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Research Article

CHARACTERIZATION OF NUTRITIONAL, RHEOLOGICAL AND INFRARED SPECTROSCOPY OF REFINED WHEAT, SOYBEAN AND SORGHUM FLOUR

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ABSTRACT

Nutritional, rheological and infrared spectroscopy of refined wheat, soybean and sorghum flour was evaluated for providing the food industry an idea about their functionality in foodstuffs preparation. Chemical composition including ash, protein and fiber content of the flours ranged from 0.50±0.10 (refined wheat flour) to 3.23±0.16% (soybean flour), 11.56±0.44 (refined wheat flour) to 35.72±0.28% (soybean flour) and 0.00 (refined wheat flour) to 5.20±0.10% (soybean flour). Total phenolic content and DPPH scavenging activity was reported highest for soybean flour with a values being of 515.04±5.0 mg/100 g GAE and 36.13±0.38%, respectively. Among all the samples, sorghum flour showed highest tannin content (48.14±0.95 mg/100 g TAE) followed by soybean flour (24.62±0.59 mg/100 g TAE) and refined wheat flour (48.14±0.95 mg/100 g TAE). High speed mixing rheological of the refined wheat dough reveled highest stability and water absorption percentage for refined wheat flour compared with sorghum and soy flour. FTIR analysis revealed presence of almost identical functional groups (C-H, C=C and amide I region) in the flour samples, with only difference in intensity of absorption.

INTRODUCTION

Nowadays, demand of cereals and legumes based functional composite flours has been increasing rapidly possibly due to the ability of reducing the celiac disease risks, availability from nutritionally rich crops for flour production and reduced cost spend on wheat flour importation (Awolu, 2017). Further, this increased demand of composite flour could also attribute with lower nutritional profile of wheat viz., dietary fiber, essential minerals and amino acids such as lysine and threonine (Eyidemir & Hayta, 2009; Choo & Aziz, 2010; Dhingra & Jood, 2002). Sorghum bicolor is an important cereal grass originated from Africa and nowadays cultivated worldwide for its food and feed value. It is a powerhouse of nutrients containing 2.41% ash, 3.83% fat, 10.72% protein and 2.32% fiber (Adeyeye, 2016) and becoming popular among the people suffering from celiac illness (Singh *et al.,* 2017). Sorghum phytochemicals viz., tannins, phenolic acids, anthocyanins, phytosterols and policosanols may improve the human health possibly due to their higher antioxidant potential (Awika & Rooney, 2004). It is widely used in formulations of different food products by researchers (Suhendro *et al.,* 2000; Khetarpaul & Goyal, 2007; Liu *et al.*, 2012; Singh *et al.,* 2013, Benhur *et al.,* 2015).

Soybean protein comprises all the essential amino acids and reported to have high mineral (Ca, P) and vitamins (A, B, C and D) profile (Taghdir *et al.,* 2017). It is a good source of polyunsaturated fatty acids viz., linolenic acid (Mohajan *et al.,* 2017) along with high level of antioxidant compounds viz., genistein and diadzein (Jalgaonkar *et al.,* 2018). Soy foods reported to effective in reducing the risk of heart disease and their regular consumption may delays the aging process along with improved physical abilities, memory power and hemoglobin levels of children (American Soybean Association, 2004; Farzana & Mohajan, 2015). Various findings are available on the utilization of soy flour (Limroongreugrat *et al.,* 2007; Serrem *et al.,* 2011; Sereewat *et al.,* 2015; Jalgaonkar *et al.,* 2018) and sorghum flour (Suhendro *et al.,* 2000; Khetarpaul & Goyal, 2007; Liu *et al.,* 2012; Singh *et al.,* 2013, Benhur *et al.,* 2015) in different food formulation, but, not much evidence are available regarding characterization of rheological and structural attributes of these flours. Rheological properties are important for investigating the dough behavior during processing conditions. Using the Mixolab, it is possible to estimate the mechanical changes owing to mixing and

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heating simulating the mechanical work and the heat conditions during bread making and bread baking processes (Hadnadev *et al.,* 2011). According to a study by Li *et al.* (2015), hardness of salted noodles prepared with djulis flour supplementation reported to be correlated directly with dough development time and dough mixing tolerance index. Further, structural properties of flours viz., infrared spectra, are crucial for estimating the structure similarity as well as difference between the samples based on the presence or absence of particular functional group (Gull *et al.,* 2015). Hence, current study intended to characterize the physicochemical and structural properties of soybean and sorghum flour to compare with refined wheat flour, thereby providing the food industry an idea about the functionality of the flours in product formulation.

MATERIAL AND METHODS

Materials

Refined wheat flour, soybean flour and sorghum flour were bought from local suppliers in Noida, India. All the flours were sieved through 250-µm sieve and kept in low density polyethylene packets for further analysis. Chemicals and reagents were of analytical grade from Sisco Research Laboratories Pvt. Ltd. (Mumbai, India) and Fischer Scientific (Mumbai, India).

Analysis of chemical composition of flours

Standard methods of AACC (2000) were used for estimation of moisture, ash, fat, protein and fiber content of refined wheat, soybean and sorghum flours. Total carbohydrate and Energy value were determined using the equations as under:

Carbohydrate (%) = (100 – moisture + ash + protein + fat + crude fiber).

Energy value (Kcal/100 g of product) = (4 × Carbohydrate) + (4 × Protein) + (9 × Fat).

Tannin content was estimated according to the method described by Ranganna (1986). Total phenolic content and %DPPH inhibition was calculated following the method suggested by Dordević *et al.* (2010) and Gull *et al.* (2016).

High speed mixing rheology of the flour dough

Rheological characteristics were determined with a Dough Lab (Model 2500, Perten, Australia) as per the Zaidul *et al.* (2004). Before starting the analysis, the thermostat of the Dough Lab was adjusted to 30 °C and weight of the flour on 14% moisture basis was determined using the following equation:

$$\text{Weight of flour (14\% moisture basis)} = \frac{100 - 14}{100 - \text{Moisture}} \times \text{Flour weight}$$

Estimated amount of flour (About 300 g of flour) calculated on 14% moisture basis was added to the mixing bowl of dough lab and the water required to make the dough was calculated automatically by the software. Five parameter including dough development time, stability time, arrival time, departure time and water absorption percentage were calculated from curve of the software.

Analysis of Fourier transfer infrared (FTIR) spectroscopy of flours

Infrared spectrum of the flours was recorded by using FTIR spectrophotometer (Agilent Technologies Cary 630 FTIR) by applying a small amount of noodle powder was placed on the sample holder and recording the spectrum between the wavelength ranges of 600-4000 cm^{1}.

Statistical analysis

The commercial statistical packages (SPSS, Inc, Chicago, IL, USA) was used in which data of triplicate observations were analyzed using one-way analysis of variance (ANOVA) and Duncan's multiple range test (at 5% significance level).

RESULTS AND DISCUSSION

Nutritional composition of flours

The proximate composition of raw flours viz., refined wheat flour, soy flour and sorghum flours are presented in Table 1.

Table 1 Chemical composition of refined wheat, soybean and sorghum flour samples.

Parameters (wet basis)	Flour samples		
	Refined wheat	**Soybean**	**Sorghum**
Moisture (%)	12.00 ± 0.10^{a}	7.60 ± 0.20^{c}	8.65 ± 0.14^{b}
Ash (%)	0.50 ± 0.10^{c}	3.23 ± 0.16^{a}	1.35 ± 0.02^{b}
Crude fat (%)	1.73 ± 0.07^{c}	14.66 ± 0.57^{a}	4.67 ± 0.09^{b}
Protein (%)	11.56 ± 0.44^{b}	35.72 ± 0.28^{a}	9.63 ± 0.47^{c}
Crude fiber (%)	Not Detected	5.20 ± 0.10^{a}	5.02 ± 0.12^{a}
Carbohydrate (%)	74.21 ± 0.57^{a}	33.59 ± 0.89^{c}	70.68 ± 0.44^{b}
Energy value	358.65	409.18	363.27
Tannin (mg/100 g TAE)	17.42 ± 0.91^{c}	24.62 ± 0.59^{b}	48.14 ± 0.95^{a}
Total phenols (mg/100 g GAE)	120.76 ± 0.82^{b}	515.04 ± 5.0^{a}	105.04 ± 2.1^{c}
DPPH (%) inhibition	17.34 ± 0.17^{c}	36.13 ± 0.38^{a}	19.75 ± 1.2^{b}

All the values are mean ± standard deviation of three independent determinations.

All the flours had optimum moisture content (<14%), with refined wheat flour had the highest value (12.20±0.10%) followed by sorghum (8.65±0.14%) and soybean flours (7.60±0.20%). These results are in agreement with those reported by Omeire *et al.* (2014) Liu *et al.* (2012) for wheat (12.26% and 12.56%), Edema *et al.* (2005) for soy (6.11%) and Benhur *et al.* (2015) and Liu *et al.* (2012) for sorghum (10.02% and 9.20%). The lowest moisture content of soybean flour might be due to its higher total dry solid content with greater emulsifying properties compared with other flours (Farzana & Mohajan, 2015). Ash content of soy flour (3.23±0.16%) was significantly higher ($p < 0.05$) than those of sorghum (1.35±0.02%) and refined wheat flours (0.50±0.10%) and in covenant with the findings of Serrem *et al.* (2011) who reported higher ash content of soy flour (6.2 g/100 g) compared with refined wheat (0.7 g/100 g) and sorghum flour (1.4 g/100 g). Similarly, Edema *et al.* (2005) reported ash content of 2.95% for soy flour, Liu *et al.* (2012) for wheat and orbit sorghum hybrid with a value being of 0.37% and 1.31%, respectively. Fat content was highest in soybean flour (14.66%) compared with sorghum (4.67±0.09%) and refined wheat flours (1.73±0.07%). Similar observation has been observed earlier by Serrem *et al.* (2011) for wheat (1.4 g/100 g) and Khalil *et al.* (1984) for sorghum flour (4.7) and Edema *et al.* (2005) for soy flour (14.03%). Protein content of soy flour (35.72±0.28) was found to be highest compared with refined wheat (11.56±0.44) and sorghum flour (9.63±0.47%). These values are in agreement with those reported by other authors for sorghum flour (Benhur *et al.,* 2015), refined wheat (Wójtowicz & Mościcki, 2014) and soy flour (Joshi *et al.,* 2015). In term of its fiber content, both soy and sorghum flour showed good compatibility with each other with a value being of 5.20±0.10% and 5.02±0.12%, respectively. These values are in agreement with those reported by Khan *et al*. (2013) for sorghum (6.46%) and Serrem *et al.* (2011) for soy (7.5%). The carbohydrate content was highest in refined wheat (74.21±0.57), followed by sorghum flour (70.68±0.44%) and soybean flours (33.59±0.89%) and in agreement with the earlier studies of Joshi *et al.* (2015).

Tannins are naturally occurring polyphenol related with reduced protein digestibility via forming complexes with proteins and inhibiting enzymes (Khalil *et al.,* 1984; Gull *et al.,* 2015). However, phenols, tannins of cereals also work as a good antioxidants sources and essential for good health, ageing and metabolic diseases. As shown in Table 1, sorghum flour had the highest tannin content (48.14±0.95 mg/100 g TAE) followed by soybean (24.62±0.59 mg/100 g TAE) and refined wheat flour (17.42±0.91 mg/100 g TAE). These values are different as reported in earlier studies (Patil & Arya, 2017; Khalil *et al.,* 1984; Gull *et al.,* 2016) that could be due to the difference in generic and environmental factors. Phenolic compounds are the vital phytochemicals drivers of health and functional foods and nutraceutical industry. In this study, total phenolic content was significantly higher ($p > 0.05$) in soybean flour (515.04±5.0 mg/100g GAE) followed by refined wheat (120.76±0.82 mg/100g GAE) and sorghum flour (105.04±2.1 mg/100g GAE). These results are in accordance with those obtained by Sreeramulu *et al.,* 2009 for wheat (109.34±23.71 mg/100 g), except sorghum and soy flour that had lower phenolic content of 57.55±2.720 mg/100 g and 100.54 ±1.08 mg/100 g. This variation in TPC could be attributed with the existence of non-phenolic reducing compounds for instance organic acids and sugars which interfere with the assessment of total phenolic content by Folin-Ciocalteu method.

DPPH is a useful method commonly used to persuade antioxidant activity, based on hydrogen donation ability and has desirable correlation with other procedure. Table 1 showed that all flours sample revealed strong antioxidant activity with a value greater than 0.5 (Gull *et al.,* 2016). % DPPH inhibition activity ranged from 17.34±0.17, 36.13±0.38 and 19.75±1.2% for the refined wheat, soy and sorghum flour. The results for %DPPH were in lines with that obtained by Gull *et al.* (2016) but opposite to the findings of Ragaee *et al.* (2006) and Sreeramulu *et al.* (2009) that could be attributed with the genetic and environmental factors.

Rheological characteristics of flours

Table 2 and Figure 1 present the rheological characteristics of raw and the composite flour samples. Dough properties such as development time, arrival time, departure time, and stability values display the dough strength and greater values indicate strong dough (Li *et al.,* 2015). Arrival time ranged from 1.83 (refined wheat) to 5.40 min (sorghum flour), development time ranged from 2.53 (refined wheat) to 9.10 (sorghum flour), stability time ranged from 0.60 (sorghum) to 1.66 min (refined wheat), departure time ranged from 3.53 (refined wheat) to 6.0 min (sorghum flour) and water absorption ranged from 51.70 to 68.46%, highest for refined wheat and lowest for sorghum flour.

Table 2 High speed mixing rheology of flours

Flour samples	Rheological characteristics of dough				
	Arrival time (min)	Development time (min)	Stability time (min)	Departure time (min)	Water absorption (%)
Refined wheat flour	1.83 ± 0.11	2.53 ± 0.28	1.66 ± 0.49	3.53 ± 0.64	63.03±2.57
Soybean flour	2.66 ± 0.64	4.63 ± 0.45	1.13 ± 0.11	4.00 ± 0.60	62.86±1.84
Sorghum flour	5.40 ± 0.30	9.10 ± 0.40	0.60 ± 0.10	6.00 ± 1.05	51.70±0.30

All the values are mean ± standard deviation of three independent determinations.

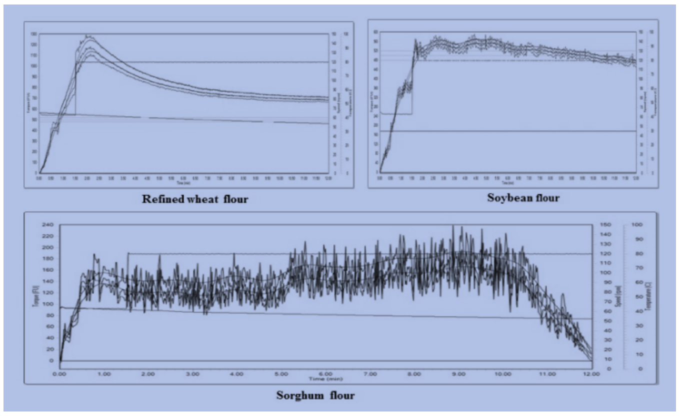

Figure 1 High speed mixing rheological of refined wheat, soybean and sorghum flour.

Arrival time of the dough is that time when top of the curve touch the 500BU line after the starting of the mixing and water introduced. This value is a measure of the rate at which water is taken up by the flour. Arrival time was highest for sorghum flour (5.40±0.30) followed by soybean (2.66±0.64) and refined wheat flour (1.83±0.11). Dough development time is the time from the water addition to the development of maximum dough consistency, improved with rise in water absorption percentage (Zaidul *et al.,* 2004), opposed to the findings of this study having highest dough development time for sorghum flour in spite of its lower water absorption. Dough stability time specify the tolerance to mixing a flour will have (Zaidul *et al.,* 2004) and may be defined as the difference in time (to the nearest 0.5 min) between the point where the top of the curve first intercepts the 500BU line (arrival time) and the point where the top of the curve leaves the 500BU line (departure time). Dough stability was reported to be minimum in case of sorghum flour, which may be due to less stable dough formation caused by addition of gluten free ingredients as described by Petitot *et al.* (2010) and Wood (2009) for wheat supplemented split pea-faba bean flours and chickpea fortified wheat flour, respectively.

FTIR spectra of flours

Results of infrared spectrums (FTIR) of flours sample are shown in Figure 2. The FTIR spectra of refined wheat flour showed absorption band at 758.91, 840.16, 854.13, 1001.84, 1142.88, 1339.51, 1538.43, 1638.64, 2916.24, 3258.88, 3842.44 cm^{-1} region. The spectra of soybean flour showed peaks at wave numbers of 627.27, 1012.40, 1399.46, 1527.4, 1649.41, 1690.74, 1923.20, 2359.31, 2845.70, 2910.01, 3282.14, 3624.46, 3673.66, 3746.40 and 3852.20 cm^{-1}. Sorghum flour showed absorption peaks at 625.86, 1005.06, 1527.06, 1697.48, 1920.90, 2360.57, 2857.61, 2923.38, 3120.01, 3227.18, 3623.63, 3674.43, 3746.27 and 3851.25 cm^{-1} region. The broad absorption band at 600-1000 cm^{-1} was due to the presence of aromatic rings (Swer *et al.,* 2018). A peak at 1055-1000 cm-[1] was attributed with the presence of cyclohexane ring vibrations of methylene group, while the band at 1420-1290 cm^{-1} was due to the occurrence of C-H groups. The absorption band between 1680-1600 cm^{-1} and 3095-3010 revealed existence of C=C, while band at 2935–2915/2865–2845 cm^{-1} was the results of presence of methylene C-H asymmetric/symmetric stretching vibrations (Coates, 2000). The absorption band between 1600-1700 region was ascribed with the occurrence of amide region originated from the C = C bond (Li *et al.,* 2017).

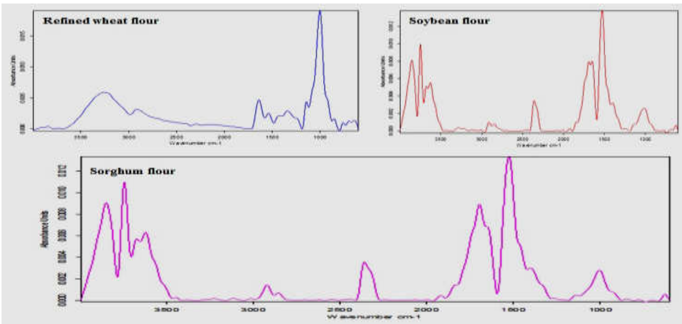

Figure 2 Fourier Transfer infrared spectroscopy of flour samples.

CONCLUSION

Increase health concern challenges the food industry to formulate the new products with special health enhancing characteristics. Present investigation shows both sorghum and soy flour revealed higher nutritional value and antioxidant profile compared with refined flour. Rheological properties of sorghum and soy flour did not show much difference compared with refined wheat flour. Fourier transfer infrared spectroscopy showed the presence of identical functional groups (C-H, C=C and amide I region), with only difference in intensity of absorption. Therefore, the result of the present study showed that both flours could be used as a potential substitute in formulation of food products with high nutritional value and improved quality characteristics.

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