09.48 ± 0.14^c	24.06 ± 0.07^a	22.09 ± 0.56^b
Ash (%)	02.08 ± 0.02^a	01.47 ± 0.07^b	01.71 ± 0.03^b	01.33 ± 0.00^d
Crude protein (%)	11.80 ± 0.30^a	10.07 ± 0.33^b	11.64 ± 0.29^a	09.60 ± 0.33^b
Crude fat (%)	01.62 ± 0.04^a	01.58 ± 0.24^a	01.55 ± 0.06^a	01.54 ± 0.07^a
Carbohydrate (%)	76.72 ± 0.36^a	77.39 ± 0.25^a	61.03 ± 0.31^c	65.44 ± 0.41^b
PEV (kcal/ 100 g)	368.7 ± 0.16^a	364.1 ± 1.16^b	304.7 ± 0.41^d	314.0 ± 0.39^c
Crude fiber (%)	05.95 ± 0.21^a	03.46 ± 0.06^c	05.70 ± 0.07^b	03.05 ± 0.12^d
TDF (g/100 g)	18.99 ± 0.06^a	12.09 ± 0.42^b	19.032 ± 0.84^a	12.09 ± 0.41^b
IDF (g/100 g)	16.20 ± 0.77^a	10.74 ± 0.43^b	16.23 ± 0.78^a	10.75 ± 0.42^b
SDF (g/100 g)	02.79 ± 0.13^a	01.35 ± 0.01^b	02.80 ± 0.13^a	01.36 ± 0.01^b

BWF: black wheat flour, YWF: yellow wheat flour, BWB: black wheat flatbread, YWB: yellow wheat flatbread, PEV- physiological energy value, IDF: insoluble dietary fiber, SDF: soluble dietary fiber, TDF: total dietary fiber, dw: dry weight basis.
All values are Mean ± SD of three replicates on dry weight basis.
^{abcd}values within the row with different superscript letters differed significantly (p<0.05) where, a>b>c>d.
Carbohydrate= 100 - (Moisture + Ash + Crude protein + Crude fat).

Wheat flour was found to have a low moisture content (<10%) whereas, it was observed that the flatbread had higher moisture content, which is a key component in the flatbread's softness. Kumari *et al*. (2020) reported a significantly higher moisture content of 9.96 and 39.18% in black wheat flour and its flatbread, respectively. The ash content of the flours and flatbreads varied significantly (p<0.05). The protein content of BWF and its flatbread was found to be significantly higher than YWF and its flatbread. Nevertheless, following baking of flatbread made with the respective flours, no significant variation in the protein content was found. No significant variation in the fat content of the flour and flatbreads made from the two varieties of wheat was observed. The fat content of flatbreads was not significantly affected by baking. There was a significant difference (p<0.05) in the carbohydrate content after baking flatbread made using the two flours. The carbohydrate content of BWF and its flatbread was found to be lower than YWF and its flatbread. The physiological energy value of BWF was found to be significantly higher than YWF. The PEV showed a significant variation following the baking of flatbreads made with the respective flours.

The content of different components of dietary fiber in BWF and its flatbread was significantly higher than in YWF and its flatbread. These results imply that, in comparison to yellow wheat, black wheat could be regarded as a good source of dietary fiber and may aid in blood glucose regulation.

3.2 Gluten content in flour

BWF showed significantly (p<0.05) lower gluten content (9.54%) as compared to the YWF (11.20%). Singh and Singh (2006) and Kaushik *et al*. (2015) also reported similar results for dry gluten in wheat with values 5.9-10.1 and 8.65-10.35%, respectively.

3.3 α-amylase inhibitory activity and α-glucosidase inhibitory activity

The findings from the inhibition of α-amylase (1:2000U/mg) (Figure 3) showed that crude extract of BWF and BWB have significantly higher enzyme inhibitory activity as compared to YWF and its flatbread (p<0.05). However, it was observed that the processing of respective flours to their flatbread showed no significant difference in the enzyme inhibitory activity.

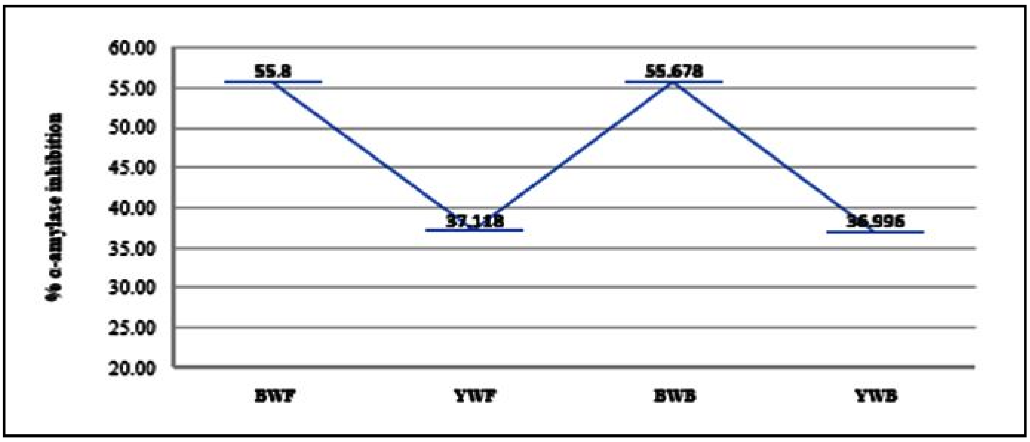


Figure 3: Per cent α-amylase inhibition in black wheat, yellow wheat flour and their flatbread.
BWF: black wheat flour, YWF: yellow wheat flour, BWB: black wheat flatbread, YWB: yellow wheat flatbread. Values are the means of three separate determinations (n =3).

The α-glucosidase(100U/mg) inhibition results (Figure 4) demonstrated that crude extract BWF and BWB have significantly higher inhibition for enzyme as compared to YWF and its flatbread (p<0.05).

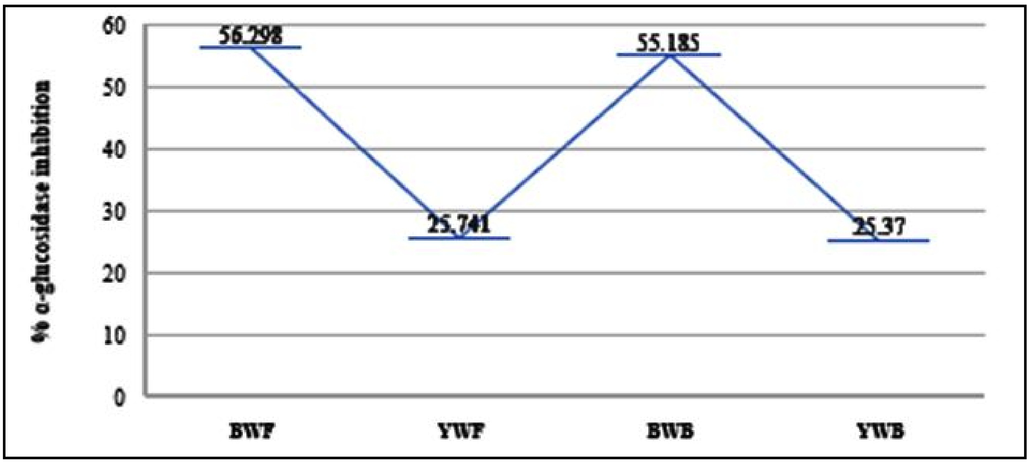


Figure 4: Per cent α-glucosidase inhibition in black wheat, yellow wheat flour and their flatbread.
BWF: black wheat flour, YWF: yellow wheat flour, BWB: black wheat flatbread, YWB: yellow wheat flatbread. Values are the means of three separate determinations (n =3).

3.4 Predicted glycemic index of flatbread

In comparison to YWB, BWB had a considerably (p<0.05) lower predicted glycemic index (pGI). Average glucose level released from the hydrolysis of starch from flatbread was estimated at each interval of 30 min. Glucose levels peaked at 60 min for YWB whereas at 120 min for BWB, thereafter showed a trend of normalization. The glycemic responses of the BWB and area under the curve were significantly lower than the YWB at all time points (Figure 5). BWB generated less percentage of hydrolysis (HI: 15.65 ± 0.48), whereas the hydrolysis value for YWB (HI: 34.68 ± 0.55) was higher. Thus, BWB showed a lower value of pGI (48.84 ± 0.28) and falls in the category of low GI (<55). Whereas, YWB having a pGI value of 59.95 ± 0.32, fell in the middle of the GI category (>55-<70).

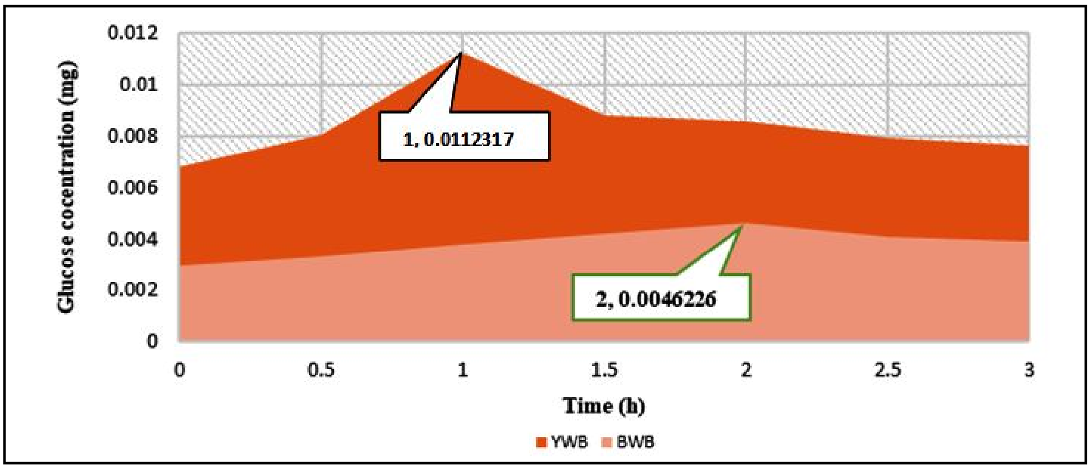


Figure 5: Area under blood glucose response curve for black wheat flatbread (BWB) and yellow wheat flatbread (YWB).

Remarkably, the results of this investigation indicate a strong negative association between the HI of flatbread and the suppression of α-amylase (r = - 0.998; p< 0.05; n = 2) and α-glucosidase (r = - 0.999; p<0.05; n = 2), potentially due to the inhibitory impact of anthocyanins on the hydrolyzing enzymes.

3.5 Sensory evaluation of flatbread

Figure 6 shows that BWB and YWB had comparable acceptance scores (no significant (p<0.05) difference) for taste, texture, flavor, and overall acceptability.

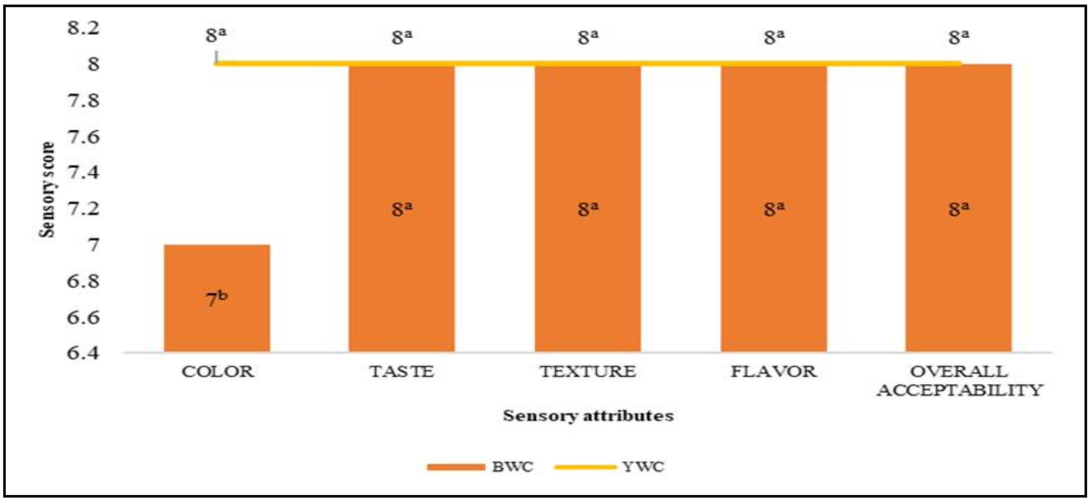


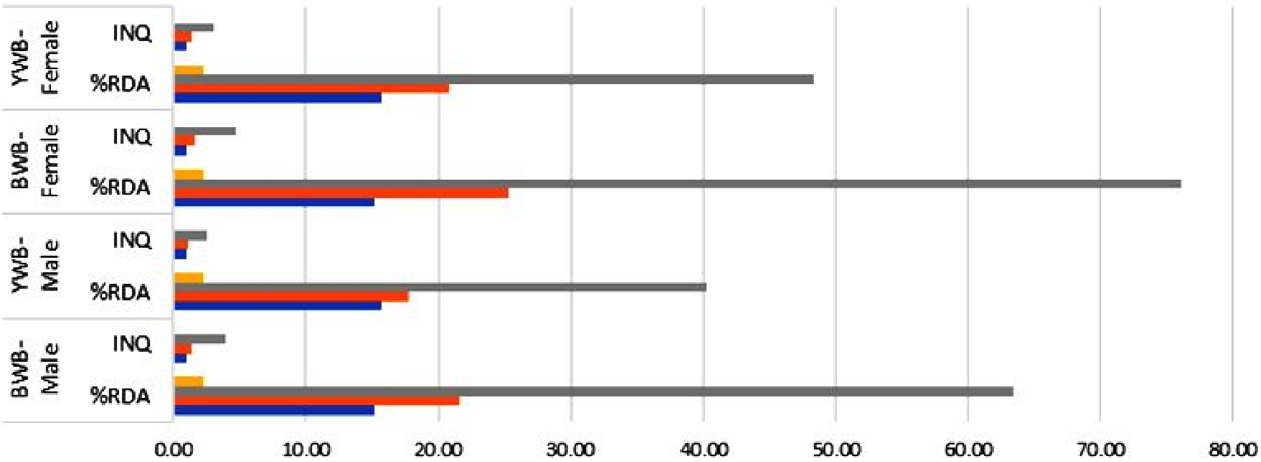
Figure 6: Sensory evaluation of black wheat flatbread (BWB) and yellow wheat flatbread (YWB).
[ab] values with different superscript letters differed significantly (p<0.05) where, a>b.

On the other hand, the color of the flatbread showed a significant (p<0.05) difference. Nonetheless, the current study's findings imply that despite its dark appearance, consumers preferred black wheat flatbread since their taste, flavor, texture and overall acceptability were similar to those of yellow wheat flatbread.

3.6 Nutrient adequacy of flatbread

Profile of 1 serving of flatbread (cooked weight-100 g), *i.e.*, 4 flatbreads, 25 g each (cooked weight) as presented in Figure 7 shows that one serving of black wheat flatbread could meet increased RDA requirements of protein up to 21% and dietary fiber up to 57% as compared to the yellow wheat flatbread in both male and female Indian adults (ICMR, 2020).

Black wheat flatbread had a higher food quality index value than yellow wheat flatbread for nutrients such dietary fiber, protein, and energy, which are essential for the control of diabetes mellitus, which makes black wheat flatbread a suitable and potential replacement for yellow wheat flatbread. Considering the INQ value of more than 1, black wheat flatbread can thus be used in tackling protein deficiencies as well as health issues associated with low dietary fiber in the diet for both men and women.



	BWB-Male		YWB-Male		BWB-Female		YWB-Female	
	%RDA	INQ	%RDA	INQ	%RDA	INQ	%RDA	INQ
Fat (g)	2.31	0.14	2.30	0.15	2.31	0.14	2.30	0.15
Dietary fiber (g)	63.43	3.95	40.30	2.54	76.12	4.74	48.36	3.05
Protein (g)	21.56	1.34	17.78	1.13	25.30	1.58	20.87	1.33
Energy (kcal)	15.25	1.00	15.70	1.00	15.25	1.00	15.70	1.00

Figure 7: Contribution to the nutrient adequacy (% RDA) and index of nutritional quality (INQ) by one serving (4 flatbreads, each having cooked weight of 25 g) of black wheat flatbread (BWB) and yellow wheat flatbread (YWB) for Indian adults. BWB: black wheat flatbread, YWB: yellow wheat flatbread. INQ>1 signifies product is a good source of nutrient (Sorenson and Hanson, 1975). RDA values for man (sedentary) were taken as standard reference (ICMR, 2020).

4. Discussion

To determine black wheat's therapeutic potential for managing diabetes, it is necessary to evaluate its nutritional quality, nutrient adequacy, and antidiabetic potential. Present study included estimation of proximate composition, dietary fiber components as well as gluten to understand its nutritional quality. A low moisture content (<10%) of wheat flours, is responsible for its extended shelf life by inhibiting the growth of microorganisms and other biochemical events that lead to spoiling. Nonetheless, it was observed that the flatbread had higher moisture content, which is a key component in the flatbread's softness. Kumari *et al.* (2020) reported a significantly higher moisture content of 9.96 and 39.18% in black wheat flour and its flatbread, respectively. Ash, which indicates the mineral composition of food and includes main elements like Na, K, Ca, and Mg as well as trace elements like Fe, Zn, and Cu (Bilge *et al.*, 2016), was found in greater concentration in BWF and its flatbread. Kumari *et al.* (2020) reported a lower value of ash content in black wheat flour (1.83%) and flatbread (1.38%). Higher mineral content in black wheat flour implies that hygroscopicity is indirectly rising due to water-mineral connections and indirect interactions between minerals and carbohydrates (St-Onge *et al.*, 2002). Additionally, because bran contains around twenty times the ash concentration of endosperm, it is an excellent signal to understand the discrimination of bran and germ from the wheat kernel during flour milling (Bilge *et al.*, 2016). Higher protein content might be attributed to the higher total amino acids (8.88-18.91%), and higher essential amino acids (7.31-18.13 %) present in black wheat as compared to conventional wheat (Tian *et al.*, 2018). BWB's increased protein content is thought to be a major contributor to wheat's economic worth and is beneficial for fulfilling the daily demand for protein. A high-protein diet is beneficial for diabetics as it supplies essential amino acids (especially sulfur-containing) that repair the tissues and stimulate insulin secretion without raising blood glucose during absorption unlike carbohydrates (Mounika and Hymavathi, 2021). Additionally, it is responsible for the quality of the developed product, *i.e.*, puffiness in the case of flatbread (Gujral *et al.*, 2008). Kumari *et al.* (2020) found a slightly higher value of protein for black wheat flour (12.14%). Other researchers found a higher value of protein for pigmented wheat varieties, such as purple wheat flour (15.17%) (Guo *et al.*, 2013) and purple durum wheat (13.82%) (Ficco *et al.*, 2016). Fat content of flatbreads was not affected by baking and similar observations were made by Kumari *et al.* (2020). Baking reduced the carbohydrate content of flatbreads made using the two flours. Lower carbohydrate content can be responsible for the improved glucose response/insulin resistance upon intervention as well as its lowering weight gain effect (Sharma *et al.*, 2020; Kumari *et al.*, 2020). The PEV showed a significant variation following the baking of flatbreads made with the respective flours.

Higher fiber content was reported to be crucial to the health benefits of food therefore, given that dietary fiber is a form of carbohydrate polymer that is not broken down by the body's own enzymes, and thus assisted in the management of diabetes, constipation, weight management, and so on (Nidhi *et al*., 2022). Ficco *et al*. (2016) and Kumari *et al*. (2020) found that colored wheat varieties (10-12%) had higher dietary fiber content than yellow wheat (8-11%). These results imply that, in comparison to yellow wheat, black wheat could be regarded as a good source of dietary fiber and may aid in blood glucose regulation. The genetic makeup of the cultivars, variations in climate, irrigation techniques, milling, soil fertility, and agricultural methods all affect wheat's chemical composition, which may account for the differences among different researches.

Gluten plays a crucial role in wheat quality since it gives produced food products their strength, flexibility, and texture as well as ensuring that flour is suitable for use in a variety of product development processes. Gluten protein and its ability to absorb water are derived from dry gluten, which is what gives gluten in flour its dry matter. The lower content of gluten in pigmented wheat cultivars may be attributed to the presence of high dietary fiber that affects both the content and conformation of disulfide bonds. Gluten proteins undergo structural alterations due to fiber; namely, in secondary and aggregate structures, disulfide, and hydrogen bonding patterns (Zhou *et al*., 2021). Nevertheless, there is no data that looked into wheat accessions' overall gluten level. To enable the value addition, a great deal of study is thus needed, especially to validate the gluten nature of black wheat (Dhua *et al*., 2021).

One important tactic for controlling postprandial hyperglycemia is to inhibit the activity of α-amylase and α-glucosidase, enzymes involved in the digestion of carbohydrates (Kim *et al*., 2005; Islam, 2006; Chethan *et al*., 2008). The existence of higher phenolic acid content in black wheat (bound total phenolic acid content (TPC) and free TPC were 1.6 times and 6 times higher, respectively) than in normal yellow wheat, is likely the reason of the increased enzyme inhibition in black wheat (Dhua *et al*., 2021). These compounds influence amylases by either irreversibly interrupting the catalytic process or by competing with the substrate to attach to the active site of the enzyme. Through non-covalent interactions, such as hydrogen binding, cation-α interactions, salt bridge interactions, or electrostatic forces (Sui *et al*., 2016), phenolic acids and starch digestion enzymes interact (Martinez-Gonzalez *et al*., 2017). This reduces the amount of surface area on starch granules that can react with enzymes that are typical of cereal starches. Furthermore, α-amylase is inhibited *in vitro* by anthocyanins such peonidin-3-glucoside, cyanidin-3,5-glucoside, cyanidin-3-glucoside, and cyanidin-3-glucoside (Sui *et al*., 2017). Studies showed that phenolic extracts of barley (Ramakrishna *et al*., 2017), millets (Ofosu *et al*., 2020), beans (Habib *et al*., 2017), nigella seeds (Balyan and Ali, 2022), and citrus fruits (Alu'datt *et al*., 2017), exhibited an inhibitory effect on porcine α-amylase. Generally, natural α-amylase inhibitors derived from plant sources often possess therapeutic potential for controlling postprandial hyperglycemia by reducing the release of glucose from starch. Wheat contained α-amylase inhibitors, which exhibit strong resistance to trypsin and pepsin digestion and thermal stability. As a result, it was anticipated that these inhibitors would continue to have their inhibitory effects even after sterilizing procedures (Oneda *et al*., 2004).

Also, of all phenolic acids, ferulic acid is the major phenolic acid present in black wheat that is the most potent α-glucosidases inhibitor, and is responsible for its antidiabetic potential (Nile and Park, 2014; Wang *et al*., 2015). Studies showed that phenolic extracts of barley (Ramakrishna *et al*., 2017), millets (Seo *et al*., 2015; Ofosu *et al*., 2020), legumes (Tan *et al*., 2017), pigmented potato (Ramdath *et al*. 2014), citrus fruits (Alu'datt *et al*., 2017), water chestnut (Gu *et al*., 2021) and cumin (Ghalib and Mehrotra, 2022) phenolic extracts exhibited inhibitory effect on α-glucosidase. These phenolic acids bind to the α-glucosidase active protein pocket and decrease glucose uptake by promoting the dissipation of the Na^+ electrochemical gradient. This gradient provides the driving force for active glucose accumulation and, consequently, glucose transport (Welsch *et al*., 1989). As a result, they are known to decrease absorption of glucose and regulate postprandial hyperglycemia (Shobana *et al*., 2009), making them potentially therapeutically useful in the management of diabetes mellitus.

Lower GI of black wheat is in accordance with the finding of Kapoor *et al*. (2022), who found that compared to regular wheat, black wheat flour had the lowest *in vitro* GI. The mechanisms of lower GI in the case of black wheat can be attributed to different factors: bioactive component (anthocyanin), dietary fiber fraction, and lower gluten content. Anthocyanins, particularly cyanidin-3-glucoside, were encircled by the side chains of the porcine pancreatic á-amylase active site. Of these, the side chain of GLU233 was thought to be crucial in imparting the inhibition activity towards the enzymes that break down carbohydrates (Sui *et al*., 2016), which decreased the digestion by 6.31 to 17.45% (Lee *et al*., 2020). Dietary fiber is an indigestible ingredient that significantly and negatively correlates with pGI ($r = -0.751$, $p<0.05$) (Kaplan *et al*., 2020). Dietary fiber in food slows down the absorption of fat and glucose from the small intestine (Oh *et al*., 2005; Adedayo *et al*., 2018). It also ferments in the gut to produce short-chain fatty acids, which help regulate glucose levels and reduce postprandial glucose and insulin responses (Lal *et al*., 2021). Additionally, the reduced gluten content in BWF may be a factor in the slower starch digestibility, which may be related to the considerably weaker hydration qualities (Kan *et al*., 2020). This might potentially impede the digestion of starch *in vitro* (De La Hera *et al*., 2013; De La Hera *et al*., 2014). These findings imply that black wheat's ability to reduce blood sugar may make it a viable substitute for yellow wheat.

Jenkins *et al*. (2002) suggested, however, that the idea of GI is not the only factor considered when managing diabetes, and that more research be done on pharmacological methods to reduce the absorption of carbohydrates, perhaps by inhibiting the enzymes α-amylase and α-glucosidase, which hydrolyze carbohydrates. Enzymes involved in the metabolism of carbohydrates include α-amylase and α-glucosidase. Strong negative correlation between HI and enzyme inhibitory activity of hydrolyzing enzymes serves as the cornerstone of the theory behind how α-amylase and α-glucosidase inhibitors lower GI.

A nine-point Hedonic scale was used to assess the acceptability of flatbread based on its color, flavor, texture, and overall acceptability which showed that of all parameters, color attribute received the lower score. Kumari *et al*. (2020) reported that the color of wheat flatbread showed similar sensory scores as white wheat flatbread. Earlier, scientific evidence mentioned that consumers prefer white or yellow-colored wheat flatbreads over colored wheat flatbread (CIMMYT, 1989).

Recommended dietary allowances (RDA) are used to determine the adequacy of nutrients in food. Depending on age and gender, RDAs are the amounts of essential nutrient intake that are sufficient to meet the recognized dietary demands of almost all healthy individuals (NRC, 1989). However, it has been presumed that the other known nutrients are consumed in suitable levels if sufficient quantities of certain important nutrients are obtained only from prudent dietary choices. Therefore, it is helpful to consider both nutrients and energy as factors while making food choices. Another crucial metric for determining food quality is the Index of Nutritional Quality (INQ), which is a ratio of food's nutrient-to-calorie content (Sorenson and Hanson, 1975). For nutrients with an INQ above 1 for flatbreads such as protein, dietary fiber and energy suggests that the product is a good provider of nutrients and can be used to replace dietary deficits, according to Markiewicz-Ukowska *et al.* (2022).

5. Conclusion

Flatbread is an important staple food that is consumed worldwide. The present study thus focused on utilizing black wheat for the development of black wheat flatbread and aimed to compare its nutritional quality, antidiabetic potential, and nutrient adequacy against yellow wheat flatbread. According to the study's results, black wheat flatbread had higher level of α-amylase and α-glucosidase inhibition and a lower GI than yellow wheat, making it a potentially better option for controlling hyperglycemia and inhibiting the breakdown of carbohydrates. Considering the good nutritional quality and higher INQ for protein and dietary fiber, consumption of black wheat as a part of the dietary regime is recommended for health benefits. Also, this crop needs to be further evaluated to establish its therapeutic potential as a functional food for diabetes and other lifestyle diseases to pave the way for industrial utilization.

Acknowledgements

The authors appreciate the help of Department of Food Science and Nutrition, G.B. Pant University of Agriculture and Technology, Pantnagar, for providing the necessary facilities to carry out the research work.

Conflict of interest

The authors declare no conflicts of interest relevant to this article.

References

AACC (2000). Approved methods of the American Association of Cereal Chemists. AACC.

Adedayo, B.C.; Adebayo, A.A.; Nwanna, E.E. and Oboh, G. (2018). Effect of cooking on glycemic index, antioxidant activities, α-amylase, and α-glucosidase inhibitory properties of two rice varieties. Food Sci. Nutr., **6**(8):2301-2307.

N.R.C. (1989). Recommended dietary allowances. 10th edn, National Research Council-National Academy Press: Washington, DC, USA.

Alu'Datt, M.H.; Rababah, T.; Alhamad, M.N.; Al-Mahasneh, M.A.; Ereifej, K.; Al-Karaki, G., Al-Duais, M.; Andrade, J.E.; Tranchant, C.C.; Kubow, S. and Ghozlan, K.A. (2017). Profiles of free and bound phenolics extracted from Citrus fruits and their roles in biological systems: Content, and antioxidant, antidiabetic and antihypertensive properties. Food Funct., **8**(9):3187-3197.

Amerine, M.A.; Pangborn, R.M. and Roessler, E.B. (2013). Principles of Sensory Evaluation of Food. Elsevier.

AOAC (1995). Official Methods of Analysis of the Association of Official Analytical Chemists. 16th ed. Arlington, VA: AOAC International.

AOAC (2012). Official Methods of Analysis of the Association of Official Analytical Chemists. 19th ed. Washington, USA: AOAC International.

Arvidsson-Lenner, R.; Asp, N.G.; Axelsen, M.; Bryngelsson, S.; Haapa, E.; Järvi, A.; Karlström, B.; Raben, A.; Sohlström, A.; Thorsdottir, I. and Vessby, B. (2004). Glycaemic index. Relevance for health, dietary recommendations and food labelling. Food Nutr. Res. **48**(2):84-94.

Asp, N.G.; Johansson, C.G.; Hallmer, H. and Siljestroem, M. (1983). Rapid enzymic assay of insoluble and soluble dietary fiber. J. Agric., Food Chem., **31**(3):476-482.

Balyan, P. and Ali, A. (2022). Comparative analysis of the biological activities of different extracts of *Nigella sativa* L. seeds. Ann. Phytomed., **11**:577-587.

Bassi, D.; Kaur, K.; Singh, T.P. and Kaur, J. (2021). Quality attributes and Flatbread making property of biofortified wheat as influenced by particle size. J. Food Sci. Technol., **58**:1156-1164.

Bilge, G.; Sezer, B.; Eseller, K.E.; Berberoglu, H.; Koksel, H. and Boyaci, I.H. (2016). Ash analysis of flour sample by using laser-induced breakdown spectroscopy. Spectrochim Acta Part B At. Spectrosc., **124**:74-78.

Bohn, T.; Carriere, F.; Day, L.; Deglaire, A.; Egger, L.; Freitas, D.and Dupont, D. (2018). Correlation between *in vitro* and *in vivo* data on food digestion. What can we predict with static *in vitro* digestion models? Crit. Rev. Food Sci. Nutr., **58**(13): 2239-2261.

Cheng, Y.F. and Bhat, R. (2015). Physicochemical and sensory quality evaluation of chapati (Indian flat bread) produced by utilizing underutilized jering (PithecellobiumjiringaJack.) legume and wheat composite flours. Int. Food Res. J., **22**(6):2244-2252.

Chethan, S.; Sreerama, Y.N. and Malleshi, N.G. (2008). Mode of inhibition of finger millet malt amylases by the millet phenolics. Food Chem., **111**(1):187-191.

CIMMYT (1989). Wheat research and development in Pakistan; CIMMYT: Mexico City, Mexico.

De La Hera, E.; Gomez, M. and Rosell, C.M. (2013). Particle size distribution of rice flour affecting the starch enzymatic hydrolysis and hydration properties. Carbohydr. Polym., **98**(1):421-427.

De La Hera, E.; Rosell, C.M. and Gomez, M. (2014). Effect of water content and flour particle size on gluten-free bread quality and digestibility. Food Chem., **151**:526-531.

Dhua, S.; Kumar, K.; Kumar, Y.; Singh, L. and Sharanagat, V.S. (2021). Composition, characteristics and health promising prospects of black wheat: A review. Trends Food Sci. Technol., **112**:780-794.

Fardet, A. (2010). New hypotheses for the health-protective mechanisms of whole-grain cereals: What is beyond fibre? Nutr. Res. Rev., **23**:65-134.

Ficco, D.B.M.; De Simone, V.; De Leonardis, A.M.; Giovanniello, V.; Del Nobile, M.A.; Padalino, L.; Lecce, L.; Borrelli, G.M. and De Vita, P. (2016). Use of purple durum wheat to produce naturally functional fresh and dry pasta. Food Chem., **205**:187-195.

Garg, M.; Chawla, M.; Chunduri, V.; Kumar, R.; Sharma, S.; Sharma, N.K.; Kaur, N.; Kumar, A.; Mundey, J.K.; Saini, M.K. and Singh, S.P. (2016). Transfer of grain colors to elite wheat cultivars and their characterization. J. Cereal Sci., **71**:138-144.

Ghalib, R. and Mehrotra, N. (2022). *In vitro* α-glucosidase inhibitory activity of nanoencapsulated *Cuminum cyminum* L. (Angiosperms: Apiaceae) and it is interaction with acarbose. Ann. Phytomed., **11**(1):465-471.

Goñi, I.; Garcia-Alonso, A. and Saura-Calixto, F. (1997). A starch hydrolysis procedure to estimate glycemic index. Nutr Res., 17(3):427-437.

Gujral, H.S.; Haros, M. and Rosell, C.M. (2004). Improving the texture and delaying staling in rice flour flatbread with hydrocolloids and α-amylase. J. Food Eng., 65:89-94.

Gujral, H.S.; Singh, G.S. and Rosell, C.M. (2008). Extending shelf-life of flatbread by partial baking and frozen storage. J. Food Eng., 89:466-471.

Guo, Z.F.; Zhang, Z.B.; Xu, P. and Guo, Y.N. (2013). Analysis of nutrient composition of purple wheat. Cereal Res. Commun., 41:293-303.

Gu, Y.; Yang, X.; Shang, C.; Thao, T.T. and Koyama, T. (2021). Inhibition and interactions of alpha-amylase by daucosterol from the peel of Chinese water chestnut (*Eleocharis dulcis*). Food Funct., 12(18):8411-8424.

Habib, H.M., Theuri, S.W.; Kheadr, E. and Mohamed, F.E. (2017). DNA and BSA damage inhibitory activities, and anti-acetylcholinesterase, anti-porcine α-amylase and antioxidant properties of *Dolichos lablab* beans. Food Funct., 8(2):881-887.

ICMR NIN (2020). Recommended Dietary Allowances and Estimated Average Requirements Nutrient Requirements for Indians. Hyderabad: Indian Council of Medical Research National Institute of Nutrition.

Islam, S. (2006). Sweetpotato (*Ipomoea batatas* L.) leaf and its potential effect on human health and nutrition. J. Food Sci., 71(2):R13-R21.

Jenkins, D.J.; Kendall, C.W.; Augustin, L.S.; Franceschi, S.; Hamidi, M.; Marchie, A.; Jenkins, A.L. and Axelsen, M. (2002). Glycemic index: Overview of implications in health and disease. The Am. J. Clin. Nutr., 76(1):266S-73S.

Kan, L.; Capuano, E.; Fogliano, V.; Oliviero, T. and Verkerk, R. (2020). Tea polyphenols as a strategy to control starch digestion in bread: The effects of polyphenol type and gluten. Food Funct., 11(7):5933-5943.

Kaplan, M.; Yüksel, F. and Karaman, K. (2020). *In vitro* glycemic index, antioxidant capacity and some physicochemical characteristics of deep-fried sorghum-based gluten free chips. J. Food Sci. Technol., 58:3725-3733.

Kapoor, P.; Kumari, A.; Sheoran, B.; Sharma, S.; Kaur, S.; Bhunia, R.K.; Rajarammohan, S.; Bishnoi, M.; Kondepudi, K.K. and Garg, M. (2022). Anthocyanin biofortified colored wheat modifies gut microbiota in mice. J. Cereal Sci., 104:103433.

Kaushik, R.; Kumar, N.; Sihag, M.K. and Ray, A. (2015). Isolation, characterization of wheat gluten and its regeneration properties. J. Food Sci. Technol., 52:5930-5937.

Kim, Y.M.; Jeong, Y.K.; Wang, M.H.; Lee, W.Y. and Rhee, H.I. (2005). Inhibitory effect of pine extract on α-glucosidase activity and postprandial hyperglycemia. Nutr., 21(6):756-761.

Kumari, A.; Sharma, S.; Sharma, N.; Chunduri, V.; Kapoor, P.; Kaur, S. and Garg, M. (2020). Influence of biofortified colored wheats (purple, blue, black) on physicochemical, antioxidant and sensory characteristics of flatbread (Indian flatbread). Molecules, 25(21):5071.

Kwon, Y.I.; Apostolidis, E. and Shetty, K. (2008). Inhibitory potential of wine and tea against α-amylase and α-glucosidase for management of hyperglycemia linked to type 2 diabetes. J. Food Biochem., 32(1):15-31.

Lal, M.K.; Singh, B.; Sharma, S.; Singh, M.P. and Kumar, A. (2021). Glycemic index of starchy crops and factors affecting its digestibility: A review. Trends Food Sci. Tech., 111:741-55.

Lee, J.J.L.; Chan, B.; Chun, C.; Bhaskaran, K. and Chen, W. N. (2020). A preparation of α-glucans and anthocyanins (LoGiCarb™) lowers the *in vitro* digestibility and *in vivo* glycemic index of white rice. RSC Adv., 10(9):5129-5133.

Markiewicz-Ukowska, R.; Pucecion-Jakubik, A.; Grabia, M.; Perkowski, J.; Nowakowski, P.; Bielecka, J. and Socha, K. (2022). Nuts as a dietary enrichment with selected minerals-content assessment supported by chemometric analysis. Foods, 11(20):3152.

Marquart, L.; Slavin, J.L. and Fulcher, R.G. (2002). Whole-grain foods in health and disease. American Association of Cereal Chemists. Inc, St. Paul., pp:187-200.

Martinez-Gonzalez, A.I.; Díaz-Sánchez, Á.G.; de la Rosa, L.A.; Vargas-Requena, C.L.; Bustos-Jaimes, I. and Alvarez-Parrilla, E. (2017). Polyphenolic compounds and digestive enzymes: *In vitro* non-covalent interactions. Molecules, 22(4):669.

Mitra, S.; Mitra, S. and Tarafdar, J. (2021). Antioxidant substances and phytonutrients in sweet potato tubers of different flesh colour. Ann. Phytomed., 10(2):384-390.

Mounika, M. and Hymavathi, T. V. (2021). Nutrient and phytonutrient quality of nutricereals incorporated flour mix suitable for diabetics. Ann. Phytomed., 10(1):132-140.

Nandini, C.D. and Salimath, P.V. (2001). Carbohydrate composition of wheat, wheat bran, sorghum and bajra with good chapati/roti (Indian flat bread) making quality. Food Chem., 73(2):197-203.

Nidhi, D. K.; Puranik, V. and Mishra, P. (2021). Effects of extraction solvents on cultivars of wheat (PBW-154 and HD-2967) bran antioxidant properties. Ann. Phytomed., 10(2):354-359.

Nile, S.H. and Park, S.W. (2014). Antioxidant, α-glucosidase and xanthine oxidase inhibitory activity of bioactive compounds from maize (*Zea mays* L.*)*.Chem. Biol. Drug Des., 83(1):119-125.

Ofosu, F.K.; Elahi, F.; Daliri, E.B., Chelliah, R.; Ham, H.J.; Kim, J.H.; Han, S.I., Hur, J.H. and Oh, D.H. (2020). Phenolic profile, antioxidant, and antidiabetic potential exerted by millet grain varieties. Antioxidants, 9(3):254.

Oh, K.; Hu, F.B.; Cho, E.; Rexrode, K.M.; Stampfer, M.J.; Manson, J.E.; Liu, S. and Willett, W.C. (2005). Carbohydrate intake, glycemic index, glycemic load, and dietary fiber in relation to risk of stroke in women. Am. J. Epidemiol., 161(2):161-169.

Oneda, H.; Lee, S. and Inouye, K. (2004). Inhibitory effect of 0.19 α-amylase inhibitor from wheat kernel on the activity of porcine pancreas α-amylase and its thermal stability. J. Biochem., 135(3):421-427.

Panghal, A.; Chhikara, N. and Khatkar, B.S, (2019). Characterisation of Indian wheat varieties for flatbread (flat bread) quality. J. Saudi Soc. Agric. Sci., 18(1):107-111.

Ramakrishna, R.; Sarkar, D.; Schwarz, P. and Shetty, K. (2017). Phenolic linked anti-hyperglycemic bioactives of barley (*Hordeum vulgare* L.) cultivars as nutraceuticals targeting type 2 diabetes. Ind. Crops Prod., 107:509-517.

Ramdath, D.D.; Padhi, E.; Hawke, A.; Sivaramalingam, T. and Tsao, R. (2014). The glycemic index of pigmented potatoes is related to their polyphenol content. Food Funct., 5(5):909-915.

Salim ur rehman, Paterson A. and Piggott, J.R. (2006). Optimization of flatbread textural quality using British wheat cultivar flours. Int. J. Food Sci. Technol., 41:30-36.

Seo, K.H.; Ra, J.E.; Lee, S.J.; Lee, J.H.; Kim, S.R.; Lee, J.H. and Seo, W.D. (2015). Anti-hyperglycemic activity of polyphenols isolated from barnyard millet (*Echinochloa utilis* L.*)* and their role inhibiting α-glucosidase. J. Korean Soc. Appl. Biol. Chem., 58:571-579.

Sharma, P. and Gujral, H.S. (2014). Anti-staling effects of α-glucan and barley flour in wheat flour flatbread. Food Chem., **145**:102-108.

Sharma, S.; Khare, P.; Kumar, A.; Chunduri, V.; Kumar, A.; Kapoor, P.; Mangal, P.; Kondepudi, K.K.; Bishnoi, M. and Garg, M. (2020). Anthocyanin biofortified colored wheat prevents high fat diet-induced alterations in mice: Nutrigenomics studies. Mol. Nutr. Food Res., **64**(13):1900999.

Sharma, S.; Chunduri, V.; Kumar, A.; Kumar, R.; Khare, P.; Kondepudi, K.K.; Bishnoi, M. and Garg, M. (2018). Anthocyanin biofortified colored wheat: Nutritional and functional characterization. PloS One, **13**(4): e0194367.

Singh, B. and Singh, N. (2006). Physico-chemical, water and oil absorption and thermal properties of gluten isolated from different Indian wheat cultivars. J. Food Sci. Technol., **43**(3):251-255.

Sorenson, A.W. and Hansen, R.G. (1975). Index of food quality. J. Nutr. Educ., **7**(2):53-57.

Sreerama, Y.N. and Malleshi, N.G. (2009). Composition and enzyme inhibitory properties of finger millet (*Eleusine coracana* L.) seed coat phenolics: Mode of inhibition of α-glucosidase and pancreatic amylase. Food Chem., **115**(4):1268-1273.

St-Onge, L.; Kwong, E.; Sabsabi, M. and Vadas, E.B. (2002). Quantitative analysis of pharmaceutical products by laser-induced breakdown spectroscopy. Spectrochim. Acta B: At. Spectrosc., **57**(7):1131-1140.

Sui, X.; Zhang, Y. and Zhou, W. (2016). *In vitro* and *in silico* studies of the inhibition activity of anthocyanins against porcine pancreatic α-amylase. J. Funct. Foods., **21**:50-57.

Swaranjeet, K.; Maninder, K. and Bains, G.S. (1982). Chapaties with leavening and supplements: Changes in texture, residual sugars, and phytic phosphorus. Cereal Chem., **59**(5):367-372.

Tan, Y.; Chang, S.K. and Zhang, Y. (2017). Comparison of α-amylase, α-glucosidase and lipase inhibitory activity of the phenolic substances in two black legumes of different genera. Food Chem., **214**:259-68.

Tian, S.Q.; Chen, Z.C. and Wei, Y.C. (2018). Measurement of colour-grained wheat nutrient compounds and the application of combination technology in dough. J. Cereal Sci., **83**:63-67.

Wang, T.; Li, X.; Zhou, B.; Li, H.; Zeng, J. and Gao, W. (2015). Antidiabetic activity in type 2 diabetic mice and α-glucosidase inhibitory, antioxidant and anti-inflammatory potential of chemically profiled pear peel and pulp extracts (Pyrus spp.). J. Funct. Foods, **13**:276-288.

Welsch, C.A.; Lachance, P.A. and Wasserman, B.P. (1989). Dietary phenolic compounds: inhibition of Na+-dependent D-glucose uptake in rat intestinal brush border membrane vesicles. J. Nutr., **119**(11):1698-1704.

Wongsa, P.; Chaiwarith, J.; Voranitikul, J.; Chaiwongkhajorn, J.; Rattanapanone, N. and Lanberg, R. (2019). Identification of phenolic compounds in colored rice and their inhibitory potential against α-amylase. Chiang Mai J. Sci., **46**(4):672-682.

Zhou, Y.; Dhital, S.; Zhao, C.; Ye, F.; Chen, J. and Zhao, G. (2021). Dietary fiber-gluten protein interaction in wheat flour dough: Analysis, consequences and proposed mechanisms. Food Hydrocoll., **111**:106203.

Citation	Krati Goel, Archana Kushwaha, Anuradha Dutta, Satish Kumar Sharma, Navin Chandra Shahi and Anil Kumar (2024). Nutritional quality of black wheat flatbread: A therapeutic alternative for diabetes management. Ann. Phytomed., 13(1):602-611. http://dx.doi.org/10.54085/ap.2024.13.1.62.