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Comparative evaluation of baking and functional qualities of black wheat flour

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Abstract
Exploring Black wheat will be advantageous to the domestic flour and baking industry and to the farmers. The baking and functional properties of Black wheat flour were determined and compared with white Netravati whole wheat flour. The Black wheat flour had good baking properties i.e. high gluten content both wet and dry (56.19% and 18.62%) and higher sedimentation value (30ml) falling number 382s value and functional properties i.e. highest WAC (1.904g/g), WAI 502g/g and WSI 5.67 g/g, higher OAC (102.7%) and higher foam stability i.e.110 percent make it useful in different foods formulation. The Black wheat flour had higher foam stability i.e.110 percent as compared to Netravati wheat flour i.e. 94 percent. The values for emulsion activity, emulsion stability, foam capacity, swelling capacity, flour dispersibility, and bulk density were found to be lesser as compared to white Netravati whole wheat flour under study.

Keywords: Black wheat, functional properties, gluten, sedimentation value, baking

Introduction

Cereals are grown for their highly nutritious edible seed, which are often referred to as grain. The major cereals consumed worldwide are wheat, rice, maize, barley, oats, rye, millet, sorghum. Among food grains, Wheat stands next to Rice, both in area and production. Wheat belongs to the cereal family *Gramineae*, subfamily *Hordeae*, tribe *Triticeae*, genus *Triticum*. Many countries add nutrients to food in order to meet human needs. Bio fortification breeding will play an important role in supplying enough nutrients. A new Black-grained wheat developed from a previously existing blue and purple line in China (Sun SC *et al* 1996, Sun SC *et al*. 1999) [37, 38] had high protein, total essential amino acids and total amino acids and antioxidant than those in white wheat varieties (Li *et al*. 2003) [19].

Commercial wheats are mostly white or red-colored grains. Although anthocyanin-pigmented wheat grains (i.e., purple, blue, and black wheats) are currently produced in small amounts, they have attracted more attention in recent years since they can be used to make special and colorful foods due to their phytochemical composition and distinctive colors (Ficco *et al.*, 2014) [9]. They thus have potential use as functional foods or as important functional ingredients for wheat-based products (Pasqualone *et al*., 2015; Ficco *et al*., 2016) [27, 6]. Because of the presence of many bioactive compounds, black grain wheat may be the potential resource of nutraceutical and functional materials for the development of different value added food products.

However, the use of any grain flour in various food formulations is dependent on their nutritional and functional properties. Therefore, an investigation was carried out first, to elucidate the baking and functional properties of Black wheat in comparison with Netravati wheat as white coloured. This is expected to give insight into the possible utilisation of Black wheat as partial substitutes of white wheat flour in bakery, extruded, snack, confectionary and other traditional food products.

Material and Methods

Raw materials

Black wheat grains (Protein content 14.49 percent) were obtained from local area of Punjab and Netravati wheat variety (Protein content 11.86 percent) was obtained from Seed Research Centre VNMKV, Parbhani.

Chemicals and Glassware

Chemicals used in this investigation were of analytical grade and sufficient glassware required was available in the laboratory, Department of Food Engineering, College of Food Technology, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani.

Baking qualities of wheat flour

Wet and dry gluten determination

The dry gluten content was determined by drying the wet gluten obtained according to AACC (2000) [2] Method 38-12.01. The wet gluten content of flour was measured by hand washing using dilute salt (2% NaCl) solution as described in AACC (2000) [2] Method 38-12.01. Wheat flour (3 g) was placed in a porcelain cup and sufficient distilled water was added starting from 2 ml to form the firm ball dough and the dough left to stand at 25°C for 30 min before washing. The dough was kneaded gently in stream of washing water over nylon cloth until starch and all other soluble matter was removed. Washing continues until 2 to 3 drops of wash water obtained by squeezing from gluten mass made no white cloud in clean water contained in clean beaker. The gluten obtained was left to stay in washing water for about 1 h and pressed as dry as possible between the hands and then roll it into a ball, place it in, a weighed flat bottom weighing dish and the net mass was recorded as wet gluten. The mass of dry gluten had been taken after drying as wet gluten for 24 h at 100°C.

Sedimentation Value

The sedimentation value of flour was measured by AACC Method 22-12. A small sample of flour or ground wheat (3.2 grams) was weighed and placed in 100-milliliter glass-stoppered graduated cylinder. Water (50 ml) was added to the cylinder and mixed for 5 minutes. Lactic acid solution was added to the cylinder and mixed for 5 minutes. The cylinder was removed from the mixer and kept in upright position for 5 minutes. The sedimentation volume was recorded. Sedimentation values could be in the range of 20 or less for low-protein wheat with weak gluten to as high as 70 or more for high-protein wheat with strong gluten.

The falling number value

The falling number instrument analyses viscosity by measuring the resistance of a flour-and-water paste to a falling stirrer. It indicates an index of enzyme activity in a wheat or flour sample and the results were expressed in time as seconds. A high falling number (for example, above 300 seconds) indicates minimal enzyme activity and sound quality wheat or flour. A low falling number (for example, below 250 seconds) indicates substantial enzyme activity and sprout damaged wheat or flour. The falling number of Black wheat flour was determined by a method given by Meera Kweon (2010) [23].

A 7-gram sample of ground wheat or flour was weighed and combined with 25 ml of distilled water in a glass falling number tube with a stirrer and shaken to form a slurry. When grinding a wheat sample to perform a falling number test, it should be at least 300 grams to assure a representative sample. As the slurry heated in boiling water bath at 100 degrees Celsius and stirred constantly, the starch gelatinizes and forms a thick paste. The time it takes the stirrer to drop through the paste was recorded as the falling number value. The greater the number, the higher the viscosity and the lower the alpha-amylase activity. Falling number values of greater than 250 sec are generally acceptable for breadmaking.

Functional properties of black wheat flour

Swelling capacity

The swelling capacity was determined by the method described by (Okaka and Potter, 1977). 100 ml graduated cylinder was filled with the flour to 10 ml mark. The distilled water was added to give a total volume of 50 ml. The top of the graduated cylinder was tightly covered and mixed by inverting the cylinder. The suspension was inverted again after 2 min and left to stand for a further 8 min. The volume occupied by the flour was taken after the 8th min.

Water absorption capacity

The water absorption capacity was determined by the method of (Sosulski *et al*., 1976). One gram of flour mixed with 10 ml distilled water and allow to stand at ambient temperature (30±20C) for 30 min and centrifuged for 30 min at 3000 rpm or 2000 x g. Water absorption was examined as percent water bound per gram flour.

Fat (oil) absorption capacity

The fat absorption capacity was determined by the method of (Sosulski *et al*., 1976). One gram of flour mixed with 10 ml soybean oil (Sp. gravity: 0.9092) and allows to stand at ambient temperature (30±20C) for 30 min, then centrifuged for 30 min at 3000 rpm or 2000 x g. Fat/oil absorption capacity was examined as percent fat/oil bound per gram flour.

Emulsion activity (%) and Emulsion stability (%)

The emulsion activity and stability were determined by the method of (Yasumatsu *et al*., 1972). The emulsion (1.0 g flour, 10 ml distilled water and 10 ml soybean oil) was mixed in calibrated centrifuged tube. The emulsion was centrifuged at 2000g for 5 min. The ratio of the height of emulsion layer to the total height of the mixture was calculated as emulsion activity in percentage. The emulsion stability was estimated after heating the emulsion contained in calibrated centrifuged tube at 800C for 30 min in a water-bath, cooled for 15 min under running tap water and centrifuged at 2000g for 15 min. The emulsion stability expressed as percentage was calculated as the ratio of the height of emulsified layer to the total height of the mixture.

Foam capacity (%) and Foam stability (%)

The foam capacity (FC) and Foam stability (FS) were determined as described by (Narayana and Narasinga Rao, 1982) with minute modification. The 1.0 g flour sample was added to 50 ml distilled water at 30±20C in a graduated cylinder. The suspension was mixed and shaken for 5 min to foam development. The volume of foam at 30 sec after whipping was expressed as foam capacity using the formula:

$$\text{Foam capacity (\%)} = \frac{\text{Volume of foam AW} - \text{Volume of foam BW}}{\text{Volume of foam BW}} \times 100$$

Where,

AW = after whipping, BW = before whipping

The volume of foam was recorded one hour after whipping to determine foam stability as per percent of initial foam volume.

Flour Dispersibility

Dispersibility of flour was determined by method adopted by Kulkarni *et al*., (1991) [17]. Sample of 10g was dispersed in distilled water in a 100 ml measuring cylinder and distilled water was added up to 50 ml mark. The mixture was stirred vigorously and allowed to settle for 3 h. The volume of settled particles was noted and percentage dispersibility was calculated as follows:

$$\text{Dispersibility (\%)} = \frac{(50 - \text{volume of settled particle})}{50} \times 100$$

Water absorption index (WAI)

Water absorption index (WAI) and water solubility (WSI) determine by the method of Suraiya Jamal *et al*. (2016) [39]. 1 g of sample was weighed and placed in a centrifuge tube. Then 6 ml of distilled water was added for suspension. The tubes along with the samples were heated in shaking water bath at the temperature of 80 °C for 30 minutes. The solution was centrifuged at 2500rpm for 10 minutes. After the centrifugation, the supernatants were carefully poured into Petri dish for drying at 105 °C for 10 hours in an oven, while the sediments were weighed as such.

$$\text{WAI} = \frac{\text{Wt. of wet sediment}}{\text{Dry wt. of sample}}$$

Water absorption index was calculated on the basis of wet sediments, while water solubility index was calculated on the basis of difference in the weight of dried supernatant and initial sample.

Water Solubility Index (WSI)

Water Solubility Index (WSI) The water solubility index of starches was carried out as described by Anderson and Sefa-dedeh (2001) [3] with little modification. 1 g each of the starches and 10 ml of water were mixed in a 15 ml plastic centrifuge tube and were immersed in water bath for 30 min at 37 oC. This was then centrifuged at 4000 rpm for 10 min after which the supernatant was collected in a pre -weighed beaker and the residue was weighed after the water was evaporated at 105 ° C; the percentage of residue with respect to the amount of starch used was taken as the water solubility index.

$$\text{WSI (\%)} = \frac{\text{Wt. of dried supernatant}}{\text{Dry wt. of sample}}$$

Bulk Density

The volume of 100 g of the flour was measured in a measuring cylinder (250 ml) after tapping the cylinder on a wooden plank until no visible decrease in volume was noticed, and based on the weight and volume, the apparent (bulk) density was calculated (Jones *et al*., 2000) [12].

$$\text{Bulk Density} = \frac{\text{Mass of the materials (M)}}{\text{Volume of the materials } (V_B)}$$

Results and Discussion

Baking qualities of Black wheat flour

Cheng Xue *et al*. (2019) [5] stated that baking quality of wheat flour is determined by grain protein concentration (GPC) and its composition and is highly influenced by environmental factors such as nitrogen (N) fertilization management. It is an important to determine the quality of wheat flour to produce various bakery products. In broader meaning, baking quality in terms of dry and wet gluten percentage, sodium dodecyl sulfate (SDS) sedimentation value, falling number, fermentation value and dough raising capacity all comes under baking quality. The data related to baking qualities of Black wheat flour in relation with control Netravati wheat flour are presented in table 1.

The dough developed by mixing wheat flour with water possesses the viscoelastic characteristics vital for dough handling and final product quality. The viscoelsatic nature of dough is attributed to gluten. It is revealed from table 10 that the Black wheat flour had high gluten content both wet and dry (56.19% and 18.62%) and higher sedimentation value (30ml) respectively than Netravati wheat flour(43.51% and 14.19%) and 26ml respectively. This might be owing to higher concentration of protein in black than Netravati wheat flour. Beta *et al* (2006) [18] reported that Chinese black-grained wheat (BGW) exhibited 41.96% and 17.15% wet and dry gluten and 13.3 ml/g SDS sedimentation values. SDS sedimentation value is positively correlated with gluten strength where as the higher SDS sedimentation value corresponds to strong gluten strength.

Table 1: Baking qualities of Black wheat flour

Parameter	Flour Type	
	Black Wheat	Netravati Wheat
Wet gluten(%)	56.19	43.51
Dry gluten(%)	18.62	14.19
Sedimentation value (ml) (after 5minutes)	30	26
Falling Number(s)	382	370

*Each value is average of three determinations

The Falling Number test provides an index of α-amylase in a flour or ground-wheat sample. It is used as one of the key indicators of wheat baking quality. The flour having high level of alpha-amylase activity requires less amount of water for mixing, softens the dough, weakens the bread structure and produces a soft, sticky crumb. The Black wheat flour had 382s falling number value as higher than 370s of that Netravati wheat flour. A high falling number of Black wheat flour i.e. above 300 seconds indicates minimal enzyme activity and sound quality wheat or flour.

The results for the flour prepared from Skorpion variety(wheat grain containing blue aleurone) exhibited 251s falling number value (Kurt and Evers, 2017) [1] and AF Jumiko and PS Karkulka (wheat grains containing purple pericarp) varieties exhibited higher values(407-460s) indicating low activity of amylase enzymes (Ranken, Kill and Baker, 1997) [1] and concluded as the flours prepared from colored wheat grains exhibited variations in the values of Hagberg falling number and Zeleny sedimentation volume.

Functional properties of black wheat flour

Functional properties describes the behavior of ingredients during product preparation and cooking, as well as how they affect the finished food products in terms of how it looks, feels and tastes. These include swelling capacity, water absorption capacity, oil absorption capacity, emulsion activity, emulsion stability, foam capacity, foam stability, viscosity, particle size, flour dispersibility, bulk density, water absorption index and water solubility index play an important role in the development of bakery and confectionery products.

Table 2: Functional properties of black wheat flour

Parameters	Flour type	
	Black wheat	**Netravali wheat**
Water absorption capacity(g/g)	1.904	1.874
Water absorption Index(g/g)	502	473
Water solubility Index(g/100g)	5.67	6.15
Oil absorption capacity(%)	102.7	100.8
Emulsion Activity(%)	58.60	62.16
Emulsion stability(%)	70.7	83.3
Foam Capacity(%)	8	16
Foam Stability(%)	110	94

*Each value is average of three determinations

Water absorption capacity is the ability of flour to absorb water and swell for improved consistency in food. It is desirable in food systems to improve yield and consistency and give body to the food [Osundahunsi *et al.* (2003) [25]]. The water absorption capacities (WAC) of the flours ranged from 1.874 to 1.904g/g of flour (Table 2). Black wheat flour had the highest WAC (1.904g/g) while Netravali wheat flour had the lowest (1.874 g/g). The latter may be partly due to the large particle size of Netravati wheat flour, which translates to a smaller surface area that is exposed to water (Mariotti *et al.* 2009). Moreover, a significant negative relationship was found between WAC and crude fat content. The hydrophobic property of fats reduces the ability of the flour to absorb water. The effect of low water absorption capacity of the flour samples was probably due to the loose association of amylose and amylopectin in the native granules of starch and weaker associative forces maintaining the granules structure [Lorenz *et al.* (1990) [20]].The results of WAC for black wheat flour was more as compared to 1.21g/g for both yellow and Black wheat flour as reported by Subhamoy Dhua *et al.* (2021) [36].
The WAI is an indicator of the ability of flour to absorb water and swell for desirable consistency in food system, which improves yield and consistency, and gives body to the food product developed. The Water absorption capacity or index represent the ability of a product to associate with water under conditions where water is limited (Singh, 2001) [35]. The Black wheat flour had WAI 502g/g and WSI 5.67 g/g. The WSI is used to indicate starch degradation, and thus it determines the amount of free polysaccharide or polysaccharide released from the granule on the addition of excess water.
Oil retention has been attributed to the physical entrapment of the lipid by the protein (Quin and Benchat, 1975; Padmashree *et al.*, 1987) [29, 26]. OAC is the ability of the flour protein to physically bind fat by capillary attraction and it is of great importance, since fat acts as flavor retainer and also increases the mouth feel of foods, especially bread and other baked foods (Kinselle, 1976) [16]. The OAC of Black wheat flour was higher(102.7%) as compared to Netravati wheat flour(100.8%). The results of OAC for black wheat flour was more as compared to 0.81g/g for Black wheat flour as reported by Subhamoy Dhua *et al.* (2021) [36]. The rate of oil absorption is very high in foods with high protein content. The oil and water binding capacity of protein in food depend on the intrinsic factors such as protein conformation, amino acid composition, and surface polarity or hydrophobicity (Suresh and Samsher, 2013) [40].
The emulsifying capacity, also called emulsion capacity (EC), of foods is associated with the amount of oil, non-polar amino acids residues on the surface of protein, water, and other components in the food. The EA of Black wheat flour was lower (58.60%) as compared to Netravati wheat flour (62.16%). The results of EC for black wheat flour was more (51.37%) as reported by Subhamoy Dhua *et al.* (2021) [36] as compared to Black wheat flour under study. Difference in the EA of protein may be related to their solubility exhibited the lowest emulsifying activity and highest emulsion stability. Hydrophobicity of protein has been attributed to influence their emulsifying properties (Kaushal *et al.*, 2012) [15]. These properties are influenced by many factors among which are solubility, pH and concentration. Emulsion stability of foods is to the ability of a food emulsion to resist any change in its properties over time (McClements, 2004) [22].
Product foam ability is related to the rate of decrease of the surface tension of air/water interface caused by absorption of protein molecules. The foam stability (FS) refers to the food ability to stabilize against mechanical and gravitational stresses (Fennama 1996) [8]. There is always an inverse relationship between the foaming capacity and the foam stability. Flours with high foaming capacity may form large air bubbles encircled by thinner less flexible protein film. Consequently, this air bubbles may collapse easily and consequently lower the foam stability (Jitngarmkusol *et al.*, 2008) [11]. Good foam capacity and stability are desired attributes for flours intended for use in the production of various baked products such as angel cakes, muffins, *akara*, cookies, etc., and also perform as functional agents in many other food formulations (El-Adawy, 2001) [7]. The Black wheat flour has 8percent foaming capacity which was found to be less but had higher foam stability i.e.110 percent as compared to Netravati wheat flour i.e.16percent as FC and 94 percent as FS. The results of FC for black wheat flour was more as compared to 7.95% for Black wheat flour as reported by Subhamoy Dhua *et al.* (2021) [36]. Protein in the dispersion can lower the surface tension at the air-water interface, thus often due to protein which forms continuous cohesive thin film around air bubbles in the foam (Kaushal *et al.*, 2012) [15]. The results of functional properties of wheat flour were in close agreement with the results as OAC 110%,EA 12.8%,ES 18.6%,FC 20.4% and FS 63.2% by Horsfall *et al.* (2007) [10].

Table 3: Functional properties of black wheat flour

Parameters	Flour type	
	Black wheat	**Netravati wheat**
Swelling capacity (ml)	9.8	9.9
FD(%)	69	70
BD(g/ml)	0.46	0.50

*Each value is average of three determinations

It was found that the swelling capacity of Black wheat flour was less i.e.9.8ml as compared to Netravati wheat flour (9.9ml). The values for SC were less as compared to results reported by Alviola & Monterde (2018) [13] for swelling power i.e.11.01g/g. The swelling capacity (index) of flours are influenced by the particle size, species variety and method of processing or unit operations (Suresh and Samsher, 2013)

[40]. Swelling power is mainly influenced by amylose content, especially with the presence of other flour components. According to Shimelis and co-authors (2006) [34], amylose and lipids form insoluble complexes that decrease swelling power. Similarly, proteins lower the swelling power by forming a stiff matrix when they are being embedded in the starch granules, thus limiting the access of water (Aprianita *et al*. 2014) [4]. From these, it is commonly reported that swelling power is inversely proportional to protein, fat, and amylose content (Sasaki & Matsuki 1998; Phattanakulkaewmorie *et al*. 2011) [33, 28]. [Moorthy and Ramanujam (1986) [24]] reported that the swelling capacity of flour granules is an indication of the extent of associative forces within the granule. The variation in the swelling capacity indicates the degree of exposure of the internal structure of the starch present in the flour to the action of water [Ruales (1993) [30]].

Bulk density is very important in determining the packaging requirement, material handling and application in wet processing in the food industry [Yellavila *et al*. (2015) [32]]. The bulk density of Black wheat flour was found to be 0.46g/ml indicating less denser flour with low flour dispersibility too i.e.69 percent as compared to Netravati wheat flour with 0.50g/ml bulk density and 70 percent flour dispersibility. The higher the bulk density, the denser the flour and vice-versa. The higher bulk density is desirable for greater ease of dispensability of flours. In contrast, however, low bulk density would be an advantage in the formulation of complementary/weaning foods for infants [Kavitha and Parimalavalli (2014) [31]]. The change in bulk density is generally affected by the particle size and the density of the flour, it is very important in determining packaging requirement and material handling [Karuna *et al*. (1996) [14]]. The values for BD were less as compared to results reported by Horsfall *et al*. (2007) [10] for BD i.e.0.63g/cm^3. The results of BD for black wheat flour was more as compared to 0.606g/ml for Black wheat flour as reported by Subhamoy Dhua *et al*. (2021) [36].

Conclusion

The basic baking and functional properties of Black wheat flour in comparison with white Netravati wheat flour have been determined in a laboratory environment. The findings of this study showed that the Black wheat since rich in protein (14.49%) which could be exploited for nutrition and flour of this could be used to fortify conventional flours which are low in protein. The consumption of foods based on Black wheat would be important step towards alleviating protein malnutrition. The Black wheat flour had good baking properties i.e. high gluten content both wet and dry (56.19% and 18.62%) and higher sedimentation value (30ml) falling number 382s value and functional properties i.e. highest WAC (1.904g/g), WAI 502g/g and WSI 5.67 g/g, higher OAC (102.7%) and higher foam stability i.e.110 percent make it useful in different foods formulation. The Black wheat flour had higher foam stability i.e.110 percent as compared to Netravati wheat flour i.e. 94 percent. The values for emulsion activity, emulsion stability, foam capacity, swelling capacity, flour dispersibility, and bulk density were found to be lesser as compared to white Netravati whole wheat flour under study. It can be concluded that Black wheat flour was functionally superior in most of the functional characteristics than the white Netravati whole wheat flour. So it can be used easily in formulating different type of products.

In the future, it is necessary to study carefully the chemical composition, phytochemical contents, rheological analysis and processing aspects of wholegrain black wheat flour, to establish how it changes during baking, extrusion and other processing conditions including cooking to substantiate the different properties of this flour, and to improve its production technology. This is going to allow its wider use in food products, and will certainly contribute to improving the people's health. However, all these properties are dependent upon the genotype of the wheat grain, post-harvest treatments, storage conditions (such as temperature) and the environmental conditions under which it grows.

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