Effect of physicochemical and rheological properties of flour from different local wheat varieties on the quality of *varanphal*: an Indian traditional product

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Abstract *Varanphal* is an Indian traditional product which is similar to pasta. The suitability of four local varieties of wheat flour (Lokwan, Sharbati, MP cross S.H.R. and MP Lokwan) was determined by evaluating their physicochemical and rheological properties. The rheological properties such as farinographic characteristics, dough hardness, stickiness, and spreadability of dough were also evaluated for the same. Flour and dough properties of wheat varieties were correlated with *varanphal* quality characteristics. The correlation coefficient data indicated that amongst the physicochemical properties of flour such as protein, dry gluten, and damaged starch content were the indices in predicting the *varanphal* quality. The rheological properties such as farinograph water absorption, dough stability, hardness and spreadability were found to be highly correlated with *varanphal* quality. The strong relationship were observed between dry gluten content with spreadability, L* value flour with dough stickiness, dough hardness with protein content, dough hardness with overall acceptability and cohesiveness of dough with the cohesiveness of *varanphal*.

Keywords *Varanphal* · Wheat varieties · Gluten · Flour properties · Farinograph · Texture

Introduction

Wheat (*Triticum aestivum* L.) is one of the major cereals grown all over the world. India accounts for 12% of global wheat production (Singh et al. 2007). Lokwan, Sharbati, MP cross S.H.R. and MP Lokwan are majorly consumed wheat varieties in the western part of India (Maharashtra and Gujarat). It is the crucial raw material used for bakery and household food products. It needs to be pulverized into fine flour before being utilized for culinary preparations. Wheat is processed into whole flour in chakki and hammer mills and is used in the preparation of traditional flatbread such as *chapatti*, *puri*, *parotta*, etc. The quality of the product depends upon the properties of flour used (Pari-mala and Sudha 2015).

Varanphal is Indian traditional food, mostly consumed in the western zone of India particularly in Maharashtra, Gujarat, and Rajasthan and locally also known as *Chakolya*, *dal dhokali* and *daalpithi*, respectively. This product is quite similar to pasta. It is prepared using whole wheat flour and pigeon pea dal (*Cajanus cajan*). Pulses and cereals have complementary nutritional benefits and their consumption together fulfills the balanced dietary requirement. *Varanphal* is made from dough obtained from whole wheat flour and water. It is further rolled to the desired thickness just like chapatti and cut into a square or rectangular shape; final product resembling flat noodles or pasta and cooked in boiling spicy dhal. The consumption of *varanphal* is predominant in a rural area than urban area due to elaborate and time-consuming operations involved in preparation. Hence, there is a need for the mechanization of *varanphal* production in order to promote its popularity.

Various studies have been carried out to study the effect of flour and dough properties on the final product. Prabhasankar et al. (2014) reported that the different flour

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characteristics and dough water absorption were most significantly correlated to *chapatti* quality. Zubair Farooq et al. (2001) also stated that quality of product varied with respective physicochemical and dough rheological properties of wheat varieties as well as flour properties of wheat varieties influenced the texture of the leavened flatbread (naan). According to Indrani and Rao (2000), the chemical and dough rheological properties determine the overall quality of parotta. Zhu et al. (2001) have reported dough stickiness deteriorated the quality of Chinese steamed bread. Burešová et al. (2014) reported the influence of dough characteristics on gluten-free bread. Kaur et al. (2015) evaluated the relationship of various flour properties with noodle making characteristics. However, an Indian wheat-based traditional food like *varanphal* has not been studied for the impact of flour and dough properties on its quality parameters. In the present study, the effect of physicochemical and rheological properties of most commonly used wheat flour varieties were evaluated and correlated with *varanphal* quality. Suitability of commonly used wheat varieties was determined for optimal quality of *varanphal*.

Materials and methods

Materials

Four different local wheat varieties (Lokwan, Sharbati, MP cross S.H.R. and MP Lokwan) were procured from the APMC market, Navi Mumbai, Maharashtra, India. The procured wheat varieties were cleaned, conditioned for 48 h at 14% moisture. The conditioned wheat was milled followed by sieving through a 40 mesh (425 μ) and was stored at 4 °C until further use.

Physicochemical properties of wheat flour

The moisture, ash, protein, dry gluten and, damaged starch content were determined according to the method of AACC (2000). The color of whole wheat flour was analyzed according to the method of Hunter lab Colorimeter (Colorflex, USA) in terms of L*, a* and b* values (Kaur et al. 2015).

Dough rheological properties of wheat flour

Dough mixing properties of flour were analyzed by the method 54–21 AACC (2000) on a Brabender farinograph (Duisburg, Germany). Wheat flour having 14% moisture content (50gm) was loaded in mixing bowl and water was added to yield a dough consistency of 500 Brabender Unit (BU). Water absorption, dough development time, dough

stability and, mixing tolerance index were determined by farinograph (Lee et al. 2008).

Dough hardness

Dough characteristics were evaluated by texture profile analysis (TPA) with a texture analyzer (Stable Micro Systems, Surrey, UK; 25 kg load cell). Doughs for the test were prepared according to the appropriate recipe in dough maker; mixing time was 7 min at low speed for 3 min and medium speed for next 4 min. The doughs were covered and rested for 30 min subsequently, 10 gm of dough was moulded to a cylindrical shape having 22 mm height and 22 mm diameter. Parameters for the TPA procedure were as followed: 35 mm diameter cylinder aluminum probe, test speed 1.0 mm/s, compression distance (measured from dough surface) 11 mm, recovery period between the two strokes 5 s. Values for hardness was recorded by force values. The results shown are the average value of four measurements for each sample (Wehrle et al. 1999).

Dough stickiness by texture analyzer

The dough parameters such as dough stickiness, work of adhesion and, cohesiveness of wheat flour were studied using Chen–Hoseney dough stickiness cell (A/DSC) in stable microsystems texture analyzer by the method reported by Shalini and Sonali (2017). Each sample was analyzed for ten times.

Dough spreadability by texture analyzer

The spreadability of the dough was tested by stable microsystems texture analyzer which was equipped with 100 mm diameter cylindrical probe under the following conditions; pre-test: 1, 0 m/s; test speed: 1.7 m/S, distance: 20 mm; force value: 180 g. The dough was rolled into shape with constant weight and fixed dimensions. The constant force was applied, and the dimensions of out-spread were measured by the Vernier calliper. Percentage of relative spreadability was calculated as given by Arya and Madiwale (2012).

Preparation of *varanphal*

Varanphal were prepared by traditional method adapting mechanization with certain modifications. A dough was prepared using 100 g wheat flour and adding required amount of water with 2% sodium chloride in a dough mixer which was operated at low speed for 3 min and medium speed for next 4 min. The dough was then passed through the sheeting machine to produce the sheet of 3 mm thickness. It was then folded and passed through the rolls twice.

The dough sheet was rested at 25° C for 1 h and then rolled through the sheeting machine again to obtain the final thickness of 2 mm. The sheet was then cut into rectangles of dimensions of 2 cm × 3.5 cm × 2 mm to obtain the shape of *varanphal*. The rectangular pieces of *varanphal* so obtained were subjected to cooking in boiling water to estimate the cooking properties of *varanphal*.

Cooking properties of *varanphal*

Cooking properties of *varanphal* was determined by the AACC method with slight modifications.

Cooking time

Four rectangular pieces *varanphal* (weighing approximately 10 g) were cooked in 250 ml of boiling water in a 500 ml beaker. The completion of cooking was determined by squeezing the sample between two glass slides until the white core disappears. The time required for the same is considered as the cooking time for *varanphal*.

Cooking loss

Ten-gram *varanphal* sample was cooked in 150 ml boiling water for an optimum time in a beaker. The beaker was covered with a watch glass during cooking to prevent the water loss due to evaporation. The cooking water was drained into a pre-weighed evaporating dish and subjected to drying in a hot air oven 100 ± 1 °C till constant weight was obtained. The difference between initial and final weight was taken into consideration to calculate the percent cooking loss.

Water absorption of *varanphal*

Cooked *varanphal* was rinsed with distilled water and drained for 30 s, then weighed to determine the water absorption. The analysis reflected the amount of water absorbed by the *varanphal* during the cooking process. The Water absorption of *varanphal* was equivalent to the difference between the weight of cooked *varanphal* (W_2) and uncooked *varanphal* (W_1), expressed as

$$\% \text{ Water absorption of } \textit{varanphal} = \frac{W_2 - W_1}{W_1} \times 100.$$

Swelling volume of *varanphal*

The volume of *varanphal* was determined by volume = length × height × width. All dimensions were measured by Vernier calliper before and after cooking. Swelling volume of *varanphal* was determined by the

difference between the volume of cooked *varanphal* (V_1) and volume of uncooked *varanphal* (V_2) which was expressed as Aydin and Gocmen (2011)

$$\% \text{ swelling volume} = \frac{v_2 - v_1}{v_1} \times 100.$$

Textural properties of cooked *varanphal*

Cooked Samples were cooled with distilled water to avoid overcooking of the *varanphal* and drained for 30 s. The firmness of cooked *varanphal* was measured by texture analyzer with knife (HDP/BS) blade set probe of test speeds: 3 mm/s, 0.5 mm/s and 2 mm/s. Ten randomly selected samples were measured (Martinez et al. 2007).

Textural properties (springiness and cohesiveness) of cooked *varanphal* were measured using Texture Profile Analysis (TPA) with a Texture Analyser, TA-XT2i (Stable Micro Systems, Surrey, UK). The TPA was estimated from the area of the force–time curves of two compressions using a flat-end cylindrical plunger (25-mm probe) descending to 70% of the original height of the *varanphal*. Crosshead speeds of 4.0, 1.0 and 1.0 mm/s were recorded for pre-test, and post-test settings, respectively. Ten replicates were recorded using cooked *varanphal* strands (Barak et al. 2014).

Sensory analysis of cooked *varanphal*

Ten trained students from food engineering department evaluated the cooked *varanphal* for appearance, color, texture, mouthfeel, taste and overall acceptability in triplicate. Panelists were instructed to eat and swallow each sample and rate the intensity of each attribute using a nine-point scale (1 = dislike extremely and 9 = like extremely) (ISO 11136:2014). For each sample, panelists received a sample served in plate coded with a digit number. Participants were provided with mineral water to clean their mouth between tastings. Presentation orders were systematically varied over assessors and replicates in order to balance the effects of serving order and carryover (Rathod and Annapure 2017).

Statistical analysis

Data were analyzed by analysis of variance (ANOVA) and means was separated using Duncan multiple range test at 5% probability level. Pearson's correlation coefficient (r) between parameters was obtained through the software SPSS 22.0.

Results and discussion

Physicochemical properties of different wheat flours

The physicochemical properties indicated a variation in the quality properties of different flours (Table 1). The protein content was observed to be 11.94–13.68% and dry gluten content was 11.66–13.49%. The variation observed in the values of protein and gluten content among different varieties of wheat might be due to their genetic variations. Also, it was due to varying environmental and production conditions (Khan et al. 2009). Ash content ranged between 1.02 and 1.08%. Ash content in flour determines the contamination with bran particles during milling. It also indicates the degree of separation of germ and bran from endosperm during milling (Kaur et al. 2016). The damaged starch values ranged from 16.66 to 20%. Lokwan had the minimum and MP Cross S.H.R. had the maximum damaged starch (Table 1). L^* , a^* and b^* values of flours from different varieties ranged from 87.23–87.78, 1.35–1.80 to 11.25–11.53, respectively. MP Cross S.H.R. had the maximum L^* value and minimum a^* value which indicated the highest brightness and lowest redness of the flour as compared to other varieties. Lokwan had higher b^* values which indicated more yellowness of the flour than the other varieties. The high amount of carotenoid and xanthophyll might be responsible for elevated yellowness (Kaur et al. 2015).

Rheological properties of different wheat flours

The farinographic water absorption of flours differed widely from 77.70 to 84.80%. It was maximum for the MP Cross S.H.R. flour followed by MP Lokwan, Sharbati, and Lokwan (Table 2). The variation in water absorption may be attributed to higher damaged starch content in a flour

(Rao et al. 1989). Anjum and Walker (2000) reported that protein content influences the water absorption of flour. Dough development time ranged from 3.70 to 6.45 min, Sharbati and MP Cross S.H.R. had lowest dough development time, while Lokwan had highest Dough development time. The more dough development time is associated with less damaged starch in the flour (Rao et al. 1989). Mostly the optimum dough development time varies, with respect to the type of flour (Singh et al. 2011). Dough stability ranged from 1.6 to 3.25 min. The MP Cross S.H.R. had low dough stability and Lokwan had high dough stability. Mixing tolerance index ranged from 58 to 96 BU. Sharbati and MP Lokwan had low mixing tolerance indices and MP Cross S.H.R. had highest mixing tolerance indices. These differences in farinographic dough properties were observed due to variations in protein content (Kaur et al. 2016) and gluten content in the flour (Anjum and Walker 2000).

Significant variation was found in the hardness, stickiness, work of adhesion and cohesiveness (dough strength) of doughs prepared from four varieties of wheat. Lokwan showed the dough hardness as high as 13.33 whereas, MP Lokwan showed the lowest dough hardness value of 8.30. Dough stickiness (viscous properties) of dough varied between 35.62 and 44.14, being the lowest for Lokwan and highest for MP Cross S.H.R. These difference in dough stickiness were observed may be due to the gliadin content in the flour (Singh et al. 2011). It has been reported that dough stickiness is directly proportional to water absorption of flour (Ghodke 2009). Work of adhesion ranged between 1.29 for MP Cross S.H.R. to 2.42 for MP Lokwan which was higher as compared to other varieties. Lokwan and Sharbati showed the highest value (1.10) of dough cohesiveness. Dough strength may be associated with glutenin content in the flour (Singh et al. 2011). Similar findings were reported by Navickis et al. (1982) stating that

Table 1 Physiochemical properties of flours from different wheat varieties used for *varanphal* production

Physicochemical properties of wheat flour	Varieties of wheat			
	Lokwan	Sharbati	MP cross S.H.R.	MP Lokwan
Protein N $\times$ 5.7 (%)	13.68 $\pm$ 0.02 ^c	13.15 $\pm$ 0.04 ^b	12.09 $\pm$ 0.14 ^a	11.94 $\pm$ 0.10 ^a
Ash (%)	1.05 $\pm$ 0.05 ^a	1.02 $\pm$ 0.03 ^a	1.05 $\pm$ 0.03 ^a	1.08 $\pm$ 0.10 ^a
Dry gluten (%)	13.49 $\pm$ 0.04 ^b	12.95 $\pm$ 0.02 ^b	11.89 $\pm$ 0.14 ^a	11.66 $\pm$ 0.62 ^a
Starch damage (%)	16.66 $\pm$ 0.50 ^a	19.00 $\pm$ 0.30 ^c	20.00 $\pm$ 0.20 ^d	17.00 $\pm$ 0.50 ^b
L^*	87.23 $\pm$ 0.15 ^a	87.73 $\pm$ 0.02 ^c	87.78 $\pm$ 0.01 ^d	87.42 $\pm$ 0.01 ^b
a^*	1.80 $\pm$ 0.02 ^c	1.41 $\pm$ 0.02 ^b	1.35 $\pm$ 0.02 ^a	1.77 $\pm$ 0.02 ^c
b^*	11.53 $\pm$ 0.00 ^d	11.38 $\pm$ 0.00 ^c	11.31 $\pm$ 0.02 ^b	11.25 $\pm$ 0.11 ^a

^aAll the values are mean $\pm$ SD of three individual determinations

^bMeans followed by the same superscript along the row are not significantly different using duncan multiple ranges test at 5% probability level

Table 2 Rheological properties of flours from different wheat varieties used for *varanphal* production

Rheological properties of flours	Varieties of wheat			
	Lokwan	Sharbati	MP Cross S.H.R	MP Lokwan
Water absorption (%)	77.70 ± 0.20 ^a	78.35 ± 1.95 ^a	84.80 ± 0.00 ^b	78.20 ± 0.30 ^a
Dough development time (min)	6.45 ± 0.25 ^c	3.70 ± 0.00 ^a	4.00 ± 0.00 ^b	6.23 ± 0.25 ^c
Dough stability (min)	3.25 ± 0.15 ^b	2.50 ± 0.00 ^a	1.60 ± 0.00 ^c	3.10 ± 0.15 ^b
Mixing Tolerance Index (BU)	71.66 ± 0.20 ^b	58.00 ± 1.73 ^a	96.00 ± 0.60 ^c	59.33 ± 1.15 ^a
Dough hardness (N)	13.33 ± 0.46 ^c	10.05 ± 0.44 ^b	8.85 ± 0.39 ^a	8.30 ± 0.55 ^a
Dough stickiness (g)	35.62 ± 0.43 ^a	42.40 ± 0.46 ^c	44.14 ± 0.40 ^d	38.98 ± 0.20 ^b
Work of adhesion	1.94 ± 0.02 ^b	1.70 ± 0.11 ^b	1.29 ± 0.45 ^a	2.42 ± 0.04 ^c
Cohesiveness	1.10 ± 0.10 ^b	1.04 ± 0.07 ^b	0.82 ± 0.05 ^{ab}	0.71 ± 0.19 ^a
Spreadability (%)	140.63 ± 0.55 ^a	141.95 ± 3.00 ^b	148.02 ± 0.85 ^c	149.47 ± 0.40 ^d

^aAll the values are mean ± SD of three individual determinations^bMeans followed by the same superscript along the row are not significantly different using duncan multiple ranges test at 5% probability level

the water content and protein content of flour influences the dough properties. Spreadability is one of the properties of machinability. The sheeting of dough is the most important steps in *varanphal* preparation. Spreadability of dough ranged between 140.63 and 149.47. Lokwan and Sharbati had low dough spreadability and MP Cross S.H.R. and MP Lokwan had high dough spreadability (Table 2) may be attributed to more water absorption of flour and gluten content in the flour.

Cooking and textural properties of *varanphal* made by different wheat flour

Cooking properties are the most important factor that controls the quality of product (Singh and Singh 2010). The optimum cooking time of *varanphal* ranged between 9 and 10 min. *Varanphal* from MP Cross S.H.R. took a shorter time than other samples. Water absorption of *varanphal* ranged from 76.70 to 85.09%. *Varanphal* from MP cross S.H.R. showed the highest water absorption of *varanphal*. These variances may be associated with protein content and damaged starch of the flour. Cooking loss of *varanphal* varied between 6.02 and 6.45%, being the lowest for Lokwan and highest for MP cross S.H.R. Manthey and Schorno (2002) stated that the cooking loss differences in whole wheat spaghetti may be because of the variance in the quantity of soluble components in the bran and aleurone layers of different cultivars. Swelling volume of *varanphal* varied between 180.52 and 212.91%, being the lowest for Sharbati and the highest for other varieties. This swelling is may be associated with damaged starch that has happened during the milling process. However, increased damaged starch during the milling process is not desirable, because it may be associated with high cooking loss and excess surface swelling.

Textural properties like firmness, springiness, and cohesiveness of *varanphal* were evaluated. The obtained results indicated that the wheat varieties influence the textural properties of *varanphal*. The values of *varanphal*—varied in the range from 2.68–4.03, 0.47–0.54 to 0.66–0.72, respectively. Firmness indicates about the resistance to the first bite. *Varanphal* from MP Cross S.H.R. showed the lowest firmness of *varanphal* while those made from Sharbati showed higher firmness values. Springiness is the sensitivity of product pliability in the mouth and indicates the extent to which the structure is disintegrated by the first deformation (Singh and Singh 2010). Springiness was observed to be the lowest for MP Cross S.H.R. and the highest for Lokwan. Cohesiveness gives a relative measure of the extent to which the material break down under mastication. It says about the resistance of the material during second deformation relative to its behavior during the first deformation (Singh and Singh 2010). MP Lokwan produced the least cohesive *varanphal* while Lokwan and Sharbati produced the most cohesive *varanphal*. It has been reported by Rathod and Annapure (2017) that, protein content has a major impact on the textural quality of noodles prepared from lentil.

Sensory evaluation of cooked *varanphal* from different wheat flour

The sensory characteristics shown in Table 3 indicated significant differences in the quality of *varanphal* made from different flours. The *varanphal* overall acceptability scores ranged from 6 to 8.33 indicating that Lokwan variety yielded very good *varanphal*, whereas MP cross S.H.R, Sharbati, and MP Lokwan produced moderate *varanphal* making quality. The results indicated that appearance scores ranged from 6.0 to 7.0, color scored

Table 3 Cooking, textural properties and sensory evaluation of *varanphal* made of different wheat varieties

<i>Varanphal</i> properties	Varieties of wheat			
	Lokwan	Sharbati	MP Cross S.H.R	MP Lokwan
Cooking time (min)	10.0 ± 0.00 ^a	9.5 ± 0.00 ^a	9.0 ± 0.00 ^a	9.5 ± 0.00 ^a
Cooking gain (%)	77.14 ± 0.00 ^a	79.2 ± 0.00 ^b	85.09 ± 0.26 ^c	76.70 ± 0.62 ^a
Cooking loss (%)	6.02 ± 0.04 ^a	6.24 ± 0.06 ^{ab}	6.45 ± 0.16 ^b	6.16 ± 0.14 ^a
Swelling volume (%)	208.91 ± 8.51 ^b	180.52 ± 3.05 ^a	212.91 ± 5.05 ^b	202.33 ± 3.60 ^b
Firmness (N)	4.03 ± 0.05 ^c	3.03 ± 0.05 ^b	3.00 ± 0.045 ^b	2.68 ± 0.046 ^a
Springiness (ratio)	0.54 ± 0.01 ^c	0.50 ± 0.01 ^b	0.47 ± 0.00 ^a	0.47 ± 0.11 ^a
Cohesiveness (ratio)	0.80 ± 0.00 ^c	0.77 ± 0.00 ^c	0.72 ± 0.00 ^b	0.66 ± 0.02 ^a
Appearance	7.0 ± 0.00 ^a	6.0 ± 0.00 ^a	7.0 ± 0.00 ^a	6.0 ± 0.00 ^a
Colour	7.0 ± 0.00 ^a	6.0 ± 0.00 ^a	8.0 ± 0.00 ^a	7.0 ± 0.00 ^a
Texture	8.67 ± 0.57 ^c	7.0 ± 0.00 ^b	6.0 ± 0.00 ^a	6.0 ± 0.00 ^a
Mouthfeel	8.67 ± 8.66 ^c	7.0 ± 0.00 ^b	6.0 ± 0.00 ^a	6.0 ± 0.00 ^a
Taste	8.0 ± 0.00 ^a	7.0 ± 0.00 ^a	8.0 ± 0.00 ^a	7.0 ± 0.00 ^a
Overall acceptability	8.33 ± 0.28 ^d	7.0 ± 0.00 ^b	7.50 ± 0.00 ^c	6.0 ± 0.00 ^a

^aAll the values are mean ± SD of three individual determinations^bMeans followed by the same superscript along the row are not significantly different using duncan multiple ranges test at 5% probability level

ranged from 6.0 to 8.0, texture and mouthfeel scores ranged from 6.0 to 8.67 and taste scored ranged from 7.0 to 8.0. The sensory score for taste, texture, and mouthfeel was highest for Lokwan followed by MP cross S.H.R., Sharbati, and MP Lokwan flours. The most desirable texture and mouthfeel were found in Lokwan among the varieties of wheat. Based on these observations, the overall acceptability was found the maximum for *varanphal* prepared from Lokwan variety of wheat.

Physicochemical properties of wheat flours and correlation to the dough rheological properties of wheat flour

The correlation coefficients between values of physicochemical properties and rheological properties of different

wheat flour is shown in Table 4. The protein content of flour correlated positively to hardness and cohesiveness of dough ($r = 0.89$, $P < 0.01$ and $r = 0.80$, $P < 0.01$), while negatively correlated with spreadability of dough ($r = -0.98$, $P < 0.01$). A similar relationship between a protein with dough machinability has been reported (Suhendro et al. 1993). The gluten content of flour directly proportional to dough hardness ($r = 0.87$, $P < 0.01$) and cohesiveness of dough ($r = 0.85$, $P < 0.01$) but inversely proportional to the spreadability of dough (-0.93 , $P < 0.01$). Arya et al. (2016) also reported the similar relationship gluten content of flour with hardness and cohesiveness of the dough. Damaged starch correlated positively to farinographic water absorption ($r = 0.75$, $P < 0.01$), Dough stickiness ($r = 0.98$, $P < 0.01$) and negatively correlated to dough development time

Table 4 Correlation between physicochemical and rheological characteristics of wheat flours

	WA-F	DDT	DS	MTI	D-Hard	D-Stick	WOA	D-Cohes	Spread
Protein	− 0.51	0.14	0.42	− 0.25	0.89**	− 0.51	0.04	0.80*	− 0.98**
Ash	− 0.01	0.36	0.09	− 0.00	− 0.08	− 0.18	0.22	0.01	0.34
Dry gluten	− 0.45	0.12	0.37	− 0.22	0.87**	− 0.47	0.01	0.85*	− 0.93**
Starch damage	0.75**	− 0.93**	− 0.94**	0.48	− 0.57	0.98**	− 0.79**	− 0.20	0.30
L*	0.64*	− 0.95**	− 0.88**	0.35	− 0.59*	0.98**	− 0.70**	− 0.18	0.28
a*	− 0.66*	0.97**	0.90**	− 0.43	0.41	− 0.93**	0.82**	0.04	− 0.09
b*	− 0.36	0.23	0.38	− 0.028	0.95**	− 0.56	− 0.04	0.65*	− 0.89**

^a* $P < 0.05$; ** $P < 0.01$ ^bWA-F water absorption of flour, DDT dough development time, DS dough stability, MTI mixing tolerance index, D-hard dough hardness, D-stick dough stickiness, WOA work of adhesion, D-Cohes dough cohesiveness, Spread spreadability

($r = -0.93$, $P < 0.01$), dough stability ($r = -0.94$, $P < 0.01$) and work of adhesion ($r = -0.70$, $P < 0.01$). Rao et al. (1989) reported similar levels of correlations between damaged starch with farinographic water absorption and dough development time. L^* value of flour correlated positively to dough stickiness ($r = 0.98$, $P < 0.01$) and water absorption of flour ($r = 0.64$, $P < 0.05$) while negatively correlated to dough development time ($r = -0.95$, $P < 0.01$), dough stability ($r = -0.88$, $P < 0.01$) and hardness of dough ($r = -0.59$, $P < 0.05$). The correlation table 4 presented that a^* value of flour positively correlated to dough development time ($r = 0.97$, $P < 0.01$) and dough stability ($r = 0.90$, $P < 0.01$) while negatively correlated to water absorption of flour ($r = -0.66$, $P < 0.05$) and dough stickiness ($r = -0.93$, $P < 0.01$). Yellowness (b^* value) of flour the positively correlated with dough hardness ($r = 0.95$, $P < 0.01$) and cohesiveness ($r = 0.65$, $P < 0.05$) while negatively correlated with dough spreadability.

Physicochemical properties of wheat flour and correlation to the quality of *varanphal*

The correlation coefficients between values of physicochemical properties of different wheat flours and quality of *varanphal* is presented in Table 5. The correlation coefficient data shown that the protein content of flour was correlated positively to cooking time ($r = 0.76$, $P < 0.01$), firmness ($r = 0.82$, $P < 0.01$), springiness ($r = 0.93$, $P < 0.01$), cohesiveness ($r = 0.89$, $P < 0.01$), and overall acceptability ($r = 0.70$, $P < 0.05$) of cooked *varanphal*. A similar positive relationship was observed by Park and Baik (2004) between protein content of flour and cooking time of noodles while dealing with white salted noodles. Park and Baik (2004) and Kaur et al. (2016) stated that the protein content of flour influences the noodles quality. A similar association was observed between the protein content and quality of *varanphal*. The dry gluten content of flour correlated positively to cooking time ($r = 0.71$, $P < 0.01$), firmness ($r = 0.77$, $P < 0.01$), Springiness ($r = 0.92$, $P < 0.01$), cohesiveness ($r = 0.813$, $P < 0.01$), and overall acceptability of the cooked *varanphal* ($r = 0.68$, $P < 0.05$). The damaged starch of flour showed a positive correlation with the water absorption of *varanphal* ($r = 0.86$, $P < 0.01$) and cooking loss ($r = 0.82$, $P < 0.01$) while the negative correlation with cooking time ($r = -0.89$, $P < 0.01$). Hatcher et al. (2002) observed similar correlations of starch damage with water absorption and cooking loss of noodles. The higher content of damaged starch in the flour increased the water absorption of dough, which adversely affected the textural properties of *varanphal* (Barrera et al. 2013). The lightness (L^* value) of the flour significantly correlated with positively to water

Table 5 Correlation between physicochemical characteristics of flour and *varanphal* properties

	CT	WA-V	CL	SV	Firm	Spring	Coh-V	Apr	Colour	Texture	MF	Taste	OA
Protein	0.76**	-0.37	-0.48	-0.39	0.82**	0.93**	0.89**	0.23	-0.51	0.92**	0.92**	0.23	0.70*
Ash	-0.02	-0.04	0.17	0.26	-0.13	0.04	-0.48	0.00	0.23	-0.15	-0.15	0.00	-0.19
Dry gluten	0.71**	-0.31	-0.35	-0.37	0.77**	0.92**	0.81**	0.24	-0.47	0.87**	0.87**	0.24	0.68*
Starch damage	-0.89**	0.86**	0.81**	-0.11	-0.51	-0.56	-0.11	0.00	0.22	-0.60*	-0.60*	0.00	-0.11
L^*	-0.86**	0.78**	0.77**	-0.24	-0.58	-0.55	-0.12	-0.14	0.08	-0.63*	-0.63*	-0.14	-0.21
a^*	0.78**	-0.82**	-0.73**	0.22	0.38	0.39	-0.08	-0.03	-0.10	0.44	0.44	-0.03	-0.01
b^*	0.73**	-0.28	-0.59*	-0.09	0.93**	0.87**	0.91**	0.47	-0.24	0.93**	0.93**	0.47	0.83**

** $P < 0.05$; ** $P < 0.01$

^bCT cooking time, WA-V water absorption of *Varanphal*, CL cooking loss, SV swelling volume, Firm firmness, spring springiness of *varanphal*, Coh-V cohesiveness of *varanphal*, Apr appearance, MF Mouthfeel, OA overall acceptability

absorption of *varanphal* ($r = 0.78$, $P < 0.01$) and cooking loss of *varanphal* ($r = 0.77$, $P < 0.01$) while negatively correlated to cooking time ($r = -0.86$, $P < 0.01$), texture and moufeel of the *varanphal* ($r = -0.63$, $r = -0.63$, $P < 0.05$ respectively). The b^* value of the flour correlated positively to cooking time ($r = 0.73$, $P < 0.01$), textural properties of *varanphal* and overall acceptability of cooked *varanphal* ($r = 0.83$, $P < 0.05$) while negative correlated to cooking loss ($r = -0.59$, $P < 0.05$). Indrani and Rao (2000) observed similar a positive correlation between protein, dry gluten, and b^* value of flour with overall acceptability of parotta.

Dough rheological properties of different wheat flours and correlation to the quality of *varanphal*

The correlation coefficients between values of physico-chemical properties and rheological properties of different wheat flour is presented in Table 6. Dough rheological properties of different wheat flours and the quality of *varanphal* showed that rheological properties influenced cooking properties, textural properties and sensory attributes of *varanphal*. Among the farinograph characteristics, the water absorption of flour was positively correlated to water absorption of *varanphal*, cooking loss of *varanphal* and color of cooked *varanphal* ($r = 0.92$, $r = 0.76$, $r = 0.78$, $P < 0.01$ respectively) while negatively correlated to cooking time ($r = -0.82$, $P < 0.01$). Dough development time correlated positively to cooking time of *varanphal* ($r = 0.68$, $P < 0.05$) while negatively correlated to water absorption of *varanphal* ($r = -0.70$, $P < 0.05$) and cooking loss of *varanphal* ($r = -0.65$, $P < 0.05$). The dough stability correlated positively to cooking time ($r = 0.89$, $P < 0.01$) but negatively correlated to water absorption and cooking loss of *varanphal* ($r = -0.97$, $r = -0.84$, $P < 0.01$). Hou et al. (2013) also reported a positive correlation between dough stability and cooking time of Chinese noodles. MTI showed a positive relationship with water absorption of *varanphal* ($r = 0.83$, $P < 0.01$) and swelling volume of cooked *varanphal* ($r = 0.71$, $P < 0.01$). The hardness of dough showed a positive correlation with cooking time ($r = 0.79$, $P < 0.01$), textural properties, mouthfeel and overall acceptability of *varanphal* while negatively correlated with cooking loss of *varanphal* ($r = -0.58$, $P < 0.05$). Indrani and Rao (2000) also similar result observed that positive correlation existed between dough hardness and mouthfeel of parotta. The dough stickiness was positively correlated with water absorption and cooking loss of *varanphal* ($r = 0.80$, $r = 0.80$, $P < 0.01$ respectively) while negatively correlated with firmness ($r = -0.63$, $P < 0.05$) and springiness ($r = -0.65$, $P < 0.05$) value of *varanphal* which indicated that the dough stickiness adversely

Table 6 Correlation between rheological characteristics of flour and *varanphal* properties

	CT	WA-V	CL	SV	Firm	Spring	Cohe-V	Apr	Colour	Texture	MF	Taste	OA
WA-F	-0.82**	0.92**	0.76**	0.50	-0.24	-0.55	-0.19	0.49	0.75**	-0.51	-0.51	0.49	0.12
DDT	0.68*	-0.70*	-0.65*	0.40	0.38	0.33	-0.15	0.10	0.08	0.40	0.40	0.10	0.03
DS	0.89**	-0.97**	-0.84**	-0.16	0.35	0.51	0.08	-0.28	-0.48	0.52	0.52	-0.28	-0.07
MTI	-0.55	0.83**	0.51	0.71**	0.17	-0.22	0.04	0.81**	0.87**	-0.20	-0.20	0.81**	0.45
D-Hard	0.79**	-0.34	-0.58*	0.03	0.95**	0.93**	0.81**	0.48	-0.21	0.94**	0.94**	0.48	0.80**
D-Stick	-0.91**	0.80**	0.80**	-0.14	-0.63*	-0.65*	-0.22	-0.12	0.18	-0.70**	-0.70**	-0.12	-0.27
WOA	0.62*	-0.92**	-0.62*	-0.18	-0.07	0.13	-0.30	-0.56	-0.35	0.15	0.15	-0.56	-0.46
Cohes-D	0.50	-0.12	-0.26	-0.35	0.61*	0.75**	0.67*	0.21	-0.45	0.66*	0.66*	0.21	0.52
Spread	-0.69*	0.30	0.44	0.48	-0.75**	-0.88**	-0.92**	-0.18	0.39	-0.87**	-0.87**	-0.18	-0.68*

* $P < 0.05$; ** $P < 0.01$

^aWA-F water absorption of flour, DDT dough development time, DS dough stability, MTI mixing tolerance index, D-Hard dough hardness, D-Stick dough stickiness, WOA work of adhesion, D-Cohes dough cohesiveness, Spread spreadability, CT cooking time, WA-V water absorption of *Varanphal*, CL cooking loss, SV swelling volume, MF firmness, Spring springiness of *varanphal*, Cohe-V cohesiveness of *varanphal*, Apr appearance, MF Mouthfeel, OA overall acceptability

affected the textural properties of *varanphal*. It was found that the work of adhesion was positively correlated with cooking time ($r = 0.62$, $P < 0.05$) while negatively correlated with water absorption ($r = -0.92$, $P < 0.01$) and cooking loss of *varanphal* ($r = -0.62$, $P < 0.05$). The cohesiveness of dough was positively correlated with textural parameters and texture of *varanphal*. Furthermore, spreadability of dough was negatively correlated to cooking time ($r = -0.69$, $P < 0.05$), firmness ($r = -0.75$, $P < 0.01$), springiness ($r = -0.88$, $P < 0.01$), cohesiveness ($r = -0.92$, $P < 0.01$) and overall acceptability of *varanphal* ($r = -0.68$, $P < 0.05$).

Conclusion

The quantity of protein in flour was found to be the best index of *varanphal* quality. Damaged starch and gluten content influenced dough rheological properties as well as *varanphal* cooking properties such as cooking time and cooking loss. Farinographic water absorption, protein content, gluten content, and damaged starch were found to be highly correlated to the overall quality of *varanphal*. This study demonstrated the effect of protein and gluten content on the different parameters of *varanphal* quality mainly textural properties. Based on higher protein and gluten content along with minimum damaged starch; Lokwan variety can be considered as most suitable for *varanphal* qualities followed by Sharbati variety.

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