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Development of value-added snacks using black wheat flour

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Abstract
Black wheat, a nutritionally superior variety developed through conventional breeding, holds immense potential in addressing both dietary deficiencies and the rising demand for functional foods. Enriched with antioxidants, anthocyanins, dietary fiber, and essential micronutrients like iron, calcium, and zinc, black wheat offers several health benefits, including anti-inflammatory, antidiabetic, and cardioprotective effects. The present study aimed to utilize this health-promoting cereal in the formulation of value-added snack items-ladoo, biscuits, and muffins-by replacing conventional wheat flour entirely with black wheat flour.

Raw black wheat grains were procured and processed into flour. Standard recipes were modified with 100% black wheat flour substitution and evaluated for sensory acceptability using a semi-trained panel (n=25) through a 9-point hedonic scale. Cost analysis and statistical validation (paired t-test) were also carried out.

Results indicated that while the color and appearance scores of black wheat *ladoos* and biscuits were significantly lower than their conventional counterparts ($p \leq 0.05$), attributes like taste, texture, aftertaste, and overall acceptability remained statistically comparable. Muffins made with black wheat flour showed no significant difference across all sensory parameters, and in some cases, even demonstrated slight improvements. Cost per portion remained economically viable making them accessible and affordable options for health-conscious consumers.

This study demonstrates that black wheat flour can be successfully used as a functional ingredient in snack product development without compromising consumer acceptability.

Keywords: Black wheat, sensory evaluation, value-added snacks, *ladoo*, biscuits, muffins

Introduction
Cereal crops play a crucial role in the global food supply and have significant importance for both human nutrition and the economy. Wheat is a versatile cereal grain that is widely cultivated and consumed, providing a significant source of energy, carbohydrates, fiber, and various essential nutrients in the human diet. Black wheat, developed through conventional plant breeding techniques at NABI (National Agro-Food Biotechnology Institute University, Mohali, Punjab), has emerged as a preferred option among farmers due to its enhanced health advantages compared to brown wheat. Coloured wheat has gained much interest, as wheat is a cheap energy source and anthocyanin addition gives it functionality [1]. (Kumari & Tzudir., 2021) [1, 2].

The black wheat is rich in protein, iron, zinc, antioxidant, anthocyanins and procyanidins. The essential amino acid profile of black wheat, polyunsaturated fatty acids such as linoleic and linolenic acid more (30-50%) than white wheat. The regular consumption of black wheat is associated with pronounced health benefits such as anti-inflammatory, anticancer, preventing cardiovascular diseases [2]. Besides this, Black Wheat is rich in total essential amino acids [3]. Additionally, black wheat comprises a range of non-starch polysaccharides such as arabinoxylan, structural components including lignin and cellulose, simple sugars, phytic acid, and significant quantities of dietary fiber. It is also a source of essential vitamins-namely niacin, B5, K, and E-and vital minerals such as iron, zinc, calcium, copper, manganese, selenium and phosphorus. Furthermore, it is enriched with high-value bioactive compounds like total phenols, flavonoids and anthocyanins [4]. These constituents contribute not only to

fundamental physiological functions, including energy provision, water balance regulation, and tissue building, but also offer notable health benefits. These include supporting gastrointestinal health through fecal bulking, aiding in weight management, alleviating constipation, and reducing the risk of metabolic disorders such as diabetes and cardiovascular diseases [2, 5].

Cereals are essential to a healthy diet because they are one of the most important food items. Wheat is the most popular grain, and it is used in a wide variety of foods, including bread, noodles, and biscuits. Black wheat is a novel option which may serve this purpose as its nutritional value is very high as compared to traditional wheat [6]. It is more nutritious compared to the traditional wheat. Its needs to be popularized among the population. Black Wheat is a non-GMO product and an excellent choice for having a high amount of antioxidants, fibres, protein, and fewer carbohydrates [7]. It can aid to some extent in eradicating a serious and universal problem of 'malnutrition,' with modest care on a global and national scale. Supplementing our diet with black wheat products may help us improve body resilience and boost our immune system against illnesses. Good research and extension work are required on black wheat. It is an excellent source of bioactive phytochemicals with preventive effects against inflammation, metabolic syndrome, obesity, diabetes, dyslipidaemia, aging, and Neurodegeneration [4]. Cooking the coloured wheat reduces anthocyanin and other phytochemicals content but does not reduce the antioxidant activity. It is expected to become a trendy functional food in many countries eventually. Therefore, value-added *ladoo*, biscuits and muffins were developed in the present study using black wheat flour.

Methodology

Procurement of raw materials

Black wheat (NABI variety) was procured from an agriculture farm in Raipur, Chhattisgarh. The grains were then sifted and thoroughly washed to eliminate infested, discolored and decayed grains and dirt, followed by drying and grinding to produce black wheat flour (Figure 1a & 1b). Other ingredients for different recipes were purchased from the local market. All the ingredients were purchased at one go to avoid varietal differences.

Fig 1a: Black wheat

Fig 1b: Black wheat flour

Formulation and standardization of recipes- Recipe standardization was carried out in the Food Science Laboratory of the university. Standard recipes of *Ladoo* (NWL), biscuits (NWB) and muffins (NWM) were developed using whole wheat flour and were used as control. For test recipes, 100% replacement was implemented by incorporating black wheat flour, while the remaining ingredients remained the same as the standard recipe. The tesr recipes were coded as BWL, BWB and BWM, respectively.

Organoleptic evaluation of recipes

A semi-trained panel of 25 members was selected using the sensitivity threshold test for sugar solutions. The sensory evaluation of the products was done, using a 9-point hedonic scale where '1' was dislike extremely and '9' was like extremely. The objectives were explained to the panellists before evaluation. The sensory scores were obtained for each of the products according to the colour, appearance, taste, after taste and overall acceptability.

Plate 1: Formulation of Ladoos

Plate 2: Formulation of Biscuits

Plate 3: Formulation of Muffins

Cost analysis of the developed products

The cost of developed products was calculated according to the market rate of the ingredients existing at the time of product formulation.

Statistical analysis

The analysis involved calculating the mean±standard deviation (SD) for the data. The determination of significant differences was done using paired t-tests using Microsoft Excel version 2010 with Megastat add-ins.

Results

Mean sensory scores of all the developed products have been discussed in subsequent sections.

Ladoo

Table 1: Mean sensory scores of *ladoo*

Sensory Attributes	NWL	BWL
Colour	8.84±0.37	8.0±0.6*
Appearance	8.76±0.4	8.16±0.5*
Texture	8.6±0.5	8.56±0.5
Taste	8.68±0.4	8.6±0.5
After taste	8.72±0.4	8.6±0.5
Overall Acceptability	8.72±0.4	8.56±0.5

Mean±SD (n = 25) with * are significantly different ($p \leq 0.05$)

The results of mean scores of the sensory attributes are presented in Table 1. A significant fall ($p \leq 0.05$) was found in sensory attributes- colour and appearance, which can be attributed to complete replacement with black wheat flour as compared to the control. The scores for colour for NWL and BWL *ladoos* were 8.84±0.37 and 8.0±0.6, respectively and for appearance 8.76±0.4 and 8.16±0.5. There was no significant difference in the mean scores of taste, texture and overall acceptability of BWL *ladoos*.

The cost of the *ladoo* was calculated according to the market rates of the ingredients existing at the time of product formulation. The cost of one portion of *ladoo* (30g) was Rs. 5.45.

Muffins

Table 2: Mean sensory scores of muffins-

Sensory Attributes	NWM	BWM
Colour	8.24±0.96	8.16±0.74
Appearance	8.2±0.76	8.2±0.57
Texture	8.12±0.92	8.36±0.63
Taste	8.08±0.81	8.24±0.66
After Taste	8.12±0.88	8.2±0.64
Overall Acceptability	8.12±0.83	8.24±0.59

Mean±SD (n = 25) with * are significantly different ($p \leq 0.05$)

The sensory evaluation of Black wheat muffins (Table 2) revealed minimal variation in all the sensory attributes. The control (NWM) and 100% Black wheat flour sample received an identical appearance score of 8.2, indicating no adverse effect of full substitution. Minor increases were observed in scores of texture, taste, after taste and overall acceptability, while colour remained relatively stable. These findings demonstrate that black wheat flour can be successfully incorporated up to 100% in muffin formulations without compromising sensory quality. The cost of one portion muffin (50g) was 9.16 Rs.

Biscuits

Table 3: Mean sensory scores of biscuits

Sensory Attributes	NWB	BWB
Colour	8.56±0.7	7.72±0.7*
Appearance	8.48±0.5	7.96±0.7*
Texture	8.04±0.9	7.8±0.9
Taste	8.24±0.7	7.76±1.1
After taste	8.24±0.8	7.76±1.2
Overall Acceptability	8.32±0.5	7.88±0.8

Mean±SD (n = 25) with * are significantly different ($p \leq 0.05$)

The results of mean scores of the sensory attributes are presented in Table 3. Similar to the scores obtained for Black wheat flour *ladoos*, scores for NWB and BWB biscuits showed a significant fall ($p \leq 0.05$) in colour and appearance with complete replacement with black wheat flour. The scores of 8.24±0.7, 8.24±0.8 and 8.32±0.5 were obtained for taste, after taste and overall acceptability, respectively, in the control product, whereas the corresponding values were 7.76±1.1, 7.76±1.2 and 7.88±0.8 in the black wheat formulation of biscuits. The results thus indicate that the black wheat was as acceptable as normal wheat by the panel. The cost of one portion of biscuit (40g) was 5.05 Rs.

Conclusion

The development of value-added snacks using black wheat flour proved to be both nutritionally beneficial and sensory acceptable. Despite minor variations in color and appearance, products such as *ladoos*, biscuits, and muffins retained favorable taste and texture even with 100% substitution. These findings underscore black wheat's potential as a functional ingredient in everyday diets, especially in the fight

against micronutrient deficiencies and chronic diseases. Its affordability further strengthens its appeal as a sustainable, health-promoting grain that deserves greater consumer and industry attention.

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