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Research Article

Physicochemical, functional, pasting and antioxidant properties of flours from different cereals: A comparative evaluation

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ABSTRACT:

The study was conducted on flours from different cereals in relation to their physicochemical, functional, pasting and antioxidant properties. Among the all flours, the proximate composition and mineral content was observed to be highest in oat flour. The colour values differed significantly ($p \leq 0.05$) among different flours. The L* values was found highest for wheat flour whereas a*, b* and ΔE values was the highest for oat flour. The maximum concentration of minerals like Cu, Mn, Na, K were detected in oat flour and Zn, Fe in barley flour. The bran fraction of all flours showed significantly ($p \leq 0.05$) higher antioxidant potential followed by whole and refined flour. Barley flour showed highest antioxidant properties followed by maize flour. The significant correlations were observed between different antioxidant properties of bran, whole and refined flours fractions of different cereals. The flour from barley showed the highest peak (2752cP) and threshold viscosity (1661cP) and rice flour showed highest final (3257cP) and setback viscosity (2033cP).

Keywords: bran, antioxidants, minerals, total phenols, colour characteristics

[1] INTRODUCTION

Wheat, rice, maize are the major cereal grains with oats and barley being considered as minor grains. The grains consist of three main fractions: endosperm, germ, and bran (including aleurone). The grain weight of about 75-80% is composed of starchy endosperms. For various grains with their different varieties, the germ and bran contribution to the total weight may also vary [1]. In grains, most of the biologically active compounds are derived from the bran and germ fractions. Grains contain the significant quantities of protein, energy, dietary fibre, vitamins, minerals (Ca, Mn Mg, K, P, Zn, Na and Fe) and basic amino acids [2]. The functional properties represent the action of nutrients in foods during handling, storage and processing as they influence on the quality of food and its acceptability. The proteins contribute to the foaming of flours which form a continuous adherent film around the air bubbles in the foam. Foaming stability (FS) is important property as the utilization of whipping agents rely on their capability to maintain the foam for a long time. During processing, the emulsion activity (EA), emulsion stability and fat binding are the basic functional properties of protein in foods such as salad dressings, comminuted meat products, mayonnaise and frozen desserts [3]. The OAC represents the emulsifying capacity, a highly desirable quality in products like mayonnaise [4]. The WAC is effected by the amount of disintegration of native starch granules, indicating that undamaged starches have low capacity to absorb water [5]. The physicochemical properties have an effect the physical and chemical characteristics of food during processing. Pasting involves the changes that takes place after gelatinization upon additional heating and these involves further swelling of granules that leads to leaching of molecular components from the granules and finally disruption of granules chiefly with the utilization of shear forces [6]. Due to the presence of several phytochemicals (phytates and phenolic compounds), the whole grains have high antioxidant activity [7]. The cereal grains contain various phenolic compounds having antioxidant properties that are associated with the health benefits. The phenolic compounds have the benzene ring with one or more hydroxyl groups. For instance, the phenolic acid, condensed tannins, flavonoids, coumarins and alkyl resorcinol are the phenolic compounds. The antioxidants are present in all plant based foods and have influence on their appearance, colour, flavour and oxidative stability. The occurrence of undesirable factors such as changes in flavour and nutritional quality of foods can be prevented by antioxidants. In cereal grains, the antioxidants are mainly present in the pericarp, therefore their concentration is higher in bran layer [8]. The study was undertaken to evaluate the proximate composition, physicochemical, functional, antioxidant and pasting properties of flours from different cereal grains.

[II] MATERIALS AND METHODS

2.1. Procurement of raw material

Five cereal crops, wheat (*Triticum aestivum*), rice (*Oryza sativa*), maize (*Zea mays)*, barley (*Hordeum vulgare*) and oats (*Avena sativa*) were obtained from PAU, Ludhiana. The grains were conditioned to 14% moisture content. Flour from wheat and maize was obtained by using Brabender Quadrametric Junior Mill (Duisberg, Germany) and Super Mill (Newport, Australia). Rice, barley and oats were first dehulled and then milled to produce flour. Bran from these cereals was obtained by using abrasive debraner. The whole grain meal, flour samples and bran were kept in a refrigerator until further analysis

2.2. Physicochemical properties

Flour samples from different cereal grains were estimated for their protein, moisture, ash, fat and fibre contents by standard methods of analysis [9]. The colour characteristics were measured using a Hunter colorimeter (Hunter Associates Laboratory, U. S. A.). The colorimeter was standardized using standard tile. The flour was filled in sample cup and kept in the sample platform and its colour was expressed as L*, a* and b* values. The L* values stand for whiteness to darkness. The chromatic portion is analysed by a* (+) redness and a* (-) greenness, b* (+) yellowness and b* (-) blueness.

2.3. Minerals

Minerals from different cereal grains were analysed after digesting the samples in di-acid mixture ($HClO_4$:HNO_3 in 4:1 ratio). Then the digested extract was measured by Agilent 240 FS AA model Atomic Absorption Spectrophotometer for mineral determination.

2.4. Functional properties

The water absorption capacity (WAC), oil capacity absorption (OAC) and least gelation concentration of flours were determined using the method described by [10]. Emulsion activity and stability were measured according the method of [11]. The foaming capacity and stability were determined by the method of [12].

2.5. Pasting properties of flour

Pasting properties of flours were analysed by using Rapid Visco-Analyzer (Model RVA-3, Newport Scientific Pvt. Ltd., Australia). The flour sample of 3g was mixed with 25ml of distilled water in the RVA sample canister to make a flour suspension of 28 g. The time temperature consist of a heating phase of sample from 50 to 95ºC at 6ºC/min after 1 min of equilibrium time at 50ºC and then 5 min of holding step at 95ºC. After that the cooling was done from 95 to 50ºC at 6ºC/min with 2 min of holding phase at 50ºC. The parameters that recorded were pasting temperature, peak viscosity, hold viscosity, final viscosity, breakdown viscosity (peak viscosity - trough viscosity) and setback viscosity (final viscosity - trough viscosity).

2.6. Antioxidant properties of whole flour, refined flour and bran of different cereals

Antioxidant activity is also known as DPPH Radical Scavenging Activity. The antioxidant activity of flour extracts was determined according to the method of [1]. The TPC of sample extracts was determined using the Folin-Ciocalteu reagent by the method of [13]. The reducing power assay was determined using the method of [14]. The metal chelating activity of sample extract was measured as described by [15].

2.7. Statistical analysis

The data reported in all the tables is averages of triplicate observations. The data was subjected to statistical analysis using Minitab Statistical Software version 17 (Minitab Inc., USA).

[III] RESULTS AND DISCUSSION

3.1. Physicochemical properties

The nutrient composition (protein, fat, fibre, ash and moisture) of flours from different grains is presented in Table I. Protein content varied substantially among flours. Oats and wheat flour had significantly ($p \leq 0.05$) higher protein content (13.7%) than other flours while barley contained intermediate levels, averaging 11.9% followed by maize. Rice grain exhibited the lowest level of protein (9.3%). Pomeranz [16] reported that in most cases, high nitrogen fertilization increases storage proteins and thus total protein of barley. Oats showed significantly ($p \leq 0.05$) higher ash content (2.02%) followed by barley, wheat and maize (1.37, 1.32 and 1.16%) respectively. Fat content ranged from 1.7% to 5.16% with oats flour showed significantly ($p \leq 0.05$) higher fat content [Table I]. The high content of fat in oats is due to the presence of embryo which is rich in oil content. Maize and barley contained relatively lower fat (3.68 and 2.44% respectively) as compared to oats. The grains having high content of fat such as oats and maize should be taken into consideration during storage and processing. Hoseney, Varriano-Marston & Dendy [17] observed that the quality of millet flour deteriorates during storage and it turns bitter due to high level of unsaturated fatty acids and high enzymatic hydrolytic activities. Oats and barley showed significantly ($p \leq 0.05$) higher fibre content (3.17 and 3.31% respectively) followed by maize, wheat and rice flour (2.46, 1.08 and 0.75% respectively). In oats and barley, b-glucan is the major component of fibre. Bhatty [18] concluded that in barley, b-glucan ranged at level of about 22% of the total dietary fibre, followed by pentosan (19.7%), klason lignin (7.8%) and resistant starch (6.3%).

Hunter L* value varied significantly among different and it ranged from 76.0 to 90.7 as shown in Table I. The L* value represents the lightness 0-100 that indicates darkness to lightness. L* values was higher for wheat and oat flour but lower for maize flour. The highest L* values of wheat flour showed that it was lighter in colour as compared to other flours. Among the various flours, oat flour had significantly ($p \leq 0.05$) highest values of a*, b* and ΔE. The a* values of different flours varied from 0.98 to 6.44. The higher a* values of oat flour indicated that it had more redness than other flours. The b* value of flours ranged from 8.51 to 27.36, lowest for wheat flour. The total difference in colour in different flours is indicated by ΔE and it ranged from 76.9 to 93.41. Due to the different coloured pigments, the colour parameters of different flours varied that depends on the biological origin of the plant.

3.2. Minerals

The mineral content of different grains is represented in Table II. Among the different cereal grains, oats reported highest levels of copper, manganese, sodium and potassium and was second highest in zinc (33.1 mg/kg) and iron (201 mg/kg) content after barley. Wheat and rice had moderate level of Cu, Zn, Mn, Na and Fe followed by maize. Maize was deficient in minerals except Mg and K. Similar trends of minerals have been represented by Ragaee, Abdel-Aal & Noaman [19].

3.3. Functional properties

The water absorption capacity was found significantly ($p \leq 0.05$) highest in maize flour (1.47g/g) followed by rice and barley flour (1.27-1.36g/g) [Table III]. There was a slight difference in water absorption capacity of different flours. Butt & Batool [20] reported that variation in WAC in different flours may be due to different protein concentration, their degree of interaction with water and their conformational characteristics. It was reported that increase in the WAC has always been associated with the increase in the amylose leaching and solubility, and loss of starch crystalline structure. Kaushal, Kumar & Sharma [3] studied that WAC varied from 1.3 to 2.4 % for different flours. Kuntz [21] studied that the lower WAC in some flours may contribute to less availability of polar amino acids in flours. The oil and water binding capacity of food proteins relied on the inherent factors like protein confirmation, amino acid composition and hydrophobicity or surface polarity. The barley had significantly ($p \leq 0.05$) highest oil absorption capacity (2.56%) than other flours and it was lowest for maize flour (1.7%). The protein of barley flour has ability to bind with oil and makes it able to use in food systems where oil absorption is important. This favours the barley flour to have desired functional uses in food systems such as sausage production. The flour having high OAC is suitable for facilitating enhancement in flavour and mouth feel when utilize in food preparations. OAC was the potential of flour protein's to physically bind fat by capillary attraction, therefore increases the mouth feel of food as fat functions as a flavour retainer [3].

The proteins act as the surface active agents creating electrostatic repulsion on oil droplet surface and can form and stabilize the emulsion. The emulsion activity and stability of different flour is shown in Table III. The emulsion activity of flours varied from 45.9-49.4%. It was significantly ($p \leq 0.05$) highest for barley and rice flour and lowest for maize flour. The difference in composition of total protein i.e. soluble and insoluble, as well as other components such as carbohydrates may give rise to the emulsification properties of flours [22]. The emulsion stability varied from 45.6-50.1%, with rice showed significantly ($p \leq 0.05$) higher values than other flours. There is a little variation in emulsion activity and stability of different flours. Wagner and Gueguen [23] proposed that the emulsifying properties depend basically on two effects: (i) the protein adsorption at the oil-water interface substantial decrease in interfacial energy and (ii) the destabilisation processes opposes interfacial layer causes the electrostatic, structural and mechanical energy barrier. Moure, Dominguez & Parajo [24] showed that the solubility also plays an important role as the highly insoluble proteins are not good emulsifiers and can cause coalescence.

The foaming capacity and foaming stability varied among different flours as shown in Table III. Foaming capacity was significantly ($p \leq 0.05$) highest for wheat i.e. 50.6% and lowest for maize flour (10.1%). The proteins are surface active and they foams when whipped. This may be attributed to the characteristics of proteins and the varying concentration. Foaming capacity is due to dispersion in protein which lowers the surface tension at the water-air interface. The foaming of the flours depends upon the proteins which form a substantial cohesive film on the sides of the air bubbles in the foam [25]. High foaming capacity of wheat flour may be contributing to its acceptability to be applicable in food system to enhance the leavening and textural attributes of products where foaming properties is required such as cakes, ice-cream, toppings and confectionery products. Foam stability of different cereal flours was determined by measuring the decrease in foam volume as a function of time. Lin, Humbert, & Sosulski [11] concluded that the foam stability is important as the success of whipping agents depends largely on their ability to maintain the foam as long as possible. The flours showed highest foaming stability after 10 min (93.9-99.4%) and then decreased up to the storage of 60 min (72.0-94.5%). The foam stability depends on the formation of film around the entrapped air bubbles which remain intact without draining followed by highly surface-active solutes which forms the stable foams [26].

Least gelation concentration of flours varied from 8-16% due to the variation in constituents such as carbohydrates, lipids and proteins of different flours [Table III]. The highest LGC was found in maize flour and lowest in oats and barley flour. The properties of gelation are interrelated to water absorption capacities of flour. The flour having higher protein concentration forms the gel more readily due to the greater intermolecular contact during heating. Wiltoon, Larry, Beuchat, & Dixon [27] reported that for gelation, the high protein solubility is important. The competition for available water content between starch gelatinization and protein gelation affects the gelation capacity of flour [28].

3.4. Pasting properties

The pasting attributes are useful in the choice of product for use in the industry as a binder, thickener, or for any other purpose. The selection process also related to the viscosity of the gel formed during and after heating. Pasting temperature (PT) signifies the minimum temperature demanded to cook the flour. Peak viscosity (PV) appeared at the equilibrium point between swelling and polymer leaching due to which viscosity increased and then polymer alignment rupture which cause it to decrease. The PV of rice was observed significantly ($p \leq 0.05$) higher for rice flour and lower for oat flour. All the flours showed a slight increase in viscosity due to the removal of water by the granules from the exuded amylose as they swell with increase in their temperature [29]. Swelling power of flours depend on their starch and protein content. The flours having high protein content restricts the swelling by causing the starch granules to be embedded in the stiff protein matrix which lowers the starch access to water. The high carbohydrate and low protein contents of rice flour resulted in their higher swelling ability. Due to amylose retrogradation, hardening of cooled flour suspensions is the setback viscosity and it ranged from 987 to 1837 cP (Table IV). On cooling, wheat and maize flour pastes were stable which showed by their lowest setback viscosities. The lowest setback viscosity of wheat flour showed their high resistance to retrogradation and therefore would form stable paste as it is important characteristic in porridge making. Breakdown viscosity represents the ability of swollen granules to rupture. BV was significantly ($p \leq 0.05$) higher for barley flour (1105cP) than other flours. BV affects the strength of flour pastes. Final viscosity is the tendency of the material to form viscous paste determined by retrogradation of soluble amylase on cooling and it ranged from 2003 to 3257 cP which was lowest for maize flour and highest for rice flour.

3.5. Antioxidant Properties

The antioxidant properties of whole flour, refined flour and bran from different grains were analysed.

The bran fraction from all grains showed higher antioxidant activity followed by whole flour and refined flour. AOA of bran varied significantly ($p \leq 0.05$) among different cereal grains and ranged from 20.8 to 87.1% (Figure I). AOA of whole flour and refined flour also varied significantly and ranged from 10.6 to 22.8% for whole flour and 6.8 to 12.8% for refined flour of different grains. The outer layers of grain i.e bran showed highest antioxidant activity. As it separates from the grain, the antioxidant activity decreases. DPPH scavenging activity of whole and refined flour fractions from different cereals was in the following order: barley > maize > oats ~ wheat > rice. Zielinski & Kozlowska [30] showed the similar results of antioxidant activity of various grains. The radical scavenging activity or the antioxidant properties are determined by DPPH which is a stable free radical. To eliminate the per oxidation chain reaction, DPPH quenches or directly reacts with peroxide radicals. The variation in antioxidant activity of grains was influenced by environmental and genetic factors [31].

The highest and lowest TPC was found in barley and maize respectively as shown in Figure II. The TPC of whole flour, refined flour and bran varied significantly ($p \leq 0.05$) among different cereals and ranged from 919 to 1841.3, 421 to 835.66 and 2114.6 to 3387.66 µg GAE/ g respectively (Figure 2). Barley had the highest total phenolic content while rice represented the lowest content. The highest concentration of phenolic compounds is in the cell walls of the outer layer of grains which are mostly esterified to the arabinose side groups of arabinoxilanes [32]. From the outer layers, concentration of phenolic compounds diluted by endosperm, therefore, whole flour had lower TPC than bran and higher than that of refined flour. Similarly, the refined flour showed the lowest TPC as compared to the bran and the whole flour. Sorghum, oats, barley had possessed intermediate total phenolic content followed by wheat and rice. Adom & Liu [33] concluded that the highest TPC was found in corn (15.55±0.60 µmol of GAE/g of grain) followed by wheat (7.99±0.39 µmol of GAE/g of grain), oats (6.53±0.19 µmol of GAE/g of grain), and rice (5.56±0.17 µmol of GAE/g of grain). Zielinski & Kozlowska [30] showed that the oats and barley whole grains had highest total phenolic content as compared to wheat and rye but lower than that of buckwheat. Ragaee, Abdel-Aal & Noaman [20] showed similar results of TPC.

The reducing power of whole flour, refined flour and bran varied significantly ($p \leq 0.05$) among various cereal grains and ranged from 1168 to 2227.66 µg AAE/ g in whole flour, 552 to 1367.7 µg AAE/ g in refined flour and 1853.7 to 4240.5 µg AAE/ g in bran (Figure III). Barley had highest reducing power while that of rice showed the lowest. Sreeramulu, Reedy & Raghunath [34] showed that the finger millets, millets and kidney beans had the highest reducing power, the values being 4.54, 1.73 and 4.89 mg/g respectively while wheat and black gram had least (0.36 and 0.77 mg/g). As reducing power contributes to the antioxidant activity, the lipid per oxidation reactions formed by oxidized peroxides can be reduced by reducing agent i.e. electron donor compounds. Therefore, these compounds may be primary or secondary antioxidants [35].

In food and biological systems, the transition metal such as ferrous ion initiates per oxidation. Ferrous ions cause the formation of hydroxyl radicals in the body and therefore promote disease conditions and aging. Chelating agents are also known as secondary antioxidants as they inhibit the generation of metal ions that catalyse per oxidation. The metal chelating activity of whole flour, refined flour and bran varied significantly ($p \leq 0.05$) among different grains and ranged from 17.3-57.5% in whole flour, 10.4-31.4% in refined flour and 31.6 to 78.3% in bran (Figure IV). The chelating activities were highest for barley and least for the rice. As the ferrous ions form a complex with ferrozine, therefore the intensity of the purple colour of the complex decreases in the presence of chelating agents [36].

[IV] CORRELATION

Effective correlations were observed between different antioxidant properties, foaming stabilities and fibre content of bran, whole and refined flours fractions different cereals under study. AOA of whole flour was positively correlated with AOA of refined flour, TPC of bran, reducing power of bran and metal chelating of whole and refined flour ($r = 0.968$ ($p \leq 0.01$), 0.910, 0.905, 0.956, 0.922 and 0.905 respectively, $p \leq 0.05$). A positive correlation was also found between AOA of refined flour, TPC of whole flour and bran, RP of bran and metal chelating of bran, refined and whole flour ($r = 0.972$, $p \leq 0.01$, 0.956, 0.933, 0.924 ($p \leq 0.05$), 0.982 and 0.961 ($p \leq 0.01$) respectively). TPC of whole flour exhibited a positive correlation with TPC of bran, reducing power of bran, fibre content and metal chelating of bran, whole and refined flour ($r =$ 0.919, 0.917, 0.914, 0.921, 0.922 ($p \leq 0.05$) and 0.978 ($p \leq 0.01$) respectively). TPC of refined flour also showed a positive correlation with reducing power of whole and refined flour ($r =$ 0.902 and 0.942, ($p \leq 0.05$). TPC of bran was positively correlated with reducing power of whole flour and bran, metal chelating of refined and whole flour and bran ($p \leq 0.952$, 0.913, 0.946 ($p \leq 0.05$), 0.998 and 0.983 ($p \leq 0.01$). Reducing power of whole flour exhibited a positive correlation with reducing power of bran, metal chelating of whole flour and bran ($r = 0.924$, 0.957 ($p \leq 0.05$) and 0.990 ($p \leq 0.01$) respectively). Reducing power of bran also showed appositive correlation with metal chelating of whole flour and bran ($r = 0.935$ and 0.927 ($p \leq 0.05$) respectively. Metal chelating of whole flour showed a positive correlation with metal chelating of refined flour and bran ($r = 0.941$ and 0.984, ($p \leq 0.05$, $p \leq 0.01$ respectively). Metal chelating of refined flour exhibited a positive correlation with metal chelating of bran and fibre content ($r =$ 0.918 and 0.909, ($p \leq 0.05$) respectively. Foaming stability after 10 min showed a positive correlation ($p \leq 0.05$) with foaming stability after 20 min ($r = 0.888$). A positive correlation was found between foaming stability after 20 and 40 min ($r = 0.990$ and 0.972, $p \leq 0.01$ respectively). Foaming stability after 40 min was positively correlated ($p \leq 0.01$) with foaming stability after 60 min ($r = 0.993$).

[V] **CONCLUSION**

It may be concluded that the cereals are good sources of antioxidants and minerals. The different cereal grains showed significant variations in their proximate composition, physicochemical, functional and antioxidant properties. Wheat flour had the highest L* values which showed that it was lighter in colour as compared to other flours and oat flour showed significantly ($p \leq 0.05$) highest values of a*, b* and ΔE. The oats had highest levels of minerals such as Cu, Mn, Na and K and second highest in Zn and Fe after barley. Wheat flour exhibited high foaming capacity which contributes to its acceptability in foods such as cakes and other bakery products where foaming properties are important. The barley flour had high OAC which makes it suitable for enhancement in flavour and mouth feel when use in food preparations. The antioxidants are mostly concentrated in the bran fraction as compared to the other milled fractions. The barley flour showed highest level of antioxidant properties followed by maize, oats, wheat and rice respectively. The differences in functional properties among cereal flours can be attributed to the relation of protein, starch and other constituents in their flours. The rice flour showed the highest setback viscosity which showed its highest ability to retrograde and wheat flour paste was stable on cooling which showed its lowest setback viscosity. The various significant correlations were observed among different antioxidant properties.

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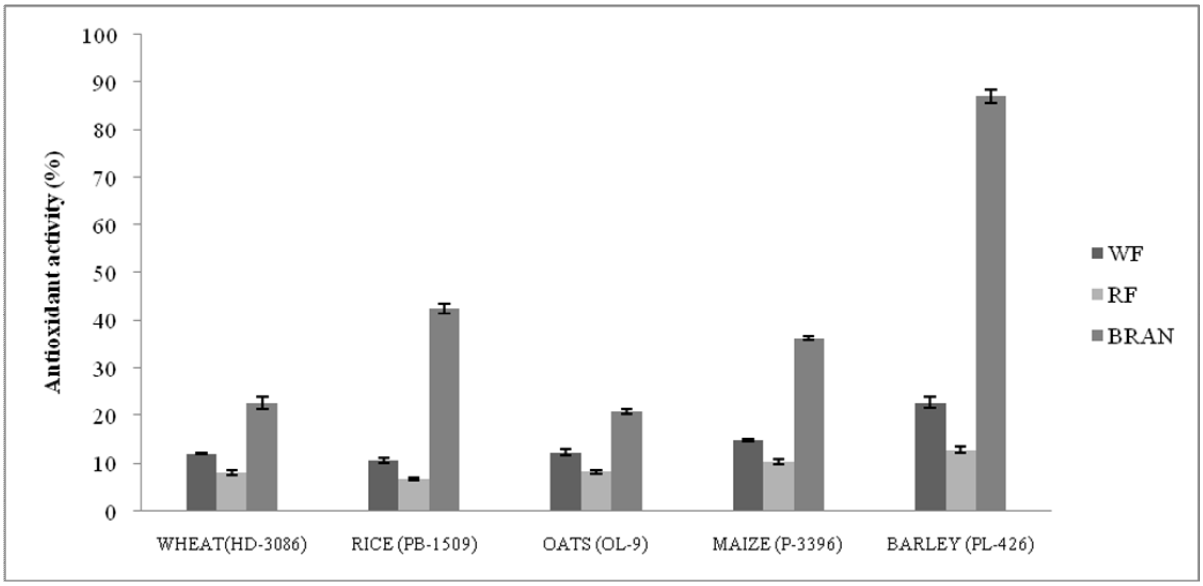

Figure 1. Antioxidant activity of fractions from different cereal grains

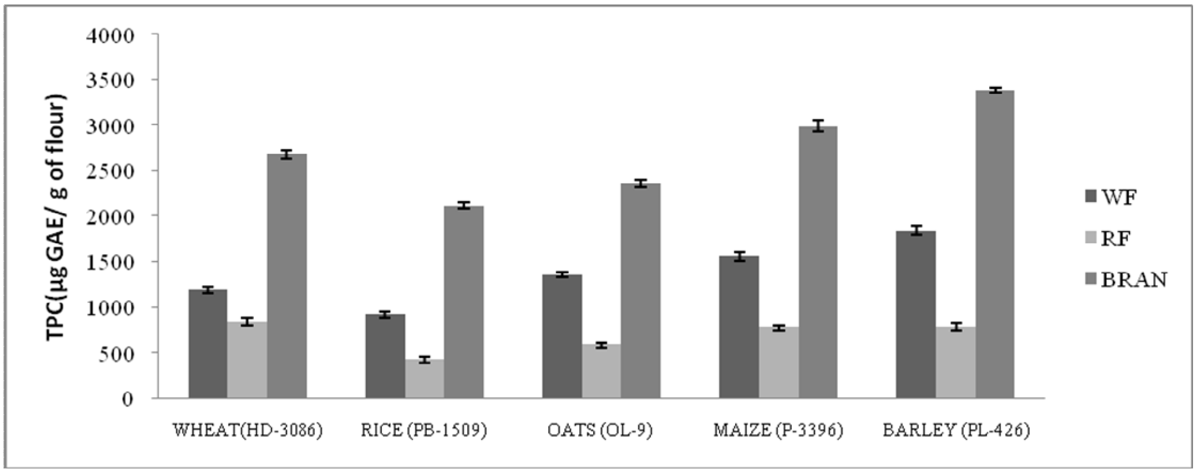

Figure 2. Total phenolic content of fractions from different cereal grains

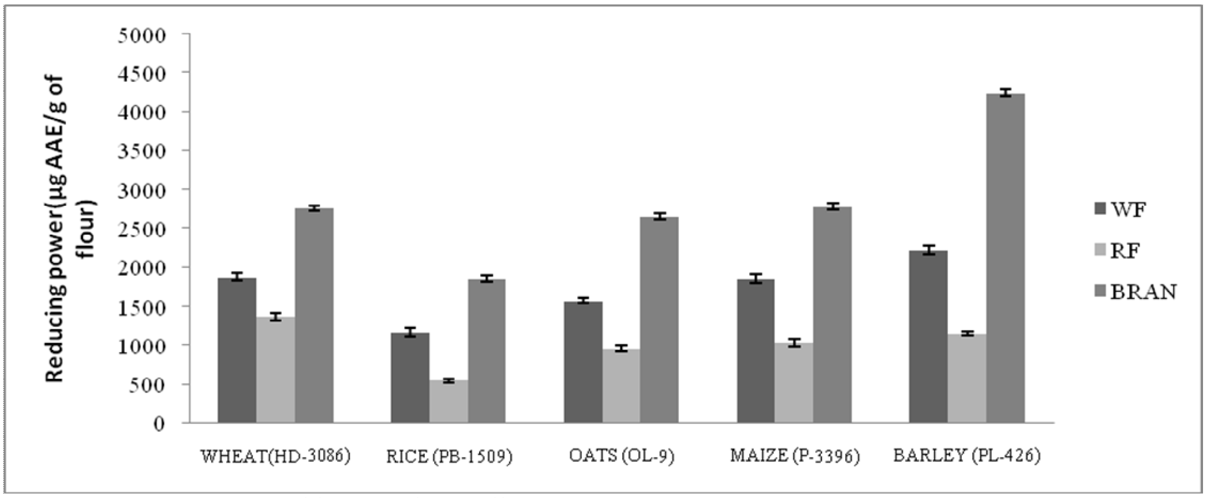

Figure 3. Reducing power of fractions from different cereal grains

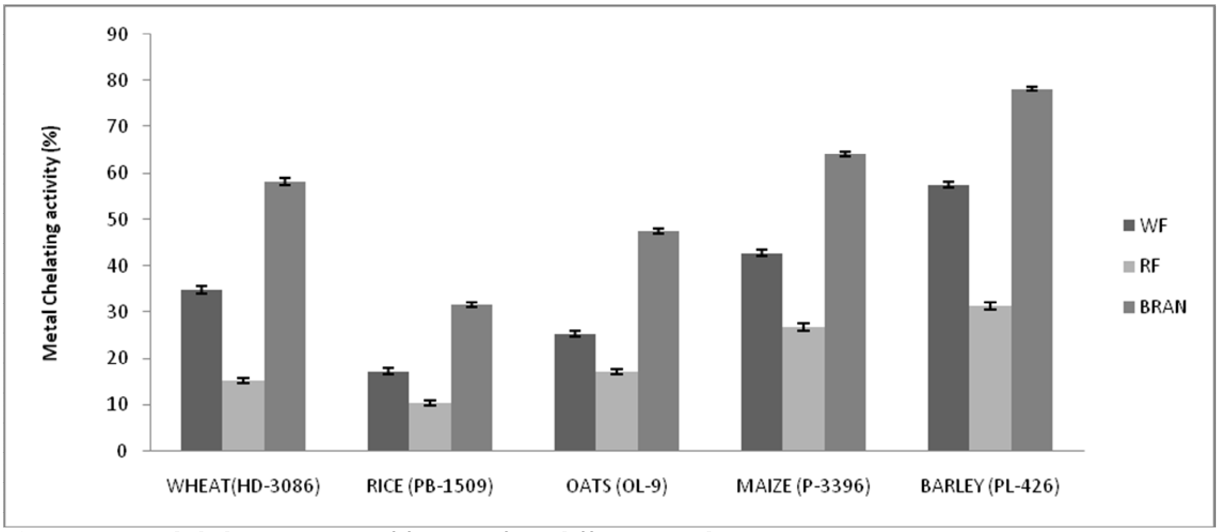

Figure 4. Metal chelating activity of fractions from different cereal grains

TableI: Proximate composition and color values of flours from different cereals

Parameter	Wheat (HD-3086)	Rice (PB-1509)	Maize(P-3396)	Oats (OL-9)	Barley (PL-426)
Moisture (%)	10.7 ± 0.09^{b}	12.4 ± 0.19^{a}	10.8 ± 0.60^{b}	9.93 ± 0.43^{b}	12.5 ± 0.27^{a}
Fat (%)	1.7 ± 0.10^{d}	2.37 ± 0.16^{cd}	3.68 ± 0.41^{b}	5.16 ± 0.25^{a}	2.44 ± 0.24^{c}
Protein(%)	13.7 ± 0.36^{a}	9.3 ± 0.27^{d}	10.7 ± 0.50^{c}	13.7 ± 0.32^{a}	11.9 ± 0.43^{b}
Ash (%)	1.32 ± 0.12^{b}	1.0 ± 0.03^{b}	1.16 ± 0.25^{b}	2.02 ± 0.14^{a}	1.37 ± 0.13^{b}
Fibre (%)	1.08 ± 0.17^{c}	0.75 ± 0.13^{c}	2.46 ± 0.25^{b}	3.31 ± 0.25^{a}	3.17 ± 0.09^{a}
L*	90.7 ± 0.32^{a}	86.7 ± 0.11^{c}	76.0 ± 0.7^{d}	89.0 ± 0.05^{b}	86.2 ± 0.14^{c}
a*	1.05 ± 0.07^{c}	0.98 ± 0.01^{d}	1.56 ± 0.05^{b}	6.44 ± 0.08^{a}	1.11 ± 0.01^{c}
b*	8.51 ± 0.23^{d}	9.27 ± 0.08^{c}	10.2 ± 0.06^{b}	27.3 ± 0.15^{a}	8.67 ± 0.06^{d}
ΔE	91.1 ± 0.30^{b}	87.2 ± 0.09^{c}	76.9 ± 0.04^{e}	93.4 ± 0.02^{a}	86.6 ± 0.08^{d}

Mean ± SD with different superscripts in a row differ significantly ($p < 0.05$; n = 3).

Minerals	Wheat (HD-3086)	Rice (PB-1509)	Oats (OL-9)	Maize (P-3396)	Barley (PL-426)
Cu	4.3	6.2	9.2	2.2	7.2
Zn	29.1	28.2	33.1	17.3	34.7
Mn	12.6	12.05	27.7	7.1	13.9
Na	39	27.3	42	31.9	22.9
Mg	992	1172	1667	1377	1706
K	1128	1188	2556	1109	2178
Fe	128	201	203	99	227

Table II: Mineral composition (mg/kg) of flours different cereals

Cultivar	WAC (g/g)	WSI (%)	OAC (g/g)	Emusion activity(%)	Emulsion stability (%)	LGC (%)	Foaming capacity (%)	Foaming stability			
								10min	20min	40min	60min
Wheat (HD-3086)	1.22 ± 0.04^{bc}	6.44 ± 0.24^{b}	2.23 ± 0.04^{ab}	48.1 ± 0.35^{b}	45.6 ± 0.2^{c}	**10**	50.6 ± 0.3^{a}	93.9 ± 0.3^{d}	88.0 ± 0.3^{d}	78.4 ± 0.3^{d}	72.0 ± 0.7^{d}
Rice (PB-1509)	1.36 ± 0.05^{b}	7.36 ± 0.13^{a}	1.82 ± 0.04^{ab}	49.2 ± 0.4^{ab}	50.1 ± 0.4^{a}	**12**	16.5 ± 0.2^{c}	94.9 ± 0.3^{c}	94.2 ± 0.4^{c}	91.5 ± 0.4^{c}	90.8 ± 0.1^{c}
Oats (OL-9)	1.07 ± 0.07^{d}	3.3 ± 0.47^{d}	2.18 ± 0.02^{ab}	47.9 ± 0.49^{b}	49.9 ± 0.4^{ab}	**8**	21.4 ± 0.2^{b}	99.1 ± 0.3^{ab}	97.5 ± 0.4^{ab}	95.4 ± 0.2^{b}	93.0 ± 0.4^{b}
Maize (P-3396)	1.47 ± 0.05^{a}	4.9 ± 0.21^{c}	1.7 ± 0.05^{b}	45.9 ± 0.36^{c}	48.8 ± 0.3^{b}	**16**	10.1 ± 0.2^{e}	99.4 ± 0.2^{a}	98.1 ± 0.3^{a}	96.5 ± 0.3^{a}	94.5 ± 0.3^{a}
Barley (PL-426)	1.27 ± 0.00^{bc}	5.13 ± 0.08^{c}	2.56 ± 0.02^{a}	49.4 ± 0.45^{a}	49.4 ± 0.5^{ab}	**8**	11.8 ± 0.7^{d}	98.1 ± 0.4^{b}	95.9 ± 0.8^{b}	95.5 ± 0.2^{b}	93.5 ± 0.3^{ab}

Mean ± SD with different superscripts in a row differ significantly ($p < 0.05$; n = 3).

Table III: Functional properties of flours from different cereals

Cultivar	Pasting temperature (ºC)	Peak viscosity (cP)	Holding viscosity (cP)	Breakdown viscosity (cP)	Final viscosity (cP)	Setback viscosity (cP)
Wheat (HD-3086)	90.6±0.11^{c}	1739±12.7^{c}	1082±11.6^{d}	657±8.62^{b}	2101±13.53^{c}	1019±9.1^{c}
Rice (PB-1509)	92.3±0.2^{b}	1880±8.02^{b}	1422±10.6^{b}	458±6.03^{c}	3257±12.5^{a}	1835±14.5^{a}
Oats (OL-9)	94.9±0.2^{a}	1043±8.19^{e}	1254±13.53^{c}	211±6.0^{e}	3091±16.04^{b}	1837±15.5^{a}
Maize (P-3396)	88.4±0.2^{d}	1423±8.19^{d}	1016±13.75^{e}	407±9.17^{d}	2003±13.58^{d}	987±13.05^{d}
Barley (PL-426)	89.3±0.84^{d}	2752±9.9^{a}	1661±9.9^{a}	1091±9.19^{a}	3061±16.3^{b}	1400±12.73^{b}

Mean ± SD with different superscripts in a row differ significantly ($p < 0.05$; $n = 3$).

Table IV: Pasting properties of flours from different cereals