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A Comparison of Physico-Chemical Properties, Total Phenolic Content and Antioxidant Activity of Whole Grain Flours

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Abstract :
Whole grains are a source of several functional ingredients and their consumption is essential for a healthy lifestyle. Some food grains still remain underutilized despite their rich nutritional profile. Whole flours of QPM (quality protein maize; commercially available mixture) and selected locally developed varieties of oat (OL 9) and soybean (SL 525) were studied for their proximate composition, crude fibre and dietary fibre composition and compared with whole wheat (PBW 621) flour. Soyflour had significantly ($p \leq 0.05$) higher protein, fat and ash contents than other grains. Amongst cereals, oats and QPM were found to have significantly ($p \leq 0.05$) higher fat and crude fibre than whole wheat flour. In terms of dietary fibre composition, NDF (neutral detergent fibre) was significantly higher in whole wheat than oats and QPM. Study revealed that soyflour had highest total phenolic contents and anti-oxidant activity (DPPH inhibition) among the crops studied. Anti-oxidant activity for QPM flour was significantly higher ($p \leq 0.05$) than whole wheat flour. This signified their superior nutritional quality and suitability for functional food use.

***Keywords**: Whole grains, oats, quality protein maize, dietary fibre, anti-oxidant activity*

1. Introduction

Whole grains have been a part of human diet for the past 3000-4000 years (Slavin, 2004). However, in last 100 years, refined grain products have gained greater popularity. More recently, interest in whole grains has grown due to the health benefits that these are associated with. Whole grain consumption prevents several diseases such as cancers, diabetes and cardiovascular diseases (Fardet *et al*., 2008). This is because whole grains are known to possess several functional ingredients such as dietary fibre, phenolic constituents, resistant starch, inulin, unsaturated fatty acids and so on. Most of the phytochemicals have good antioxidant potential. Dietary antioxidants reduce free radical activity in the body and reduce disease occurrence. Dietary antioxidants of whole grains are mostly located in the outer and the bran fractions of grains (Čukelj *et al.*, 2010). Besides, these are rich in minerals and vitamins that are essential for healthy well being. Daily diet, in a healthy lifestyle, should thus include a large proportion of wholegrain products.

Whole grains include endosperm, bran and germ portion, which normally gets separated during refining. Wheat is the most commonly consumed whole grain in this Indian context. However, it contains gluten and may lead to several allergies. Moreover, excessive dependence on wheat is making our soils deficient in essential nutrients. Hence, it becomes important to study other grains for their food use potential. These include oats, maize, millets, barley and legumes such as soybean. These grains may be considered as highly underutilized as they have not been used as much for food as they should be. They contain several phytochemicals that are considered essential for human well being and may be classified as functional foods.

Although, oats have been cultivated in India mainly for fodder purposes (ICAR, 2006), they possess major potential as functional ingredient in food products. They are rich in phytochemicals such as β-glucan (Gambuś *et al*., 2011). Quality Protein Maize (QPM), developed through conventional maize breeding methods, has about 10 percent protein like any Normal Maize (NM) variety. However, its protein has about 70 percent higher levels of the essential amino acids - lysine and tryptophan (Giwa & Ikujenlola, 2009). Soybean is a leguminous crop, high in protein content and contains several physiologically functional components such as isoflavones, phytosterols and unsaturated fatty acids (Sugano, 2006).

The objective of this study was to determine the physico-chemical properties of one indigenously developed variety each of whole flours of four different food grains and estimate their phenolic contents and antioxidant activities. This would serve to assess their suitability for functional food use.

2. Materials and Methods

Wheat (PBW 621) kernels, oat (OL-9) grains and soybean (SL 525) grown in the year 2012-13 were procured from Punjab Agricultural University, Ludhiana, India. Quality protein maize (QPM) was obtained from Directorate of Maize Research, Karnal, India. Grains were cleaned to remove dust, straw, stalks, stones etc. Grains were assessed for physical parameters such as thousand grain weight, hectolitre weight and bulk density (AACC, 2000). They were stored at room temperature in plastic bins till further use. Wheat kernels and QPM were ground whole using hammer mill (Milcent Magnum, Anand, India) to 100 mesh size. Bran obtained was again fed to the mill until the entire branny mass was ground. The flour obtained was sealed in low density polyethylene bags and stored (10±2 °C). Oat grains were dehulled using Laboratory Impact Oat dehuller (Creative India, Mohali, Punjab). The mixture of groats and husk was separated in laboratory aspirator. Groats were separated from hulled grains by hand sorting and milled using hammer mill to 100 mesh size. Soybeans were soaked in tap water for 4 h at room temperature (25-30 °C). Beans were wrapped in a white muslin cloth and steamed at 15 PSI (pounds/sq. inch) for 5 min in autoclave (Equitron, Medica Instrument Manufacturing Company, New Delhi). These were then dried in forced air cabinet drier (Narang Scientific Works, New Delhi) at 50±5 °C to 7±0.5 per cent moisture. The dried soybeans, along with their hulls, were ground with their hulls in hammer mill to 100 mesh size and stored in low density polyethylene bags (10±2 °C).

Moisture, crude protein, crude fat, total ash and crude fibre contents of flour samples were determined (AACC, 2000). Carbohydrate content (db) was calculated by subtracting sum of crude protein, crude fat and total ash content from 100 (Merril and Watt, 1973). Fibre composition of flour samples was determined in terms of neutral detergent fibre (NDF), acid detergent fibre (ADF), acid detergent lignin (ADL), hemicellulose, cellulose and lignin using method of Van Soest (1967).

Total phenolic content (TPC) was determined by Folin-Ciocalteu method (Singleton and Rossi 1965; Das et al. 2013). Absorbance was measured at 750 nm using a spectrophotometer (Spectronic 200, Thermo Fisher Scientific, India) using gallic acid as standard. The results were expressed as mg of gallic acid equivalents (GAE) per g of fresh material. The DPPH assay was based on the method of Michalska *et al*. (2007). The percentage of inhibition or the percentage of discolouration was calculated as follows:

Inhibition $\%=A_{blank}-A_{sample}\times 100/A_{blank}$

where A is the absorbance at 517 nm.

All statistical procedures were performed using CPCS 1 software package (Cheema & Singh, 1990). A one-way analysis of variance (ANOVA) was carried out using completely randomized design at $p\leq 0.05$. The results are presented as means±S.D. (standard deviation) of triplicate analyses.

3. Results and Discussion

Test weight values (kg/hl) for whole grains of wheat (PBW 621), oats (OL 9), QPM (quality protein maize) and soybean (SL 525) were 77.80±0.00, 45.53±0.15, 73.77±0.06 and 75.30±0.10, whereas, 1000-grain weight values were 43.72±1.40, 29.14±0.08, 278.53±1.57 and 104.74±3.05, g, respectively. Physical properties are an indicator of grain quality.

Moisture contents of whole flours of all these grains were below 11% (Table 1), giving them good storage stability and low susceptibility to microbial attack. Crude protein varied significantly ($p\leq 0.05$) among wheat, oats, QPM and soybean flours. Soybean had the highest protein content. It is considered as one of the most important source of dietary protein. Soy protein is predominantly composed of storage globulins and is rich in essential amino acids (Liu, 1997). Among cereals, protein was highest in oats. Crude fat ranged from 1.64-19.63% in the grains studied; highest being for soybean. Crude ash content in soybean flour was significantly ($p\leq 0.05$) higher than the other flours. Oat flour was found to have higher fat content than the other cereals. Carbohydrates were the major components in QPM and wheat flours. They are the major source of energy in plants and include starch, fibre and free sugars.

Grain	Moisture	Crude protein (db)	Crude fat (db)	Total ash (db)	Carbohydrates (by difference) (db)
Wheat	7.19±0.19	11.28±0.04	1.64±0.19	1.53±0.08	85.55±0.10
Oat	10.07±0.06	16.07±0.04	6.17±0.03	1.33±0.01	76.43±0.07
QPM*	10.97±0.30	10.00±0.31	3.06±0.22	1.20±0.20	85.75±0.09
Soybean**	5.51±0.32	35.64±0.34	19.63±0.56	4.43±0.41	40.31±0.76
CD (0.05)	0.45	0.43	0.59	0.44	0.73

Table 1: Proximate composition of whole flours
**Quality protein maize, **Full fat soybean*

Crude fibre contents (5.23±0.20 %) were significantly ($p\leq 0.05$) higher in soybean than oats and maize. Hull fraction of soybean may have contributed to higher fibre content. Dietary fiber is classified into soluble fibre and insoluble fibre. Soluble fibre such as β-glucan slows down the digestion of carbohydrate in sugars and starches, resulting in better glucose metabolism. Insoluble dietary fibre binds with water in the intestine and helps remove waste from the body and prevent constipation. Liu (2007) suggested that it may also help prevent hemorrhoids (piles), diverticular disease, polyps and cancer of the colon or large intestine. Fibre was expressed in terms of NDF (neutral detergent fibre), ADF (acid detergent fibre), ADL (acid detergent lignin), hemicellulose, cellulose and lignin. NDF varied from 6.97-16.42%. Wheat had significantly ($p\leq 0.05$) higher NDF, hemicellulose

and lignin contents than the other grains studied. High NDF is associated with high hemicellulose contents (Krishnan et al. 1987). Among the cell wall components, lignin is reported to have maximum interaction with other dietary components, leading to decreased bioavailability of nutrients (Prosky, 2000). ADF, ADL and cellulose were highest in soybean flour.

Grain	Crude fibre	NDF[a]	ADF[b]	ADL[c]	Hemicellulose	Cellulose	Lignin
Wheat	1.71±0.23	16.42±1.81	3.98±0.20	1.54±1.35	12.44±1.72	2.44±1.32	1.65±0.05
Oats	3.55±0.13	6.91±0.32	2.00±0.41	0.60±0.20	4.91±0.10	1.40±0.61	0.28±0.21
QPM*	2.38±0.38	13.15±1.07	2.89±0.42	1.44±0.24	10.27±1.40	1.44±0.24	0.87±0.01
Soybean**	5.23±0.20	13.47±0.57	4.80±0.78	1.89±0.29	8.67±0.36	2.90±0.65	1.31±0.03
CD(0.05)	0.48	2.07	0.97	NS	2.12	NS	0.20

Table 2: Crude fibre and fibre composition of whole flours

*[a] Neutral detergent fibre, [b] Acid detergent fibre, [c] Acid detergent lignin, * Quality protein maize, **Full fat soybean*

Phenolic acids are the major antioxidants in germ and bran in whole grains (Miller *et al.*, 2000). Soybean had highest total phenolic content (Fig 1) and antioxidant activities (Fig 2) followed by QPM, wheat and oat flours samples. This is in agreement with findings of Adom and Liu (2002). This activity in soybean is mainly due to dietary flavonoids and isoflavones (Heim *et al.*, 2002).

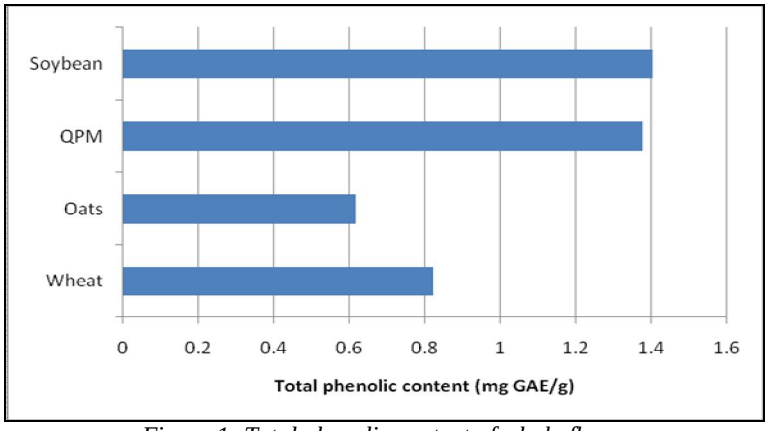

Figure 1: Total phenolic content of whole flours

Although oats had lower total phenolic content, they contain unique antioxidant compounds known as avenanthramides that have shown excellent antioxidative effect in humans (Chen *et al*., 2007). Antioxidant activity has also been correlated with high total phenolic content (Kumar *et al.*, 2010). Phenolic compounds in whole grains may be in free and bound form, as conjugates with sugars, fatty acids or as proteins (Sun & Ho, 2008). Their predominant biological functions include antioxidant, anti-inflammatory and anti-cancer activities that can protect the human body against endogenous and exogenous free radicals.

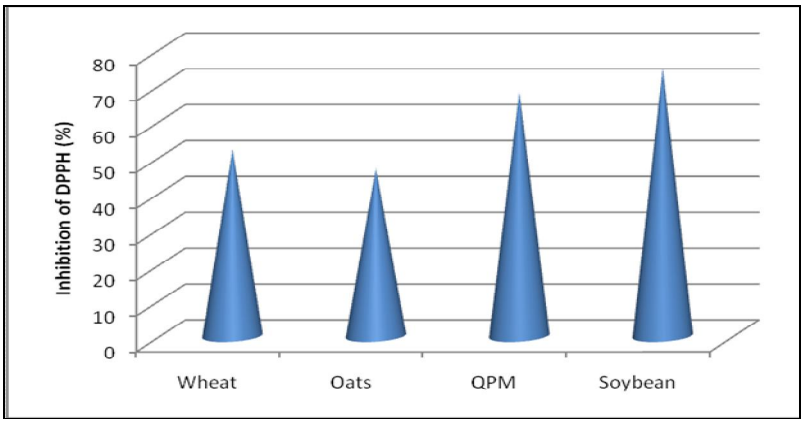

Figure 2: Anti-oxidant activity of whole flours

4. Conclusion

Whole flours from wheat (PBW 621), oats (OL9), quality protein maize (QPM) and soybean (SL 525) were studied for proximate composition, dietary fibre composition, total phenolic content and antioxidant activity. Soybean had the highest crude protein, crude fat, total ash, crude fibre, total phenols and antioxidant (DPPH) activity. Among the cereals, QPM had highest phenolic content and antioxidant activity. As compared to whole wheat flour, oat, QPM and soybean flour had superior physiologically

functional attributes. Hence they showed excellent potential for use in functional foods either in suitable combination with whole wheat or alone. Further, studies may be conducted on techno-functional properties for these flours for acceptable product quality.

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