J Food Sci Technol (April 2019) 56(4):2296–2304
https://doi.org/10.1007/s13197-019-03721-w

ORIGINAL ARTICLE

Functional characterization of whole wheat flours for chapatti quality and acceptability

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Revised: 8 March 2019 / Accepted: 12 March 2019 / Published online: 14 March 2019

Abstract Chapattis or flat breads act as integral component in the diet of people in India and its subcontinents and, therefore, function as the main source of nutrition and energy. The major ingredient used for chapatti preparation is whole wheat flour and as a result chapatti quality is primarily dependant on the quality of wheat utilized. In this study, Whole wheat flours obtained from twenty diverse wheat cultivars were characterized for quality traits and chapatti acceptability. The chapatti prepared from different cultivars showed high diversity in overall acceptability score i.e. from 38.5 to 81.0. The results showed that chapatti color was significantly and negatively impacted by ash content (r = − 0.605), protein content (r = − 0.669), SDS (r = − 0.521), Damaged starch (r = − 0.522) and Cu content (r = − 0.612) of whole wheat flour, while chapatti pliability was found to be positively and significantly linked to the dough water absorption (r = 0.775). The chapattis made from dough having higher water absorptions were found to be pliable since during baking it puffs more (r = 0.452) due to proper steam generation and retention of moisture.

Keywords Whole wheat flour · Chapatti · Flat bread · Quality · Wheat · Rheological

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Introduction

Chapatti is a thin flat bread made of unleavened dough and baked on a hot-plate. It closely resembles Mexican tortilla in shape and size but has a softer texture because of difference in type of flour used e.g. tortilla is prepared from corn flour and chapatti is made from whole-wheat flour (known as Atta in India). Wheat is the staple crop in India and 80–85% of this crop is consumed in the form of chapatti and provide the nutritional requirements of more than 600 million people living in the Indian subcontinent (Haridas Rao and Sai Manohar 2003). The dough of chapattis is prepared from whole-wheat flour by mixing and kneading flour with water and salt, the dough is then sheeted to desired thickness and diameter, baked and followed by puffing. As chapatti is prepared from whole wheat flour, it retains most of the essential nutrients such as dietary fiber, minerals, and antioxidant components, as compared to white bread where the nutritionally beneficial constituents primarily located in the wheat germ and bran layer are removed during the milling process (Steinfurth et al. 2012). Consumer acceptability of chapatti depends primarily on its appearance and texture, with symmetrically round shape and softer texture being preferred. The wheatish flavour, little sweetish taste and puffing ability is also desirable characteristics of good chapattis. Another factor that significantly affects key sensory attributes of chapatti is the serving temperature as it directly affects the softness and extensibility of chapatti, with freshly baked hot chapatti being preferred. As a result, in majority of households, restaurants and industrial canteens, chapattis are freshly prepared and served hot. With increasing trends towards grain-based and whole grain diet, the market for chapatti has expanded. Additionally, changing demographics in the first world countries has created a demand of ethnic food world-wide, elevating the demand of packed fresh/frozen chapattis.

There are huge variations in grain quality requirements for the baked products such as bread, pastries, and cookies (Parimala and Sudha 2015). Similarly, the grain quality required to produce flat bread, like Indian chapatti is different from that required to produce pan-type bread (Peña-Bautista 1998).

Although Indian wheat is widely consumed in the form of chapattis, however, there are limited studies to establish chapatti characteristics of Indian wheat cultivars and assist in selection of wheat varieties suitable for chapatti production. Therefore, the present study aimed to assess the diversity in grain, flour, dough rheological properties amongst Indian wheat cultivars and establish their relationship with chapatti quality.

Materials and methods

Grain characteristics

Twenty wheat varieties were selected on the basis of their diversity for chapatti making quality and obtained from different agricultural stations institutes (India). Single Kernel Characterization System (SKCS, Model 4100, Perten Instruments, Sweden) was used to measure width/diameter, hardness, weight, and moisture content of all the wheat cultivars. Grain length and hectoliter weight was obtained by using method described by Kundu et al. (2017). Wheat varieties were cleaned and milled to obtain whole wheat flour samples using a laboratory mill (Navdeep Atta Chakki) for further analysis and chapatti preparation.

Analysis of whole wheat flour

The moisture, falling number, protein (N × 5.7) content, wet gluten, dry gluten, gluten index (38-12) and damaged starch (76-31) for whole-wheat flour samples were analysed according to standard AACC methods (2000). SDS sedimentation volume of flour was obtained by using the method of Axford et al. (1979). Mineral composition of whole wheat flour was determined according to the standard AOAC method using Atomic absorption spectrophotometer (PerkinElmer Inc. USA). Micro-doughLAB (Chopin Technologies, France) was used to obtain water absorption and dough rheological properties such as maximum peak, arrival time, development time and departure time.

Chapatti preparation and quality evaluation

Chapattis were prepared from the whole wheat flours obtained from different wheat varieties and evaluated for sensory characteristics i.e. Color, Pliability, Nature of Spots, Texture, Mouth feel and overall acceptability score as described by Kundu et al. (2017).

Statistical evaluation

SPSS software version 16.0 (SPSS Inc., USA) was used to obtain Pearson correlation coefficients (significance levels at $P < 0.01$ and $P < 0.05$). Principal component analysis (PCA) was also carried out on the chapatti sensory data to understand the intercultivar variation in chapatti sensory properties and represent the most diverse wheat varieties in terms of sensory properties.

Results and discussion

Grain characteristics

The physical properties of different wheat grains are depicted in Table 1. Grain length and diameter or width of different wheat varieties varied from 6.54 to 7.59 mm and 2.77 mm to 3.38 mm, respectively. HD 2932 showed lowest grain length, while UP 2382 showed the highest. WH 283 and WH 1025 showed lowest grain diameter, whereas HW 2004 showed highest. Thousand kernel weight (TKW) was lowest in WH 283 (27.04 g), whereas the wheat variety HW 2004 (46.25 g) had the highest. In other words, the variety HW 2004 had sound and plumpy grains. The results indicated that grain weight was a function of grain width (r = 0.914) and was not related with grain length. Hectoliter weight (HLW) reflects the grain bulk density and it ranged from 70.5 to 87.3 kg/hL. WH 283 showed lowest HLW, while HI 1531 showed highest. HLW was also significantly correlated with grain weight (r = 0.344) which is apparent because kernels with higher bulk density will also have higher grain weight. Grain hardness (GH) is associated with the milling properties of wheat and represents the resistance of the grains to fracture and ability to be reduced into fine flour. It ranged between 40.8 N and 90.8 N (Table 1). WH 147 had the least GH and therefore, whereas MACS 2496 showed the highest GH amongst the cultivars studied. Only wheat variety WH 147 had the lower grain hardness of 40.8 N. Based on the hardness values, almost 25% of the varieties exhibited grain hardness of above 80 N and were considered hard, while majority of the wheat varieties had grain hardness of 60–80 N and therefore can be categorized medium-hard.

Table 1 Grain traits and whole wheat flour characteristics of different wheat varieties

Variety	Wheat grain characteristics						Whole wheat flour characteristics							
	GM	GL	GD	HLW	TKW	GH	FM	Fat	Ash	PC	WG	SDS	FN	DaS
C 306	9.65e	6.80c	3.14k	82.72j	38.24m	69.31f	7.87d	1.62g	1.38bc	11.57bcd	17.14ab	32.25b	311.5a	11.24c
CBW 38	12.26k	6.92d	2.94ef	77.92c	33.78d	78.77k	10.74hi	1.83hi	1.64ij	12.30de	18.01c	55.50n	457.0de	13.47g
GW 322	11.86i	7.02e	2.92dc	81.76gh	34.80f	87.92n	8.29d	1.79h	1.46defg	13.65gh	31.27k	45.50j	599.0n	15.63k
HD 2932	12.14j	6.54a	2.95ef	80.42f	33.24c	66.44e	10.61hi	2.24k	1.46cdefg	11.67bcd	20.92efg	43.50hi	448.5d	10.64b
HI 1077	9.82f	7.41i	2.87c	80.33f	36.52j	82.65l	9.32e	2.64m	1.68j	14.76i	28.55j	57.00o	589.0lm	15.73k
HI 1531	6.86a	6.73b	3.10j	87.34l	40.35o	82.55l	7.86d	1.84hi	1.27a	9.63a	24.31i	47.25k	660.0o	13.26g
HI 977	8.5c	7.08f	3.05i	84.24k	38.66l	77.19i	9.33e	2.60m	1.52gh	13.56gh	24.47i	54.25m	637.5n	15.73k
HW 2004	6.94b	6.68b	3.38l	76.20b	46.25p	77.37j	5.96a	1.86i	1.47efg	11.20b	16.95a	38.75e	467.0ef	11.66d
MACS 2496	14.45o	7.18g	2.89cd	77.99c	33.83d	90.82o	10.78hi	2.31l	1.77k	13.39gh	30.37jk	44.25i	564.5jk	15.95l
PBW 396	9.83f	7.25h	2.94ef	82.35hij	38.64l	70.91g	7.26b	1.47d	1.50g	12.41e	19.35cde	41.13g	536.5i	13.94h
PBW 550	12.54m	7.28h	3.14k	82.75j	39.44n	86.61m	9.89fg	1.68g	1.39bcde	12.58ef	16.65a	43.38hi	554.5k	16.17m
PBW 590	8.94d	6.93d	2.92ef	80.00e	35.41gh	62.80d	7.05b	1.44c	1.42bcdef	13.66gh	25.28i	44.25i	413.0bc	11.46d
PBW 621	10.42h	6.78c	2.97fg	76.00b	35.06g	60.91b	7.81dc	2.00j	1.37h	13.26fg	21.79fgh	43.25h	414.0c	12.47f
UP 1109	12.47l	7.24h	2.96ef	82.55ij	36.27i	73.26h	10.47hi	1.33b	1.67ij	11.13b	22.61ghi	39.25f	585.0l	14.36i
UP 2382	12.66m	7.44i	3.07i	82.44ij	40.66o	76.52i	11.07i	1.52ef	1.66ij	12.48ef	27.42j	32.75c	535.5i	14.45i
WH 1021	9.23d	6.91d	3.03hi	81.83h	37.34k	61.47c	7.37bc	1.82hi	1.38bcd	11.2b	22.09fgh	34.25d	502.0g	11.68d
WH 1025	9.77f	6.71b	2.77a	78.92d	31.05b	62.93d	8.19d	1.33b	1.65ij	12.06cde	22.38fghi	30.25a	402.0b	12.38f
WH 1080	10.14g	6.9d	2.85bc	75.91b	31.36b	62.89d	8.17d	1.22a	1.93l	14.10hi	18.47bcd	50.25l	518.5h	12.04e
WH 147	13.93n	7.31hi	3.02hi	74.77b	34.34e	40.77a	10.83i	1.33b	1.48fg	9.75a	17.59bc	39.25ef	413.0bc	9.24a
WH 283	10.26g	7.00e	2.64a	70.54a	27.04a	65.26e	8.31d	1.44d	1.54gh	14.47hi	27.82j	42.00h	246.0a	14.75ij

Mean values followed by different letters within a same column differ significantly ($P > 0.05$)

GM grain moisture (%), *GL* grain length (mm), *GD* grain diameter (mm), *HLW* hectolitre weight (kg/hL), *TLW* thousand kernel weight (g), *GH* grain hardness (N), *FM* flour moisture (%), *PC* protein content (%), *WG* wet gluten (%), *SDS* SDS sedimentation value (mL), *FN* falling number (s), *DaS* damaged starch (%)

Whole-wheat flour characteristics

The moisture, fat and ash content of whole-wheat flours ranged from 6.0 to 11.7%, 1.22% to 2.64% and 1.27% to 1.93%, respectively (Table 1). HI 1531 which had maximum HLW showed least ash content, while wheat variety WH 1080 which had HLW towards lower side depicted maximum ash content. This can be attributed to the fact that the endosperm/bran ratio is higher with higher HLW that results in lower ash content (r = 0.385) and vice versa. Ash content indicates the efficiency of separation of bran and germ from endosperm during milling. Ash content of whole-wheat flour is higher as compared to the refined flour since the whole wheat flour represents the same composition as of wheat grain, while in refined flour the outer layers of wheat grain (bran and germ) which are rich in minerals and fat are removed to obtain the white flour. Prabhasankar et al. (2002) also reported the ash content of whole wheat flour in the range from 1.4 to 2.1%. Mineral composition of different wheat flours has been mention in Table 2. Among the minerals analysed, Magnesium was the maximum i.e. from 113 to 450 ppm.

Protein content of flours ranged from 9.63 to 14.76%. Whole wheat flour obtained from HI 1531 and WH 147 showed the lowest, while from HI 1077 and WH 1080 had the highest protein content. While considering the wheat quality, protein content and protein quality are important criterion. Almost 80% of wheat protein consists of gluten proteins which imparts the unique viscoelastic characteristic to wheat based dough (Khatkar et al. 1995). The protein content and quality is influenced by genetic as well as by non-genetic factors (Subda 1991). Most of the flour samples had protein content ≥ 10%, while Wet gluten (WG) content ranged from 16.7 to 31.3%. PBW 550 showed lowest value, while GW 322 showed the highest value for WG. SDS sedimentation value (SDS SV) which relies on the swelling ability of glutenin proteins and depicts the protein quality and strength varied from 30.2 to 57.0 mL. The highest value was observed for HI1077 and the lowest for WH 1025. Sedimentation tests are associated with gluten strength and superior bread quality (Ayoub et al. 1993; Eckert et al. 1993). Katyal et al. (2016) and Kaur et al. (2013) also reported SDS SV of flours from different Indian wheat varieties varied between 36 to 56 mL and 27.5 to 51 mL, respectively.

Falling number (FN) represents the α-amylase content in flour. The FN values are lower if wheat is exposed to unfavourable conditions during storage or harvesting. Falling number varied from 246 to 660 s (Table 1). Prabhasankar et al. (2002) also reported falling number values

Table 2 Mineral composition of whole wheat flours

Variety	Iron(mg/100 g)	Copper (mg/100 g)	Zinc (mg/100 g)	Manganese (mg/100 g)	Magnesium (mg/100 g)
C 306	2.65e	0.16a	4.12j	1.47b	193.05j
CBW 38	4.95l	0.33de	4.99o	2.55j	141.32d
GW 322	2.66e	0.41f	3.26h	1.57c	163.14i
HD 2932	4.13k	0.26c	2.81d	1.85f	229.37l
HI 1077	4.16k	0.43fg	4.66n	2.44i	155.32g
HI 1531	3.39i	0.42fg	4.44k	2.11h	446.06o
HI 977	3.05h	0.61h	4.50l	2.11h	349.25n
HW 2004	1.89c	0.25c	2.63c	2.13h	243.27m
MACS 2496	2.77f	0.45g	3.20g	2.53j	129.33c
PBW 396	1.80b	0.25c	2.40b	2.05g	218.87k
PBW 550	2.71ef	0.31d	2.42b	1.56c	139.49d
PBW 590	7.80n	0.32d	3.49i	2.52j	113.21a
PBW 621	1.64a	0.20b	2.07a	1.41a	138.61d
UP 1109	3.53j	0.36e	2.08a	1.61d	139.82d
UP 2382	2.37d	0.35e	3.16g	2.15h	155.77g
WH 1021	2.91g	0.17a	2.95f	1.73e	158.40h
WH 1025	2.38d	0.24c	4.56m	1.73e	147.93f
WH 1080	5.29m	0.31d	2.85de	2.01g	123.59b
WH 147	3.01h	0.20b	7.72q	1.60cd	150.51f
WH 283	3.24i	0.33de	5.39p	1.74e	144.2e

Mean values followed by different letters within a same column differ significantly ($P > 0.05$)

of whole-wheat flour ranging from 347 to 684. WH 283 had the highest amount of α-amylase activity as indicated by the lowest falling number value, whereas HI1531 showed the highest falling number i.e. had least α-amylase.

Another important parameter evaluated was damaged starch, which indicates the starch damaged during milling of grain. Damaged starch (DaS) content of flours ranged between 9.24 and 16.17%. WH147 showed the lowest value for DaS, while PBW 550 showed highest value. The lower damaged starch in case of WH147 was due to softer endosperm texture of grains (lowest GH of 40.7 N) which are easy to grind and the starch granules fracture less during milling. Prabhasankar et al. (2002) reported DaS values of whole-wheat flours ranged from 14.6 to 23.3%.

Dough rheological characteristics

Rheological parameters of whole-wheat flours were determined using Micro-doughLab. The flours showed water absorption (WA) between 59.2 and 78.8%, however, majority of them were ranged between 65 and 72% (Table 3). WH147 showed the lowest WA, while PBW 550 showed the highest. It could be noted that PBW 550 had harder grains, while variety WH 147 had softer grains which appears to be the reason for wide variation in water absorption of whole wheat flour samples of these varieties. Therefore, it was evident that grain hardness had significant effect on the water absorption capacity of flours, with flour from harder varieties absorbing more water (r = 0.774). Damaged starch content also showed a positive relationship with water absorption capacity. Dough development time (DDT) ranged between 1.65 min for the variety HW 2004 to a maximum of 9.10 min for the variety PBW550. Majority of cultivars showed DDT between 2.8 and 5 min. Dough stability (DS), represents tolerance upon extended mixing ranged from 1.60 to 14.15 min and GW322, WH1021 and WH1025 showed the least DS, while HI 1077 showed the highest. Kaur et al. (2013) reported DS between 1.7 and 13.8 min for refined wheat flours from Indian wheat varieties. Majority of cultivars used in present study showed that DS ranged between 1.6 and 4 min. Further, most of the varieties with lower DS also had shorter DDT (r = 0.500). Softening of dough ranged between 13.50 and 99.0 BU, where majority of the varieties showed degree of softening between 30 and 70 BU. HI1077 showed the lowest, whereas UP2382 showed higher degree of softening. Flour protein content positively influenced the DDT (r = 0.42) and stability (r = 0.45). SDS also showed a significant and positive correlation with DDT (r = 0.52) and stability (r = 0.66), whereas it was

Table 3 Rheological characterization of whole wheat flours using microDoughLAB

Variety name	Water absorption (%)	Dough development time (min)	Stability (min)	Softening (FU)
C 306	71.65hij	3.00bc	2.05a	73.50h
CBW 38	69.05ef	7.20m	5.50c	31.00b
GW 322	68.00de	2.85b	1.60a	86.00i
HD 2932	66.00bc	5.00h	3.15b	31.00b
HI 1077	73.75k	6.40k	14.15f	13.50a
HI 1531	75.15l	3.05bc	2.25a	36.50bc
HI 977	72.25ij	5.15hi	3.85b	29.00b
HW 2004	71.65hij	1.65a	2.00a	36.00bc
MACS 2496	71.80hij	4.35g	2.30a	44.50cde
PBW 396	70.75ghi	4.35g	3.35b	46.50def
PBW 550	78.75m	9.10o	3.20b	53.50f
PBW 590	70.75ghi	6.55l	5.75c	47.00def
PBW 621	67.70de	8.70n	3.35b	46.50def
UP 1109	67.75de	5.60j	3.25b	54.00f
UP 2382	71.85hij	3.50d	2.10a	99.00i
WH 1021	66.75cd	2.85b	1.60a	91.50ij
WH 1025	65.00b	3.15c	1.80a	66.00gh
WH 1080	67.50d	8.65n	6.60d	41.50cd
WH 147	59.15a	3.95f	3.60b	51.00ef
WH 283	67.50d	3.55de	1.95a	91.00i

Mean values followed by different letters within a same column differ significantly ($P > 0.05$)

negatively related to dough softening (r = − 0.69). UP 2382, WH1025 and C306 cultivars having lower sedimentation value (30.2–32.8 mL) had lower dough stability (1.80–2.05 min). On the basis of rheological characterization, the wheat varieties GW322, C306, HW2004, HI1531, WH1025 and WH 1021 yielded weak flour, whole wheat flour from varieties CBW38, HI977, HI1077, PBW550, PBW590, PBW621 and WH1080 were classified as strong and remaining seven had medium-strong flour.

Functional characterization of wheat varieties for chapatti quality

The chapattis prepared from different wheat varieties were scored (0–10) subjectively for the sensory attributes including: color, puffed height, pliability, nature of spots, shape, handfeel, texture, mouthfeel and taste & aroma and all the scores were summed to attain the chapatti overall acceptability. The higher the score for a particular attribute, better the quality of chapatti.

The creamish white colour of the chapattis with few light brown spots was desirable in terms of appearance in contrast to the brown colour with charred spots. Relationship of grain and flour characteristics with chapatti quality is shown in Table 4. It is clear that chapatti color was significantly and negatively correlated with ash content (r = − 0.605), protein content (r = − 0.669), SDS SV (r = − 0.521), Damaged starch (r = − 0.522) and Cu content (r = − 0.612) of whole wheat flour. These parameters also significantly impacted the nature of spots developed after baking of the chapatti (Table 4). The darker color of chapatti has a negative influence on the overall quality of chapatti. Thus, varieties that yielded darker chapattis had lower overall acceptability.

Puffing is another attribute which adds on to the chapatti quality and was measured by giving the subjective scores to the prepared chapattis. The chapatti is dense in texture, comprising mostly crust with little or no crumb as compared to bread. Complete and full puffing turns the chapatti into two uniform layers, however, in some cases; the chapatti does not puff uniformly leading to compact structure. Soft and pliable texture is a desirable characteristic of chapatti that makes it easy to fold and form into a scoop for picking up curry during consumption (Dhaliwal et al. 1996). It was found that pliability score ranged from 2.0 to 9.0, texture score ranged from 3.0 to 8.3 and

Table 4 Inter-relationships among selected wheat quality traits and chapatti quality

Wheat characteristics	Chapatti quality characteristics					
	Col	Plia	N Spot	Tex	MF	COA
Grain characteristics						
GL	− 0.446**	Ns	− 0.523**	− 0.329*	− 0.591**	− 0.447**
GD	0.435**	0.634**	Ns	0.328*	Ns	0.472**
TKW	0.374*	0.677**	Ns	0.399*	Ns	0.509**
GH	Ns	0.548**	Ns	Ns	Ns	Ns
Whole wheat flour characteristics						
Ash	− 0.605**	− 0.337*	− 0.533**	Ns	− 0.334*	− 0.456**
PC	− 0.669**	Ns	− 0.408**	Ns	− 0.392*	− 0.380*
WG	− 0.350*	Ns	Ns	Ns	Ns	Ns
SDS	− 0.521**	Ns	− 0.575**	− 0.578**	− 0.531**	− 0.527**
FN	Ns	0.378*	− 0.442**	Ns	Ns	Ns
DaS	− 0.522**	Ns	− 0.404**	Ns	− 0.461**	Ns
Fe	Ns	Ns	Ns	− 0.332*	− 0.322*	− 0.400*
Cu	− 0.612**	Ns	− 0.554**	− 0.388*	− 0.446**	− 0.477**
Rheological characteristics						
WA	Ns	0.775*	Ns	Ns	Ns	Ns
DDT	− 0.429**	Ns	− 0.491**	− 0.363*	− 0.593**	− 0.430**
DS	− 0.484**	Ns	− 0.544**	− 0.455**	− 0.398*	− 0.433**

*Correlation is significant at the 0.05 level (2-tailed). **Correlation is significant at the 0.01 level (2-tailed). *Ns* not significant

GL grain length, *GD* grain diameter, *TLW* thousand kernel weight, *GH* grain hardness, *PC* protein content, *WG* wet gluten, *SDS* SDS sedimentation value, *FN* falling number, *DaS* damaged starch, *Fe* Iron, *Cu* Copper, *WA* water absorption, *DDT* dough development time, *DS* dough stability, *Col* color, *Plia* pliability, *NSpot* nature of spots, *Tex* texture, *MF* mouth feel, *COA* chapatti overall acceptability score/total score mouthfeel score ranged from 2.5 to 9.0 which clearly exhibits that chapattis prepared from different wheat varieties were quite diverse. The pliability was found to be positively and significantly linked to the dough water absorption (r = 0.775). The chapattis made from dough having water absorptions tend to be pliable since during baking it puffs more (r = 0.452) due to proper steam generation and after baking they also retain more moisture.

A soft texture, easy to chew, slightly sweetish taste with pleasant wheatish flavour and aroma are desirable attributes for good chapattis. The chapatti overall acceptability score ranged from 38.5 to 81.0. PCA map representing the placement of wheat varieties in terms of sensory characteristics has been shown in Fig. 1. It was observed that wheat varieties were quite spread on the map highlighting that they were quite differentiated in terms of sensory characteristics; the ones with similar sensory attributes were closer on the map, while the ones with differentiated attributes were clustered on the extremes. As can be observed from Fig. 1, wheat variety HI977 had uneven shape with charred spots which was typically due to dough strength of this variety as a result of which the chapattis after sheeting and cutting tended to recoil. The wheat varieties HI1077, HI977 and MACS2496 had the lower color score, whereas C306, HI1531, HW2004, PBW396 and WH 1021 had the highest. The chapattis prepared from WH147 had the lowest puffing height score, lowest on pliability and were brittle, whereas HW2004 had the highest puffing score and PBW 550 had most flexible texture. The wheat varieties with best overall acceptability were HI 1531, C306 and HW2004 had desirable attributes including soft pliable texture, easy to chew, creamish white color with uniform light brown spots and completely puffed. The wheat varieties PBW621, WH1021 also had distinct characteristics typically in appearance and taste.

Based on overall quality scores, wheat varieties were grouped into good, satisfactory and poor. Out of 20 varieties, 5 varieties yielded good, 7 yielded satisfactory and 8 yielded poor chapattis (Fig. 1). Representative chapattis pictures from different clusters are shown in Fig. 2. The chapatti overall acceptability was found to be negatively influenced by ash content, protein quality as well as protein content. Also, among the minerals, higher copper and iron content of whole wheat flours reduced chapatti overall acceptability mainly due to impact on colour, nature of spots and chapatti taste profile.

Conclusion

The results showed wide diversity in the physicochemical and rheological characteristics of whole wheat flours. Wheat variety WH147 was found to be the softest with Grain hardness of 40 N, while 70% of the varieties were

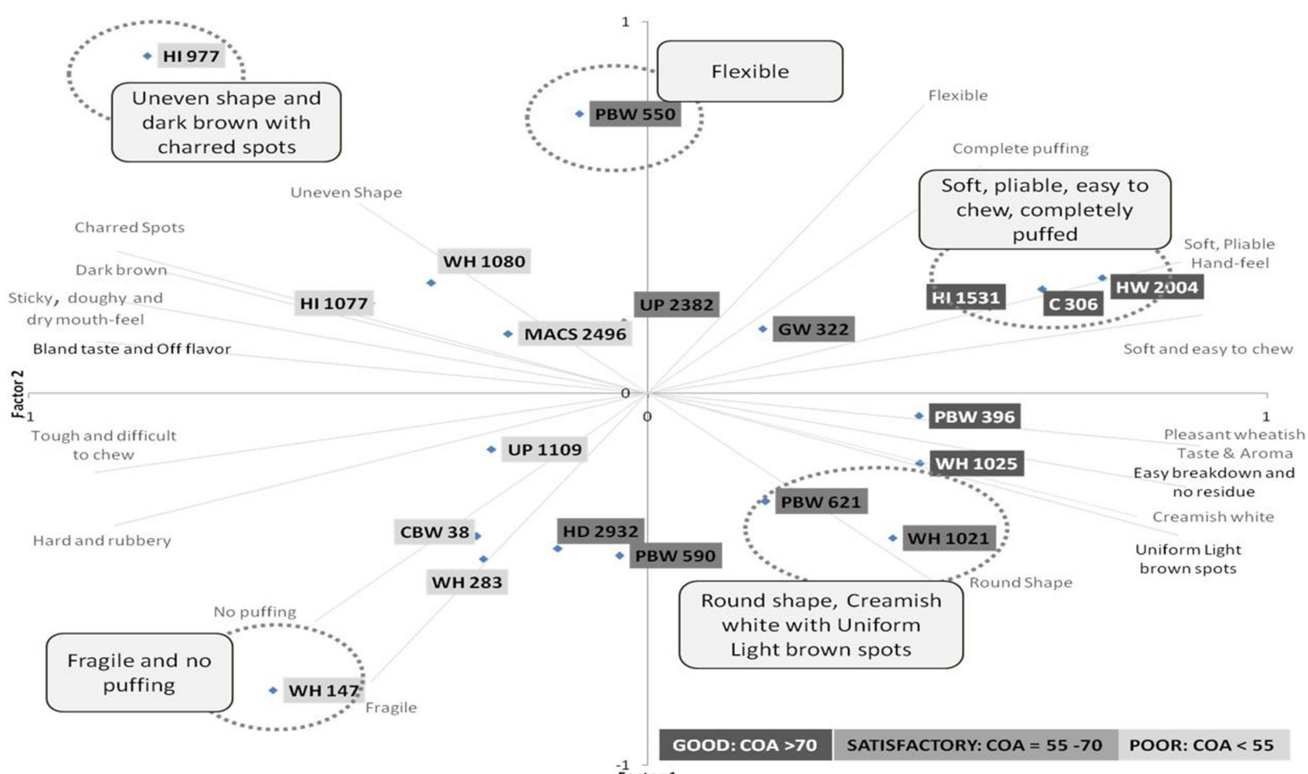

Fig. 1 Functional properties of whole wheat flours for chapatti quality

Fig. 2 Representative chapattis from different clusters

medium hard with the grain hardness values ranging from 60 to 80 N. The whole wheat flours showed water absorption (WA) between 59.2 and 78.8%, with flour from harder varieties absorbing more water (r = 0.774). Dough stability (DS), indicating flour tolerance to extended mixing ranged from 1.60 to 14.15 min. The flours with lower DS also had shorter dough development time (DDT) (r = 0.500). Flour protein content and quality parameters positively influenced the DDT and DS. The different flours showed a huge variation in the chapattis prepared from them and accordingly the wheat varieties were classified as good, satisfactory and poor performing for chapatti making. Wheat quality traits like grain hardness, water absorption, damaged starch, ash content, protein content and quality parameters were found to be significantly impacting the chapatti sensory attributes and overall acceptability. These parameters therefore can be used for selection of chapatti making wheat varieties.

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