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SCREENING OF PAKISTANI SESAME CULTIVARS FOR NUTRITIVE VALUE AND BIOACTIVE COMPONENTS

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Protein energy malnutrition (PEM) has emerged a key health problem in Pakistan. It mostly affects the well-being of pregnant women and young children. Almost 1/3 children under the age of five years are underweight, and rest are affected by stunting and wasting. Hence, there is a great need to explore the nutritional attributes and health benefits of locally grown crops for alleviating malnutrition among the masses. In this study, the nutritive and therapeutic potential of eight Pakistani sesame cultivars including four white (TH-6, TS-5, TS-3, Til-89) and four black (S-122, S-117, S-131, Latifi) were assessed for their proximate composition, mineral profile, amino acids composition, antioxidants potential and functional components. The proximate and mineral composition of sesame flours of white and black cultivars revealed varying degree of moisture, protein, crude fat, crude fiber, ash and nitrogen free extract. Regarding antioxidant potential and bioactive components, total phenolics, sesamin, sesamol and sesamolin were ranged from 1.56±0.025 to 7.32±0.219 mg GAE/g, 1521.00±27.30 to 3996.00±129.90 ppm, 3121.00±86.60 to 4303.00±133.37 ppm and 1532.33±31.89 to 3564.00±65.82 ppm, respectively. Among the different cultivars, the maximum value of sesamin was observed in TH-6, whereas sesamol and sesamolin concentrations were higher in S-122 (black cultivar). It is obvious from the results that sesamin and sesamol contents were higher in white sesame cultivars whereas sesamolin was more in black cultivars. In crux, indigenously grown sesame cultivars can contribute good quality protein as well as functional ingredients like phenolics, sesamin, sesamol and sesamolin which have the potential to alleviate PEM as well as numerous allied health disorders especially in developing countries.

Keywords: Protein energy malnutrition, antioxidants, *Sesamum indicum*, sesamin, sesamol, sesamolin.

INTRODUCTION

The protein energy malnutrition and micronutrient deficiencies are escalating in individuals of under-developed and developing economies mainly due to poverty and food insecurity. The children are severely affected by stunting, wasting, under-weight, Marasmus and Kwashiorkor due to consumption of monotonous diets and reliance on poor sources of protein. Consequently, edema, wasting of body tissues, subcutaneous and muscular fat, poor health and inadequate mental and physical activities are significant among the children (Shakeel *et al*., 2009). In Pakistan, nutrition surveys and food balance sheets have shown existence of varying degrees of nutrient deficiencies just because of low quantity as well as quality of protein especially in vulnerable groups of the population (GOP, 2011). School aged children are mainly affected by wasting and stunting. These circumstances demand dietary interventions to reduce the deficiencies and develop their health status.

Sesame (*Sesamum indicum* L.), also named as *gingely, sim-sim, till* and beniseed, belong to family *Pedaliaceae*. It is commonly cultivated in tropical and subtropical regions of Asia and ranked at 9th position globally among commercially grown oilseeds. The production of sesame at global level is about 3.66 million tonnes mainly shared by the Asian and African countries (Sarkis *et al*., 2014). China, India, Myanmar and Sudan are the major growers, collectively producing about 60% of the world's total production. The chemical composition of sesame seed revealed presence of oil (50%), protein (25%), water (5.8%), carbohydrates (10-15%), ash (4.7-5.6%) and fiber (3.2%). Moreover, it is rich source of minerals and antioxidants like vitamin E, phosphorus and calcium (Lee *et al*., 2005). It has balanced proportion of essential as well as non-essential amino acids, with high net protein utilization (54%) and chemical score (62%) (Alobo, 2006). These features make sesame a potential applicant for supplementation in variety of food products to increase their protein, amino acid profile and quality as well. Sesame seed is also termed as "queen of the oil seed crops" due to the presence of maximum oil content (Gandhi and Taimini, 2009). Oilseeds and processed legumes have great potential as snack food for school going children (Estevez *et al*., 2000). We hypothesized that sesame flour being rich in protein, dietary fiber, vitamins and minerals can be used for the production of innovative and economical value-added products. The current study was undertaken to screen out Pakistani sesame cultivars for their nutritive and functional perspectives in food applications. The information derived will be helpful in accelerating use of indigenous sesame cultivars into value-added products for the masses.

MATERIALS AND METHODS

***Procurement and Preparation of Raw Materials*:** Seeds of Pakistani white (TH-6, TS-3, TS-5 and Til-89) and black sesame cultivars (S-122, S-117, S-131 and Latifi) were procured from Oil Seed Section, Ayub Agricultural Research Institute (AARI), Faisalabad and Agriculture Research Institute (ARI), Tandojam, Pakistan. Manual cleaning of sesame seeds was done to remove the physical impurities followed by oil extraction through Manual Oil Press (Carver Inc., Wabash, IN, USA). Subsequently, sesame cake samples were ground to get sesame cake flour. For further analysis and utilization, all these samples were packed in polyethylene zip bags and stored at 25ºC.

***Analysis of Raw Materials*:** All sesame flour samples were analyzed for proximate composition, minerals, amino acids, antioxidant potential and functional components using their respective methods. The brief explanation of each is as under:

***Proximate Composition*:** Defatted sesame flour samples were analyzed for moisture (AACC Method No. 46-30), crude protein (Method No. 46-10), crude fat (Method No. 30-25), crude fiber (Method No. 32-10), ash (Method No. 08-01) and nitrogen free extract (NFE) according to methods described in AACC (2000).

***Mineral Contents*:** Sesame flour samples were probed for mineral profile after wet digestion (AOAC Method No. 975.03B). Flame Photometer-410 (Sherwood Scientific Ltd., Cambridge, UK) was used to examine sodium (Na) and potassium (K) contents whereas Atomic Absorption Spectrophotometer (Varian AA240, Varian Medical Systems, Australasia Ltd., Belrose, Australia) was used to analyze calcium (Ca), magnesium (Mg), phosphorus (P), iron (Fe) and zinc (Zn) content. First digestion of sample (0.5g dried) was done at 60-70°C for 20min on hot plate using HNO_3 (10mL) in a 100mL conical flask followed by second digestion with $HClO_4$ (5mL) at 190°C till the contents in the flask become transparent. Digested sample was diluted in 100mL volumetric flask using deionized water and then filtration was performed. Samples of known strengths were run to measure the standard curve (AOAC, 2016).

***Amino Acid Profile*:** The amino acids profile of sesame flours was analyzed by using ion-exchange chromatography with automatic Amino Acid Analyzer, (Hitachi L8500, Tokyo, Japan), following the method described by Walsh and Brown (2000). The defatted ground sample (30mg) was taken along with 5µmol norleucine and 5mL of 6M HCl into glass ampoules. These were further emptied by using liquid N_2, vacuum-packed and dried in an oven (110°C) for one day. After cooling and filtration, samples were dried under vacuum in rotary evaporator (40ºC). For neutral and acidic amino acids, 5µL of dilution was made with acetate buffer having pH 2.2 whereas for basic amino acids, 10µL dilution was made. Subsequently these dilutions were spread over the cassette of amino acid analyzer. The complete sequence of amino acids was quantified by comparing the peak of each amino acid with its standard.

***Total Phenolic Contents*:** Total phenolics of sesame flour samples were analyzed through UV/Vis spectrophotometer (VIS-1100 Spectrophotometer, Biotechnology Medical Services, Medifield, MA, USA). The sesame flour extract (125µL) obtained by adding/mixing sesame seed flour (5g) with 80:20 (v/v) of ethanol/distilled water was combined with Folin-Ciocalteau (FC) reagent (125µL) by adding distilled water (500µL) and endorsed to stand for 5min at 22°C. 4.5mL solution of sodium bicarbonate (7%) was poured in the mixture after following the resting duration. The absorbance of each sample was observed at 765nm after 90min against the control. The unit used to express the total polyphenols was Gallic acid equivalent (mg gallic acid/g) (McDonald *et al*., 2001).

***Free Radical Scavenging Ability*:** Free radical scavenging activity assay was carried out by following the method of Lee *et al*. (2006) and Muller *et al*. (2011). For this purpose, sample extract (1mL), 0.5mL of 0.3M Methanolic 1,1-diphenyl-picrylhydrazyl (DPPH) solution and standard or blank (ethanol/n-hexane 1 + 1, v/v) were shaken at 25±1°C, 1000rpm in a thermo shaker. The absorbance was taken at 540 nm after 15 min and inhibition was measured by the given formula:

Reduction of absorbance (%) = [(AB - AA) / AB] × 100

Where; AB = absorbance of blank sample (t = 0 min); AA = absorbance of tested extract solution (t = 15 min)

***Antioxidant Activity (β-carotene bleaching method)*:** Coupled oxidation of linoleic acid and beta-carotene was assessed for total antioxidant activity of the sesame flour samples (Kenari *et al.*, 2013). 2mg of β-carotene was dissolved in chloroform (20mL) and Tween-20 (400mg). After chloroform removal, emulsion (3mL) was added in prepared sample (0.10mL). It was further placed in a water bath (120min). The oxidation of β-carotene was determined at absorbance of 470nm.

***Functional Components*:** Samples were extracted according to the modified methods of Rangkadilok *et al*. (2010) and Amber *et al*. (2012). Ground sample (2g) was passed through a screen (0.25mm) and 200mg weighed flour was shifted into a cuvette (10mL) having 80% ethanol (5mL). Centrifugation of samples (vortex-mixed) was done at 17500g for 5min. In volumetric flask, the supernatant was transferred, and the residue was extracted again with 80% ethanol (5mL). Filtration of all extracted solutions was done through filter of nylon membrane (0.45µm pore size) before performing HPLC analysis. Sesame cake flours functional components like sesamin, sesamolin and sesamol were examined according to procedures described by Shahidi *et al*. (2006) and Kaya *et al*. (2012) by using high-performance liquid chromatography (Perkin Elmer Series 200 HPLC Systems, Perkin Elmer Life and Analytical Sciences, Shelton, USA). A reversed-phase C_{18} column (5µm particle sizes, 150 × 4mm) was used for amino acid analysis. Quantification and evaluation was performed on Total Chrome Software. The mobile phase *i.e*. methanol/deionized water (80:20%) was passed at a rate of 0.8mL/minute with constant temperature of 40°C. The injection volume was 10µl; elution rate was 2.0mL/min. For the determination of compounds in the samples, the working standard solutions (HPLC grade solvents *i.e*. MeOH were purchased from the Merck (Merck KGaA, Darmstadt, Germany) and sesamol, sesamin and sesamolin standards from Sigma-Aldrich (Sigma-Aldrich, Tokyo, Japan) were analyzed at 290nm with the samples. Peak areas and retention time of both samples as well as sesamol, sesamin and sesamolin standards (5, 10 and 20minutes) were used to quantify the respective component.

***Statistical Analysis*:** The collected data obtained from all parameters in triplicates were statistically analyzed using Statistical Package (SPSS). Level of significance was evaluated by analysis of variance techniques (ANOVA). Means were compared through Tukey's honest significance test (Steel *et al.*, 1997).

RESULTS

***Proximate Composition*:** Means for moisture contents of different sesame cultivars (Table 1) were ranged from 7.23±0.32 to 11.82±0.38%. Among the different cultivars, the highest moisture (11.82±0.38%) was observed in Latifi followed by S-131 (11.32±0.14%) and S-117 (10.87±0.34%). The lowest moisture (7.23±0.32%) was in TH-6 followed by TS-5 (8.19±0.17%). Comparatively, the moisture content was low in white cultivars than that of black ones. Means for crude protein content (Table 1) of sesame cultivars revealed values ranged from 33.59±0.08 to 38.97±0.28%. The highest protein (38.97±0.28%) was observed in TH-6 followed by TS-5 (38.21±0.40%), TS-3 (37.15±0.50%) and Til-89 (36.04±0.13%). The lowest protein content (33.59±0.08%) was found in Latifi followed by S-131 (34.21±0.18%). Statistical results indicated that protein contents varied significantly among different sesame cultivars. White varieties recorded more protein as compared to black counterparts. Means for crude fat content (Table 1) showed values ranged from 10.25±0.52 to 17.23±0.29%. Among the white and black cultivars, the highest fat content (17.23±0.29%) was observed in S-122 followed by S-117 (16.75±0.39%), whereas the lowest fat (10.25±0.52%) was found in Til-89 followed byTS-3 (11.15±0.38%). Results for fat content in white sesame cultivars revealed significant differences from those in black cultivars. Mean crude fiber content (Table 1) ranged from 3.62±0.05 to 8.77±0.14%. Among the different cultivars, the highest fiber content (8.77±0.14%) was observed in S-122 followed by S-117 (8.18±0.23%) and S-131 (7.80±0.20%). Likewise, the lowest fiber content (3.62±0.05%) was in Til-89 followed by TS-3 (4.23±0.12%). It is obvious from the results that white sesame contains significantly less fiber content than black ones. Mean ash content (Table 1) of sesame cultivars ranged between 4.73±0.11 to 9.93±0.18%. The highest ash content (9.93±0.18%) was noted in TH-6 followed by TS-5 (9.15±0.22%), and TS-3 (8.65±0.28%). The lowest ash content (4.73±0.11%) was noticed in Latifi. Overall, ash content in white sesame cultivar flour showed significant differences from black sesame cultivars. Mean NFE content (Table 1) showed values ranged from 22.75±0.52 to 32.42±1.45%. Regarding white and black varieties, the highest NFE content was observed in Til-89 (32.42±1.45%) followed by TS-3 (29.94±0.71%), whereas the lowest NFE was found in S-122 (22.75±0.52%) followed by S-117 (23.79±0.18%). The variations in the proximate composition of white and black sesame cultivars might be due to genetic variations, different climatic conditions, milling actions, and agronomic practices during the cropping season. Sesame seed contains high quality protein due to presence of all essential amino acids in balanced proportions. Selected cultivars showed significant differences for protein contents due to genetic changes among cultivars, fertilizer level, environmental aspects, location of growing areas, conditions and cropping seasons. In a study, sesame flour supplemented

Table 1. Proximate composition (%) of sesame flours of different cultivars.

Variety	Moisture	Crude Protein	Crude Fat	Crude Fiber	Ash	NFE
TH-6	7.23±0.32e	38.97±0.28a	12.83±0.33b	5.84±0.16d	9.93±0.18a	25.30±0.36cde
TS-5	8.19±0.17de	38.21±0.40ab	11.90±0.26bc	5.09±0.11d	9.15±0.22ab	27.79±0.51bc
TS-3	8.72±0.25d	37.15±0.50bc	11.15±0.38cd	4.23±0.12e	8.65±0.28bc	29.94±0.71ab
Til-89	9.32±0.19cd	36.04±0.13cd	10.25±0.52d	3.62±0.05e	7.66±0.18c	32.42±1.45a
S-122	10.16±0.14bc	35.33±0.38de	17.23±0.29a	8.77±0.14a	6.33±0.18d	22.75±0.52e
S-117	10.87±0.34ab	34.74±0.51def	16.75±0.39a	8.18±0.23ab	5.70±0.27de	23.79±0.18de
S-131	11.32±0.14ab	34.21±0.18ef	16.20±0.18a	7.80±0.20bc	5.16±0.17e	25.33±0.56cde
Latifi	11.82±0.38a	33.59±0.08f	15.83±0.11a	7.25±0.25c	4.73±0.11e	26.67±0.69bcd

White sesame cultivars: TH-6, TS-3, TS-5 and Til-89; Black sesame cultivars: S-122, S-117, S-131 and Latifi; Means having same letters in a column are statistically non-significant (P>0.05); Means ± S.D high protein and energy food bars were developed. The results showed that defatted sesame flour of white sesame cultivar (TH-6) contains 2.19% moisture, 51.5% crude protein, 1.49% crude fat, 3.46% crude fiber, 6.15% ash and 45.56% nitrogen free extract (Abbas *et al*., 2016). According to USDA National Nutrient Database for Standard Reference Library, 100 g edible portion of dry decorticated and partially defatted sesame flour contains water (6.61 g), protein (40.32 g), fat (11.89 g), carbohydrate (35.14 g), and zero cholesterol (USDA, 2018). In another study, sesame protein concentrates were developed from sesame meals and their proximate composition revealed varying amounts of moisture content (6.8%), crude protein (36.24%), crude fiber (3.46%), ash (6.15%), crude fat (9.5%) and NFE (37.85%) (Onsaard *et al*., 2010).

Mineral contents**:** Results for sodium (Na) content showed values ranged from 29.24±0.82 to 60.12±0.89mg/100g (Table 2). Among the different cultivars, the highest sodium content was observed in TH-6 (60.12±0.89mg/100g) followed by TS-5 (58.77±1.07mg/100g), TS-3 (56.32±0.73mg/100g) and Til-89 (54.12±1.21mg/100g).The lowest sodium content (29.24±0.82mg/100g) was noted in Latifi followed by S-131 (33.61±0.97mg/100g). Potassium (K) content (Table 2) showed values ranged from 52.78±1.20 to 81.79±1.62mg/100g. Among the different cultivars, S-122 showed the highest potassium content (81.79±1.62mg/100g) followed by S-117 (78.23±1.86mg/100g), S-131 (73.58±1.00mg/100g) and (70.45±1.89mg/100g) in Latifi. The lowest potassium content (52.78±1.20mg/100g) was observed in Til-89 followed by TS-3 (57.43±1.61mg/100g). Mean values for calcium (Ca) content (Table 2) were between 46.82±0.55 and 80.21±1.90 mg/100g. Among the different cultivars, S-122 (80.21±1.90mg/100g) showed the highest calcium content followed by S-117 (76.21±1.39mg/100g) and S-131 (73.32±1.28mg/100g). The lowest calcium content (46.82±0.55mg/100g)was found in Til-89 followed by TS-3 (52.56±0.89mg/100g).Results for magnesium (Mg) content (Table 2) showed values ranged from 33.45±0.95 to 59.23±1.48 mg/100g. Among the different cultivars, the highest magnesium content was observed in TH-6 (59.23±1.48mg/100g) followed by TS-5 (56.87±1.95mg/100g), TS-3 (53.29±0.77mg/100g) and Til-89 (50.46±1.99mg/100g). The lowest magnesium content was found in Latifi (33.45±0.95mg/100g) followed by S-131 (37.23±0.77mg/100g). Zinc (Zn) content in white and black cultivars (Table 2) varied from 7.23±0.16 to 19.53±0.36 mg/100g. Among the different cultivars, the highest zinc content (19.53±0.36mg/100g) was found in S-122 followed by S-117 (17.06±0.61mg/100g). The lowest zinc content (7.23±0.16 mg/100g) was observed in Til-89 followed by TS-3 (9.25±0.32mg/100g).Whereas, iron (Fe) content (Table 2) showed values from 2.21±0.06 to 10.21±0.30 mg/100g. Among the different cultivars, S-122 showed the highest value (10.21±0.30mg/100g) of iron followed by S-117 (8.36±0.10mg/100g) and S-131 (6.02±0.13mg/100g) whereas the lowest iron (2.21±0.06mg/100g) content was observed in Til-89 followed by TS-3 (4.34±0.12mg/100g). Phosphorus (P) content (Table 2) exhibited the highest value(63.47±1.11mg/100g) in TH-6 followed by TS-5 (57.58±1.22mg/100g), and TS-3 (53.24±1.51mg/100g). The lowest phosphorus content (29.67±0.49mg/100g) was found in Latifi followed by S-131 (33.68±0.31mg/100g).

Amino Acids Profile**:** Means for essential amino acids (Table 3) indicated concentrations of isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, valine and histidine were ranged from 1.52±0.02 to 4.34±0.10, 3.86±0.12 to 7.54±0.24, 1.11±0.07 to 3.34±0.09, 1.25±0.04 to 3.47±0.09, 2.24±0.05 to 4.48±0.06, 2.55±0.07 to 4.38±0.12, 0.81±0.01 to 2.57±0.06, 2.55±0.05 to 5.20±0.14 and 1.83±0.05 to 3.10±0.08 g/100g, respectively. Among the different cultivars, the maximum concentration (4.34±0.10g/100g) of isoleucine was found in TH-6 followed by TS-5 (3.80±0.04g/100g), TS-3 (3.25±0.09g/100g) and S-122 (3.21±0.12 g/100g) whereas the lowest isoleucine was found in Latifi (1.52±0.02g/100g). Regarding leucine (Table 3), TH-6 exhibited the highest value (7.54±0.24g/100g) followed by TS-5 (6.91±0.15 g/100g), S-122 (6.67±0.14 g/100g) and TS-3 (6.46±0.21g/100g). The lowest value of leucine (3.86±0.12g/100g) was observed in Latifi followed by S-131 (4.76±0.16g/100g). Results for lysine (Table 3) revealed the maximum content(3.34±0.09 g/100g) in TH-6 whereas the lowest value of lysine

Table 2. Mineral contents (mg/100g) of sesame flours of different cultivars.

Variety	Sodium	Potassium	Calcium	Magnesium	Zinc	Iron	Phosphorus
TH-6	60.12±0.89a	67.32±1.01cd	62.48±2.43c	59.23±1.48a	13.47±0.35c	7.23±0.14c	63.47±1.11a
TS-5	58.77±1.07ab	61.62±1.78de	56.67±1.24cd	56.87±1.95ab	11.87±0.21c	6.58±0.14cd	57.58±1.22b
TS-3	56.32±0.73ab	57.43±1.61ef	52.56±0.89de	53.29±0.77ab	9.25±0.32d	4.34±0.12e	53.24±1.51bc
Til-89	54.12±1.21b	52.78±1.20f	46.82±0.55e	50.46±1.99bc	7.23±0.16e	2.21±0.06f	51.69±1.05c
S-122	42.56±1.89c	81.79±1.62a	80.21±1.90a	44.42±0.92cd	19.53±0.36a	10.21±0.30a	42.82±0.99d
S-117	38.43±0.96cd	78.23±1.86ab	76.21±1.39ab	41.83±1.17de	17.06±0.61b	8.36±0.10b	38.21±0.84de
S-131	33.61±0.97de	73.58±1.00bc	73.32±1.28ab	37.23±0.77ef	15.46±0.11b	6.02±0.13d	33.68±0.31ef
Latifi	29.24±0.82e	70.45±1.89c	70.45±1.94b	33.45±0.95f	12.21±0.32c	4.23±0.10e	29.67±0.49f

White sesame cultivars: TH-6, TS-3, TS-5 and Til-89; Black sesame cultivars: S-122, S-117, S-131 and Latifi; Means having same letters in a column are statistically non-significant (P>0.05); Means ± S.D.

Table 3. Essential amino acids composition (g/100g) of sesame flours of different cultivars.

Variety	Ile	Leu	Lys	Met	Phen	Thr	Trp	Val	His
TH-6	4.34±0.10a	7.54±0.24a	3.34±0.09a	3.47±0.09a	4.48±0.06a	4.38±0.12a	2.57±0.06a	5.20±0.14a	3.10±0.08a
TS-5	3.80±0.04b	6.91±0.15ab	2.85±0.06b	2.97±0.07b	3.97±0.08b	3.87±0.15ab	2.18±0.12b	4.80±0.10a	2.62±0.02b
TS-3	3.25±0.09c	6.46±0.21bc	2.34±0.06bc	2.51±0.04c	3.52±0.08c	3.53±0.08bcd	1.74±0.01c	4.23±0.07b	2.11±0.03cd
Til-89	2.78±0.04d	5.92±0.21cd	2.01±0.04cd	1.92±0.05d	3.03±0.06d	3.02±0.10de	1.23±0.02d	3.79±0.05cd	1.76±0.05e
S-122	3.21±0.12c	6.67±0.14abc	2.73±0.03b	2.82±0.08b	3.97±0.04b	3.83±0.16ab	2.03±0.04b	4.09±0.12bc	3.24±0.08a
S-117	2.72±0.05d	5.23±0.20de	2.54±0.05b	2.33±0.06c	3.43±0.08c	3.39±0.10bc	1.61±0.02c	3.58±0.09d	2.73±0.09b
S-131	2.08±0.05e	4.76±0.16e	1.88±0.03d	1.72±0.03d	2.93±0.06d	2.92±0.09e	1.10±0.02d	3.05±0.04e	2.25±0.03c
Latifi	1.52±0.02f	3.86±0.12f	1.11±0.07e	1.25±0.04e	2.24±0.05e	2.55±0.07e	0.81±0.01e	2.55±0.05f	1.83±0.05de

White sesame cultivars: TH-6, TS-3, TS-5 and Til-89; Black sesame cultivars: S-122, S-117, S-131 and Latifi; Means having same letters in a column are statistically non-significant (P>0.05); Means ± S.D.

Table 4. Non-essential amino acids composition (g/100g) of sesame flours of different cultivars

Variety	Ala	Arg	Asp	Glu	Gly	Cys	Pro	Ser	Tyr
TH-6	5.27±0.14a	4.83±0.09a	8.95±0.28a	18.67±0.20a	5.96±0.13a	3.15±0.09a	3.85±0.07a	3.90±0.08a	4.25±0.07a
TS-5	4.79±0.09b	4.01±0.09b	8.51±0.13ab	17.13±0.51ab	5.42±0.09b	2.81±0.04b	3.41±0.03b	3.36±0.10b	3.89±0.12b
TS-3	4.25±0.05c	3.63±0.06bc	7.89±0.02b	16.54±0.38bc	4.97±0.06c	2.29±0.11c	2.87±0.05c	2.83±0.11c	3.36±0.10c
Til-89	3.86±0.07d	3.37±0.12cd	7.03±0.12c	16.07±0.29cd	4.53±0.14d	1.79±0.04d	2.36±0.06d	2.33±0.05d	2.91±0.07d
S-122	2.18±0.03e	3.01±0.15d	6.82±0.11c	15.62±0.46bcd	2.82±0.05e	2.23±0.06c	2.28±0.02b	1.42±0.05e	2.86±0.06d
S-117	1.86±0.03e	2.85±0.06de	6.76±0.06cd	14.03±0.19de	2.33±0.04f	1.72±0.03d	1.79±0.09c	1.03±0.02f	2.54±0.08de
S-131	1.23±0.03f	2.24±0.02e	6.14±0.12de	13.42±0.21e	1.74±0.02g	1.08±0.03e	1.25±0.06d	0.59±0.01g	2.35±0.06e
Latifi	0.78±0.02g	1.87±0.08f	5.87±0.16e	12.23±0.22f	1.19±0.02h	0.57±0.01f	0.75±0.03e	0.23±0.01h	1.82±0.05f

White sesame cultivars: TH-6, TS-3, TS-5 and Til-89; Black sesame cultivars: S-122, S-117, S-131 and Latifi; Means having same letters in a column are statistically non-significant (P>0.05); Means ± S.D

(1.11±0.07 g/100g) was noticed in Latifi and S-131 (1.88±0.03 g/100g). The highest methionine content (3.47±0.09 g/100g) was recorded in TH-6, followed by TS-5 (2.97±0.07 g/100g) and S-122 (2.73±0.03 g/100g) whereas the lowest methionine (1.25±0.04 g/100g) was found in Latifi followed by S-131 (1.72±0.03 g/100g) (Table 3). Results for the phenylalanine (Table 3) exhibited the values ranged from 2.24±0.05to 4.48±0.06g/100g. The highest threonine concentration (4.38±0.12 g/100g) was observed in TH-6 (white sesame cultivar) and TS-5 (3.87±0.15 g/100g). The lowest levels of threonine (2.55±0.07 g/100g) were found in Latifi and S-131 (2.92±0.09 g/100g). Tryptophan (Table 3) showed the highest value (2.57±0.06) in TH-6, whereas the minimum value of tryptophan (0.81±0.01 g/100g) was found in Latifi. Results for valine showed in Table 3, exhibited the maximum content (5.20±0.14 g/100g) in TH-6 followed by TS-5 (4.80±0.10 g/100g), TS-3 (4.23±0.07 g/100g) and S-122 (4.09±0.12 g/100g) in Til-89. The highest histidine (3.24±0.08 g/100g) was observed in S-122 followed by TH-6 (3.10±0.08 g/100g), whereas, the least amount was in Til-89 (1.76±0.05 g/100g) followed by Latifi (1.83±0.05 g/100g).

Overall, all essential amino acids were significantly higher in white sesame cultivars except histidine which was higher in black sesame. Means for non-essential essential amino acids (Table 4) indicated overall values of alanine, arginine, aspartic acid, glutamic acid, glycine, cysteine, proline, serine and tyrosine were ranged from 0.78±0.02 to 5.27±0.14, 1.87±0.08 to 4.83±0.09, 5.87±0.16 to 8.95±0.28,12.23±0.22 to 18.67±0.20, 1.19±0.02 to 5.96±0.13, 0.57±0.01 to 3.15±0.09,0.75±0.03 to 3.85±0.07, 0.23±0.01 to 3.90±0.08, and 1.82±0.05 to 4.25±0.07 g/100g, respectively. Among the different cultivars, the highest concentration of alanine (5.27±0.14g/100g) was found in TH-6 followed by TS-5 (4.79±0.09g/100g) and TS-3(4.25±0.05g/100g) whereas the lowest value was recorded in Latifi (0.78±0.02g/100g). Mean values for arginine (Table 4) exhibited maximum concentration of arginine (4.83±0.09g/100g) in TH-6 followed by TS-5 (4.01±0.09g/100g). However, the lowest value of arginine was observed in Latifi (1.87±0.08g/100g). Results for aspartic acid (Table 4) exhibited the values ranged from 5.87±0.16 to 8.95±0.28 g/100g. Among different cultivars, the maximum content of aspartic acid was obtained in TH-6 (8.95±0.28g/100g) followed by TS-5 (8.51±0.13g/100g), TS-3 (7.89±0.02g/100g) and Til-89 (7.03±0.12g/100g). The lowest content of aspartic acid was found in Latifi (5.87±0.16g/100g) followed by S-131 (6.14±0.12g/100g). Means for glutamic acid (Table 4) demonstrated the values ranged from 12.23±0.22 to 18.67±0.20 g/100g. Among different cultivars, the maximum concentration of glutamic acid was found in TH-6 (18.67±0.20g/100g) followed by TS-5 (17.13±0.51g/100g), TS-3 (16.54±0.38g/100g) and Til-89 (16.07±0.29g/100g). The minimum concentration of glutamic acid was found in Latifi (12.23±0.22g/100g) followed by S-131 (13.42±0.21g/100g). Results for glycine (Table 4) revealed the values ranged from 1.19±0.02to 5.96±0.13 g/100g. Among various cultivars, the highest value of glycine was found in TH-6 (5.96±0.13g/100g) followed by TS-5 (5.42±0.09g/100g) and TS-3 (4.97±0.06g/100g) whereas the lowest value (1.19±0.02g/100g) was in Latifi and S-

131(1.74±0.02g/100g). Mean values for cysteine (Table 4) were the highest in white sesame cultivars (1.79±0.04 to 3.85±0.07g/100g) than that of black sesame cultivars (0.57±0.01 to 2.23±0.06 g/100g). Means for proline (Table 4) were ranged from 0.75±0.03 to 3.85g/100g. Among the different cultivars, TH-6 showed the maximum value (3.85±0.07g/100g) of proline whereas the minimum value of cysteine was observed in Latifi (0.75±0.03g/100g) followed byS-131 (1.25±0.06g/100g). Mean results for serine and tyrosine (Table 4) exhibited the values ranged from 0.23±0.01to 3.90±0.08 and 1.82±0.05 to 4.25±0.07g/100g, respectively. Among different cultivars, TH-6 showed the highest concentration (3.90±0.08g/100g and 4.25±0.07) of these amino acids whereas the lowest concentrations (0.23±0.01g/100g and 1.82±0.05g/100g) were found in Latifi and S-131 (0.59±0.01 and 2.35±0.06g/100g).

***Antioxidant Potential*:** Means for total phenolic contents (Table 5) exhibited values ranged from 1.56±0.025 to 7.32±0.219 mg GAE/g. Among the different cultivars, the maximum value of total phenolic contents was observed in S-122 (7.32±0.22mg GAE/g) followed by S-117 (6.58±0.12 mg GAE/g), and S-131 (5.69±0.09mg GAE/g). The minimum phenolics were present in Til-89 (1.56±0.03mg GAE/g)and TS-3 (2.69±0.06mg GAE/g). Overall, black sesame cultivars showed highest values for total phenolic contents.

Mean results for DPPH scavenging activity (Table 5) showed the values ranged from 51.65±0.98 to 61.16±2.13 % inhibition. S-122 revealed the highest scavenging activity (61.16±2.13 % inhibition) followed by S-117 (59.23±0.80%), S-131 (56.72±1.63%) and TH-6 (56.55±1.09 % inhibition). It is apparent from the results that DPPH scavenging activity of black sesame cultivars was slightly higher than that of white varieties. The lowest inhibition was observed in Til-89 (51.65±0.98%). Antioxidant activities of sesame extracts were analyzed by using 2, 2-dipheny l-1-picrylhydrazyl (DPPH) methods. Means for β-carotene bleaching activity (Table 5) revealed the values ranged from 35.14±0.95 to 46.92±1.34 % inhibition. The results of various sesame cultivars exhibited higher value (46.92±1.34 % inhibition) in S-122 followed by S-117 (43.63±0.35 % inhibition), and TH-6 (42.63±1.10 % inhibition).

***Bioactive Components*:** Data regarding bioactive components in sesame flours of different cultivars represented significant variations in bioactive components *i.e*. sesamin, sesamol and sesamolin. Means for the sesamin, sesamol and sesamolin (Table 6) exhibited the values ranged from 1521.00±27.30 to 3996.00±129.90 ppm, 3121.00±86.60 to 4303.00±133.37 ppm and 1532.33±31.89 to 3564.00±65.82 ppm, respectively. Among the different cultivars, the maximum value of sesamin was observed in TH-6 (3996.00±129.90) followed by TS-5 (3753.00±120.67 ppm) and TS-3 (3502.00±59.47 ppm), whereas, the minimum sesamin concentration (1521.00±27.30 ppm) was observed in Latifi and S-131 (1756.00±48.50 ppm). Results revealed that

Table 5. Antioxidant potential of sesame flours of different cultivars.

Varieties	Total phenolic contents (mg GAE/g)	DPPH scavenging activity (% inhibition)	β-carotene bleaching activity (% inhibition)
TH-6	4.86±0.06d	56.55±1.09abc	42.63±1.10abc
TS-5	3.72±0.076e	54.34±0.63bc	40.86±0.43bcd
TS-3	2.69±0.064f	52.13±0.93c	37.21±0.90de
Til-89	1.56±0.025g	51.65±0.98c	35.14±0.95e
S-122	7.32±0.219a	61.16±2.13a	46.92±1.34a
S-117	6.58±0.115b	59.23±0.80ab	43.63±0.35ab
S-131	5.69±0.087c	56.72±1.63abc	41.02±0.56bcd
Latifi	4.02±0.075e	53.41±0.92bc	38.37±1.32cde

White sesame cultivars: TH-6, TS-3, TS-5 and Til-89; Black sesame cultivars: S-122, S-117, S-131 and Latifi; Means having same letters in a column are statistically non-significant (P>0.05); Means ± S.D

Table 6. Bioactive components (ppm) in sesame flours of different cultivars.

Varieties	Sesamin	Sesamol	Sesamolin
TH-6	3996.00±129.90a	3837.00±134.36a-d	2257.00±95.84d
TS-5	3753.00±120.67ab	3587.00±130.48cde	1942.00±83.14de
TS-3	3502.00±59.47bc	3342.00±98.15de	1778.00±53.12e
Til-89	3201.00±105.83c	3121.00±86.60e	1532.33±31.89e
S-122	2141.33±70.14d	4303.00±133.37a	3564.00±65.82a
S-117	1979.00±39.58d	4152.00±68.13ab	3321.00±119.51ab
S-131	1756.00±48.50de	3908.00±80.25abc	3102.00±110.85bc
Latifi	1521.00±27.30e	3652.00±104.50bcd	2862.00±75.06c

White sesame cultivars: TH-6, TS-3, TS-5 and Til-89; Black sesame cultivars: S-122, S-117, S-131 and Latifi; Means having same letters in a column are statistically non-significant (P>0.05); Means ± S.

white cultivars of sesame contain more sesamin contents as compared to black cultivars. The results for the sesamol (Table 6) showed the highest concentration (4303.00±133.37 ppm) of sesamol in S-122 followed by S-117 (4152.00±68.13 ppm) and S-131 (3908.00±80.25 ppm) Likewise, sesamolin contents (Table 6) were higher in S-122 (3564.00±65.82 ppm) and S-117 (3321.00±119.51 ppm) with the lowest levels in Til-89 (1532.33±31.89 ppm).

DISCUSSION

Earlier, findings of a study conducted by Egbekun and Ehieze (1997) have indicated higher protein contents in defatted sesame flours that can be supplemented in low protein flours of cereals for the preparation of infant foods and further used for growth and development of children. Furthermore, as a result of removal of crude fat from 48.8 to 10.9%, fiber content was increased from 3.6 to 5.8% along with increase in the ash contents from 5 to 6.93%, respectively. In another research, defatted sesame meal was prepared (Jimoh and Aroyehun, 2011) for African catfish as a replacer for soybean meal. The proximate composition of defatted sesame meal exhibited presence of moisture (10.58%), crude protein (38.32%), fat (12.70%), fiber (5.09%), ash (4.28%) and carbohydrates (30.01%).

The variation in the mineral contents in sesame flours of white and black cultivars were due to differences in degree of milling, the type of soil, agro-climatic conditions and genetic makeup. In addition, the method applied, and instruments used for screening of minerals might also resulted in small differences. The results are in conformance with the study conducted on the raw, defatted and protein concentrate of sesame flour. The results of this study exhibited, greater degree of differences among the samples. These values of essential macro and micro-minerals obtained from the defatted sesame flours can satisfy the consumer needs (Ogungbenle and Onoge, 2014). Findings of another research conducted in Ethiopia on the mineral and anti-nutritional contents of different varieties of sesame seed revealed the highest phosphorus contents (660.61-867.0 2mg/100g) followed by potassium (610.15-808.65mg/100g). The recent results indicated that sesame seed is a good source of essential minerals vital for human nutrition (Deme *et al*., 2017). A study was conducted by supplementing various levels of defatted sesame flour of white cultivar i.e. TH-6 form Pakistan to develop high protein and energy food bars. The results showed that defatted sesame flour of TH-6 contains 385 mg/100g potassium, 7.63 mg/100g sodium, 6.19 mg/100g iron and 20.3 mg/100g calcium (Abbas *et al*., 2016). According to USDA National Nutrient Database for Standard Reference Library, 100 g edible portion of partially defatted sesame flour contains Ca (150 mg), Mg (362 mg), P (810 mg), Fe (14.30 mg) and Zn (10.70 mg), respectively (USDA, 2018).

In a study, amino acid analysis of black and white sesame varieties from Chinese origin revealed significant amount of both essential and non-essential amino acids in both type of cultivars when compared with WHO/FAO standards for both infants and adults except lysine which were insufficient to fulfill the requirements of infants. Furthermore, sulphur containing amino acids like methionine and cysteine were also found in significantly higher quantities than that of WHO standards for both infants and adults. The non-essential amino acids were also higher in these varieties (Radha *et al*., 2008).In another study, amino acid profile of white and black sesame cultivars exhibited their equal effectiveness for supplementation in low protein flours from cereals for infant feeding. These types of products could be helpful to curtail different disorders related to protein deficiency like Kwashiorkor and Marasmus in children (Elleuch *et al*., 2007). In another study, sesame-wheat flour cookies were developed and assessed for nutritional profile and consumer acceptability. The results revealed presence of essential as well as non-essential amino acids particularly glycine (5.4 g/100g), leucine (6.34 g/100g), methionine (2.91 g/100g), arginine (6.07 g/100g), aspartic acid (10.66 g/100g) and glutamic acid (16.26 g/100g). It was further found that the proportion of amino acids in sesame seed was comparable to those in pumpkin, melon and gourd seeds, and their utilization is suggested to achieve the recommended daily allowance of these amino acids (Olagunju and Ifesan, 2013).

It is obvious from the results that black sesame cultivars were rich in phenolics than that of white cultivars (Table???). In a study, sesame extract was analyzed for the total phenolic compounds as gallic acid equivalents/gram of sample. The results revealed that black varieties contain more polyphenols (5.38mg/g) as compared to white ones, which can be extracted and further utilized in pharmaceutical and cosmetics industries (Zheng and Wang, 2001). Djeridane *et al*. (2006) found sufficient phenolic compounds (2.88mg/g) in white sesame varieties. They further recommended their utilization to alleviate several human diseases by altering metabolism of and reduction in mortality due to the presence of numerous phytochemicals. The white sesame varieties showed inhibiting effects against DPPH (upto 56.37%) as compared to standard commercial antioxidants *i.e*. BHA and TBHQ (Srinivasan, 2005). In a comparative study, sesame cake extracts of both black and white sesame were studied for antioxidants activity using DPPH method. The results revealed higher ability of inhibiting DPPH in black sesame extracts. Moreover, the yield of ethanolic extract of black sesame in powder form was 78.4mg/g (Anilakumar *et al.*, 2010). In a study, white sesame cake extracts of different cultivars were studied. There was strong correlation in phenolic compounds and antioxidants activity. These compounds are widely distributed in plants including oilseeds like sesame seeds. These are natural sources of antioxidants with the potential utilization in array of foods. Further, it was found that sesame seeds exhibit greater antioxidant potential as indicated by β-carotenebleaching assay (Kumar, 2009). Black sesame extracts were examined for antioxidant activity by using β-carotenebleaching method. The results showed comparatively higher inhibiting power in black sesame extracts than that of white ones mainly due to high phenolic compounds in them. This study also revealed that antioxidant activity is further dependent on the extraction solvent, concentration of extract and the assay chosen (Visavadiya *et al*., 2009).

It is obvious from the results that sesamin and sesamol contents were higher in white sesame cultivars whereas sesamolin was more in black cultivars. The variation in functional components were might be due to genetic differences, geographical locations, agronomic practices, cropping season and processing methods. In a study, 62 Chinese cultivars of sesame seeds of mixed colors *i.e*. white, black, and brown were assessed for various bioactive components. The results showed higher concentrations of sesamin and sesamol (3602ppm and 3011 ppm) in cultivar *Muzhenbai*, from *Anhui* and the cultivar having the lowest sesamolin contents (1350ppm) was from *Shanxi*. It was further reported that sesamin and sesamol levels were higher than those grown in other countries like Thailand (Rangkadilok *et al*., 2010). Through successful breeding programs, levels of bioactive components can be elevated with more utilization as functional foods, pharmaceutical products and cosmetics (Rao, 2004). Though, seed coat color plays an important role in sesame lignin pathways, but the findings of this instant activity revealed more sesamol and sesamolin contents in black varieties as compared to white ones (Tashiro *et al*., 1990). However, black sesame cultivars have limited utilization in the development of different food products due to less appreciation for the black color of the end products and presence of some inherent components that may cause slightly bitter taste.

Conclusion: The present study revealed that sesame seed flour is a potential source of good quality protein, essential minerals, and also contains higher number of bioactive components *i.e*. sesamin, sesamol and sesamolin along with antioxidants that improves functional properties of the sesame flour. Owing to the presence of plenty of active ingredients, sesame seed cultivar TH-6 should be used as a protein supplement and functional ingredient in a variety of formulated/fabricated foods.

Conflict of interest: The authors don’t have any conflict of interest.

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