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A COMPARATIVE STUDY ON CHEMICAL COMPOSITION, COLOR, AND FUNCTIONAL CHARACTERISTICS OF FLOURS AND PROTEIN CONCENTRATES FROM DIFFERENT OAT CULTIVARS

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ABSTRACT

Flours and protein concentrates from eight Indian oat cultivars were compared for their proximate composition, color characteristics, and functional properties. The oat protein concentrates (OPC) were prepared by alkaline extraction followed by isoelectric precipitation at pH 5. The results so obtained revealed that oat flours had higher moisture and ash contents in the range of 6.97-8.55 % and 0.84-3.54 %, respectively in comparison to OPC which had values ranging between 3.33-6.01% and 0.84-1.86%. The hunter L* value of the flours were significantly ($P<0.05$) higher (79.72-87.81) than the protein concentrates (51.73-69.93). OPC had higher protein content values varying between 65.22-76.88 % than their corresponding flours (6.12-13.33%). With regard to functional properties, OPC had higher bulk density (0.745-0.947 g/ml), superior water and oil absorption, foaming capacity and emulsion properties than their counterpart flours. Several significant ($P<0.05$) correlations between measured properties of OPC were also observed as revealed by Pearson correlation analysis.

INTRODUCTION

Protein is vital for human metabolism, and protein energy malnutrition is a major issue in developing countries, especially among children (WHO, 2000). In recent years, proteins derived from plant sources are becoming one of the food industry's fastest growing and most-innovative ingredient segments owing to cost, health and religion (Nieto-Nieto *et al*., 2014). Plant proteins possess high potential as sustainable protein source in the diet of next generations, but their poor solubility and technological functionality restrict their applicability in various food products (Nivala *et al*., 2013). The proteins extracted from plant sources can be sold as either isolates (90% or more protein) or concentrates (generally 50-70% protein). Humans do not consume oats extensively as a source of protein though they provide a potential source of low cost proteins with good nutritional value.

Oat is a unique cereal due to its relatively high protein content and its distinct protein composition in comparison to other cereals (Nivala *et al*., 2013). Oats possess the highest protein level among cereals, typically ranging from 12% to 20% (Mohamed *et al*., 2009). Nutritional importance of oats has been revealed due to abundant innovation in food and nutrition (Chauhan *et al*., 2018). Oats are commercially utilized in many forms such as flakes, rolled or as flour (Kaur & Singh, 2017). Oat flour plays an important role in breakfast cereals, biscuits, infant food, cookies, and flour blends. The unique gluten-free protein composition of oats makes it an allowed food ingredient for celiac patients in many countries (Fric, Gabrovska, & Nevoral, 2011). Moreover, the nutritional quality of oat protein is good. Lysine, methionine, and threonine are the limiting amino acids although the lysine content in oat is somewhat higher than that in other cereals (Lapvetelainen & Aro, 1994). Oat protein concentrate shows better nutritive quality due to relatively high content of limiting amino acid lysine (Klose & Arendt, 2012). The major group of protein in oats is globulin, which has poor solubility in water under neutral and slightly acidic pH condition (Loponen *et al*., 2007). Oats are unique among major cereal grains due to its major storage proteins fraction globulin opposed to the prolamin fraction. Ma & Khanzada (1987) reported that protein isolates and concentrates prepared from oats possess good emulsifying and binding properties. Ma & Harwalkar (1984) studied four solubility fractions from oat seeds for their functional properties and reported that albumin had excellent foaming properties. Effect of various modifications such as acetylation, succinylation and deamination on oat proteins which improve their solubility, water hydration capacity and other functional

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properties have also reported earlier (Ma, 1984, Ma & Khazad,1987, Mirmoghtadaie *et al*., 2009). There are several studies where oat proteins solubility (Jiang et al., 2015), emulsifying (Mohamed *et al*., 2009; Wu *et al*., 1977) , gelling (Niento- Niento *et al*., 2014) and foaming (Konak et al., 2014; Ma & Harwalkar, 1984) properties have been explored. Value-added opportunities exist for oat proteins to be used as a new gelling ingredient in food formulations such as meat binder and as a fat replacer to create foods with improved quality and nutritive value (Niento- Niento *et al*., 2014). Therefore, this work aimed to carry out a systematic study of the physicochemical and functional properties of oat protein concentrates and flours from various Indian oat cultivars and to establish possible correlations between them.

MATERIAL AND METHODS

Materials

Representative samples of eight Indian oat cultivars: OL-9, OL-10, Kent (PAU, Ludhiana.), OS-6, OS-7, OS-364, HFO-114 (CCS HAU, Hisar) and PLP-1 (CSK HPKV, Palampur) were procured. Seeds were cleaned for dirt, damaged seeds, foreign material, and stored at 20°C until further use. All the reagents used in the study were of analytical grade.

Oat flour and Oat protein concentrates (OPC)

Oat flour was prepared by grinding dehusked oats in a super mill (Newport Super Mill-1500, Newport Scientific Pvt. Ltd, Warriewood, Australia) and flours so obtained were passed through 60 BSS mesh screen. Oat protein concentrates were prepared by isoelectric precipitation using method as described by Liu *et al* (2009). Oat flour (100 g) was mixed with 600 ml of water, and the initial pH of the solution was adjusted to 10.0 using NaOH (2M). The solution was magnetically stirred at 25°C for 2 h. The slurry was then filtered and was centrifuged at 3000g for 15 min. The supernatant was taken and its pH was adjusted to~5.0 using HCl (0.5 M), followed by centrifugation at 3000g for another 15 min at 4°C.. The resultant protein pellet was washed thrice with 100 ml of distilled water and their pH was adjusted to 7.0 and finally freeze dried (Heto PowerDry, Allerod, Denmark). The protein powder was kept in a refrigerator until further use.

Chemical composition

Flour and protein concentrates from different oat cultivars were analyzed for their moisture, ash and protein (%N × 6.25) by standard methods of analysis (AOAC, 1990).

Color characteristics

Color measurements of the samples was carried out using a Hunter colorimeter Model D 25 optical Sensor (Hunter Associates Laboratory Inc., Reston,VA, USA) on the basis of L*, a* and b* values.

Functional properties

Flour and Protein concentrate from different oat cultivars were evaluated for various functional properties such as bulk density (Kaur and Singh, 2005), water absorption capacity (Sosulski, 1962), oil absorption capacity (Lin, Humbert and Sosulski, 1974), emulsifying properties (Naczk, Diosady and Rubin, 1985) Foaming capacity and stability (Lin, Humbert and Sosulski, 1974).

Statistical analysis

The data reported in all tables are an average of triplicate observations and was subjected to statistical analysis using Minitab Statistical Software version 14 (Minitab Inc., USA).

RESULTS AND DISCUSSION

Chemical composition

The flour and protein concentrate from different oat cultivars were analyzed for moisture, ash, protein contents and the results are given in Table 1. The moisture content of flours from different oat cultivars ranged between 6.97-8.55%, with the highest values found in OS-346 cv. and the lowest value was found in OL-9 cv. Moisture content of oat flours in the present study was in close agreement to that reported earlier for different oats by Huttner *et al*. (2010) and Sandhu *et al*. (2017). The moisture content for oat protein concentrates (OPC) from the different cultivars was the highest for OS-346 cv. (6.01%) and was the lowest for OL-10 cv. (3.33%). Ash content of the flours was in the range of 0.84-3.54%, with OS-6 cv . showing the highest and HFO-114 cv. showing the lowest ash content. Similar values of ash content in oat flours were also reported earlier (Sandhu *et al*., 2017; Chauhan *et al*., 2018). Ash content for OPC was found in the range of 0.76- 1.86 %, where OS-6 cv. exhibiting highest ash content. Ash content of OPC observed in present study was lower than reported earlier (2.4%) by Nivala *et al*. (2017). Protein content of flours from different oat cultivars ranged between 6.12-13.13 %, with the highest value found in OL-9 cv. and lowest in HFO-114 cv. Earlier studies reported the protein content in the oat flours of 5.46% (Chauhan *et al*.,2018) and 113.75 to 177.5 $g \cdot kg^{-1}$ (Vilmane *et al*., 2015). The protein content of OPC was in the range of 65.22- 76.88 % indicating that the extracted oat protein is a concentrate, with small amounts of ash and moisture. A positive correlation of moisture with ash and protein content of OPC was observed (Table 2).

Table 1 Chemical composition of flour and protein concentrates (OPC) from different oat cultivars

Parameters	Moisture (%)		Ash (%)		Protein (%)	
Cultivars	Flour	OPC	Flour	OPC	Flour	OPC
OL-9	6.97±0.01	4.09±0.02	1.87±0.06	0.99±0.03	13.33±0.37	76.88±0.22
OL-10	7.82±0.01	3.33±0.03	2.16±0.13	1.03±0.11	11.28±0.04	75.22±0.01
KENT	7.82±0.02	4.06±0.05	1.74±0.11	0.89±0.09	8.74±0.05	69.84±0.30
OS-6	8.51±0.03	4.12±0.07	3.54±0.04	1.86±0.11	9.63±0.04	66.05±0.07
OS-7	8.23±0.03	3.55±0.02	2.00±0.08	0.79±0.04	10.50±.02	75.71±0.19
OS-346	8.55±0.04	6.01±0.03	2.42±0.08	1.19±0.19	11.38±0.04	76.37±0.28
HFO-114	8.31±0.04	4.02±0.01	0.84±0.06	0.76±0.01	6.12±0.02	65.22±0.07
PLP-1	7.37±0.02	4.21±0.09	2.31±0.12	1.04±0.10	10.98±0.01	72.24±0.15

Values are an average of triplicate observations (± standard deviation).

Table 2 Pearson correlation coefficients between composition and functional properties of protein concentrates from different oat cultivars

	Moisture	Ash	Protein	FC	BD	EA	WAC
Ash	0.235						
Protein	0.407	-0.127					
FC	-0.560	-0.271	-0.522				
BD	0.367	0.323	-0.126	0.199			
EA	0.664	-0.80	0.296	-0.631	-0.135		
WAC	0.004	0.353	0.728*	-0.402	-0.072	-0.056	
OAC	-0.500	0.159	0.082	0.316	0.226	-0.729*	0.501

*Correlation is significant at 0.05 levels

FC- Foaming capacity; **BD**-Bulk density; **EA**-Emulsion activity; **WAC**-Water absorption capacity; **OAC**-Oil absorption capacity

Color characteristics

Hunter color values (L*, a* and b*) of flours and protein concentrate from different oat cultivars are presented in Fig 1. L* (lightness) values of the flours varied from 79.72-87.81, with Kent cv. showing the highest values (Fig 1a). OPC showed L* values in the range of 51.2-69.93, with OS-346 cv. showing the highest values. The lower L* values of OPC in comparison to oat flours showed the shift of the product from lighter to darker color. The extraction procedure involving alkali extraction and acid precipitation produces permanently dark colored protein concentrates or isolates due to the oxidation of inherent phenolic compounds, which decreased biological and nutritional value and functional properties (Arntfield, 2004). The values of a* and b* for oat flours ranged from 1.11-2.12 and 11.28-15.92, respectively (Fig 1b). PLP-1cv. was significantly ($p<0.05$) different from other cultivars in its lowest L* and highest a* and b* values. OPC exhibited a higher a* values ranging from 3.79-5.28 as compared to corresponding flours. The b* values of the OPC in the range 10.41-18.05 were higher than the flours (Fig 1c). The highest value for a* for OPC was found in OS-7 cv. and highest value for b* was found in PLP-1 cv. This increase in a* and b* values shows the shift towards redness and yellowness of the OPC.

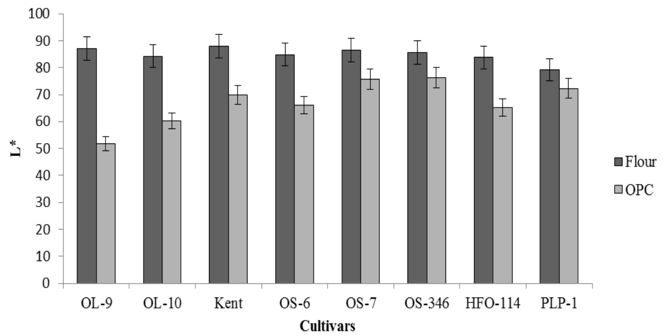

Figure 1a Hunter L* value of flour and protein concentrates from different oat cultivars

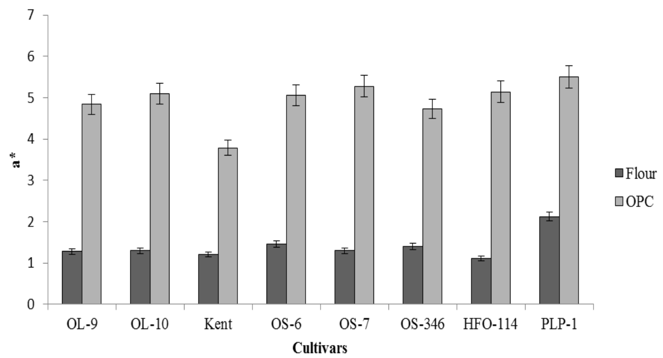

Figure 1b Hunter a* value of flour and protein concentrates from different oat cultivars

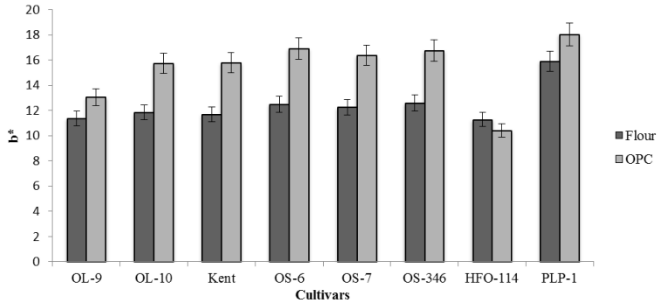

Figure 1c Hunter b* value of flour and protein concentrates from different oat cultivars

Functional properties

Functional properties of flours play a significant role in food industry as their successful performance as food ingredients depend upon their functional characteristics and sensory quality, which they impart to various products (Kaur & Singh, 2007). The functional properties of the flours are provided not only by the proteins, but also by the complex carbohydrates such as pectin and mucilage (Kaur & Singh, 2005).

Bulk density

Bulk density of oat flours and OPC from different oat cultivars is shown in Fig 2. Bulk density of flours and OPC in the present study was in the range of 0.511-0.610 g/ml and 0.745-0.947 g/ml, respectively. Bulk density of flours was observed to be lower than earlier reported values of 0.73-0.77 g/ml for oat flours (Sandhu *et al*., 2017). Bulk density of OPC was positively correlated to moisture, ash and negatively correlated to protein contents (Table 2)

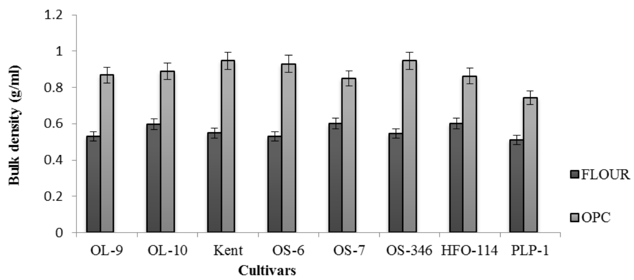

Figure 2 Bulk density of flour and protein concentrates from different oat cultivars

Foaming properties

Foaming capacity (FC) is the ability of substance in a solution to produce foam after shaking vigorously (Kaur and Singh, 2017). Foam capacity of oat flours showed very little variation among different cultivars varying between 10-13%. The foaming of flours is due to proteins, which form a continuous cohesive film around the air bubbles in the film (Njintang *et al*., 2001). The FC of OPC were significantly ($P<0.05$) higher (68-94%) in comparison to their counterpart flours (10-13%) (Table 3). FC of OPC showed a non-significant positive correlation to OAC and negative correlation with WAC (Table 3). The good foamability of flour makes it useful in food system that requires aeration for textural and leavening properties (Kaur and Sandhu, 2010). Similar results were also reported for hydrolysates obtained from oat bran (Guan *et al*., 2007). Foams are used to improve texture, consistency and appearance of foods (Akubor, 2007). In order for proteins to make foam, they must be soluble in the aqueous phase so that they can align themselves at the interface. They should have the ability to unfold to form cohesive layers of protein around air droplets as they are formed, possess sufficient viscosity and mechanical strength to prevent rupture and coalescence of air bubbles formed (Mirmorghtadaie, Kadivar & Sahedi, 2009). The decrease in foam volume with the passage of time (after 90 min) to determine foam stability (FS) was also studied (Table 3). The FS of OPC was significantly (P<0.05) lower than that of oat flours. FS after 90 min for OPC varied between 45-66% while that of oat flours were 92.03-94.68 %. Although the oat flours produced lower volume of foam with large, airy, bubbles but they did not collapse with time. The lower FS of OPC might be due to the lack of formation of a viscoelastic, thick and cohesive film around gas bubbles that prevented the foams from collapsing (Halling, 1981; Damodaran, 1990).

Table 3 Foaming properties of flours and protein concentrates from different oat cultivars

Parameters	Foaming capacity (%)		Foam stability (%) after 90 min	
Cultivars	**Flour**	**OPC**	**Flour**	**OPC**
OL-9	12±0.8	86±1.1	92.85	66
OL-10	10±0.2	93±1.9	92.03	65
KENT	12±0.3	94±0.9	94.38	64
OS-6	11±0.9	76±1.0	92.68	59
OS-7	13±1.0	68±0.8	94.68	45
OS-346	10±0.8	70±1.3	93.82	52
HFO-114	12±0.9	86±0.7	94.23	56
PLP-1	11±1.1	76±1.0	94.25	53

Values are an average of triplicate observations (± standard deviation).

Emulsifying properties

The Emulsion activity (EA) and Emulsion stability (ES) of oat flours and OPC from different cultivars are shown in Fig 3. EA of the flours varied between 7.49-15.70%. Kent cv. was significantly (p<0.05) different from other cultivars in its lowest EA but exhibited highest ES of 40.77%. EA of OPC was significantly (P<0.05) higher than those of flours with the highest value for OS-346 cv. (71%) (Fig 3a). Emulsion stability of OPC were significantly (P<0.05) higher than their counterpart flours (Fig 3b). EA of OPC showed a significant negative correlation with OAC (r = -0.729, P<0.05) (Table 2). Earlier studies showed that the emulsifying capacity of the oat protein isolates was about the same as that of soy protein isolate, whereas its emulsion was far more stable (Mohamed *et al*. 2009).

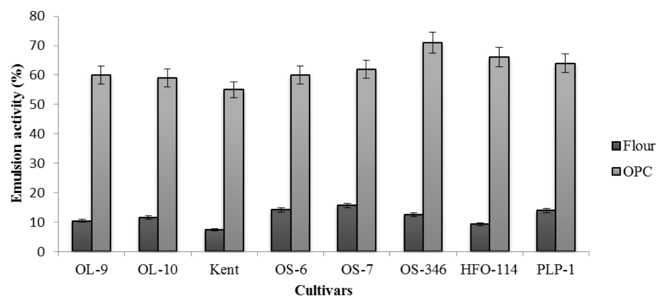

Figure 3a Emulsion activity (%) of flour and protein concentrates from different oat cultivars

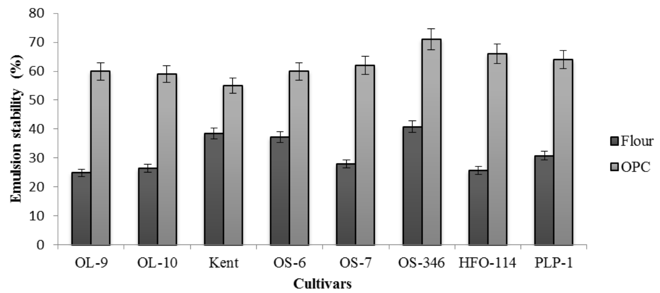

Figure 3b Emulsion stability (%) of flour and protein concentrates from different oat cultivars

Water and Oil absorption capacity

Oil absorption capacity (OAC) and water absorption capacity (WAC) directly influences the important functions of flours and protein in food systems. High water absorption of proteins helps to reduce moisture loss and maintains freshness and moist mouth feel of baked foods (Phongthais *et al*., 2017). WAC of proteins and flours from different oat cultivars is presented in Table 4. WAC of the flours was in the range of 4.00-7.24 g/g with the highest value being observed in OL-10 cv and lowest value being observed in HFO-114 cv. The variations in the WAC of the flours may be attributed to different protein structure and presence of different hydrophilic carbohydrates in the flour (Kaur, Sandhu & Singh, 2007). Flours with good water absorption may prove to be useful in products where good viscosity is required such as gravies and soups (Kaur, Kaushal & Sandhu, 2013). WAC of OPC was found to be significantly (P<0.05) higher than flour, ranging between 5.24-8.04 g/g, with the highest being observed in OL-9 cv. A significant positive correlation (r = 0.728, P<0.05) between protein content and WAC for OPC was observed (Table 2).

Oil absorption is important from an industrial view point since it reflects the emulsifying capacity (Kaur *et al*., 2007). High OAC is essential in the formulation of food systems such as sausages, or cake batters (Zhang *et al*., 2012). OAC of oat flours were significantly lower (3.15-6.28 g/g) in comparison to OPC (4.24-7.23 g/g). A positive correlation of OAC with WAC of OPC was observed. The highest values for OAC in flour and protein concentrates were observed in Kent cv. and OL-10 cv., respectively. The mechanism of OAC is attributed to the combination of physical entrapment of oil and the hydrophobicity of the material (He *et al*., 2013).

Table 4 Water and Oil absorption capacity of flours and protein concentrates from different oat cultivars

Parameters	Water absorption capacity (g/g)		Oil absorption capacity (g/g)	
Cultivars	**Flour**	**OPC**	**Flour**	**OPC**
OL-9	6.04±0.18	8.04±0.12	5.28±0.03	6.74±0.01
OL-10	7.24±0.07	7.33±0.22	5.97±0.08	7.23±0.04
KENT	6.95±0.08	7.19±0.20	6.28±0.03	6.42±0.08
OS-6	5.10±0.05	7.25±0.16	5.48±0.03	6.01±0.05
OS-7	6.49±0.01	7.94±0.30	5.32±0.01	6.61±0.04
OS-346	6.46±0.06	7.98±0.14	4.28±0.02	5.01±0.02
HFO-114	4.00±0.04	5.24±0.07	3.15±0.04	4.24±0.03
PLP-1	5.12±0.04	7.85±0.29	4.34±0.05	5.01±0.01

Values are an average of triplicate observations (± standard deviation).

CONCLUSION

This study carried out on comparison of functional and compositional properties of flours and protein concentrates from different oat cultivars revealed significant differences among them. Various cultivars differed significantly in their measured properties and the protein concentrates exhibited superior functional properties than their corresponding flours but were darker in color, which limits their use in dark colored food products as protein contributing ingredient. Pearson correlation analysis revealed several significant correlations between properties of oat protein concentrates.

Conflict of Interest: None.

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