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BIOCHEMICAL AND FUNCTIONAL PROPERTIES OF PROCESSED FLAXSEED (*Linum usitatissimum*) FLOUR

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ABSTRACT

Flaxseed is a rich source of polyunsaturated fatty acids containing about 80% total oil with a high quantity of ω-3-fatty acids as well as mineral content. The objective of present study was to estimate the effect of different processing treatments *viz*., roasting, defatting and combination of both on the functional and biochemical properties of flaxseed flour. Flaxseed grains were processed as full fat non-roasted flour, full fat roasted flour, partially defatted roasted flour and partially defatted non-roasted flour. The results revealed that partial defatting and roasting increased crude protein (34.0%), ash (5.57%), crude fibre (12.34%) and total phenol (301.25 mg 100 g^{-1}) contents as well as antioxidant activity (92.3%) in flaxseed flour. However, crude fat (37.7%), free fatty acid (0.37%), peroxide value (2.95 meq kg^{-1}), phytic acid (950.2 mg 100 g^{-1}) and tannins (318.4 mg 100 g^{-1}) were highest in full fat non-roasted flour. Water absorption capacity (2.25 gg^{-1}), foam capacity (21.76%) and foam stability (84.6%) were higher in partially defatted roasted flour. Based on functional and biochemical parameters partially defatted roasted flaxseed flour was found best.

Key words: Flax flour, foam capacity, foam stability, minerals, phytic acid, tannin

INTRODUCTION

The search for novel high-quality cheap sources of protein and energy has attained more attention in developing counties so as to meet the challenges of hunger and starvation (Shahzad *et al*., 2008). Attention is focused on cheap grains containing relatively high amount of proteins that can help in enhancing the food quality. Flaxseed (*Linum usitatissimum*) is one of the grains that has gained acceptance in this regard. It is an erect ~1.2 m tall annual plant and belongs to the family *Linaceae.* The plant has slender stem and lanceolate leaves. The flowers are blue in colour, measure 15-25 mm in dia. and have five petals. Its fruits are round, dry capsule is 5-9 mm dia. and contains several glossy brown seeds. India ranks 3rd in area under flax crop after Canada and China, and occupies 11.82% of world acreage (Pandey *et al*., 2014). In India, flax is grown in temperate and sub-tropical areas wherever sufficient moisture during winter and spring is available (Chaudhary *et al*., 2015).

Flaxseed is consumed mainly as food and also for medicinal purpose as it contains valuable nutritional compounds like α-linolenic acid, lignin and dietary fibre. The proximate composition of flaxseed has revealed that it approximately contains 30% protein, 35% lipids, 4% ash, 35% fibre and 6% carbohydrates (Kajla *et al*., 2015). It is also a rich source of polyunsaturated fatty acids consisting about 80% of total oil with a high quantity of ω-3-fatty acids which are essential and eaten as a part of diet since the body does not manufacture them from another source (Simopoulos, 1999). It serves as a good source of minerals especially K and Ca. Flaxseed contains small amounts of water soluble and fat soluble vitamins (Morris, 2007). Flax seed has high lignin and ω-3-fatty acids. Lignin benefits the heart and has anti-cancer properties (Chaudhary *et al*., 2015). In spite of multiple clinical benefits of flaxseeds, people are unaware about its nutritional and therapeutic use. Nutritionists all over the world suggest incorporation of ω-3-fatty acid sources in diet. Flaxseed serves as the best ω-3-fatty acid source to the non-fish eaters. Edible flaxseed products include the whole flaxseed, ground meal and extracted oil or mucilage (Singh *et al*., 2011).

Dry heat (roasting) is widely used processing method for cereal products, fruits and vegetables (Hwang *et al*., 2007) and is known to improve the availability of nutrients, inactive enzymes which accelerate nutrient damage, destroy undesirable microbes and food contaminants. During processing, cooking and preservation of food, the application of roasting has mixed effects on its nutritive value (Biglar *et al*., 2012). Roasting of flaxseed has traditionally is used to prevent gastrointestinal complicacies. Similarly, partial defatting of flax flour improved foam capacity, foam stability and water absorption capacity (Hussain *et al.,* 2008). However, information on the nutritional profile, minerals and functional and antioxidant properties of raw full fat flour and partially defatted seed flour is scanty (Hussain *et al*., 2006). The present study was aimed to assess the functional properties, chemical composition and mineral profile of different flaxseed flours.

MATERIALS AND METHODS

Collection of raw material and processing

Flaxseed grains (mixed variety) were procured from local market. Grains were cleaned manually to remove any foreign materials. The cleaned flaxseed grains were divided into four lots (5 $kglot^{-1}$). One lot was milled as such into flour and treated as full fat non-roasted flaxseed flour. Microwave roasting was performed to the 2^{nd}lot with a household microwave oven at 450 W for 3 min, cooled and then milled into flour. The 3^{rd}lot of flaxseed grains was roasted for 3 min in household microwave oven at 450 W and defatted in oil expeller to reduce oil (passed through expeller in single press to less than 12% fat by weight). It was finally cooled and milled into flour. The 4^{th}lot of flaxseed was defatted in oil expeller to reduce oil content, cooled and milled into flour. All the prepared flours were analyzed for various physicochemical and functional characteristics. The experiment was conducted in a completely randomized design and each treatment replicated thrice. The data were analyzed by using analysis of variance (website: *www.hau.ernet.in*).

Functional parameters of flours

Water absorption capacity: The determination of water absorption capacity was carried out according to the method of Anderson *et al*. (1969). A 2.5 g sample was dispersed in 25 g distilled water, using a glass rod to break up any lumps. After stirring for 30 min, the dispersions were rinsed, volume made up to 32.5 g and centrifuged at 5000 rpm for 10 min. The water absorption capacity is the weight of gel obtained per gram dry ground sample evaporated from the water absorption determination.

Foam capacity and foam stability: The foam capacity and stability was determined by standard procedure (Baljeet *et al*., 2014). Fifty mililitre water was taken in a cylinder, and 1 g flour samples was mixed with it at 30± 2°C. The suspension was properly hand shaken to foam and the volume of foam recorded after 30 sec. The foam volume was recorded after 1 h of whipping as foam stability.

Chemical composition of flaxseed flours

Moisture, crude protein, ash, crude fat, crude fibre and nitrogen free extract contents were estimated by standard methods (AOAC, 1995). Free fatty acid content was determined using titration method (AACC, 1990). Standard AOAC (2005) procedure was adopted to determine peroxide value of samples. Free radical scavenging activity (antioxidant activity) was determined by DPPH (diphenyl picryl hydrazyl) method. The free radical scavenging activity was assessed by comparing the absorbance of sample solution with control to which distilled water was added instead of sample (Koga *et al*., 2007). Phytic acid content was estimated as per Sadasivam and Manickam (2008). The colour intensity was read to 480 nm. Tannin content was determined by Folin-Denis method (Sadasivam and Manickam, 2008). A standard curve was prepared using tannic acid and tannin concentration expressed in mg 100 g^{-1}. Total phenols were estimated as per Sadasivam and Manickam (2008) and a standard curve prepared using different concentrations of catechol. The organic matter present in sample (1 g) was wet digested with 25 mL diacid mixture (HNO_3: $HClO_4$ in 5:1 ratio) and kept overnight (AOAC, 2005). Digestion was done next day by heating the sample till clear white precipitates settled down at bottom. The crystals were dissolved by diluting with double distilled water and the contents filtered through Whatman filter paper No. 42. The filtrate volume was made upto 25 mL with distilled water. The digested samples were analyzed for calcium, iron, sodium and potassium content using atomic absorption spectrophotometer (Thermo AAS M-6 S.No. 650035).

Statistical analysis

The data was analyzed as per one-way analysis of variance using Opstat software available online at CCS, HAU, Hissar, India (website: *www.hau.ernet.in*).

RESULTS AND DISCUSSION

Functional parameters of flaxseed flours

The functional parameters i.e. water absorption capacity (WAC), foam capacity and foam stability were significantly influenced by different treatments (Table 1). Maximum WAC, foam capacity and foam stability values of 2.25 g g^{-1}, 21.76% and 84.65%, respectively, were observed in partially defatted roasted flaxseed flour. On the other hand, full fat roasted flaxseed flour recorded the lowest foam capacity (19.52%) and foam stability (81.25%) whereas, minimum WAC (1.20 g g^{-1}) and water solubility index (2.43%) were noticed in full fat non-roasted flaxseed flour. The increase in WAC could be attributed to the presence of greater amounts of hydrophilic constituents like fibre and lower amount of fat (Baljeet *et al*., 2014). The decrease in foam capacity and foam stability in roasted flaxseed might be due to the denaturation of protein on roasting. However, partial defatting increased foam capacity and foam stability because this property is directly linked to protein concentration, structure and solubility. Proteins can help in foaming because of their surface-active property (Miranda *et al.*, 2012).

Table 1: Effect of roasting and defatting on functional properties of flaxseed flour

Treatments	Water absorption capacity (g g^{-1})	Foam capacity (%)	Foam stability (%)
Full fat non-roasted flaxseed flour	1.20	20.04	82.00
Full fat roasted flaxseed flour	1.48	19.52	81.25
Partially defatted roasted flaxseed flour	2.25	21.76	84.65
Partially defatted non-roasted flaxseed flour	2.00	20.34	84.05
Mean	1.73	20.41	82.84
$CD_{0.05}$	0.05	0.09	0.11

Table 2: Effect of roasting and defatting on proximate composition of flaxseed flour

Treatments	Moisture (%)	Crude protein (%)	Crude fat (%)	Ash (%)	Crude fibre (%)	Nitrogen-free extract (%)
Full fat non-roasted flaxseed flour	4.32	21.05	37.72	3.34	8.01	25.56
Full fat roasted flaxseed flour	4.06	20.85	37.81	3.45	8.21	25.62
Partially defatted roasted flaxseed flour	3.82	34.00	10.86	5.57	12.34	33.41
Partially defatted non-roasted flaxseed flour	4.00	32.42	11.01	5.48	12.16	34.93
Mean	4.05	27.08	24.35	4.46	10.18	29.88
$CD_{0.05}$	0.09	0.06	0.09	0.08	0.05	0.05

Proximate composition of flaxseed flours

The highest moisture content of 4.32% was observed in full fat non-roasted flaxseed flour followed by full fat roasted flaxseed flour with a moisture content of 4.06%(Table 2). The decrease in moisture content in roasted sample appears due to the loss of water from the internal tissue of seeds during increased heating (Mahajan, 2009). Similar higher moisture content in raw flaxseed flour as compared to partially defatted flaxseed flour have been reported by Manukumar *et al*. (2014). The maximum crude protein (34.0%), ash (5.57%) and crude fibre (12.3%) contents were observed in partially defatted roasted flaxseed flour whereas, full fat roasted flaxseed flour had maximum crude fat content of 37.8% and partially defatted non-roasted flaxseed flour had highest NFE content of 34.9%. Minimum ash (3.34%) and crude fibre (8.01%) contents were noticed in full fat non-roasted flaxseed flour. However, full fat roasted flaxseed flour yielded minimum crude protein (20.85%) content. Similar results have been reported by Mahajan (2009) in *Cassia tora* seeds. Oil extraction reduced fat in partially defatted flours and concentrated other constituents; hence resulted in higher protein, ash and crude fibre contents in defatted flours (Kayitesi *et al*., 2012). Further, roasting decreased protein content which may be attributed to their denaturation when heated (Ademulegun and Koleosho, 2008).

Chemical composition of flaxseed flours

The effects of treatments on chemical parameters *viz*., free fatty acids, peroxide value, phytic acid, tannins, antioxidant activity and total phenols were significant (Table 3). The partially defatted roasted flaxseed flour showed low free fatty acid (0.14% as oleic acid), peroxide value (1.06 meq peroxide kg^{-1} sample), phytic acid (741.1 $mg100g^{-1}$) and tannins (193.5 $mg100g^{-1}$). Roasting decreased phytic acid and tannin content in flours. The reduction in tannin during roasting could be attributed to heat labile nature of tannin. Khattab and Arntfield (2009) reported reduction of tannins on microwave cooking of legumes. Phytic acid was slightly affected by roasting which could be assigned tothe strong electrostatic force existing between the oxygen atoms of contiguous phosphate radicals within phytate structure thereby imparts heat resistance to the molecules (Mittal *et al*., 2012).

Table 3: Effect of roasting and defatting on chemical composition of flaxseed flours

Flaxseed flour	Free fatty acid (%)	Peroxide value (meq. peroxide kg^{-1} sample)	Antioxidant activity (%)	Phytic acid (mg 100 g^{-1})	Tannins (mg 100 g^{-1})	Total phenols (mg 100 g^{-1})
Full fat non-roasted	0.37	2.95	87.45	950.21	318.43	283.08
Full fat roasted	0.26	2.18	88.67	815.63	230.69	289.47
Partially defatted roasted	0.14	1.06	92.32	741.14	193.51	301.25
Partially defatted non-roasted	0.19	1.47	91.85	862.35	254.11	294.76
Mean	0.24	1.91	90.07	842.33	249.18	292.84
$CD_{0.05}$	0.06	0.05	0.06	0.06	0.06	0.08

Table 4: Effect of roasting and defatting on mineral content (mg 100 g^{-1}) of flaxseed flours

Flaxseed flour	Calcium	Iron	Sodium	Potassium
Full fat non-roasted	226.90	5.85	30.00	814.71
Full fat roasted	233.25	6.00	31.92	819.34
Partially defatted roasted	382.21	10.49	52.05	1295.04
Partially defatted non-roasted	376.43	9.57	47.68	1257.33
Mean	304.69	7.97	40.41	1046.60
$CD_{0.05}$	0.10	0.06	0.08	0.06

The highest total phenol content (294.76 mg100g^{-1}) was observed in partially defatted non-roasted flaxseed flour; whereas partially defatted roasted flaxseed flour had highest antioxidant activity (92.32%). Roasting increased total phenolic content and antioxidant activity in flaxseed flour. Dewanto *et al.* (2002) reported that thermal processing may release bound phenolics from cellular constituents. Additionally, heating induces production of Maillard reaction products, especially melanoidins, which reportedly have antioxidant activity (Michalska *et al.*, 2008). Total phenolic content was significantly higher in partially defatted flaxseed flour than in full fat flaxseed flour. This could possibly be due to oil extraction in defatted flour that concentrates other constituents hence an increase in total phenolic content (Kayitesi *et al.*, 2012).

Mineral content of flaxseed flours

The mineral content (calcium, iron, sodium and potassium) varied significantly among the treatments (Table 4). The highest calcium content of 382.21 mg100 g^{-1}, iron content of 10.49 mg100 g^{-1}, sodium content of 52.05 mg100 g^{-1} and potassium content of 1295.0 mg100 g^{-1} were observed in partially defatted roasted flaxseed flour followed by partially defatted non-roasted flaxseed flour with calcium content of 376.43 mg100 g^{-1}, iron content of 9.57 mg100 g^{-1}, sodium content of 47.68 mg100 g^{-1} and potassium content of 1257.3 mg100 g^{-1}. Minerals increased on roasting because there is breakdown of bonds between phytate and phosphorous. Partially defatted flaxseed sample contain high amount of mineral contents than raw, which means that the presence of oil/fat hinders the availability of mineral elements. Thus, defatting increased mineral content (Manukumar *et al.*, 2014).

Conclusion: Based on the results, it may be concluded that roasting of flaxseed flour prior to defatting results in reduction of phytic acid and tannins and improvement in functional properties *viz.*, water absorption capacity, foam capacity and foam stability of flour. The improvement in functional properties of flaxseed flour ultimately is likely to increase its suitability for use in preparation of a number of food products.

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