Rheological, physico-sensory, nutritional and storage characteristics of bread enriched with roller milled fractions of black gram (*Phaseolus mungo* L.)

D. Indrani · Suresh D. Sakhare · Milind ·
Aashitosh A. Inamdar

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Abstract Black gram grains were fractionated using roller flour mill. Effect of combination of additives (CA) namely dry gluten powder, sodium stearoyl-2-lactylate, fungal α -amylase on the rheological and bread making characteristics of wheat flour partly replaced with roller milled fractions of black gram was studied. With increase in the addition of straight run flour (SRF), protein rich fraction (PRF), protein and fiber rich fraction (P&FRF) from 0 to 20 %, fiber rich fraction, FRF (0–15 %), the farinograph water absorption increased and dough stability decreased; amylograph pasting temperature increased and peak viscosity decreased; bread volume decreased and crumb firmness value increased indicating adverse effect of these fractions on the rheological and bread making characteristics of wheat flour. Sensory evaluation showed that breads were acceptable only up to the level of 15 % for SRF, PRF & P&FRF and 10 % for FRF. However, when CA containing dry gluten powder, sodium stearoyl-2-lactylate and fungal α -amylase was incorporated the overall quality of the products improved. Use of these fractions increased the protein and fiber contents of bread by 1.24–1.66 and 1.48–3.79 times respectively. The results showed that possibility of utilising roller milled black gram fractions along with CA to improve the taste, texture and nutritional quality of bread.

Keywords Black gram · Rheological properties · Bread quality · Texture analysis

Introduction

Black gram (*Phaseolus mungo* L.) or urid is one of the important tropical legume crop in India. It belongs to the family *Leguminosae* and is reported to be originated in India. Black gram is a rich protein food with protein content ranging from 26.0 to 28.4 % on a dry-weight basis. Proteins of black gram are easily digestible and very good sources of phosphoric acid and vitamins (Girigowda et al. 2005). Like most other legume proteins, black gram proteins are deficient in sulfur-containing amino acids and are rich in lysine. Black gram is mainly used in preparation of fermented foods such as *idli*, *papadams*, *dosa*, and other regional fermented foods in India (Reddy et al. 1982).

Epidemiological observations reveal that several diseases of “civilization”, such as coronary heart disease, diabetes, and some common diseases, are most prevalent in western countries have heightened interest in the inclusion in our diets of nonnutritive fiber that resists human digestive secretions and intestinal flora (Pomeranz et al. 1977). Other major nutritional problem in most of the developing countries is protein calorie malnutrition. Therefore, identification of inexpensive high protein materials is an important task in these countries (El-Adawy 1995). Addition of different ingredients in bakery products to improve its health effects have been investigated in many studies. The results show that many beneficial ingredients such as fiber materials (Pomeranz et al. 1977), marine ingredients (Kadam and Prabhasankar 2010), dairy ingredients (Kenny et al. 2000), etc. can be used in the bread industry to increase its functionality and result in healthy products, low in calories, cholesterol and celiac disease (Rahaie et al. 2014).

Several studies reported the incorporation of protein and fiber rich supplements in different food preparations to increase the overall nutritive score of the diet. El-Adawy (1995) studied the effect of incorporation of the sesame products in

D. Indrani · S. D. Sakhare · Milind · A. A. Inamdar (✉)
Department of Flour Milling, Baking & Confectionery Technology,
CSIR-Central Food Technological Research Institute,
Mysore 570020, India
e-mail: aainamdar@cftri.res.in

wheat flour and reported increased content of not only protein but also minerals and total amino acids, especially lysine and also improved in-vitro protein digestibility. Increasing the protein content of the wheat flour by the addition of full fat or defatted cocoa powder (Aremu et al. 1995) and legumes and oil seeds can improve the nutritional quality of bread, especially the lysine content (El-Soukkary 2001).

Traditionally, fiber supplementation has focused on the use of milling by-products of cereal grains. All of the milling by-products of wheat, corn, sorghum and other grains, as well as the by-products from the wet milling of corn and wheat, have been investigated as possible fiber supplements (Mckee and Latner 2000). Indrani et al. (2010) reported 2.5 times increase in the dietary fiber content as compared to control in bread made by supplementing wheat flour with flours from soya bean, fenugreek seeds, flaxseed, sesame seeds and oats.

Dry milling is the separation of the anatomical parts of the grain as cleanly as possible. The bran and germ are relatively rich in protein, dietary fiber, B vitamins, minerals, and fat, and the separated endosperm is therefore lower in these components than the original grain. Thus, while milling increases the palatability of cereal products, it decreases the nutritional value of the main product obtained (Delcour and Hoskeney 2010). Sakhare et al. (2014) studied the roller flour fractionation of green gram and reported that distribution of protein, dietary fiber, ash and fat in different flour streams and by-products from roller milled fractions of green gram showed wide variation. Roller flour milling of the black gram will give the different fraction part wise, with different nutritive values. Objective of the present study was to produce different fractions from the black gram grain using the roller flour mill process, which can be further partially incorporated in the wheat flour bread formulation to increase its protein and fiber content. Additives have shown an overall quality improvement of the food products in several studies. Another objective was to study the influence of the fractions of black gram on rheological characteristics of the dough, quality of bread; effect of additives on the rheological, quality characteristics of bread with black gram fractions at different levels, their storage and nutritional characteristics.

Materials and methods

Raw materials

Black gram, wheat flour, compressed yeast, salt, sugar and fat were brought at local market.

Additives

Fungal α -amylase (FAA) (50 000 Sandstedt Kneen and Blish units/g, from *Aspergillus oryzae*), Dry gluten powder (DGP)

and sodium stearoyl-2-lactylate (SSL) and were procured from P.D. Fine Chemicals, Bangalore, India.

Preparation of black gram for roller milling

Labofix, Brabender®; a mini-cleaner and grader was used to clean the black gram grains. Impurities like, dust, chaffs, mud balls, sticks, sand were removed. Impurities percentage was found to be 1.25 %. Water addition followed by drying in hot air oven (Cell Bios) was used as a pretreatment. Water was added to increase the moisture content from 11 to 19 % and allowed to condition for overnight. Then the conditioned grains were placed in the wire mesh tray and kept in the oven at 65 °C for 540 min to reduce the moisture content to about 9 %.

Roller milling of black gram and chemical characterization of fractions obtained

Cleaned and conditioned black gram was roller milled using laboratory mill MLU 202 (Buhler, Switzerland). The fractions were obtained as coarse bran, fine bran and flours from six passages [three break (B1, B2, B3) and three reduction (C1, C2, C3) rolls]. Fine bran was further passed through the bran finisher to separate the endosperm from the fine bran and packed as bran duster flour. All the obtained fractions were analyzed for moisture, ash and protein according to AACC (2000) method and dietary fiber analysis of all the fractions was carried out according to AOAC (1999) method. Based on analysis the fractions were categorized as protein rich fraction (PRF), which was the flour obtained from bran finisher and as fiber rich fraction (FRF), which was the fraction of coarse bran. Fraction of fine bran was categorized as protein and fiber rich fraction (P&FRF) and the mix of all the flour streams as straight run flour (SRF).

Flour blends preparation

Flour blends were made with the incorporation of 10, 15, and 20 % each of SRF, PRF and P&FRF into wheat flour. For FRF, blends were prepared by mixing 5, 10, and 15 % FRF with wheat flour. Apart from this, four blends were made using combination of additives (CA), wheat flour and 15, 15, 10 and 15 % each of SRF, PRF, FRF and P&FRF respectively. CA consisted of the additives viz., 2 % DGP, 0.002 % FAA and 0.5 % SSL. The level of incorporation of different fractions in the blends and level of each additive in CA was based on preliminary baking trials.

Rheological characteristics

Effect of addition of black gram blends and CA on mixing properties of dough was determined by Brabender Farinograph using a 50 g bowl, and on pasting characteristics of wheat flour

was determined by Brabender Micro-Visco-Amylograph as approved by American Association of Cereal Chemist Methods (AACC 2000).

Bread preparation

Breads were prepared using 100 g wheat flour, different black gram blends and CA separately as mentioned in 2.5; compressed yeast 2.0 g, salt 1.0 g, sugar 3.0 g, hydrogenated fat 1.0 g and water as per farinograph water absorption. Ingredients were mixed in a Hobart mixer (Model N-50, Hobart, GmbH, Offenburg, Germany) having rpm of 61 for 4 min, followed by the fermentation of dough for 90 min in a chamber having maintained a relative humidity of 75 % and 30 °C temperature. Dough was remixed, rounded and again fermented for 25 min, moulded, proofed for 55 min at 30 °C, 85 % RH and baked for 25 min at 220 °C, cooled and packed. All breads were made in triplicate.

Evaluation of bread

Physical and sensory characteristics of bread

Loaf weight was evaluated using a digital balance with 0.01-g accuracy and volume was determined by millet seeds displacement method. Crumb firmness was measured according to AACC (2000) procedure using texture analyzer (Model TA-HDi, Stable Microsystems, Surrey, U.K.) The values reported were the mean of three replicates. Overall quality score (100) which is combined quality score maximum sensory score (10); shape (20); crumb colour (15); crumb grain (20); mouthfeel (20) and taste (15) was carried out according to the method described by Farheen et al. (2012).

Composition of bread

Moisture and protein analysis of breads for was carried out according to AACC (2000) method and dietary fiber according to AOAC (1999) method.

Storage characteristics

Storage characteristics of the bread were studied by comparing the moisture content and texture in terms of crumb firmness value (carried out as described in 2.8.1) of fresh bread to that of the bread stored for 7 days at room temperature in a HDPE packaging.

Statistical analysis

Data obtained for each parameter were subjected to statistical analysis to determine the level of significance using analysis of variance in completely randomized design and the means were further compared through Duncan's new multiple range tests as described by Steel and Torrie (1960). The significant level was established at $P \leq 0.05$.

Results and discussions

Chemical analysis

Table 1 shows the moisture, protein, total ash and total dietary fiber contents of the wheat flour and the different roller milled fractions of black gram. The results show highest protein content in PRF as compared to the other fractions, whereas FRF was found to have highest dietary fiber content. P&FRF showed a protein content of 16.2 ± 0.11 % and dietary fiber content of 47.5 ± 0.22 %, which were next only to PRF and FRF values for protein and fiber respectively.

Dough rheology

Farinograph characteristics

Farinograph data of wheat flour (control) and those of the different flour blends are shown in Fig. 1. Substituting wheat flour with different blends of black gram fractions increased

Table 1 Chemical characteristics of wheat flour and black gram fractions

Parameters	Wheat flour	Black gram fractions			
		SRF	PRF	FRF	P&FRF
Moisture (%)	11.2 ± 0.11	9.3 ± 0.02	9.5 ± 0.02	9.8 ± 0.04	9.6 ± 0.03
Protein (%)	10.4 ± 0.15	23.8 ± 0.11	28.6 ± 0.05	9.7 ± 0.12	16.2 ± 0.11
Total ash (%)	0.5 ± 0.01	3.7 ± 0.01	3.5 ± 0.02	3.8 ± 0.03	3.6 ± 0.02
Dietary fiber (%)	3.12 ± 0.15	7.6 ± 0.15	9.21 ± 0.12	66.2 ± 0.30	47.5 ± 0.22

Except moisture, all values are on dry weight basis

SRF straight run flour, PRF protein rich fraction, FRF fiber rich fraction, P&FRF protein and fiber rich fraction

Values in the row with the same letter in superscript are not significantly different from each other at $p \leq 0.05$

the water absorption required for optimum bread making in all the blends (from 58 % in control to 60.4, 60.8, 61.8 and 61 % in blends having 20 % SRF, 20 % PRF, 15 % FRF and 20 % P&FRF respectively). The increased water absorption was attributed to increased total protein and pentosan content in black gram fractions. Paradkar et al. (2002) reported a pentosan content of 7.5 % in black gram and Reddy et al. (1989) reported a non-cellulosic polysaccharide content of about 10 % in black gram. It is believed that fiber incorporated dough is known for its ability to absorb significant amounts of water. Ahmed et al. (2013) found an increase in water absorption of the dough with addition of fibers. The quantity of added water is considered to be very important for the distribution of the dough materials, their hydration and the gluten protein network development. Mohammed et al. (2012) reported an increase in the water absorption of wheat flour when replaced with chick flour. Prasad Rao et al. (2007) studied the effect of addition of non-starch polysaccharides (NSP) on the rheological characteristics and concluded that the water absorption values slightly increased and attributed it to their higher arabinose content. Indrani et al. (2014) reported an increase in the farinograph water absorption when the wheat flour was supplemented with the fractions of green gram due to higher protein and fibre contents. Decrease in dough stability was observed with increase in supplementation of the control wheat flour with the SRF, PRF, FRF and P&FRF. Dough stability of control sample was found to be 6.8 min, whereas it decreased to 5.5, 4.8 and 4.3 min in blends containing 10, 15 and 20 % PRF respectively. Similar results for dough stability were obtained in other blends as compared to control. In general, the stability value is an index of the dough strength, with higher values indicating stronger dough. The changes in dough characteristics upon addition of black gram fractions may be attributed to dilution of gluten-forming

Fig. 1 Effect of black gram roller milled fractions addition on farinograph characteristics of wheat flour. Error bars indicate the standard deviation of replicates. $n=3$. SRF: straight run flour, PRF: protein rich fraction, FRF: fiber rich fraction, P&FRF: protein and fiber rich fraction, CA: combination of 2 % dry gluten powder + 0.002 % Fungal α amylase + 0.5 % Sodium stearoyl-2-lactylate

Fig. 2 Effect of black gram roller milled fractions addition on amylograph characteristics of wheat flour. Error bars indicate the standard deviation of replicates. $n=3$. PT: Pasting temperature; PV: Peak viscosity; CPV: Cold paste viscosity; BD: Break down; SB: Set back. BU; Brabender units. Please see Fig 1 for other abbreviations

proteins causing weakening of dough (Belitz et al. 1986). Variation in hydration behaviour of two proteins may be another reason for differences in dough characteristics (Mohammed et al. 2012). Influence of soy protein on rheological properties and water retention capacity of wheat gluten was studied by Roccia et al. (2009) and they concluded that soy protein produced more resistant, less extensible and weaker mixtures. The substitution of wheat protein by soy protein decreased mixture elasticity and increased mixture viscosity due to the network weakening. Jyotsna et al. (2012) observed an increase in farinograph water absorption and decrease in dough stability with incorporation of green gram flour.

Amylograph characteristics

Influence of the addition of black gram fractions on amylograph characteristics of wheat flour are shown in Fig. 2. A gradual increase in the pasting temperature was observed with the increase in the level of addition of SRF, PRF, FRF and P&FRF as compared to control (65.1 °C). Pasting temperature

Fig. 3 Effect of black gram roller milled fractions addition on bread characteristics of wheat flour. Error bars indicate the standard deviation of replicates. CFV: Crumb firmness value, OQS: Overall quality score. $n=3$. Please see Fig 1 for other abbreviations

Fig 4 Photograph of breads. (a) Control; (b) 15 % SRF; (c) 15 % SRF and CA; (d) 15 % PRF (e) 15 % PRF and CA; (f) 10 % FRF; (g) 10 % FRF and CA; (h) 15 % P&FRF; (i) 15 % P&FRF and CA. $n=3$. Please see Fig 1 for abbreviations

was observed to be 65.3, 65.8 and 66.2 °C for the blends containing 10, 15 and 20 % SRF respectively. It varied from 65.6 to 66.4 °C with varied levels of PRF, 65.7–67.2 °C for FRF and from 67.2 to 68.8 °C at different levels of P&FRF. Control samples showed a peak viscosity of 913 BU, cold paste viscosity of 1161 BU, break down value of 325 BU and set back value of 573 BU. These values decreased, as the level of SRF, PRF, FRF and P&FRF increased. Yin and Walker (1992) observed that pentosans decreased peak viscosity of the starch pasting curve. The high pasting temperature for black gram starches indicated their higher resistance towards swelling (Singh et al. 2004). Dearherage et al. (1955) reported that various normal legume starches have a rather high content (30–36 %) of linear fractions. Referring this observations, Schoch and Maywald (1968) attributed the decrease in swelling and increase in the viscosity stability of waxy maize, normal corn starch and high amylose corn starch to the reinforcement imparted by long-linear molecules meandering through the granule structure. They also speculated that high contents of other components, especially protein and fiber, influence the swelling power and pasting properties of starches. The results are in agreement with the prior observations made by Jyotsna et al. (2012).

Bread evaluation

Values obtained for volume (ml), crumb firmness (g) and overall quality score for the breads prepared by addition of

roller milled black gram fractions are presented in Fig. 3 and are compared with control. Decrease in volume, as compared with control was observed with increase in the amount of supplementation of SRF, PRF, FRF and P&FRF. This could be due to dilution of the gluten network by addition of the black grain fractions. Rocchia et al. (2009) demonstrated that gluten was weakened as a consequence of the interference effect of soy proteins on their structure, and the smaller availability of water to the build-up of the gluten network. They also reported substitution of wheat protein by soy protein decreased mixture elasticity indicating network weakening. Decrease in bread loaf volume at higher levels of soy and chick pea flour supplementation was also reported by Yousseff et al. (1976). Decreased bread volume is also in consensus with the findings of Singh et al. (1991), who studied the effect of addition of 10, 20 and 30 % supplementation of wheat flour with chick pea flour on baking characteristics and reported decrease in loaf volume, specific volume and crumb softness of bread with the increase in chickpea flour in the blends. Crumb firmness value increased significantly with increase in the amount of supplementation of all the black gram roller milled fractions. Mohammad et al. (2012) observed that addition chickpea flour in wheat flour for bread making suppress the amount of steam generated, as a result of their high water absorption capacity, leading thus to reduced loaf volume and greater crumb firmness. Replacing the wheat flour with black gram fractions decreased the overall quality score, a measure of combined scores of crust and

Fig 5 Effect of black gram roller milled fractions addition on texture of breads during storage. Error bars indicate the standard deviation of replicates. $n=3$. Please see Fig 1 for abbreviations

crumb. It was 85 out of maximum score of 100 for control and was reduced to 61, 64, 62 and 58 for samples with 20 % SRF, 20 % PRF, 15 % FRF and 20 % P&FRF respectively.

Effect of combination of additives (CA) on rheology and bread quality

Influence of addition of CA on the rheological characteristics of wheat flour with different black gram blends is presented in Fig. 1. Addition of CA to 15 % SRF, 15 % PRF, 10 % FRF and 15 % P&FRF increased the farinograph water absorption and the dough stability. Figure 2 shows that pasting temperature increased in all the blends and a decrease in peak viscosity, hot paste viscosity, cold paste viscosity was observed in SRF, PRF and FRF blends. Increase in peak viscosity, hot paste viscosity, cold paste viscosity was observed in P&FRF blend. Bread volume increased from 440, 450, 465 and 440 ml to 545, 560, 585 and 575 ml respectively for 15 % SRF, 15 % PRF, 10 % FRF and 15 % P&FRF blends. Addition of CA decreased the crumb firmness value from 880, 860, 640 and 900 g to 510, 480, 440 and 450 g respectively for SRF, PRF, FRF and P&FRF blends indicating improvement in texture of bread. Singh et al. (1991) reported that addition of gluten at 3 % level was found to effectively improve the rheological, loaf volume and crumb characteristics of wheat chickpea flour blends. In Fig. 4, photograph C, E, G and I shows the crumb grain has become finer and uniform with thin cell walls on addition of CA in all the blends. There was significant improvement in the overall quality score from 68 to 74 in SRF, 71 to 78 in PRF, 66 to 74 in FRF and 64 to 76 in P&FRF after addition of CA.

Nutritive composition of breads

Control bread was found to have protein content of 9.05 % and dietary fiber content of 2.6 %. Addition of black gram fractions has increased the protein content of breads to 13.24, 15.05, 11.21 and 12.6 % respectively for 15 % SRF, 15 % PRF, 10 % FRF and 15 % P&FRF. There was also a significant increase in the dietary fiber content which was found to be 3.86, 4.12, 9.85 and 9.52 % for SRF, PRF, FRF and P&FRF respectively. Thus additions of the roller milled black gram fractions have improved the nutritive value of the breads.

Effect on texture during storage of breads

Moisture content of bread was evaluated on day 1 and day 7. On day 1 of storage, it was found to be 31.6 % for control bread and 33.9, 34.5, 36.5 and 36 % for the breads incorporated with SRF, PRF, FRF and P&FRF. Moisture level was found to be higher for breads with the fiber rich compared with other breads. There was not a major difference in the moisture levels on day 1 and day 7 for all the breads. Effect of

black gram roller milled fractions addition on texture of breads during storage is presented in Fig. 5. Crumb Firmness Value was lower in the breads supplemented with fiber rich fractions than other breads. On the storage for 7 days, crumb firmness value increased for all breads. However, the increase was less in the FRF and P&FRF supplemented breads than the breads with SRF and PRF which is due to high fiber content.

Conclusions

In conclusion, it can be seen that addition of roller milled black gram fractions to wheat flour have modified the rheological properties, pasting properties and overall quality of breads produced. With increase in the addition of SRF, PRF, P&FRF from 0 to 20 %, and FRF (0–15 %), the farinograph water absorption increased and dough stability decreased; amylograph pasting temperature increased and peak viscosity decreased; bread volume decreased and crumb firmness value increased indicating adverse effect of these fractions on the rheological and bread making characteristics of wheat flour. The reason is that these factors attributed primarily to the gluten fraction, which was diluted by the addition of black gram fractions. Addition of CA improved the dough strength, overall quality, storage characteristics of breads with 15 % SRF, PRF, P&FRF and 10 % FRF. Use of these fractions increased the protein and fiber contents of bread by 1.24–1.66 and 1.48–3.79 times respectively. Development of the bread recipes with the supplementation of black gram roller milled fractions would be beneficial to improve the nutritive value of the bread. Study also indicates an opportunity for the application of roller mill technology for fractionation of black gram and use of the flour streams in development of the speciality flours.

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