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FOOD SCIENCE & TECHNOLOGY | RESEARCH ARTICLE

Physicochemical and pasting properties of unleavened wheat flat bread (*Chapatti*) as affected by addition of pulse flour

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Abstract: Unleavened flat bread (*chapatti*) was prepared from wheat–pulse composite flours wherein wheat flour was replaced from 5–20% by kidney bean and black gram flours. Water absorption for dough making increased significantly ($p \leq 0.05$) in composite flours. Sensory evaluation of flat breads produced from wheat–pulse composite flours showed significant decrease in color, taste, aroma, breakability, and overall acceptability score at 15% or higher level of replacement. Pasting properties of composite flours and breads produced thereof displayed significant decrease in peak, trough, final, and setback viscosity while increase in pasting temperature was observed. This suggested that starch has gelatinized considerably and flat breads have been baked sufficiently. Significant lower setback viscosity of composite flour than control wheat flour indicates that composite flat breads can maintain freshness for longer time than control bread.

Subjects: Bioscience; Food Science & Technology; Physical Sciences

Keywords: flat bread; pulse; protein; flour; sensory

1. Introduction

Wheat (*Triticum aestivum* L.) is a cereal belonging to the family Gramineae. The annual world production of wheat exceeds that of any other grain, legume, or food crop. It is consumed worldwide after milling it into flour, primarily in the form of breads, and is a major source of nutrients (FAO, 2013). Unleavened flat breads-*chapattis* are made from whole wheat flour and have served as staple diet to the inhabitants of India, Pakistan, and parts of the Middle East (Nandini & Salimath, 2001; Nurul-Islam & Johansen, 1987). *Chapattis* are consumed fresh in households where it may represent

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PUBLIC INTEREST STATEMENT

Unleavened flat bread (*Chapatti*) from wheat flour is a staple food of India. A major portion of Indian population is non-vegetarian, thus depending mainly on cereals as a source of energy and proteins. Besides cereals pulses are also taken as a source of proteins by the Indian population. Cereals like wheat are deficient in essential amino acid lysine and pulses are deficient in essential amino acids like methionine and cystine. Thus, replacing part of wheat flour with kidney bean and black gram flour (5–20%) will not only improve the protein uptake but will also improve the protein quality consumed by vegetarian population. This will help in reducing the protein calorie malnutrition in developing countries.

90% of the dietary energy intake (Rao, 1993). Almost 90% of the wheat produced in India is consumed in the form of chapatti. Only 10% of the wheat produced in India is consumed in making bread/biscuits/cake and such other products. The most important parameters of chapatti quality are its texture and flavor. The former is generally evaluated in terms of tenderness, flexibility, and its suitability to be folded into a spoon shape for eating with curried preparations but the flavor is judged mainly in terms of sweetish taste and fresh typical wheatish aroma. Chapatti acceptability can be related to the behavior of the dough during preparation, rheological characteristics, and final sensory qualities such as color and texture. The amount and type of proteins in flour are critical for its end use (Rehman, Mahmood, Siddique, & Gilani, 1988) and play a primary role in chapatti-making qualities (Prabhasankar, 2002). Total storage protein and contents of individual classes of gliadin and glutenins are important for the viscoelastic properties of dough (Rehman, Paterson, & Piggott, 1997). Hydrated wheat gluten yields a protein mass which is viscoelastic in nature that can be sheeted (Kuktaite, Larsson, & Johansson, 2004). High water absorption of flour, because of high gluten-forming protein fractions assists in the formation of viscoelastic dough films (Srivastava, Meyer, Haridas Rao, & Seibel, 2002) that ensure softness and functionality in final chapatti.

Chapattis are an economical source of protein, and contribute to satiety through abundant dietary fiber that reduces constipation and diverticular disease, rates of chronic bowel disease, and diet-related cancers (Inglett, Carriere, & Maneepun, 2005). However, chapattis made from wheat flour is low in essential amino acids like lysine. Pulse flour can be successfully used in chapattis to obtain a protein-enriched product with improved amino acid balance as Indian subcontinent heavily depends on pulses as a source of proteins due to economic and social reasons. Therefore, the combination of wheat with pulse flours would provide better overall essential amino acid balance and help to overcome the national protein calorie malnutrition problem (Livingstone, Feng, & Malleshi, 1993). Pulse flours are reportedly incorporated into flat bread (Kadam, Salve, Mehrajatema, & More, 2012) and other baked products (Spink, Zabik, & Uebersax, 1984). The objective of the present study was to evaluate the effect of incorporation of pulse flour from kidney bean and black gram on physico-chemical, sensory, and pasting properties of chapatti.

2. Materials and methods

2.1. Materials

Certified seeds of “French Yellow” cultivar of kidney bean (*Phaseolus vulgaris* L.) was procured from Sher-e-Kashmir University of Agricultural Sciences and Technology, Shalimar, Srinagar, J & K, India and “T-9” cultivar of black gram (*Phaseolus mungo* L.) was procured from National Seed Corporation Pusa, New Delhi, India. These were selected for flat bread making because they are commonly grown cultivars of India. The commonly cultivated wheat cultivar PBW-343 was selected for blending with pulse flour and was procured from Punjab Agriculture University, Ludhiana, India.

2.2. Methods

2.2.1. Production of wheat and pulse flour

Wheat was milled in a stone mill (Amar Industries, Amritsar, India) to produce whole wheat flour with 100% extraction rate having wet gluten content of 30.31 ± 0.35 and ash content of 1.2 ± 0.2 . To produce pulse flour, whole seeds of kidney bean and black gram were milled in a laboratory mill (Newport Supermill-1500, Newport Scientific Pvt. Ltd., Warriewood, Australia). The resulting flour was then passed through 60-mesh screen to get flour to be blended with wheat flour for flat bread making (Wani, Sogi, Wani, & Gill, 2013). Pulse flour from kidney bean cv French Yellow had protein content of $23.1 \pm 0.85\%$ (Wani, Sogi, Wani, et al., 2013) while black gram cv T-9 had $24.5 \pm 0.87\%$ (Wani, Sogi, & Gill, 2013).

2.2.2. Preparation of wheat–pulse (WP) composite flours

In order to improve the quality and quantity of protein in wheat flour flat bread it was supplemented with pulse flours. Wheat flour was replaced with pulse flour from 5–20%. Kidney bean and green gram flour 10–40 g each were added to 180–195 g of wheat flour.

2.2.3. Flat bread (*chapatti*) from pulses

Preliminary trials were carried out to determine the amount of water to be added to the flour (200 g) to develop non-sticky viscoelastic dough that could be easily rolled and sheeted to make flat bread (Gujral & Pathak, 2002). The flour was mixed with optimum water (137.4–150 mL) for three minutes in a laboratory pin mixer (National Manufacturing Company, Lincoln, NE). The dough was left to rest for half an hour. Dough ball (50 g) was rounded and then placed on a rolling board and sheeted with a rolling pin. The dough was rolled in one direction, inverted, and then rolled in a perpendicular direction. The raw flat bread was immediately placed on an electric hot plate at $280 \pm 3.0^\circ\text{C}$ and baked on one side and then inverted and baked on the other side followed by final baking on the first side. The baking time varied from 70 to 94 s due to differences in dough water absorption. The flat bread was allowed to cool for 10 min at 25°C (80% relative humidity) and weight was recorded to determine the amount of water lost upon baking and this was reported as bake loss. Puffing of the flat bread during baking is a desirable characteristic and it was reported as percentage of the flat bread upper layer that puffed during baking. The change in the flat bread diameter before and after baking was also noted and the reduction in diameter was reported as percentage shrinkage.

2.2.4. Sensory evaluation of flat bread

A semi-trained panel of 15 members comprising of staff and students from the Department of Food Science and Technology, Guru Nanak Dev University, Amritsar, India evaluated the sensory properties of the flat breads. The samples were coded with specific code numbers to eliminate bias. Panelists were instructed to evaluate color, taste, aroma, breakability, chewability, stickiness, and overall acceptability. A nine-point hedonic scale with 1-dislike extremely, 5-neither like nor dislike, and 9-like extremely was used (Yadav et al., 2009). Water was provided to rinse the mouth between evaluations.

2.2.5. Drying of flat bread and production of flat bread flour

Flat breads were freeze dried at -40°C and then ground in laboratory mill (Newport Supermill-1500, Newport Scientific Pvt. Ltd., Warriewood, Australia) to produce flour which passes through 60-mesh sieve. The resulting flour was then packed in airtight containers and stored at refrigerated temperature until used.

2.2.6. Pasting properties of composite flours and flat breads

Pasting properties of flat breads and flour blends were determined according to the method of Wani, Sogi, Wani, and Gill (2013).

2.3. Statistical analysis

Mean values, standard deviation, analysis of variance (ANOVA), and correlation coefficients were computed using a commercial statistical package SPSS 16.0 (SPSS Inc, Chicago, USA). These data were then compared using Duncan's multiple range tests at 5% significance level.

3. Result and discussion

3.1. Physical characteristics of flat bread

Water absorption capacity for dough making of control wheat flour and WP composite flour is presented in Table 1. Water absorption for dough making of control wheat flour and WP composite flours was 68.7 and 72.3–75.0%, respectively. Composite flours had significantly ($p \leq 0.05$) higher water requirement for dough making than control flour. The higher water absorption of composite flours might be due to more water absorption of pulse flour due to its higher protein content. The

Table 1. Physical characteristics of flat breads prepared from WP composite flours (n = 3)

Flour type	Pulse flour (%)	Water absorption for dough making (%)	Puffing (%)	Bake loss (%)	Shrinkage (%)	Baking time (s)
Wheat (control)	0	68.7 ± 0.9 ^a	100.0 ± 0.0 ^c	14.3 ± 0.7 ^c	2.6 ± 0.2 ^{bc}	76.7 ± 2.9 ^{bc}
Wheat–kidney bean flour	5	72.3 ± 0.8 ^b	90.0 ± 10.0 ^c	14.1 ± 1.1 ^c	2.1 ± 0.4 ^{abc}	94.0 ± 6.0 ^d
	10	74.0 ± 1.0 ^{cd}	100.0 ± 0.0 ^c	13.3 ± 2.1 ^{bc}	5.5 ± 0.6 ^c	92.5 ± 2.5 ^d
	15	75.0 ± 1.1 ^d	100.0 ± 0.0 ^c	12.7 ± 1.0 ^{bc}	2.8 ± 0.4 ^{bc}	97.5 ± 2.5 ^d
	20	73.9 ± 1.0 ^{bcd}	100.0 ± 0.0 ^c	11.2 ± 0.3 ^a	3.7 ± 1.0 ^c	93.0 ± 3.0 ^d
Wheat–mash bean flour	5	73.8 ± 1.2 ^{bcd}	100.0 ± 0.0 ^c	11.9 ± 0.3 ^{ab}	1.7 ± 0.3 ^a	81.0 ± 1.0 ^c
	10	72.8 ± 0.3 ^{bc}	62.5 ± 12.5 ^b	11.5 ± 0.1 ^a	3.0 ± 0.8 ^{bc}	74.0 ± 1.0 ^{ab}
	15	73.8 ± 0.6 ^{bcd}	15.0 ± 0.0 ^a	11.4 ± 0.4 ^a	2.6 ± 1.1 ^{bc}	71.5 ± 2.5 ^{ab}
	20	73.6 ± 0.5 ^{bcd}	7.5 ± 2.5 ^a	11.3 ± 0.3 ^a	1.9 ± 0.0 ^{ab}	74.0 ± 5.0 ^{ab}

Notes: Values expressed are mean ± standard deviation.

Means in the column having different superscript are significantly different at $p \leq 0.05$.

present results are in agreement with the previously reported values (Rehman, Paterson, Hussain, Anjum Murtaza, & Mehmood, 2007).

Puffing is a highly desirable characteristic of flat bread during baking and consumer prefers flat bread that puffs during baking. Flat bread made from wheat flour (control) showed 100% puffing (Table 1). Flat breads made from WP composite flours displayed puffing in the range of 7.5–100%. Breads made from kidney bean–wheat (KBW) composite flours did not show significant ($p > 0.05$) decrease in puffing percentage. However, significant ($p > 0.05$) and progressive decrease in puffing percentage was observed in flat breads made from blackgram–wheat (BGW) composite flours at 10% or higher level of replacement. It can also be hypothesized that the black gram flour suppress the amount of steam generated, as a result of their high water absorption capacity due to the presence of galactoarabinan-rich pectic polysaccharide (Tharanathan, Changala Reddy, Muralikrishna, Susheelamma, & Ramadas Bhat, 1994) thus leading to reduced puffing.

Bake loss is an indicator of the amount of water lost from the bread during baking. Bake loss was significantly higher (14.3%) in control wheat flat bread than composite flour flat breads (Table 1). In composite flour flat breads bake loss was observed from 11.2–14.1%. It progressively decreased with increase in replacement of wheat flour with pulse flour. Mohammed, Ahmed, and Senge (2011) reported enhanced water retention capacity of composite flours (chickpea–wheat flour blend) used in bread formulations. Besides, higher water retention capacity of composite breads was observed. The lower bake loss of composite breads could be attributed to increased protein content of these blends which retained more water during baking. Control wheat flat bread had shrinkage of 2.6% whereas composite flour flat breads had 2.1–5.5% (Table 1). Significant ($p \leq 0.05$) differences in shrinkage between control and composite flour flat breads and among composite flour flat breads were found. Dervas, Doxastakis, Hadjisavva-Zinoviadi, and Triantafillakos (1999) reported a decrease in bread volume with increasing levels of lupin or soy flour. The decrease in bread volume is also consistent with the findings of El-Adawy (1997) who worked with sesame seed protein preparations and reported that sesame protein isolate incorporation provided loaves with a lower specific volume, the extent of reduction depending on the substitution level.

Baking time of control flat bread was 76.7 s. Breads made out of WP composite flours had baking time in the range of 71.5–97.5 s (Table 1). This may be attributed to increased levels of polysaccharide in the composite flour due to incorporation of kidney bean flour. It has been postulated that these polysaccharides resemble to pectic substance and result in increased water absorption capacity and viscosity (Tharanathan et al., 1994), consequently showing an increase in baking time.

3.2. Sensory characteristics of flat bread

Sensory characteristics of flat breads prepared from WP composite flours on Hedonic scale of 0–9 are presented in Table 2. Color score for control flat bread was 7.18. Color values of flat breads prepared from wheat–kidney bean flour blends decreased significantly ($p \leq 0.05$) at 10% or higher level of addition of kidney bean flour. Rehman et al. (2007) observed similar decrease in color score of flat bread prepared from composite flour (wheat flour—detoxified Indian vetch). The decrease in quality score for color may be attributable to an increased Maillard reaction taking place owing to the high lysine content (Hallén, İbanoğlu, & Ainsworth, 2004). Significant decrease was not observed in color score of breads prepared from wheat–black gram composite flours (6.08–7.05). Breads prepared from WP protein isolates have color values from 5.96–7.18. The color score between control flat bread and those prepared from WP composite flours did not show significant differences. Marchais, Foisy, Mercier, Villeneuve, and Mondor (2011) reported decrease in the whiteness and an increase in the yellowness of the crumb, while inducing an increase in the blackness and a decrease in the yellowness of the crust with the substitution of wheat flour with pea protein isolate.

Control wheat flat bread had taste score of 6.45. Taste score of composite flour breads was lower than control bread and it decreased significantly ($p \leq 0.05$) from 6.0 to 3.6 (Table 2). Decrease in taste score of breads prepared from composite flour (wheat flour—detoxified Indian vetch) at 20 and 30% level of replacement of wheat flour by vetch flour was reported (Rehman et al., 1997). Khan, Anjum, Pasha, Sameen, and Nadeem (2010) also reported decrease in taste score of composite flour (wheat–soya flour) flat breads. The highest aroma score (7.95) was reported for control breads. Aroma score of composite flour flat breads was observed from 4.05–7.00 (Table 3). It decreases significantly ($p \leq 0.05$) at 15% or higher level of replacement of wheat flour with pulse flour.

Breakability score of control flat bread was 5.63. Breakability of composite flour breads was in the range of 5.06–6.60 (Table 2). Breakability of wheat–kidney bean flour breads decreased at 10% or higher level of replacement. However, for black gram wheat (MBW) flour breads it decreased at 15 and 20% level of replacement. This may be related to under development of gluten network in composite flours due to gluten dilution and interaction of pulse proteins with gluten proteins.

Chewability score of control flat bread was 6.30. Chewability score of flat breads made out of WP composite flours was in the range 5.40–6.60 (Table 2). Significant differences were not found between control and composite flat breads and among the composite flat breads. Decrease in chewability score of composite flat bread has been reported after the replacement of 10% wheat flour with soya flour (Khan et al., 2010).

Table 2. Sensory characteristics of flat breads prepared from WP composite flours (n = 15)

Flour type	Pulse flour (%) in wheat flour	Color	Taste	Aroma	Breakability	Chewability	Stickiness	Overall acceptability
Wheat (control)	0	7.18 ± 0.78 ^c	6.45 ± 0.90 ^d	7.95 ± 0.57 ^c	5.63 ± 0.26 ^{ab}	6.30 ± 0.26 ^{ab}	7.18 ± 0.78 ^{cd}	6.59 ± 0.74 ^d
Wheat–kidney bean flour	5	7.20 ± 0.73 ^c	6.00 ± 0.85 ^{cd}	6.80 ± 0.57 ^c	5.70 ± 0.42 ^{ab}	6.60 ± 0.92 ^b	5.40 ± 1.47 ^{ab}	6.36 ± 0.22 ^{cd}
	10	5.40 ± 1.60 ^b	6.00 ± 0.98 ^{cd}	6.40 ± 0.75 ^{bc}	5.25 ± 0.21 ^a	6.30 ± 0.64 ^{ab}	5.10 ± 1.12 ^{ab}	5.76 ± 0.15 ^{abc}
	15	5.32 ± 1.70 ^b	4.20 ± 0.49 ^{ab}	6.60 ± 1.30 ^{bc}	5.10 ± 0.56 ^a	5.40 ± 0.37 ^{ab}	5.10 ± 1.70 ^{ab}	5.19 ± 0.15 ^a
	20	3.75 ± 0.21 ^a	3.60 ± 0.49 ^a	5.00 ± 0.57 ^{ab}	5.85 ± 0.37 ^{ab}	6.15 ± 0.76 ^{ab}	4.20 ± 1.12 ^a	5.10 ± 0.15 ^a
Wheat – mash bean flour	5	6.90 ± 0.21 ^{bc}	5.20 ± 0.75 ^{bc}	7.00 ± 1.57 ^c	6.60 ± 0.85 ^b	6.45 ± 1.06 ^b	8.70 ± 0.42 ^d	6.69 ± 0.72 ^d
	10	7.05 ± 0.85 ^{bc}	4.80 ± 0.49 ^b	6.60 ± 1.70 ^{bc}	5.85 ± 0.64 ^{ab}	5.85 ± 0.64 ^{ab}	7.50 ± 0.42 ^{cd}	6.03 ± 0.26 ^{bcd}
	15	6.75 ± 0.90 ^{bc}	4.35 ± 0.30 ^{ab}	4.65 ± 0.57 ^a	5.40 ± 1.16 ^a	5.96 ± 0.50 ^{ab}	6.98 ± 0.45 ^c	5.67 ± 0.54 ^{ab}
	20	6.08 ± 1.40 ^{bc}	3.75 ± 0.30 ^a	4.05 ± 0.90 ^a	5.06 ± 0.43 ^a	5.40 ± 0.26 ^{ab}	6.08 ± 0.86 ^{bc}	5.09 ± 0.28 ^a

Notes: Values expressed are mean ± standard deviation.

Means in the column having different superscript are significantly different at $p \leq 0.05$.

Stickiness score of KBW flour flat breads was significantly lower (4.2–5.4) than control flat bread (7.18). Composite flour flat breads made from wheat–black gram flour blends showed significantly lower stickiness score than control flat breads at 10% level and higher. This might be attributed to increase in amylose content of composite flours as pulses contain higher level of amylose than cereals. Gianibelli, Sissons, and Batey (2005) also found that an increase in the amylose content increased firmness and decreased the stickiness in wheat spaghetti with addition of broad bean flour.

Overall acceptability score of control flat bread was 6.59 and for WP composite flour flat breads it was from 5.10–6.69. Overall acceptability score of WP composite flour flat breads was significantly ($p \leq 0.05$) lower than control bread at 10% or higher level of replacement of wheat flour with pulse flour. So, pulse flour up to 15% can be incorporated in wheat flour to produce acceptable chapattis with comparable overall acceptability compared to whole wheat flour

3.3. Pasting properties of composite flours

Pasting properties of WP flour blends are presented in Table 3. Peak viscosity (PV) of control wheat flour was 1,818.7 cP. Progressive decrease in PV was observed as replacement of wheat flour with pulse flours increased from 5–20%. The PV of KBW composite flours was observed in the range of 1,605.5–1,728.5 cP and for MBW composite flours it was 1,743.0–1,795.0 cP. This may be attributed to lower starch content of pulse flours than wheat flour. Gomez, Oliete, Rosell, Pando, and Fernandez (2014) also reported PV of chickpea wheat composite flours (877–1,032 cP) was lower than the control wheat flour (2,621 cP). Trough viscosity (TV) of control wheat flour was 1,325.7 cP. It decreased significantly ($p \leq 0.05$) in KBW composite flours (1,107.5–1,325.0 cP) at 15 and 20% of replacement. However, in MBW composite flours it decreased at all the levels of replacement (1,025.8–1,111.0 cP). Breakdown viscosity (BDV) of control wheat flour was 502.0 cP while composite wheat flours had 388.0–749.8 cP. Final viscosity of WP composite flours was in the range of 2,233.8–2,328.0 cP. It decreased significantly ($p \leq 0.05$) in KBWF blends at 15% or higher level of replacement and in MBWF blends at all the levels of replacement. When temperature is lowered the viscosity increases due to reassociation of amylose called as setback. Setback viscosity for control flour was 1,697.7 cP. In WP composite flours it was 1,201.5–1,649.0 cP. KBW composite flours have significantly lower setback at 15 and 20% of replacement of wheat flour and for MBW composite flours decrease was observed at all the levels of replacement. Gomez et al. (2014) also reported decrease in final and setback viscosity of chickpea–wheat composite flours. Devi and Haripriya (2014) reported decrease in setback viscosity from 1,718.3 to 1,452.7 of soya enriched wheat flour at 5% level. Lower setback viscosity of composite flours than control flour suggest that composite flour flat breads would be softer than control flat breads as the staling (retrogradation) is less. Pasting temperature (PT) is a measure of

Table 3. Pasting properties of WP composite flour (n = 3)

Flour type	Pulse flour (%) in wheat flour	PV (cP)	TV (cP)	BDV (cP)	FV (cP)	Setback viscosity (cP)	PT (°C)
Control flour	0	1,818.7 ± 52.8 ^e	1,325.7 ± 56.2 ^d	502.0 ± 60.2 ^{bc}	3,014.3 ± 136.1 ^c	1,697.7 ± 95.5 ^c	87.4 ± 0.1 ^{bc}
Kidney bean	5	1,728.5 ± 32.5 ^{cd}	1,325.0 ± 9.0 ^d	403.5 ± 41.5 ^a	2,974.0 ± 41.0 ^c	1,649.0 ± 50.0 ^{bc}	87.7 ± 0.3 ^c
	10	1,720.5 ± 40.5 ^{bc}	1,292.0 ± 24.0 ^d	428.5 ± 16.5 ^{ab}	2,957.5 ± 57.5 ^c	1,665.5 ± 33.5 ^{bc}	86.8 ± 1.2 ^{bc}
	15	1,605.5 ± 69.5 ^{ab}	1,217.5 ± 10.5 ^c	388.0 ± 38.0 ^a	2,805.0 ± 53.0 ^b	1,587.5 ± 33.5 ^b	86.4 ± 1.0 ^b
	20	1,662.5 ± 17.5 ^{ab}	1,149.5 ± 76.5 ^b	513.0 ± 59.0 ^c	2,763.0 ± 141.0 ^b	1,613.5 ± 64.5 ^{bc}	86.6 ± 0.3 ^{bc}
Mash bean	5	1,795.0 ± 5.0 ^{de}	1,111.0 ± 7.0 ^b	684.0 ± 6.0 ^{de}	2,312.5 ± 20.5 ^a	1,201.5 ± 13.5 ^a	86.8 ± 0.5 ^{bc}
	10	1,775.5 ± 26.5 ^{cde}	1,025.8 ± 52.8 ^a	749.8 ± 26.3 ^e	2,233.8 ± 58.8 ^a	1,208.0 ± 6.0 ^a	86.4 ± 0.0 ^b
	15	1,763.5 ± 24.5 ^{cde}	1,112.0 ± 2.0 ^b	651.5 ± 26.5 ^d	2,328.0 ± 14.0 ^a	1,216.0 ± 12.0 ^a	84.8 ± 0.1 ^a
	20	1,743.0 ± 4.0 ^{cd}	1,107.5 ± 6.5 ^b	635.5 ± 10.5 ^d	2,323.5 ± 18.5 ^a	1,216.0 ± 12.0 ^a	84.4 ± 0.4 ^a

Notes: Values expressed are mean ± standard deviation.

Means in the column having different superscript are significantly different at $p \leq 0.05$.

Table 4. Pasting properties of WP flour composite flat breads (n = 3)

Flat bread type	Pulse flour (%) in wheat flour	PV (cP)	TV (cP)	BDV (cP)	FV (cP)	Setback viscosity (cP)	PT (°C)
Control flat bread	0	1,169.3 ± 113.5 ^d	531.3 ± 9.0 ^d	638.0 ± 120.0 ^d	991.3 ± 6.7 ^d	460.0 ± 10.4 ^e	93.6 ± 0.2 ^a
Kidney bean	5	565.1 ± 17.4 ^a	532.0 ± 12.0 ^d	37.6 ± 10.9 ^a	908.0 ± 15.0 ^c	385.0 ± 30.0 ^{cd}	94.7 ± 0.1 ^d
	10	556.9 ± 33.2 ^a	479.1 ± 7.8 ^{bc}	77.8 ± 16.8 ^a	793.5 ± 24.5 ^b	317.6 ± 24.1 ^b	94.1 ± 0.1 ^{ab}
	15	503.5 ± 18.5 ^a	452.5 ± 21.5 ^{ab}	50.5 ± 2.5 ^a	763.0 ± 55.0 ^b	310.5 ± 33.5 ^b	94.1 ± 0.1 ^{ab}
	20	491.0 ± 5.0 ^a	423.5 ± 4.5 ^a	67.5 ± 0.5 ^a	640.0 ± 23.0 ^a	216.5 ± 27.5 ^a	94.7 ± 0.3 ^d
Mash bean	5	994.7 ± 29.1 ^c	539.3 ± 49.9 ^d	485.3 ± 20.8 ^c	920.3 ± 14.5 ^c	411.0 ± 6.1 ^d	94.2 ± 0.4 ^{bcd}
	10	979.0 ± 19.0 ^c	504.0 ± 4.0 ^{cd}	475.0 ± 15.0 ^c	896.5 ± 3.5 ^c	392.5 ± 7.5 ^{cd}	94.5 ± 0.5 ^{bcd}
	15	943.5 ± 52.5 ^{bc}	522.0 ± 1.0 ^d	421.5 ± 51.5 ^{bc}	893.5 ± 3.5 ^c	371.5 ± 2.5 ^b	93.6 ± 0.0 ^a
	20	870.0 ± 26.0 ^b	511.0 ± 7.0 ^{cd}	359.0 ± 33.0 ^b	892.0 ± 20.0 ^c	381.0 ± 13.0 ^{cd}	94.5 ± 0.0 ^{bcd}

Notes: Values expressed are mean ± standard deviation.

Means in the column having different superscript are significantly different at $p \leq 0.05$.

the minimum temperature required to cook a given food sample. PT for control flour was 87.4°C. Wheat pulse composite flours had PT from 84.4–87.7°C.

3.4. Pasting properties of composite flat breads

Pasting properties of WP composite flour flat breads are presented in Table 4. The PV of control flat bread was 1,169.3 cP and it decreased significantly in WP flour composite breads (491.0–994.7 cP). Breads had significantly ($p \leq 0.05$) lower PV than respective flours. This might be attributed to partial gelatinization of starch during baking. Zeng, Gao, Li, and Liang (2011) reported progressive decrease in PV of native corn flour with increase in replacement of native corn flour with extruded corn flour. They attributed the results to partial degradation (gelatinization) of starch. Two factors interact to determine the PV of a cooked starch paste: the extent of granule swelling (swelling capacity) and solubility. Higher swelling index is indicative of higher PV while higher solubility as a result of starch degradation or dextrinization results in reduced paste viscosity (Shittu, Lasekan, Sanni, & Oladosu, 2001). TV of control flat bread was 1,169.3 cP. WP flour composite breads has TV in the range of 423.5–532.0 cP. BDV of control flat bread was 638.0 cP while as BDV of WP composite flat breads was 37.6–485.3 cP. Final and setback viscosities for control flat bread were 991.3 and 460 cP, respectively. FV of WP composite flour flat breads was observed from 640.0–920.3 cP, while SBV was observed from 216.5–411.0 cP. PT for control flat bread was 93.6°C. WP composite chapattis had 93.6–94.7°C. Sharma and Gujral (2014) also reported decrease in pasting properties of flat breads prepared from composite (wheat–barley) flours than respective composite flours. They attributed the results to gelatinization of starch during baking. It has also been reported that all the starch present in flat breads gelatinizes completely during baking even though the baking time is very short (Gujral, Singh, & Rosell, 2008). Heating of the pre-gelatinized material led to a decrease in viscosity, due to thinning of the slurry (Sharma, Gujral, & Rosell, 2011).

4. Conclusion

Pulse flour up to 15% can be incorporated in wheat flour to produce acceptable chapattis with comparable overall acceptability compared to whole wheat flour. Besides composite flours have lower setback viscosity which suggests that composite flour chapattis will maintain freshness for longer periods compared to control wheat flour. Since chapattis form an essential component of the daily Indian diet therefore part of the wheat flour should be replaced with pulse flour to complement the essential amino acid deficiency in cereal proteins.

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Competing interests

The authors declare no competing interest.

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