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Research Article

Comparative Evaluation of Functional Properties of Commonly Used Cereal and Legume Flours with their Blends

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Abstract

The current research was conducted to explore the functional properties of commonly used cereals, legumes (wheat, refined wheat, maize and chickpea) and their blends. The properties under discussion included were such as protein solubility, swelling capacity, water holding capacity, gelling ability, bulk density and foaming capacity of flours of some commonly used cereals and legume (wheat, refined wheat, maize and chickpea) and their blends were studied. Flours blends of flours were prepared by mixing equal proportions of selected floors. Statistically significant difference ($p \leq 0.05$) in studied functional properties except bulk density was observed among cereal flours and their blends. Chickpea flour was found to possess comparatively high water holding capacity, protein solubility index and swelling capacity. The functional properties of maize and wheat flours were found to be improved when blended with chickpea. Chickpea flour and its blends with cereal flours were found to possess retained good functional score and suggested as favorable candidates for use in the preparation of viscous foods and bakery products. The overall data provided the guidelines regarding the improvement in functional properties of economically favorable cereal flours.

1. Introduction

Protein solubility, swelling capacity, water holding capacity, gelling abilities and foaming properties are intrinsic physicochemical properties of flours based on the relative strength of hydrophilic and hydrophobic groups of starch and protein. Proteins containing comparatively greater number of polar amino acids show high hydrophilic strength while the hydrophobic character of protein is based on exposure of non-polar amino acids (Alleoni, 2006). Ionic strength, pH, temperature and radiations cause denaturation of protein molecules and affect the functional properties of flour. The variation in functional properties further leads to the change in quality of food products (FAO, 2010; Moses, Olawuni, & Iwouno, 2012). Bulk density of flour depends on the structural arrangement of carbohydrates and other polymers present in flour (Adejuyitan et al., 2009).

Cereals and legumes have played a significant role in reducing the problem of malnutrition throughout the world. These are rich sources of carbohydrates, lipids and protein therefore used as major ingredient in preparation of starch and protein based food formulation. Various cereals and legumes flours differ in their biochemical composition, molecular structure, conformation of food components and show diverse functional properties. (Alleoni, 2006; Wujun et al., 2007). The variation in functional properties is attributed to the relative proportion of carbohydrates, lipids and protein in different flours. Functional properties of flours are also changed by any change in the processing conditions such as extraction, isolation, drying, milling, blending, baking, cooking and fermentation (Amza et al., 2011; Barros, Alviola, & Rooney, 2010; Basediya et al., 2013). Low quality blend formation of frequently available cereals possessing good functional characteristics may be helpful in improving the quality and economic value of

Table 1. Proportions of wheat flour (WF), refined wheat flour (RWF), Maize flour (MF) and chickpea flour (CPF) in blends

Components of the Blends	Blend Ratio (w/w)
WF + MF	1:1 (w/w)
WF + CPF	1:1 (w/w)
CPF+MF	1:1 (w/w)
CPF+RWF	1:1 (w/w)
CPF+WF+MF	1:1:1 (w/w)
CPF+RWF+MF	1:1:1 (w/w)

food products (Abou et al., 2010; Ogori et al., 2013; Olapade & Akinyanju, 2014).

Previously, studies have been performed to investigate the effect of blend formation on the functional characteristics of cereal flours. Significant variation in water and oil holding capacities, foaming capacity, emulsifying capacity bulk densities and gelling abilities have been found to be changed by altering the ratio of different flours in the blend (Adeleke & Odediji, 2010; Akpapunam & Darbe, 1994). However, no data have been found on functional properties of flours and their blends of commonly used cereals in Pakistan. Therefore, present study was designed to investigate the variation in functional characteristics of blends from those of pure flours of three commonly used cereals (wheat, maize, chickpea) in Pakistan. The data would provide useful information for the manufacturers and consumers regarding the selection of suitable cereals and their blends for preparation of good quality food products.

2. Materials and methods

2.1. Sampling and preparation of blends

Flours of different cereals and legume including wheat, maize and chickpea were purchased from local market, Multan, Pakistan. Blends were prepared by mixing flours in equal ratios (Table 1) using kitchen blender at low speed to minimize the thermal fluctuations. The flours and blends were stored in air tight glass jars at standard laboratory conditions throughout the study period.

2.2. Functional properties

2.2.1. Swelling capacity and protein solubility index

Swelling capacity (SC) and protein solubility index (PSI) were determined by the method described by Shad et al. (2011). The flour/blend (0.2 g) was homogenously dispersed in distilled water (10mL) and slurry was heated at 60ºC in thermally controlled water bath. Mixture was cooled at room temperature and centrifuged at 2200 rpm for 15 min. The residue obtained after centrifugation along with retained water was reweighed and SC was calculated using Eq. 1.

$$SC\ (\%) = \frac{W_{rw}}{W_s} \times 100 \qquad (1)$$

where, W_s is weight of the sample while W_{rw} is weight of sample along with retained water.

The supernatant was then allowed to evaporate at 100ºC and residue thus obtained was weighed to calculate PSI

Table 2. Water holding capacity, protein solubility, swelling capacity and least gelation concentration of flours and their blends

	WHC	PSI	SC	LGC
Flours of different cereals				
WF	92.45±7.86^{abc}	8.33±2.89^{b}	215±18.03^{d}	18.67±1.15^{a}
RWF	104.23±12.23^{a}	13.33±5.77^{ab}	237.28±13.57^{d}	20.30±1.04^{a}
MF	100.24±13.97^{ab}	6.67±2.89^{b}	246.97±33.67^{d}	4.67±1.15^{ef}
CPF	108.75±19.46^{a}	18.33±2.89^{a}	205.98±6.53^{de}	14.67±1.15^{b}
Blends				
WF+MF	99.77±1.56^{ab}	7.68±0.89^{b}	468.33±13.46^{ab}	4.02±0.23^{ef}
WF+CPF	89.59±3.05^{abc}	8.33±1.21^{b}	506.67±22.55^{a}	6.10±0.30^{ef}
CPF+MF	112.69±3.32^{a}	13.74±1.15^{ab}	350.19±35.64^{c}	10.07±1.99^{cd}
CPF+RWF	74.87±8.23^{bc}	7.93±2.89^{b}	462.31±27.54^{ab}	4.67±1.15^{ef}
CPF+WF+MF	87.84±4.25^{abc}	13.75±0.39^{ab}	494.62±10.55^{ab}	8.67±1.15^{de}
CPF+RWF+MF	107.77±1.47^{a}	7.40±3.31^{b}	430.93±49.77^{b}	12.00±1.15^{bc}
p-value	0.000	0.001	0.000	0.000

*Values expressed in mean ± standard deviation of three replicates; ** Means followed by the different letters in each column are significantly different at confidence level $p \leq 0.05$ using Tukey's multiple range tests.

of flour in water using Eq. 2.

$$PSI\ (\%) = \frac{W_{rc}}{W_s} \times 100 \quad (2)$$

where, W_s is the weight of sample and W_{rc} is the weight of residue obtained after centrifugation and evaporation.

2.2.2. Water holding capacity

Water holding capacity (WHC) was determined by using the method of Beuchat (1977). The maize flour (1 g) was mixed with 10 mL of distilled water taken in pre-weighed centrifuge tubes, mixed well and centrifuged at 3000 rpm for 30 min. The supernatant was decanted and excess moisture was removed by draining for 30 minutes. The centrifuge tubes were weighed again and WHC was calculated from Eq. 3.

$$WHC\ (\%) = \frac{(W_2 - W_1)}{W_0} \times 100 \quad (3)$$

where, W_0 is the weight of the sample, W_1 is the weight of tube plus sample and W_2 is the weight of the tube plus the sediments.

2.2.3. Least gelation concentration

Least gelation concentration (LGC) of the flour/blend was determined by the method described by Coffman & Garcia (1977). A series of sample suspensions of increasing concentrations such as 2, 4, 6, 8, 10, 12, 14, 16, 18 and 20% (w/v) were prepared in distilled water (10 mL). All the suspensions were heated gently for 1 hour in a boiling water bath. The heated suspensions were cooled at 4°C for 2 hours and then inverted one after the other. The LGC was taken as the concentration at which the inverted suspension did not fall or slip.

2.2.4. Foaming capacity

Foaming capacity (FC) was determined by the method of Coffman & Garcia (1977). The flour/blend (2 g) was dispersed in distilled water (100 mL) and homogenized for 2 min in a kitchen blender. The volume of suspensions was recorded before and after homogenization and FC was calculated in terms of percent increase in the volume of suspension using Eq. 4.

$$FC\ (\%) = \frac{V_2 - V_1}{V_1} \times 100 \quad (4)$$

where, V_1 is initial volume, V_2 is volume of solution after homogenization.

The foam was then allowed to stand for 8 hours at room temperature and foaming stability (FS) in terms of percentage retention of initial volume was calculated by Eq. 5.

$$FS\ (\%) = \frac{V_{rfv}}{V_{ifv}} \times 100 \quad (5)$$

where, V_{ifv} is initial foam volume and V_{rfv} is foam volume retained after 8 h.

2.2.5. Bulk density

The procedure described by Chinma, Alemede, & Emelife (2008) was used to determine bulk density (loose and packed bulk density) of flour and blends. A known weight of the flour was taken into a pre-weighed (W_1) measuring cylinder and the weight of the cylinder (W_2) as well as the volume of the flour (V_1) was noted. Loose bulk density (LBD) was calculated as g/cc using Eq. 6.

$$LBD\ \left({}^{g}/_{cc}\right) = \frac{W_2 - W_1}{V_1} \quad (6)$$

The cylinder was tapped gently to eliminate air spaces between the particles of the flour. The new volume (V_2) of the sample and mass of the cylinder (W_3) was noted and packed bulk density (PBD) was calculated as g/cc using Eq. 7.

$$PBD\ \left({}^{g}/_{cc}\right) = \frac{W_3 - W_1}{V_2} \quad (7)$$

2.3. Statistical analysis

The results for the functional properties of flours of different cereals and their blends were expressed as mean ± standard deviation of three parallel replicates. The data were statistical analyzed by one way analysis of variance (ANOVA) using statistical software (SPSS, version 14.0) and the means were separated at 95% confidence level ($p \leq 0.05$) applying Tukey's multiple range tests.

3. Results and discussion

Experimental results for water holding capacity (WHC), protein solubility index (PSI), swelling capacity (SC) and least gelation concentration (LGC) of cereals and their blends are represented in Table 2. WHC, PSI, SC

Table 3. Foaming capacity and foaming stability (%) of flours of and their blends

	FC	FS
Flours of different cereals		
WF	11.76±3.92[*b]	93.85±4.13[ab]
RWF	4.92±1.01[def]	95.90±1.95[a]
MF	2.29±0.57[ef]	97.05±0.09[a]
CPF	19.61±3.92[a]	90.11±3.81[abc]
Blends		
WF+MF	8.56±0.93[bcd**]	90.11±3.81[abc]
WF+CPF	23.43±1.72[a]	85.90±3.63[bc]
CPF+MF	6.34±0.45[bcdef]	97.54±1.58[a]
CPF+RWF	7.55±1.34[bcde]	83.72±4.96[c]
CPF+WF+MF	11.45±2.65[bc]	88.1±5.38[abc]
CPF+RWF+MF	5.65±1.10[cdef]	96.06±2.59[a]
p-value	0.00	0.00

Table 4. Bulk densities (g/cc) of flours of their blends

	LBD	PBD
Flours of different cereals		
WF	0.47±0.08*[a]	0.67±0.06[a]
RWF	0.47±0.029[a]	0.67±0.14[a]
MF	0.42±0.007[a]	0.67±0.07[a]
CPF	0.41±0.02[a**]	0.65±0.14[a]
Blends		
WF+MF	0.40±0.004[a]	0.66±0.03[a]
WF+CPF	0.41±0.02[a]	0.59±0.02[a]
CPF+MF	0.42±0.006[a]	0.64±0.02[a]
CPF+RWF	0.43±0.005[a]	0.633±0.016[a]
CPF+WF+MF	0.45±0.01[a]	0.55±0.01[a]
CPF+RWF+MF	0.44±0.01[a]	0.62±0.018[ab]
p-value	0.087	0.462

*Values expressed in mean ± standard deviation of three replicates
** Means followed by the different letters in each column are significantly different at confidence level $p \leq 0.05$ using Tukey's multiple range tests.

and LGC of selected flours and their blends ranged from 74.87±8.23 to 112.69±3.32, 6.67±2.89 to 18.33±2.89, 205.98±6.53 to 506.67±22.55 and 4.02±0.23 to 20.30±1.04% respectively. Experimental results of foaming properties and bulk densities are presented in Table 3 and 4 respectively. Foaming capacity (FC), foaming stability (FS), lose bulk density (LBD) and packed bulk density (PBD), ranged from 2.29±0.57 to 23.43±1.72, 83.72±4.96 to 97.54±1.58, 0.40±0.004 to 0.47±0.08 and 0.55±0.01 to 0.55±0.01% respectively.

Statistically significant difference ($p \leq 0.05$) in all of the studied functional properties except bulk density was observed among the flours of different cereals and their blends. The percentage variation in functional properties of blends of various flours from those of pure

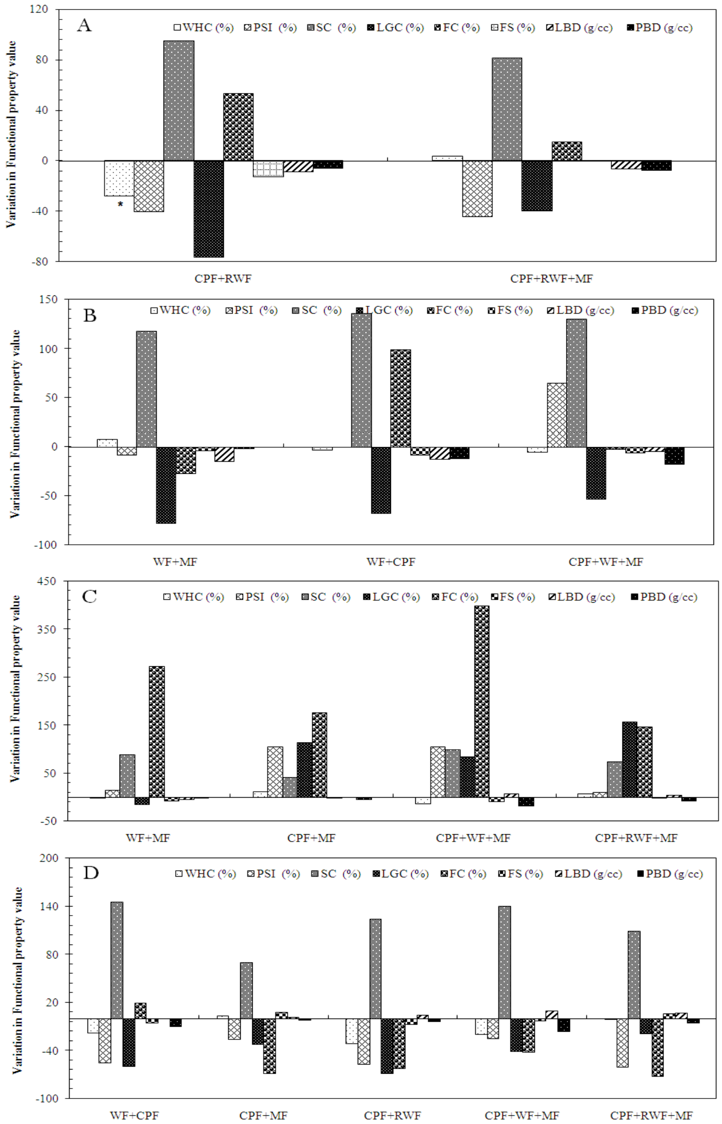

Figure 1. Variation in functional properties of blends from those of pure flours (A) Variation from pure chickpea flour, (B) Variation from pure maize flour, (C) Variation from pure wheat flour, (D) Variation from pure refined wheat flour

flours is presented in Fig. 1A-D. The values of functional properties of blend were found to be increases or decreased as compared to those of components flours of blends. WHC of WF+MF, PS of WF+MF+CPF, SC of WF+CPF, WF+CPF and WF+MF+CPF and FC of WF+MF was found to be increased by 7.92, 65.07, 117.82-135.66 and 99.23% respectively as compared to that of pure WF. LBD, PBD, LGC and FS of blends of WF with MF and CPF were found to be decreased by 4.26-14.89, 1.49-17.91, 53.56-78.56 and 3.99-8.47% respectively as compared to those of pure WF. All of the functional properties except SC and FC of RWF were found to be decreased when blended with MF and CPF. PS, SC, LBD, LGC and FC of MF were found to be increased by 10.94-106.15, 41.79-100.28, 4.76-7.14, 85.65-156.96 and 146.72-400% respectively when blended with WF, RWF and CPF. WHC was found to be increased by 7.51-12.42% in blends of MF with CPF and RWF as compared to pure MF. However, PBD, and FS of MF were found to be decreased by 1.49-17.46 and 1.02-9.22% respectively when blended with WF, RWF and CPF. SC and LBD of CPF were found to be increased by 70.01-145.98 and 2.44-9.76% respectively when blended with WF, MF and RWF. However, PS, WHC, PBD, LGC and FS of CPF were found to be decreased by 24.99-59.63, 0.90-31.15, 1.54-15.38, 18.20-68.17 and 2.23-7.09% respectively when blended with WF, MF and RWF.

Functional properties of food materials play a significant role in manufacturing, transportation, storage, stability, texture, taste and flavor of food products. These properties directly or indirectly depend on type, variety, particle size and chemical composition of floor and type of processing method. Formation of blends of different floors in an appropriate ratio may improve the functional properties and nutritional and product quality of food materials (Igbabul, Adole, & Sule, 2013; Mojisola, Lateef, & Abiodun, 2005; Okoye, Nkwocha, & Agbo, 2008).

Water absorption capacity (WAC) is the measure of association of hydrophilic functional groups of protein with water in a water stressed environment (Singh, 2001). Consistency and stability of viscous foods such as soups, gravies dough and baked products entirely depend on WAC of starch and protein present in it (Adeyeye & Aye, 1998). Comparatively high WAC of the blend of MF with CPF gave it an advantage over pure MF to be used as a thickener in liquid and semi-liquid foods. However, the blend of WF with MF and CPF showed low value of WAC which would be adventitious for use in the preparation of moisture free products.

PSI is directly correlated with digestibility and availability of protein. PSI depends on the relative proportion polar and non polar amino acids, their three dimensional arrangement in proteins and interaction with water (Capriţa, Capriţa, & Creţescu, 2010). Relatively high value of PSI of blend of MF with WF and CPF (13.75%) suggests an improvement in nutritional quality of MF while blended with other floors.

Swelling properties of floor determine the crystalline arrangement and degree of hydrogen bonding in starch granules in the floor (Biliaderis, 1982). Relatively high SC of floor is considered as more suitable for preparation of bakery products. The blend of WF with CPF due to comparatively high SC (506.67%) was found to be preferable over pure WF and its blends with other floors for such preparations.

LGC is the minimum concentration of floor at which it becomes able to form gel. It depends on relative concentration of protein, carbohydrates and lipids in the floor. The gelling ability of floor may be due to the thermal degradation of starch, denaturation of protein. Gelation process occurs by the transformation of the viscous liquid in a viscous-elastic three dimensional matrix which involves the swelling of protein and starch through ordinate polymerization of molecules on heating (Alleoni, 2006; Enwere & Ngoddy, 1986; Hermansson, 1979). The floor showing low value of LGC possesses high gelling ability and may be preferably used in the preparation of jellies, puddings, custards, soups and semiliquid beverages. The blend of each of the WF, RWF and CPF with MF resulted in low LGC compared to pure WF, RWF and CPF which suggests the preferable use of MF blends with other flours for such preparations.

Foaming properties are desirable in food products such as cakes, breads, meringues, crackers, ice creams and several other bakery items to maintain their texture and structure throughout the processing and during storage. FC depends on the surface tension at the water air interface. The cereal protein in the dispersion forms a continuous cohesive film around the air bubbles in the foam (Kaushal, Kumar, & Sharma, 2012). FS depends on relative electrostatic attractive and repulsive forces among the polypeptides and protein molecules. Non polar residues in protein increase the stability of the foam film while polar residues lead to decrease it (Alleoni, 2006). FC of the blend of WF with CPF was fond to be high among the flours and their blends. FC of MF was found to be improved when blended with CPF and WF. All the floors and their blends showed more than 80% FS after 16h. However, FS of MF and its blend with CPF was found to be maximum (>97%) among the floors and their blends. The result for FC of wheat flour was found to be comparable to that reported by Chandra & Samsher (2013).

Bulk density is the function of mass and volume of flour which depends on the size of particles and initial moisture content of the flour. Relatively high bulk density makes the flour more suitable for packaging, transportation and use in the preparations. However, low bulk density is considered favorable for formulation of complementary foods (Akpata & Akubor, 1999). No significant difference was observed in LBD of the blends and pure floors. However, PBD of blend of CPF with WF and MF was found to be comparatively lowest than those of other blends and pure flours.

4. Conclusions

The blend of CPF with MF being high in WAC and blends of CPF with WF and MF due to their high SC and PSI were found to be favorable to increase the consistency and stability of viscous foods such as soups, gravies dough and baked products. CPF, MF and their blends, due to their good FC and FS, were considered to be more favorable for preparation of bakery products. CPF was therefore, be helpful in improving functional properties and nutritional quality of cereal based food products. RWF with comparatively low value of LGC was adventitious for use in preparation of soups, jellies and other high viscosity products. Depending on the desirability for use in various food products, functional properties of cereal flours may be improved by preparing their blends with legume flours in suitable proportions.

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