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Characterization of Dietary fiber Extracted from different Oats (Avena sativa. L) cultivars with respect to Physicochemical, Functional and Phytochemicals

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Abstract: Five indigenous oat cultivars were grown under the standard agronomic practices. Dietary fiber from the selected oat cultivars was assessed for its various physico chemical, functional and phytochemical potential. The results showed that selected cultivars varied significantly ($P \leqslant 0.05$) for dietary fiber contents. SGD81 has shown the highest values for TDF (16.153±0.5273), IDF (11.23±0.38) and SDF (4.95±0.18). The lowest fraction of TDF were shown by the Avon (11.727±0.77), IDF by PD2LV65 (7.42±0.38) and SDF by PD2LV65 (3.87±0.31) respectively. Oat cultivar SGD81 showed maximum WS, WHC, and OHC due to its higher dietary fiber contents. Dietary fiber from selected oat cultivar SGD81 is also loaded with Phytochemicals including TPC, TFC, TFOC and anthocyanin. The selected cultivars varied significantly ($P \leqslant 0.05$) with respect to functional ingredients. The highest fraction of Phenolic acid was shown by the SGD81, SGD2011, PD2LV65, S2000 and Avon respectively. It is evident from the study that dietary fiber extracted from SGD81 is the best and economical alternative of expensive commercial fibers.
Keywords: physicochemical characterization, mineral profile, functional properties, phytochemical quantification, color tonality

1. Introduction:

Oat (Avena sativa. L) is a rabi crop that is now broadly cultivated in all areas of Pakistan for livestock rearing. Punjab province is the 2nd largest contributor of agriculture production having 16.68 Mha under agriculture production. Fodder crop occupies 2.05 Mha with a production of 45.97 metric tons. Oat is a major contributor among fodder crops and occupies about 35 percent (Ahmad et al. 2008).

In developing countries, value addition could be achieved through appropriate mechanization, post-harvest management and value addition. Exploration of indigenous economical resources for various bioactive is

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matter of higher interest for scientist in present scenario. Plant based diets are now preferred by the users for their potential health benefits (Alasmre & Alotaibi, 2020). Oat predominately cultivated as forage crop. Its grains are still unexplored for its value added benefits. Dietary fiber is an important functional ingredients found in cereal grains. Oat has a a maximum fraction of dietary fiber, so it has much room for its value addition.

Cereals are a rich source of dietary fiber. Urbanization and economic growth have increased the use of energy-dense food having more refined carbohydrates and low dietary fiber fraction. The use of refined and milled products from grain is the major cause of this negative transition. This resulted in reduced intake of DF, photochemical, and micronutrients which impart various physiological functions in the body. The cell wall from the outer part of the grain is loaded with these functional moieties. The structure and composition of cell wall rye and wheat are more similar than in the case of barley, corn, and oats (Bach Knudsen et al., 2017).

Dietary fiber consists of NSP, RS, oligosaccharides, and lignin. The main NSPs in cereals are arabinoxylan (AX), SDF, and cellulose. These are major compositors of the cell wall along with other polysaccharides, phenolic acid, and proteins (Izydorczyk, et al., 2008). The main NSP in cereals is AX followed by cellulose and β- glucan. Corn grain contains SDF concentrations up to 0.1%, in wheat and rye it ranged from (0.7-1.7%) and in oat it ranged from 2.8-4.1%. (Bach Knudsen, et al. 2017).

Dietary fiber is an NSP, not digestible by monogastric animals. Dietary fiber when ingested imparts various physiological and biological functions (Soliman, 2019). Dietary fiber has gained importance for its various potential health benefits. Dietary fiber was investigated for its quantification, physiological effect, and disease preventive and management perspectives including hypotensive, anti-obesity, hypocholesterolemic, and anti-diabetic having satiety function by delaying gastric emptying. A soluble fraction of dietary fiber produces a hypocholesterolemic effect by reducing total cholesterol and LDL (Dahl and Stewart, 2015). Dietary fiber plays a potential role in the management and prevention of various metabolic disorders such as hypertension, diabetes, and cardiovascular diseases (Ötles and Ozgoz, 2014). Dietary fiber in ample quantity in food regulates gut microbiota (Holscher, 2017, Carlson et al. 2018) and attenuates the insulin sensitivity of the cell. A low-fiber diet promotes the activity and growth of colonic mucus-degrading bacteria, and aggravates the risk of colitis by an enteric pathogen H. pylori (Desai et al., 2016).

"Inadequate" dietary fiber intake may lead to an increased incidence of metabolic disorders" (Das et al., 2020). Dietary fiber has a wide range of applications in the food, feed, and nutraceutical industry. Different processing operation alters the physicochemical properties of the dietary fiber; hence improving its biological activity (Dhingara et al, 2012). The physiological and biological potential of dietary fiber has gained the attention of researchers, processors, and consumers to be used as a food fortification ingredient. Dietary fiber fortification in food products lowers its energy value by substituting fat and sugar making the final product more healthy and attractive (Limidi et al., 2016; Rodriguez Garcia et al., 2013). This, when in a foodstuff also alters the physical, functional and structural properties of the final product such as WHC, perishability, OHC, ES, FC, hydration, viscosity, texture, and sensory characteristics. (Elleuch et al, 2011). Both fractions of dietary fiber including soluble and insoluble fractions have significant physiological functions. Physical properties including surface area and pore size define functional properties of the dietary fiber. The surface area enhances the absorption ability of dietary fiber in the gastrointestinal tract, hence produce health benefits. Phenolic contents are affected by the cultivars, biotic and abiotic factors including UV radiation, herbicide application, fertilizer application, physiological stress, temperature fluctuation, and low iron contents, etc. (Kovacova & MaliNoVá, 2007). Phenolic acid and its derivatives impart an anti-inflammatory role by inhibiting superoxide (Lee et al, 2005). Phenolic acids have ant proliferative action even in low concentration (Kampa et al., 2004).

Anthocyanin is a water-soluble reddish to purple flavonoids primarily located in the aleuron layer of the grain and is equipped with potential health benefits like antioxidant activity, anti-inflammatory, anticancer and hypoglycemic effects. These are widely used as colorants in various food products as functional ingredients. Potential health benefits associated with anthocyanin includes anti-oxidative, anti-carcinomic, hypoglycemic, anti-obesity, neuro generative, retinal regulation, hypolipedemic, hepatoprotective, and anti-aging (Zhu, 2018). It is evident from the study that dietary fiber from oat is an economical alternative of commercial expensive fibers, ultimately has wide range of application in various industries including baking, confectionary, beverages and nutraceutical.

2. Experimentation

2.1 Oat cultivars

Dietary fiber from indigenous oat cultivars (SGD81, SGD2011, PD2LV65, Avon and S2000) was analyzed for proximate, mineral profile, total phenol contents, total flavonoid contents, total flavones contents, radical scavengening activity, anthocyanin, total dietary fiber, soluble dietary fiber, insoluble dietary fiber and color tonality.

2.2 Functional properties of dietary fiber from different cultivars

2.3 WHC-Water- and OHC- Oil-holding capacity

WHC of dietary fiber was determined according as described by Raghavendra et al, (2004). OHC of dietary fiber was determined as per method described by Zhang et al, (2009).

2.4 WS- Water solubility

WS was determined according as described by Zhang et al, (2009). One gram of fiber sample was mixed with 50 mL of distilled water. 1 g of fiber was mixed with 50 mL of distilled water and placed it on magnetic stirrer for thirty min, after stirring sample was centrifuged for fifteen min at 4500 rpm. The residue was weighed and dried for constant weight. Water solubility was determined by following equation

WS (g/g) = Weight of dried sample / Weight of sample

2.5 Physico-chemical profiling of Oat Extract

Physico-chemical characterization of dietary fiber from five indigenous oat cultivars was done using the following protocols. All the results were recorded on a dry weight basis.

2.6 Proximate Composition

Moisture content of dietary fiber from selected oat cultivars was determined as narrated in method No. 44-15A AACC, (2000). Protein contents were determined by Kjeldahl's method as indicated AACC, (2000) method No. 46-30. Soxhelt extraction was done for fat determination of fiber as described in method No. 30-25 AACC, (2000). Fiber contents were quantified by acid digestion and neutralization by using alkali according to method No. 32-10. Ash content was estimated as given in method No. 0801. AOAC, (2000).

2.6.1 Mineral profiling of Oat Flour Extract

DF was analyzed for micronutrient including iron, zinc, copper and manganese using spectrophotometer (U-2800, Hitachi, and USA). All cultivar samples were ashed as per method No. 0801 AACC, (2000).

2.6.2 Dietary fiber contents of fiber extracted from different oat cultivars

Dietary fiber from selected oat cultivars was characterized for its TDF, IDF, and SDF fractions by gravimetric method; Megazyme Kit was used for determination of three fiber fractions in fiber sample extracted from different cultivars. TDF was determined according to AACC, (2000) method No.32-05. SDF was determined according to AACC, (2000) method No. 32-07 and IDF was determined according to AACC, (2000) Method No. 32-20.

2.6.3 Preparation of Extract

Extract of dietary fiber was prepared by dissolving fiber in methanol 1:10 ratio as narrated by Stankovic, (2011).

2.7 TPC-Total Phenolic Contents

TPC of dietary fiber were determined as described by Stankovic (2011) and singleton (1999).

2.8 TFC-Total Flavonoid Contents

TFC of dietary fiber were determined by method of Nongalleima et al. (2017).

2.9 TFoC-Total Flavonols Contents

Total Flavonols of dietary fiber from selected oat cultivars were determined by procedure described by Miliauskas et al, (2004). 0.5 mL of $AlCl3$ (20%) and1.5mL of $CH3COONa$ (10%) was added in 0.5 mL of the

fiber. Samples were kept in dark for 2.5 h and then absorbance was taken 440 nm by using Spectrophotometer. TFoC were quantified by following equation and were taken as mg of quercetin equivalent.
TFoC (mg of Quercetin equivalent) = (Sample absorbance +0.006)/0.091

2.10 Total Anthocyanin

Total anthocyanin of dietary fiber from selected oat cultivars was determined as by described Lee et al. (2005). 0.4M solution of CH3COONa (pH 4) and 0.025M solution of KCl (pH 1) was prepared. 200 micro liter of the extract was taken into the glass cuvette and 2 mL of both reagents was added in separate cuvette. Absorbance of sample was taken by spectrophotometer at 510 and 700 nm respectively. The result was expressed as mg of Cyanidine 3-glucosidekg-1 of fiber (mg C3Gkg-1).

2.11 DPPH Radical Scavenging Activity

DPPH of the dietary fiber from selected oat cultivars was determined as described by the Afify et al. (2012).

2.12 Determination of Phenolic acids

HPLC for quantification of Phenolic acids was determined as described by Peanparkdee et al, (2017).

2.13 Color tonality of Oat Fiber

Color tonality of dietary fiber from selected oat cultivars was determined by the method of Rocha et al. (2003) with the use of Konica MINOLTA Chroma meter-410 (sensing Inc., Tokyo, Japan), with reference to illuminant D65 and a visual angle of 10°, using the CIE Lab system.

2.14 Statistical Analysis

The data was analyzed through one way ANOVA using Statistix 8.1 software. Significantly different treatment means were separated through LSD ($P \leqslant 0.05$). (Steel and Torri, 1997). The graphical presentation was done by using Origin Prom 2016.

3. Results and Discussion

3.1 Functional properties of fiber extracted from different oat cultivars

Hydrocolloid water absorption, solubility and oil holding capacity is a potential features define its ultimate industrial application. The results of WS, WHC and OHC are shown in table 2. All the cultivars vary significantly ($p \leqslant 0.05$) with respect to WS, WHC and OHC. The highest value for WS (1.24±0.06), WHC (1.46±0.051) and OHC (1.97±0.10) was shown by the cultivar SGD81 due to highest fraction of dietary fiber. The lowest values for WS (0.86±0.06bc), WHC (1.10±0.10) and OHC (0.96±0.12) were shown by the S2000. Water holding capacity of the dietary fiber attenuates the viscosity of the mix and ultimately prevents final products from shrinkage (Elleuch et al, 2010). Dietary fiber fortification in food especially high fat products and emulsion enhances oil holding capacity of the mix, hence stabilizes the end product (Lv, Liu, Zhang, & Wang, 2017). Hyrdophobic properties, surface area and charge density of particles define its OHC (Chang et al, 2011).

3.2 Proximate of fiber extracted from different oat cultivars

The proximate composition of the fiber is shown in figure 1. The highest fat, moisture, ash, fiber and NFE were shown by PD2LV65 (1.34±0.21), Avon (5.31±0.25, SGD81 (83.20±0.446), PD2LV65 (35.04±0.32) and S2000 (2.93±.55) respectively. The lowest fraction of fat, moisture, ash, fiber and NFE were shown by the SGD81 (1.03±0.03), Avon (3.42±0.40), SGD81 (11.85±0.17), PD2Lv65 (59.32±0.44) and SGD81 (0.78±0.72) respectively. The cultivars varied significantly ($\leqslant 0.05$) for moisture, ash and fiber contents while non-significant ($\leqslant 0.05$) difference existed among the cultivars for NFE and fat contents. Protein contents were not detected in all samples. In fiber it is considered as impurity and removed by manipulation of Sonication and pH. Proximate analysis showed that the explored cultivars are also good source of mineral along with fiber contents.

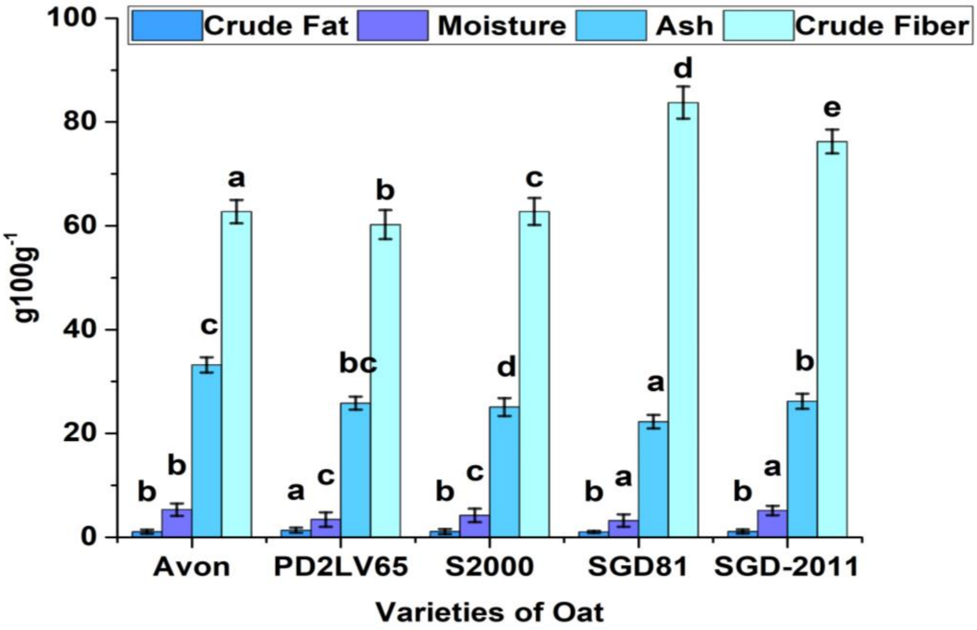

Figure 1. Proximate of the extracted fiber from different oat cultivars

3.2.1 Mineral profile of fiber extracted from different oat cultivars

The results of the mineral profile of the fiber are shown in the figure2. The highest fraction of Cu, Fe, Mn and Zn were reported in SGD2011 (6.92±0.17), SGD2011 (218.84±0.20), PD2LV65 (39.66±0.51) and Avon (37.08±0.20) respectively. Avon was found the lowest in all micronutrients fractions including Cu (0.99±0.21), Fe (8.13± 0.23), Mn (1.29±0.35) and Zn (37.08± 0.20) respectively. All the cultivars are highly significant (≤0.05) with respect to these micronutrients. Iron and zinc are among the most important micronutrients which play important role in regulation of various physiological and biochemical processes. Exploration of economical sources of these moieties will be a step forward in overcoming their deficiency.

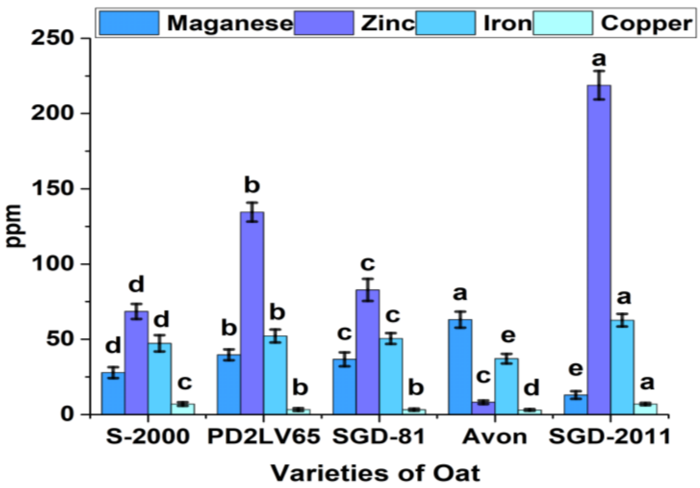

Figure 2. Mineral profile of the extracted fiber from different oat cultiv

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Table 1. Phenolic acid contents of extracted fiber mg/100g on DW

Oat cultivars	Vanillic acid mg100g-1	Gallic cid mg100g-1	Caffeic acid mg100g-1	4-Hydroxyphenylacetic acid mg100g-1	Protocatechuic acid mg100g-1	Ferulic acid mg100g-1	p-Coumaric cid mg100g-1	Cinnamic cid mg100g-1
Avon	2.99±0.11b	15.03±0.43e	13.18±0.16b	0.49±0.06d	42.26±0.16d	144.77± 0.13c	2.24±0.15c	1.90±0.12c
PD2LV65	4.31±0.25a	16.32±0.28b	14.33±0.22a	0.60±0.02b	44.71±0.07c	145.31±0.25b	3.24±0.12ab	2.03±0.21c
S2000	3.78±1.14b	15.41±0.13d	15.54±0.35b	0.48±0.04c	43.56±0.08a	143.95±0.18a	4.26±0.09bc	2.40±0.17b
SGD81	5.19±0.26a	15.94±0.31c	16.13±0.13bc	0.36±0.03a	45.18±0.07b	146.75±0.19a	4.56±0.33a	3.38±0.27a
SGD2011	3.24±0.13a	16.33±0.07a	16.68±0.20c	0.41±0.03b	44.84±0.06e	147.13±0.15b	3.40±0.15c	1.35±0.13d
LSD(p≤0.05)	0.508	0.42	0.07	0.18	0.347	0.35	0.98	0.35

V1= Avon V2=S-2000 V3= PD_2LV_{65} V4=SGD-81 V5=SGD-2011.

Table 2 Functional properties of dietary fiber from selected oat cultivars

Varieties	WS g/g1	WHC g/g1	OHC g/g
V1	0.96±0.09bc	1.34±0.06ab	1.67±0.07b
V2	0.86±0.06bc	1.10±0.10ab	0.96±0.12b
V3	0.92±0.06c	1.33±0.05c	1.63±0.04c
V4	1±0.06a	1.23±0.08a	1.56±0.15a
V5	1.24±0.06b	1.46±0.051bc	1.97±0.10b
LSD (p≤0.05)	**0.19**	**0.13**	**0.12**

V1= Avon V2=S-2000 V3= PD_2LV_{65} V4=SGD-81 V5=SGD-2011.

3.2.2 Dietary fiber contents of fiber extracted from different oat cultivars

The results regarding Total, Insoluble and soluble dietary fiber were shown in figure 3. All the cultivars vary significantly (≤0.05) with respect to all dietary fiber fractions including TDF, IDF and SDF. SGD81 has shown the highest values for TDF (16.153±0.5273), IDF (11.23±0.38) and SDF (4.95±0.18). The lowest fraction of TDF were shown by the Avon (11.727±0.77), IDF by PD2LV65 (7.42±0.38) and SDF by PD2LV65 (3.87±0.31) respectively. Chawla and Patel, (2010) reported that TDF, IDF and SDF ranges from 11.8 to 16.4%, 6.5% to 7.0% and 5.3% to 8.7%, respectively. The difference in Insoluble dietary fiber fractions may be due to cultivars, climate, soil and agronomic practices. (Manthay, 1999) studied the oat genotype for its soluble and insoluble dietary fiber fractions and reported that 3.9–5.2% and 6.0–7.1% respectively.

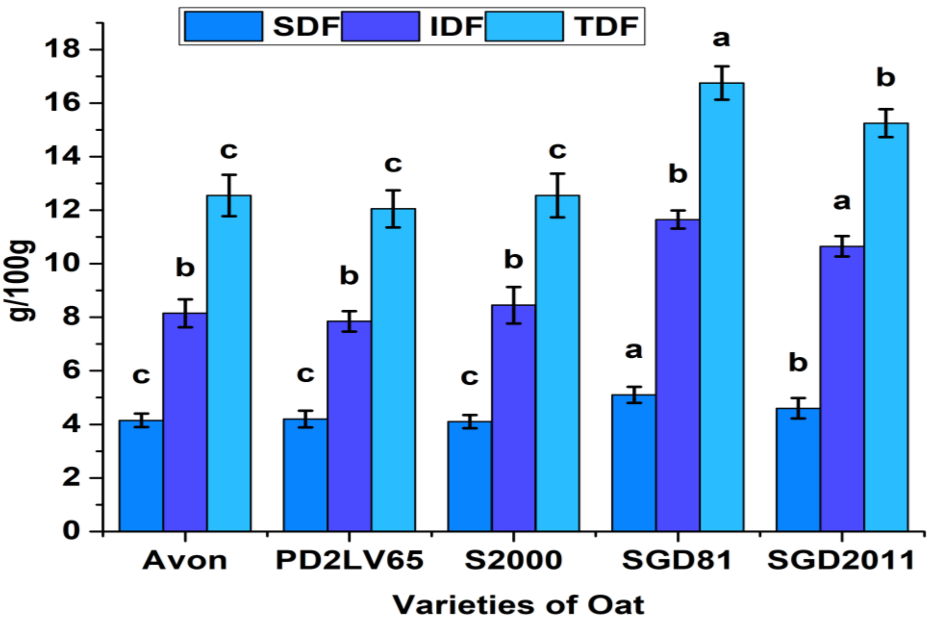

Figure 3. Total dietary fiber, Insoluble dietary fiber and soluble dietary fiber contents of the extracted fiber from different oat cultivars

3.2.3 TPC, TFC, TFoC, DPPH and Anthocyanin of fiber extracted from different oat cultivars

The result of TPC, TFC, TFoC and anthocyanin contents of extracted fiber were shown in fig 4. The highest value of TPC, TFC, TFoC, DPPH and anthocyanin was reported in SGD81 (125.78±0.2150, SGD81 (1270.2±0.2401), SGD2011 (714.21±0.3201), SGD81 (58.700±0.2000) and SGD2011 (2.9800±0.0800) respectively. The least value of these were reported in S2000 (43.253±0.1450), S2000 (900.16±0.3650), PD2LV65 (558.84± 0.2103), SGD2011 (29.213±0.2750) and S2000 (0.6833±0.065). All the cultivars are highly significant ($p \leq 0.05$) with respect to TPC, TFC, TFoC, DPPH and anthocyanin contents. (Ibrahim et al, 2020) reported the TPC (36.07 to 101.56 mg100 g-1), TFC (754.16 to 1147.08 mg100 g-1), TFoC (548.33 to 697.5 mg100 g-1), DPPH (24.33 to55.88%) and anthocyanin contents (0.5 to 2.87 mg of C3G kg-1) respectively. Difference in cited study and reported study value is due to Sonication. This effectively released the bioactive from flour. Oat flour was sonicated which resulted in excessive release of these bioactive by acoustic effect. It is evident from the study that mechanical abrasion is an effective tool to maximize the bioactive recovery as compared to simple extraction methodology.

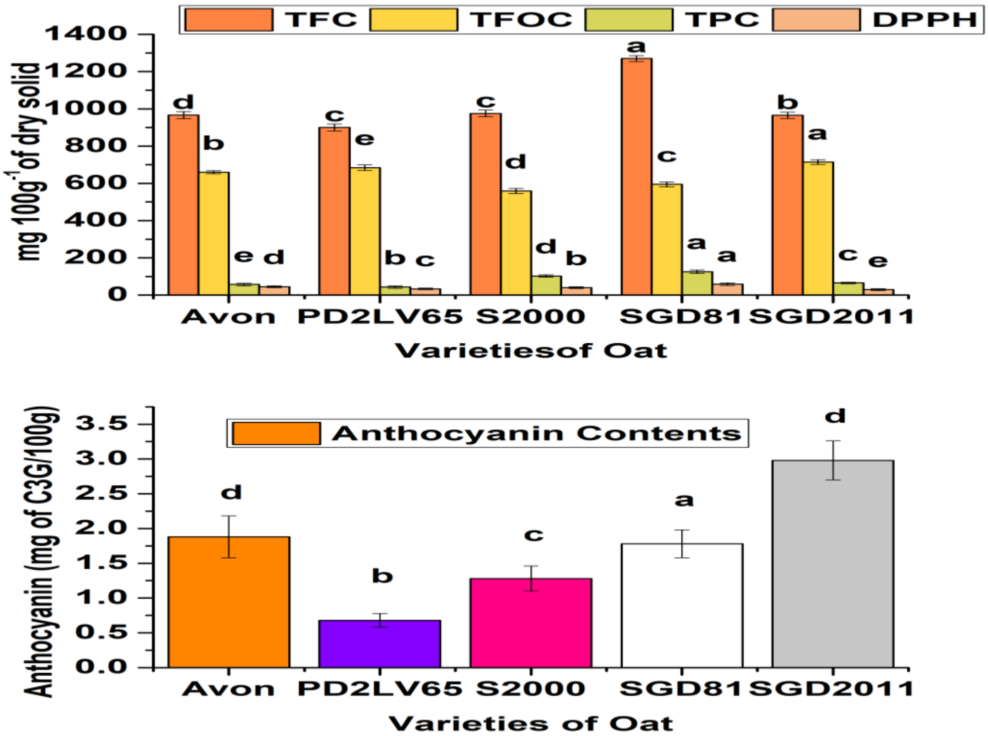

Figure 4. Phytochemical quantification of the extracted fiber from different oat cultivars

3.2.4 Phenolic acids of fiber extracted from different oat cultivars

Results regarding phenolic acid contents of different oat cultivars are shown in table 1. Result indicated that there is significant difference among the varieties ($p \leqslant 0.05$). The highest contents regarding vanillic, Gallic, cafeic, 4-hydroxyphenyl acetic acid, Proto catechoic acid, Ferulic acid, p-cumaric cid and cinamic acid were shown by SGD81 (5.19±0.26), SGD2011(16.33±0.07), SGD2011(16.68±0.20), PD2LV65(0.60±0.02), SGD81(45.18±0.07), SGD2011(147.13±0.15), SGD81(4.56±0.33) and SGD81(3.38±0.27) respectively. The lowest fraction of these acids were shown by the Avon (2.99±0.11), Avon (15.03±0.43), Avon (13.18±0.16), SGD81 (0.36±0.03), Avon (42.26±0.16), PD2LV65 (143.95±0.18), Avon (2.24±0.15) and SGD2011 (1.35±0.13) respectively. The results showed fiber from SGD 81and SGD 2011 has more phenolics acids as compared with all others, hence has potential to be used as functional ingredients. The results are consistent with the finding of Kilci & Gocmen, (2014); Soycan et al, (2019) and Skrajda-Brdak et al, (2019). Twenty one genotypes of oat were studied for ferulic and coumaric acids. The results showed that p-cumaric acid was higher than that of ferulic acid. Ferulic acid content varied in the range from 16.50 mg/100 g to 149.36 mg/100 g of grain. P-Coumaric acid ranged between 8.05 mg/100 g to 210.27 mg/100 g of grain.

3.2.5 Color tonality of Oat Fiber of fiber extracted from different oat cultivars

Color plays potential role in acceptability of food stuff by the processor, retailer and consumer as well. The extracted fiber from all cultivars was checked for its color tonality to have better acceptability of all the stakeholders. Fiber from all cultivars varied significantly ($p \leqslant 0.05$) for its L*, a*, b*, c*, h* coordinated. The results of the color tonality are shown in figure 5. The highest L* value was shown by the fiber from SGD2011 (80.4±0.23), Avon showed the highest a* value (3.25±0.03). The highest b* value was shown by the SGD81 (18.5±0.22). SGD 81 shown the highest c* value (18.653±0.2754) and the highest h* value also accounted by the SGD2011 (85.137±0.2371). The lowest count for L*, a*, b*, c* and h*was shown by Avon (70.18±0.22), SGD2011 (1.36±0.05), SGD2011 (15.98±0.23), SGD2011 (16.07±0.23) and Avon (79.59±0.09). (Hussein et al, 2011) reported that fiber addition impart the dark color on the finished product. (Pasha et al, 2011) also reported that fiber fortification of food impart potential effect on the finished food product and determines its acceptability.

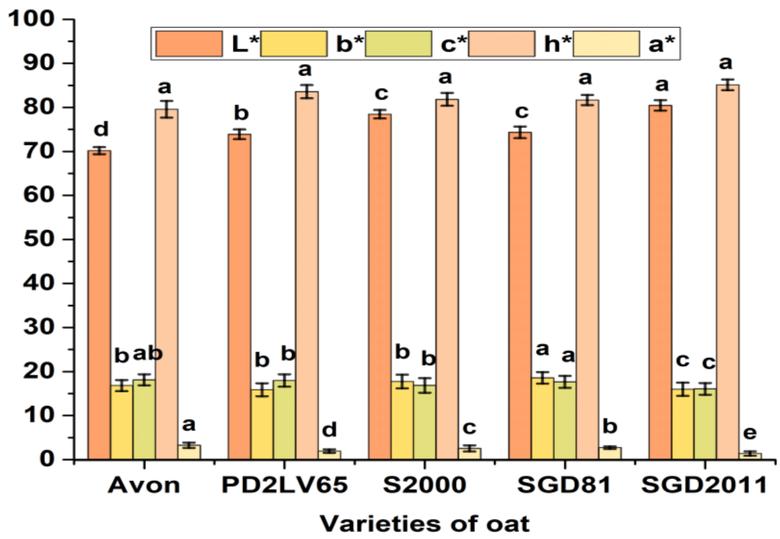

Figure 5. Color tonality of the extracted fiber from different oat cultivars

4. Conclusion

Fiber extracted by Sonication is characterized for its functional and nutraceuticals potential. Among the five selected cultivars SGD81 had maximum fiber contents and also equipped with plethora of potential bioactive. SGD81 has lot of potential for value addition as functional crop instead of forage crop. This will also provide economical fiber source for the various industrial application. Bioactive from other cultivars may be purified for use in nutraceuticals products.

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Conflict of Interest

There is no conflict of interest.

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