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EFFECT OF PEARLING ON PHYSICO-CHEMICAL, RHEOLOGICAL CHARACTERISTICS AND PHYTATE CONTENT OF WHEAT-SORGHUM FLOUR

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Abstract

The objective of this study was to evaluate the effect of pearling of grains on physico-chemical and rheological characteristics as well as phytate contents of wheat-sorghum flour. Wheat and sorghum grains were milled into flour after pearling. The amount of chemical constituents such as protein, fiber, fat, ash, phytate, Mn, Cu, Ca, Mg, Fe and Zn decreased where as nitrogen free extract in wheat and sorghum flours increased as a result of pearling of grains. Wheat flour was substituted with 15% and 30% whole and pearled sorghum grain flours which significantly affected the farinographic and amylographic characteristics of composite flours. Substitution of wheat flour with sorghum flour decreased the water absorption and dough viscosity. Composite flour containing 15% pearled sorghum and 85% pearled wheat flours showed maximum improvement in dough development time, dough stability, tolerance index and softening of dough**.** Phytic acid was also drastically affected by heat treatment during preparation of chapattis.

Introduction

Wheat is the cheapest source of protein and calories for the inhabitants of Pakistan. More than 80% of total wheat production (19.2 million tones) is milled into wholemeal flour and consumed in the form of chapatti/roti (Anon., 2003). In its refined state, its average consumption can supply 30% energy and 49% protein requirements of an individual (Anon, 1990). The chapattis should be made as much nutritionally complete as possible that can meet the dietary requirements of the people of this region. A substantial amount of minerals and vitamins exists in the outer layers of cereal grains. Studies on the trace element composition of wheat flours of different extraction rates have shown that a major proportion of the phosphorus, magnesium, chromium, zinc and manganese are located in the bran of the wheat kernel (Torre *et al.*, 1991). De-hulling improves minerals availability because the hull is rich in phytate. This compound binds iron and certain other minerals and makes them biologically unavailable (Das *et al*., 2006).

Sorghum is a crop that is widely grown all over the world for food and feed. It is a key staple in many parts of the developing world, particularly in the drier and more marginal areas of the semi-tropics (Duodu *et al*., 2003). In Africa, India and China, sorghum comes third among cereals for human consumption after rice and wheat (El Khalifa & El Tinay, 2002).

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Table 1. Preparation of composite flours.

Treatment	Whole wheat flour %	Whole sorghum flour %	Pearled wheat flour %	Pearled sorghum flour %
T_1	85	15	0	0
T_2	70	30	-	-
T_3	85	0	-	15
T_4	70	-	-	30
T_5	0	15	85	0
T_6	-	30	70	-
T_7	-	0	85	15
T_8	-	-	70	30

Various processing methods are used to increase the bioavailability of minerals of cereal grains. In milled products, the bioavailability of minerals of pearled sorghum is considered better than the corresponding un-milled grains which are attributed to the removal of interfering substances such as phytate, tannin and fiber. The bioavailability of iron and zinc is found to improve significantly by milling pearled wheat into refined flour. Similarly in the sorghum, the ionizable iron fraction increases from 18.6 to 28.7% indicating a 40% rise in the availability of iron (Sankara Rao & Deosthale, 1980). The pearling of grains to remove the fibrous seed coat can result in considerable reduction in the mineral contents of sorghum. However, the studies also showed that *in vitro* availability of iron as judged by the ionizable iron, as percentage of total iron is higher in pearled grains (Gilloly *et al.*, 1984). The composite flour technology plays a vital role to complement the deficiency of wheat grain and its essential nutrients.

Keeping in view the above facts, this project was designed to determine the effect of pearling of grains on physico-chemical and rheological characteristics and phytate content of wheat-sorghum flour.

Materials and Methods

Grains of wheat (*Triticum aestivum* L.) variety Inqulab 91 and sorghum (*Sorghum vulgare* L.) were procured from Ayub Agriculture Research Institute, Faisalabad. The grains of wheat and sorghum were pearled by barley pearler. The flours were prepared with small china grinder equipped with 1 mm mesh sieve. Composite flours were prepared by blending different proportions of wheat and sorghum flours (Table 1).

Wheat, sorghum and composite flours were analyzed for moisture, crude fat, crude fiber, crude protein, ash and nitrogen free extract (NFE) according to the methods described in Anon., (2000). The minerals such as Fe, Zn, Cu, Mn, Ca and Mg of samples were estimated by using Atomic Absorption Spectrophotometer (Model Hitachi Z-8200) as described by Lorenz *et al*., (1977). Phytic acid was determined according to the method as described by Wolfgang & Lantsch (1983). The rheological studies were carried out with farinograph and amylograph (Anon., 2000). Chapatti was prepared according to the method as described by Rehman *et al*., (1996). The data were subjected to statistical analysis using analysis of variance (ANOVA), with Minitab (v. 11.1, Minitab Inc, PA 16801-3008, USA). Significant differences between means were determined by Duncan’s multiple range test (Steel *et al*., 1997).

Table 2. Proximate composition of whole wheat, pearled wheat, whole sorghum and pearled sorghum flours (dry basis*).

Parameter	Whole wheat flour	Pearled wheat flour	Whole sorghum flour	Pearled sorghum flour
Moisture (%)	9.07a	9.21a	8.34b	8.51b
Protein (%)*	12.03a	10.68b	10.34b	9.02b
Fat (%)*	2.00c	1.70c	3.50a	2.70b
Fiber %)*	2.11c	1.20d	3.90a	2.30b
Ash (%)*	1.97b	1.61c	2.21a	1.96b
NFE (%)*	81.89c	84.81a	80.05d	84.02b

Values followed by different letters in the same row are significant ($p< 0.05$)

Table 3. Mineral contents of whole wheat, pearled wheat, whole sorghum and pearled sorghum flours.

Mineral	Whole wheat flour mg kg^{-1}	Pearled wheat flour (mg kg^{-1})	Whole sorghum flour (mg kg^{-1})	Pearled sorghum flour (mg kg^{-1})
Fe	41.1d	42.1c	53.1a	49.2b
Zn	42.3d	44.1c	54.1a	53.2b
Mn	32.4a	30.51b	22.1c	21.7d
Cu	6.9a	6.2c	7.5b	6.1c
Ca	470.1a	420.0b	260.2c	210.5d
Mg	1589.7a	1461.1b	1482.3c	1333.7d

Values followed by different letters in the same row are significant ($p< 0.05$)

Results

The results of physico-chemical analyses delineated that whole wheat flour contained higher contents of moisture, crude protein and NFE and lower contents of crude fat, crude fiber and ash as compared to sorghum flour (Table 2). The moisture, crude protein, crude fat, crude fiber, ash and NFE contents of whole wheat, pearled wheat, whole sorghum and pearled sorghum flours ranged from 8.34 to 9.21%, 9.02 to12.03 %, 1.70 to 3.50%, 1.20 to 3.90%, 1.61 to 2.21% and 80.05 to 84.81%, respectively. The highest concentrations of chemical constituents were present in whole grains except moisture and NFE.

The Fe and Zn contents ranged from 41.1 to 42.1; 49.2 to 53.1 and 42.3 to 44.1; 53.2 to 54.1 mg kg^{-1} in wheat and sorghum flours, respectively (Table 3). The results of mineral contents of wheat-sorghum composite flours are shown in Table 4. The wheat flour contained 41.12 and 42.30 mg kg^{-1} Fe and Zn which increased to 46.07 and 46.59 mg kg^{-1} as a result of substitution of whole wheat (85%) with whole sorghum (15%) flours while Mn, Cu, Ca and Mg decreased from 32.39 to 31.02, 6.91 to 6.51, 470.1 to 416.0 and 1589.7 to 1427.1 mg kg^{-1}, respectively. The composite flour (T_1) containing 70% whole wheat and sorghum grains (30%) contained highest quantities of Fe (46.07 mg kg^{-1}) and Zn (46.59 mg kg^{-1}). The highest amounts of Mn (31.02 mg kg^{-1}), Cu (6.85 mg kg^{-1}), Ca (450.1 mg kg^{-1}) and Mg (1427.1 mg kg^{-1}) were present in T_1, T_2, T_3 and T_1 followed by T_3, T_4, T_2 and T_3, respectively. Almost similar trends were observed in the chapattis because baking has no effect on mineral content (Table 5). The results of phytic acid of composite flours and chapattis are shown in Table 6. The highest amounts of phytic acid were observed in the composite flour and chapattis containing whole wheat and sorghum flours whereas the lowest amounts were found in case of composite flour and chapatti containing 70% pearled wheat and 30% pearled sorghum flours. It indicates that pearling has marked effect in reducing phytate content of flour.

Table 4. Mineral contents of wheat-sorghum composite flours (mg kg^{-1}).

Treatment	Fe	Zn	Mn	Cu	Ca	Mg
T_0	41.12c	42.30f	32.39a	6.91a	470.1a	1589.7a
T_1	46.07a	46.59a	31.02b	6.51c	416.0c	1427.1b
T_2	43.30bc	45.16bc	29.55bcd	6.85a	442.5b	1264.3cd
T_3	44.10b	45.48 b	30.85b	6.85a	450.1b	1402.2bc
T_4	42.87bc	44.43d	29.31bcd	6.70b	401.7cd	1216.9cd
T_5	44.30b	46.29a	28.27d	6.30cd	397.2cd	1320.02c
T_6	43.20bc	44.72c	28.27d	6.35cd	373.6d	1164.7d
T_7	44.10b	45.48b	29.15cd	6.26d	389.5cd	1296.08cd
T_8	42.68bc	43.80e	28.09d	6.19d	359.4e	1117.4e

Values followed by different letters in the same column are significant ($p < 0.05$)

T_0: Whole wheat flour
T_1: Whole wheat flour 85% + Whole sorghum flour 15%
T_2: Whole wheat flour 70% + Whole sorghum flour 30%
T_3: Whole wheat flour 85% + Pearled sorghum flour 15%
T_4: Whole wheat flour 70% + Pearled sorghum flour 30%
T_5: Pearled wheat flour 85% + Whole sorghum flour 15%
T_6: Pearled wheat flour 70% + Whole sorghum flour 30%
T_7: Pearled wheat flour 85% + Pearled sorghum flour 15%
T_8: Pearled wheat flour 70% + Pearled sorghum flour 30%

Table 5. Mineral contents of wheat-sorghum composite flours chapattis (mg kg^{-1}).

Treatment	Fe	Zn	Mn	Cu	Ca	Mg
T_0	41.39d	42.56e	32.7a	7.27a	470.3a	1590.01a
T_1	46.91a	46.94a	31.26b	6.98c	450.3b	1427.3b
T_2	43.61bc	45.39bc	29.78c	7.19ab	416.3c	1264.5cd
T_3	44.39b	46.06b	31.10b	7.11bc	442.9b	1402.5b
T_4	43.19bc	44.63c	29.61cd	7.10bc	402.0cd	1217.1cd
T_5	44.57b	46.66a	29.58cd	6.54de	397.5cd	1321.02c
T_6	43.42bc	44.91c	28.47de	6.57d	373.9e	1164.1d
T_7	44.51b	45.79b	29.41cde	6.48de	390.0cd	1296.2cd
T_8	42.98bc	44.08d	28.25e	6.41e	359.8 d	1117.6e

Values followed by different letters in the same row are significant ($p < 0.05$)

Table 6. Phytic acid of wheat-sorghum composite flours and their chapattis (%).

Treatment	T_0	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8
Composite flour	1.31a	1.30a	1.29a	1.24b	1.16c	0.97e	1.04d	0.90f	0.88f
Chapattis	1.02a	1.00a	1.00a	0.95b	0.87c	0.77d	0.80d	0.68e	0.64e

Values followed by different letters in the same row are significant ($p < 0.05$)

The results pertaining to farinographic and amylographic characteristics of composite flours are shown in Table 7. The water absorptions, dough development times, dough stabilities, tolerance indices, softening of dough and viscosities of wheat-sorghum flours ranged between 62-66.8%, 3.8-13 min., 20-70 BU, 65-100 BU and 400-515 BU, respectively. These characteristics were affected significantly as result of pearling of grains. Wholemeal flour contained the highest amount of water absorbing capacity which decreased as result of adding sorghum flour into wholemeal flour at different levels. The arrival times, departure times, dough development times and dough stabilities of composite flours containing whole sorghum flour declined while pearling had exerted favourable effect on these characteristics. Higher are the values of tolerance index and softening of dough, weak will be the chapatti making qualities of flour. These characteristics were favourably affected as a result of pearling of grains.

Table 7. Farinographic and amylographic characteristics of wheat-sorghum composite flours.

Treatment	Water absorption (%)	Dough development time (min)	Dough stability (min)	Tolerance index (B.U.)	Softening of dough (B.U.)	Viscosity (B.U.)
T_0	68.2a	5.8c	12.2b	50c	65f	585a
T_1	66.8b	3.0fg	3.8e	70a	90b	500b
T_2	66.2b	4.0e	4.0f	65a	90b	430d
T_3	62.0c	5.3d	7.2d	40d	85c	500b
T_4	65.0d	3.5f	4.5e	60ab	90b	400e
T_5	66.4b	6.2b	8.5c	35e	80d	470c
T_6	63.0e	3.5f	4.2ef	65a	100a	450c
T_7	65.0d	7.0a	13.0a	20f	70e	515b
T_8	66.0c	3.3f	4.8e	60ab	90b	460c

Values followed by different letters in the same column are significant ($p < 0.05$)

Discussion

Pearling has a significant effect on the chemical constituents of wheat and sorghum flours. As expected, whole grain cereal meals contained higher contents of crude fiber, fat, protein and total ash or minerals as compared to pearled wheat and sorghum flours. However, moisture and NFE contents were found to be higher in pearled grains due to the removal of outer layer of kernel during pearling. The results of proximate analysis of flours are in line with the work of Grewal *et al*. (2000) who reported that protein, fat and fiber contents of pearled wheat flour were lower than whole wheat flour. Several publications on nutrient composition in sorghum and wheat are in consistant with the present study (Lovis, 2003; Ragaee *et al*., 2005). The composition of the pearled grain shows a progressive change according to the amount of material abraded from the kernel and indicates a concentration of fiber and protein in the outer layers, in the aleurone and peripheral endosperm

In general, whole grains contained higher levels of minerals compared to pearled grains. The wheat grains contained high amount of Cu, Mn, Ca and Mg as compared to sorghum grains. However, sorghum grains contained higher quantities of Fe and Zn than wheat grains. The Fe, Zn, Cu, Mn, Ca, Mg contents were significantly ($p<0.05$) decreased as a result of pearling of wheat and sorghum grains. This decrease was observed due to the removal of outer layer of the grains because bran contains major portion of the minerals. These results are in agreement with the findings of previous studies (Ragaee *et al*., 2005) which showed that wheat contains 32 to 43 mg kg^{-1} Zn. The variation in mineral content might be due to variety, class, soil, growing conditions and processing methods during milling of grains. Similar observations were also observed in the total zinc content of whole pulses, decorticated split pulses (Beal & Mehta, 1985) and most of the cereal grains (Goplan *et al.*, 1989: Sankara Rao & Deosthale, 1981).

When these flours were mixed as composite flours, the highest contents of Fe and Zn were found in flour sample containing 85:15 ratio of whole wheat and sorghum flours, respectively. Whereas, the lowest contents of Fe and Zn were found in pearled wheat and sorghum flours in a 70:30 ratio, respectively. However, wheat flour contained lower quantities of these minerals as compared to composite flours. Similar trend was observed in chapattis prepared from these flours. The results of mineral contents in both the flours and the chapattis are already confirmed and reinforced by the identical work of Sankara Rao & Deosthale (1980).

The use of plant proteins is an attractive substitute for more expensive animal proteins in human diet. A major obstacle in using plant protein sources is their high phytic acid content which is mostly present in bran of cereals and pulses grains. Phytic acid is an unavailable phosphorus source for monogastric animals because they lack phytase, which hydrolyzes unavailable bound phosphorus to orthophosphorus. It chelates other divalent and trivalent cations such as Fe, Zn, Mg, Cu and Ca, resulting in decreased bioavailability of these minerals (Towo *et al*., 2006). A significant difference was observed in the phytate contents of composite flours. The phytic acid contents decreased significantly ($p<0.05$) in pearled grain flours. The highest value of phytic acid was observed in composite flour containing 70% whole wheat and 30% whole sorghum flours whereas, the lowest value of phytic acid was observed in composite flour containing 70% pearled wheat and 30% sorghum flours. The results obtained for phytic acid contents in this study are similar to the reports of Grewal *et al*., (2000) and Gilloly *et al*., (1984) who observed that pearling reduced the phytic acid to a considerable extent. These results also delineated that baking also reduced the phytic acid contents in chapattis to a considerable extent from 20 to 27% (Beal & Mehta, 1985; Hinnai *et al*., 2000). A significant decrease in phytic content has been demonstrated by Kashlan *et al*., (1990) and Aisha *et al*., (2004). Hydrolysis of the phytic acid (13-25%) is reported in extrusion cooking (Le Francois, 1988; Daniels & Fisher, 1981). The lost in phytate was less in leavened wholemeal bread as compared to leavened breads (Mckenzie-Parnell & Davis, 1986). The reduction of phytic acid in chapatti was 25-30% while in bread it was 87% (Windle *et al.*, 1976). The cumulative loss of phytic phosphorus after fermentation, proofing and baking has been reported to approximately 16, 19 and 22%, respectively (Tangkonchitr *et al*., 1982). Almost a complete destruction of phytic acid in wheat soaking has been found by Sandberg & Svanberg (1991). From dough mixing to baking, the content of phytic acid has also been reduced to 20% and 33% for wheat and rye, respectively (Fretzdorff & Brummer, 1992). Reduction of the phytic acid from 38 to 60% has also been observed in chapatti prepared from flours of different wheat varieties (Wahab *et al*., 2004; Akhtar *et al.*, 2005).

The results clearly indicated that contrary to other constituents, interchange of gluten proteins between sorghum and wheat flours had distinct effect on various farinographic characteristics, when compared to those of wheat flour. Wheat flour exhibited strong dough characteristics (high water absorption, dough development and dough stability) which decreased as a result of substitution of sorghum flour. However, pearling has enhanced the protein quality which strengthens farinographic characteristics of composite flour. Generally, tolerance indices of composite flours extracted from whole grains are higher than that of pearled grains flours because the substitution of whole grain flours of both the cereals weakened the mixing properties. As the whole grains flours contain larger amounts of bran and dietary fiber, these materials can be considered to disturb the continuous gluten network structure in the dough and this tendency coincides with previous studies (Gan *et al*., 1992; Maeda & Morita, 2001). The results indicated that more than 15% of sorghum supplementation negatively affected the rheological properties of dough and dough viscosity decreased when wheat flour was replaced to the extent of 30% with sorghum flour in wheat-sorghum dough. The composite flour containing 15% sorghum flour showed maximum water absorption capacity. The water absorption capacities and dough stabilities of the composite flours decreased significantly with an increase in the level of sorghum flour (Carson & Sun, 2000). However, pearling did not affect the water absorption to a greater extent. The composite flour containing 15% pearled sorghum flour and 85% pearled wheat flour (T_7) showed maximum improvement in dough development time, dough stability, tolerance index and softening of dough followed by the values of composite flour containing 85% pearled wheat and 15% pearled sorghum flours (T_5). The increase in dough development time and dough stability and decrease in tolerance index and softening of dough may be due to the differences in the physico-chemical properties of pearled grains. Dough development and dough stability times (min.) as the major indices for dough strength indicated that addition of sorghum at higher level reduced the dough development and stability periods as compared to wheat flour. Yue *et al.,* (1991) found that the higher level of substitution of sunflower protein concentrate and isolate may have been responsible for decreasing the dough stability time. This observed weakening of dough, resulting from the addition of sorghum, could be due to decrease in wheat gluten content (dilution effect) and competition between proteins of sorghum and wheat flour for water (Deshpande *et al.,* 1983; Rao & Rao, 1997). However, Fleming & Sosulski (1978) ascribed the weakening of dough with supplemented proteins to the well-defined protein starch complex in wheat flour bread.

Although, pearling; the removal of fibrous seed coat resulted in considerable reduction in protein, fat, fiber, minerals and phytate contents of wheat and sorghum grains but a considerable increase in iron and zinc contents and decrease in phytate indicated the improvement in the bioavailability of minerals in pearled sorghum and wheat composite flours. The composite flour containing 15% pearled sorghum flour and 85% pearled wheat flour (T_7) showed maximum improvement in dough development time, dough stability, tolerance index and softening of dough. Substitution of wheat flour with pearled sorghum flour to a level of 30% significantly weakened the dough mixed in a farinograph. Baking of chapattis also improved the availability of minerals and reduced the phytate in the chapattis. Higher level of substitution of wheat flour with sorghum may affect the chapatti making quality because sorghum is deficient in gluten forming protein which imparts elastic and cohesive properties to wheat flour dough.

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