Plant Archives Vol. 22, No. 1, 2022 pp. 328-333 e-ISSN:2581-6063 (online), ISSN:0972-5210

Plant Archives

Journal homepage: http://www.plantarchives.org

DOI Url : https://doi.org/10.51470/PLANTARCHIVES.2022.v22.no1.052

EXPLORING NUTRITIONAL AND FUNCTIONAL PROPERTIES OF DIFFERENT VARIETIES OF SESAME SEED CAKES: AN INDUSTRIAL BY-PRODUCT

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(Date of Receiving : 27-01-2022; Date of Acceptance : 28-03-2022)

ABSTRACT

Sesame (*Sesamum indicum*), as an oilseed, has been explored widely by the oil industry. Therefore, the production of its by-product, seed cake is also high. Since the seed cake is a high source of protein and fiber, it has the potential to be utilized as value-added food product. The present study is aimed to evaluate various functional and nutritional properties of four selected varieties of white (*Pragati* and *Shekhar*) and black (*VIP* and *Ojha*) sesame seeds and their seed cake, as obtained by solvent extraction. The study revealed significantly (p<0.01) higher water and oil absorption capacities, as well as the swelling capacity of all studied sesame seed cakes than their whole or flour of sesame seed. The study has shown that sesame seed (27.25 g/100g) and cake (48.36 g/100g) of the *Pragati* variety have exceptionally high protein content. VIP variety of sesame seed and cake are a rich source of fiber, having 18.74g/100g and 29.56 g/100g respectively. The high fiber also shows good correlations with water absorption capacity, as recorded in the case of sesame flour (r^2=0.966) and seed cake (r^2=0.916). The high functional and nutritional values of sesame seed cakes suggest their potential use in developing a functional ingredient for food and nutraceutical formulations.

Keywords: Color value, functional, nutritional, solvent extraction, sesame seed cake

Introduction

Sesame is one of the ancient oilseed crops of the world. Sesame has been widely cultivated for oil extraction and its oil has been considered sacred and is used for culinary and medicinal purposes. White and black sesame seeds are popular in India.

The sesame seeds are involved in various cuisines of the world. The white Indian sesame seeds have the desirable nutty taste and are used for making conventional sweets, baked foods, and confectionaries. The black ones are used for seasoning, *laddoo* making, and fried foods. There are also intermediate colored varieties varying from red to yellow and brown to grey. All varieties are used mainly as food ingredients in whole, broken, crushed, shelled, powdered, and paste forms (Choudhary, 2006). Such diversified involvement of sesame in food is because of the favorable structural and functional properties of sesame seeds.

Apart from various food usages, sesame is greatly employed for oil extraction. The sesame oil industry, therefore, produces sesame seed cake as the by-product. The by-product has been conventionally used as nutritional feed for cattle. Since the seed cake is also a protein and fibre-rich residue after oil extraction (Jimoh *et al*. 2011); therefore its nutritional importance cannot be neglected and could be used in combinations with other flours and proper treatment for its antinutritional content (Hassan, 2013). Given this, the functional properties of SSC play an important role in predicting the quality of a developed product. Thus, it could be incorporated into various food formulations for protein and fiber enrichments. In this regard, the present work was carried out to exhibit the functionality of whole sesame, flour, and sesame seed cake concerning its inclusion in food products. The study also explored the nutritional properties of sesame seed cakes obtained after solvent extraction from various sesame varieties.

Materials and Methods

Variety Selection of Sesame Seeds

Two white varieties of sesame namely *Pragati* and *Shekhar* were procured from Chandra Shekhar Azad Agriculture University Kanpur, India. Two black varieties namely, *VIP* and *Ojha* were obtained from Naini Market, Prayagraj, India.

Studied Sesame Forms

Whole seeds of sesame were studied for their functional and color properties while its flour, which was prepared after grinding in a mixer grinder (Butterfly Grand), and seed cake were studied for their nutritional as well as functional properties.

Solvent Mediated Oil Extraction

Oil was extracted from sesame flour of selected varieties by using n-Hexane as described by Malaviya *et al.* (2021).After oil extraction remaining residue was collected as Sesame seed cake (SSC).

Nutritional Analysis

Sesame seed flour (SSF) of all varieties and their respective seed cakes were analyzed for their nutritional constituents by standard AOAC (2005) methods.

Color Analysis

Visual color measurements of whole sesame seeds (WSS), sesame flour, and SSCs of selected varieties were measured by using an X-rite colorimeter based on CIE L^*, a^*, b^*color system.

Functional Analysis

Bulk Density and Porosity

The bulk density of selected varieties of whole sesame seed (WSS), sesame seed flour (SSF), and sesame seed cake (SSC) was measured by assessing the mass of the sample after pouring samples in a 10ml graduated cylinder without tapping and with tapping for loose and packed bulk density respectively. The result was expressed as gram per cubic centimetre (Aremu *et al.*, 2014). Porosity was calculated by

$$\text{Porosity} = 1 - \frac{\text{Loose Bulk Density}}{\text{Packed Bulk Density}}$$

Water Absorption capacity

Water absorption capacity (WAC) of the selected varieties of the sesame seed, flour and its cake samples were estimated by the method mentioned by Ahemen *et al.* (2018).The sample was mixed with distilled water (1:10) and vortexed thoroughly in a centrifuge tube. The tube was centrifuged (REMI Research Centrifuge, Model PR-24) and volume of unabsorbed water was noted. WAC was calculated as below.

$$\text{Water Absorption Capacity g/g} = \frac{(V1 - V2)\rho}{\text{weight of sample}}$$

Where V1= water added

V2=water unabsorbed

ρ = density of water = 1 g/ml

Oil Absorption Capacity

Oil absorption capacity (OAC) of all sesame samples, its flour and seed cake samples were estimated by the method given by Ahemen *et al.* (2018).Samples were mixed with refined soyabean oil (1:10) and vortexed thoroughly in a centrifuge tube. The tube was centrifuged (REMI Research Centrifuge, Model PR-24) and the volume of unabsorbed oil was recorded. OAC was calculated as below.

$$\text{Oil Absorption Capacity g/g} = \frac{(V1 - V2)\rho}{\text{weight of sample}}$$

Where V1= volume of oil added

V2= oil unabsorbed

ρ = density of oil = 0.92 g/ml

Swelling Capacity

Swelling Capacity was assessed by the method given by Robertson *et al.* (2000), with slight modification. Whole sesame seed, sesame flour, and its seed cake samples (0.1 g) were allowed to swell overnight in a graduated measuring cylinder after filling water up to 10 ml. The volume of sample filled was noted before and after swelling. The difference in volume was divided by the weight of the sample.

Statistical Analysis

All the functional, color, and nutritional analyses were carried out in triplicates. Mean of the three readings and standard deviations were done. One way ANOVA with Post Hoc Duncan test at the significance level of $p<0.01$ was also conducted to determine the test of significance among sesame seeds, flour and SSC of different varieties. This was done on IBM SPSS Statistics 20. Pearson's correlation coefficient was also done in certain parameters to find the relationship between them and also to verify the results.

Results and Discussion

Nutritional Analysis

Nutritional properties of whole sesame seed, sesame flour, and sesame seed cake have been displayed in Table 1. The moisture content of all varieties of sesame flour ranged between 3.16-3.53 g/100g, which suggests that all studied varieties, nearly have the same moisture content. The similar moisture contents of sesame seeds (3.30-3.62 g/100g) were given by Longvah *et al.* (2017) on brown and white sesame seeds. SSCs of different varieties have their moisture content as 2.98-8.71 g/100g. The results are similar to Bukaya and Vijaya Kumar (2013). Overall, the moisture content of all studied sesame flour and seed cake are low enough to store them for a longer period.

Total ash refers to the total inorganic remainder after incineration of any food sample. Generally, it refers to total minerals percentage. All the studied sesame varieties and their seed cakes have an ash content ranged between 5.85 g/100 g (*Shekhar* flour) to 12.26 g/100g (*Ojha*seed cake) (Table 1). Previously, Makinde and Akinoso (2013) reported total ash contents of two sesame seeds as 6.16 and 7.34 g/100 g. The ash contents of the seed cakes have been found significantly ($p<0.01$) high from their respective seed flours. Yasothai (2014) reported a high ash percentage of *Ghani* seed cake as 11.60 and 12.60.

The protein content of SSCs in all studied varieties was nearly two times higher than their sesame flour (Table 1). The highest protein content was found in SSF (27.25 g/100 g) and SSC (48.36 g/100 g) of the *Pragati* variety. The present result of the high protein content of sesame flour and its cake suggest that they could be one of the excellent sources of protein. Therefore they could be employed for protein enrichment in any food product. A similar result of protein content of SSC was also reported by Yasothai (2014).

Sesame seeds are well-known oilseeds; they have approximately 50 percent oil/fat content within them. Its highest fat content (53 g/100 g was found in white-colored *Shekhar* variety. After oil extraction, all seed cakes of sesame contained fat between 3.6-5.3 g/100 g. Yasothai (2014) also reported 3 percent oil in solvent-extracted SSC. The lesser, the remaining oil in seed cake, better is the extraction efficiency of the method opted for. Fat content is largely dependent upon variety and sesame seed origin.

The crude fiber of sesame seeds and their cake are presented as fiber in Table 1. Black sesame VIP is most fibrous variety (18.74 g/100 g).Its cake has also a significant amount (29.56 g/100 g) of fiber. The present result of fiber is higher than reported by Hassan (2013).The high fiber content of any food is desirable because they have a good physical effect in the gut. Different types of fiber can have different effects in the gut. For instance, high viscous fiber can have a significantly beneficial effect on blood sugar and cholesterol levels management. On the other hand, insoluble and non-viscous fiber stimulates water secretion in the large intestine, while soluble fiber having good water holding capacity can prevent dehydration. However, fiber that lacks water holding capacity and which is easily fermentable causes flatulence and constipation effect, but they have good prebiotic activity (McRorie and Mckeown, 2017).

Total carbohydrate estimation was estimated by the difference method. The carbohydrate of sesame flour ranged from 11.63-21.89 g/100 g and SSCs from 28.75-38.41 g/100 g. These results were higher than reported by Hassan (2013). Low fat in SSC can be a good choice of food having low fat and high protein.

Color Analysis

The color properties of whole sesame, sesame flour, and seed cake have been presented as *L*, *a,* and *b* value (Table 2). *L* refers to lightness of sample, *a* refers to redness and greenness and b refers to yellowness and blueness of the sample. The L value of the whole seed, flour, and seed cake of sesame ranged from 12.35-39.85, 29.42-59.38, and 33.39-65.49. The *a* value of all studied whole sesame, sesame flour and SSC varied between 0.31-4.58, 0.16-3.03, and 0.20-3.33 respectively. The *b* values were 0.26-13.86, 2.30-11.51, and 2.32-12.41 of whole, flour and seed cake of studied sesame forms. *L*, *a* and *b* value of white colored whole seeds were significantly higher than black ones (Table 2). *L* value of flour was found to be greater than their whole white or black sesame seeds. However, *a* value decreased in sesame flour. Notwithstanding, *b* value of black sesame flour increased while white sesame flour decreased. This could be due to breakage of the outer colored seed coat, during the grounding of the whole seeds into flour and hence inner lighter-colored portion of sesame seeds got revealed which led to higher *L* value, lower *a* value, lower *b* value in white sesame and high *b* value in black ones. Nearly all seed cakes have increased color values. This increase could be attributed to the loss of colored oil during extraction. Similar result was also investigated by Cui *et al.* (2021).They studied 366 germplasm accessions of sesame and reported *L* value which ranged from 10.53-63.40; *a* value from 0.08-11.22 and *b* value was reported as -0.47-18.75.Seed coat color is one of the most important agronomic traits. It is found to be associated with chemical composition, antioxidant property, and seeds' own ability to resist diseases. The native color of sesame is diverse ranging from black to white with certain intermediate colors. This diversity is due to the presence or absence of certain genes(Cui *et al.*, 2021).

Functional Analysis

Functional properties of three forms of sesame, which are WSS, SSF, and SSC, are presented in Table 3. Loose bulk density (LBD) was significantly highest ($p<0.01$) in WSS, sesame flour, and SSC of *Pragati* variety having value of 0.57, 0.51, and 0.44 g/cm^3 respectively. LBD of WSS was higher than sesame flour and seed cake of all studied varieties. Significantly ($p>0.01$) higher PBD was found in sesame flour of *Ojha* variety in comparison to other variety. Notwithstanding, all SSCs had comparatively lower LBD and PBD. A similar result was also reported by Bukya and Vijayakumar (2013).Since density is directly proportional to the mass of the sample, therefore WSS, having greater weight than flour particle or seed cake particle, have higher bulk density. Packed bulk density (PBD) was higher in all studied sesame flour than WSS and SSC. Tapping of the cylinder during estimation of bulk density allowed greater settlement of flour particles than seed cake or whole seeds. Also, flour particles had a higher compact arrangement of particles and less content of fibers in comparison to SSC. The bulk density of any sample is dependent upon the particle size of the sample and moisture content of the sample (Ahemen *et al*., 2018). A positively strong relation was found between LBD and PBD of SSC and its moisture content, which are r^2= 0.775 and r^2= 0.678 respectively. This explains that the high moisture content of SSC led to higher LBD and PBD (Pardhi *et al*., 2019). The low-fat content of SSC created a tendency to have more moisture. The statement could be validated with the strong negative correlation coefficient between LBD-PBD of SSCs with Fat content of SSC, (r^2= -0.840 and -0.929).The negative correlation explains that the lower the fat content of SSC better is its bulk density. Further, the protein content of SSC is also found to be significantly ($p>0.01$) high. Proteins are high molecular weight compounds therefore they might have caused an increase in mass of SSC particles, which led to increased bulk density of SSC with increasing protein. A correlation was found between protein of SSC and LBD (r^2= 0.808) and with PBD (r^2= 0.958). These correlations verify the statement that high protein can increase mass of SSC particles, thereby increasing its density. High bulk density is favorable for food product development while low bulk density is required in complementary foods (Ahemen *et al*., 2018). Therefore SSC having lower bulk density can be incorporated in infant formula to enhance protein and fiber value. Also, seed cakes with lower fat content and higher protein and moisture content can possess high bulk density.

Porosity is the entity to indicate the volume of empty space inside a material. High porosity indicates there is a greater difference between LBD and PBD. Therefore sample having higher PBD than LBD tend to have a more porous structure in any container. In the present study highest porous space is occupied by *VIP* sesame flour (48.33%).

Water absorption capacity (WAC) has been greatest in SSCs than other forms of sesame. Seed cake prepared from *Shekhar* (2.04 g/ml) *and VIP* (2.2 g/ml) variety possessed significantly ($p>0.01$) highest WAC. High WAC shows the presence of more hydrophilic components. Fiber content was found to positively correlated with both SSF (r^2=0.966) and SSC (r^2=0.916). This strongly recommends that high fiber in sesame flour and its seed cake can cause greater retention of water within their interspaces. A good water absorption capacity results in better dough formation, as it stretches with ease (Ahemen *et al*., 2018). Therefore SSC could be utilized in bakery product development. Further, the high fiber of seed cake can enhance fiber content of the developed product.

In the present study, the oil absorption capacity of SSCs is higher than other forms, ranging between 1.29-3.13 g/g. Highest OAC was found in *Shekhar* seed cake. The present results can be comparable with the work of Bukya and Vijayakumar (2013), who worked on whole sesame, SSC, and defatted seed cake. They reported the highest fat absorption capacity in defatted seed cake followed by SSC and whole sesame. The exact mechanism of OAC is not completely known. However, it could be attributed to the physical entrapment of fat or oil by plant proteins and also by fiber. Insoluble and hydrophobic protein can have greater oil absorption capacity. However, the concentration of proteins, number of non-polar sites, and protein-lipid carbohydrate interaction are also important considerations, which may affect the extent of oil absorption by any food sample (Zayas, 1997).

The swelling capacity of any sample is the water absorption by the particles of the sample along with the increase in their size, when a sample is immersed for a longer duration in water, thereby causing increased volume occupation by sample. Swelling capacity (SC) ranged between 0.23- 2.07 ml/g as studied in all sesame forms. The lowest range of SC is presented in whole seed, flour, and seed cake of *VIP* variety (Table 3), while significantly highest SC was recorded in SSC of *Shekhar* and *Ojha* variety (Table 3).The swelling capacity of any studied sample is dependent upon the size of the granule or particle, variety, and processing methods to which the sample is subjected (Chandra *et al*., 2015). Concerning the given fact, the whole form of sesame seeds, did not swell as much as its flour. Similarly, the cake form of the sesame seed of the same variety exhibited better SC than its whole or flour form. Maria and Victoria (2018) reported the swelling capacity of raw sesame flour as 1.54 to 1.84 mg/g which was higher than their germinated sesame flour. These values are within the range observed in the study.

Conclusion

The study on the functional properties of four varieties of sesame seed and its cake has revealed that cake have better hydration and oil absorption capacities. This is suggestive of better dough formation and flavor retaining properties of sesame seed cake in food formulations. The bulk density of sesame seed cake can be increased when the fat content of seed cake is low and the protein content of seed cake is high. Sesame seed cake contain comparatively low fat, carbohydrate and good amount of protein hence can be utilized in food products for diabetic and in cholesterol lowering diet. Further, a strong association of fiber of sesame flour and its cake with their water absorption capacities suggested that high fiber in seed cake can be desirable for its functional and nutritional properties in food formulations.

Table 1 : Nutritional properties of different white and black varieties of whole sesame, sesame flour and its seed cake (g/100 g)

Varieties	Sesame Forms	Moisture	Total Ash	Protein	Fat	Fiber	Carbohydrates
White							
Pragati	SSF	3.16±0.05^{a}	7.44±0.02^{bc}	27.25±0.21^{d}	50.5±1.32^{bc}	2.81±0.27^{a}	11.63±1.12^{a}
	SSC	8.71±1.59^{b}	11.10±0.28^{de}	48.36±0.56^{h}	3.6±0.4^{a}	8.96±0.68^{c}	28.75±4.31^{c}
Shekhar	SSF	3.33±0.20^{a}	5.85±0.15^{a}	20.88±0.10^{b}	53±1^{c}	8.79±0.21^{c}	16.93±1.11^{ab}
	SSC	7.26±1.64^{b}	11.60±0.57^{de}	38.63±0.31^{e}	5.3±0.7^{a}	16.24±0.37^{d}	37.19±1.15^{d}
Black							
VIP	SSF	3.53±0.23^{a}	6.31±0.56^{ab}	19.93±0.05^{a}	48.33±2.08^{b}	18.74±2.57^{e}	21.89±2.27^{b}
	SSC	7.55±0.77^{b}	10.5±0.5^{d}	39.66±0.10^{f}	4.06±0.11^{a}	29.56±1.60^{f}	38.21±0.18^{d}
Ojha	SSF	3.2±0.1^{a}	7.94 ±0.02^{c}	21.55±0.03^{c}	51.16±2.16^{bc}	5.32±0.05^{b}	16.13±2.44^{a}
	SSC	2.98±1.76^{a}	12.26±1.25^{e}	41.70±0.17^{g}	4.63±0.30^{a}	9.02±0.18^{c}	38.41±2.07^{d}

WSS: Whole sesame seeds; SSF: Sesame seed flour; SSC: Sesame seed cake. Mean±Standard deviation in column having same superscript do not differ significantly at $p<0.01$

Table 2 : Color properties of different black and white varieties of whole sesame, sesame flour and its seed cake

Varieties	Sesame Forms	*L* value	*a* value	*b* value
White				
Pragati	WSS	39.85±0.60^{g}	4.58±0.02^{h}	13.86±0.14^{g}
	SSF	59.38±0.02^{i}	3.03±0.02^{d}	11.51±0.02^{e}
	SSC	64.53±0.16^{j}	3.21±0.02^{e}	12.08±0.09^{f}
Shekhar	WSS	31.78±0.99^{d}	4.13±0.11^{g}	11.49±0.49^{e}
	SSF	56.57±0.02^{h}	2.92±0.02^{d}	11.06±0.02^{d}
	SSC	65.49±0.69^{h}	3.33±0.03^{f}	12.41±0.14^{f}
Black				
VIP	WSS	12.35±0.23^{a}	0.31±0.12^{bc}	0.53±0.05^{a}
	SSF	29.42±0.02^{c}	0.16±0.01^{a}	2.80±0.02^{c}
	SSC	33.39±0.29^{e}	0.20±0.02^{ab}	3.06±0.08^{c}
Ojha	WSS	14.14±0.19^{b}	0.37±0.03^{c}	0.26±0.08^{a}
	SSF	38.31±0.03^{f}	0.18±0.03^{a}	2.30±0.04^{b}
	SSC	40.28±0.25^{g}	0.38±0.00^{c}	2.32±0.02^{b}

WSS: Whole sesame seeds; SSF: Sesame seed flour; SSC: Sesame seed cake. Mean±Standard deviation in column having same superscript do not differ significantly at $p<0.01$

Table 3 : Functional properties of different black and white varieties of whole sesame, sesame flour and its seed cake

Varieties	Sesame Forms	Loose Bulk Density (g/cm^3)	Packed Bulk Density (g/cm^3)	Porosity (%)	Water Absorption Capacity (g/g)	Oil Absorption Capacity (g/g)	Swelling Capacity (ml/g)
White							
Pragati	WSS	0.57 ± 0.00^{h}	0.63 ± 0.00^{e}	8.36 ± 1.56^{a}	1.00 ± 0.00^{abc}	1.01 ± 0.10^{b}	0.83 ± 0.05^{cd}
	SSF	0.51 ± 0.012^{f}	0.84 ± 0.00^{f}	38.73 ± 1.35^{de}	0.90 ± 0.10^{ab}	1.01 ± 0.17^{b}	1.03 ± 0.05^{d}
	SSC	0.44 ± 0.01^{e}	0.47 ± 0.00^{c}	7.33 ± 2.30^{a}	1.5 ± 0.00^{ef}	1.29 ± 0.00^{c}	1.5 ± 0.00^{f}
Shekhar	WSS	0.59 ± 0.00^{i}	0.64 ± 0.00^{e}	7.83 ± 0.28^{a}	1.20 ± 0.20^{cd}	0.58 ± 0.05^{a}	1.00 ± 0.00^{d}
	SSF	0.53 ± 0.00^{g}	0.82 ± 0.00^{f}	35.83 ± 0.41^{d}	1.10 ± 0.10^{bc}	1.22 ± 0.05^{c}	1.30 ± 0.10^{e}
	SSC	0.30 ± 0.00^{b}	0.36 ± 0.00^{a}	16.76 ± 0.20^{b}	2.04 ± 0.04^{g}	3.13 ± 0.01^{f}	2.03 ± 0.05^{g}
Black							
VIP	WSS	0.44 ± 0.0^{e}	0.53 ± 0.03^{d}	15 ± 1.73^{b}	1.46 ± 0.05^{ef}	1.99 ± 0.05^{d}	0.23 ± 0.05^{a}
	SSF	0.42 ± 0.0^{d}	0.82 ± 0.01^{f}	48.33 ± 2.08^{f}	1.36 ± 0.15^{de}	1.34 ± 0.05^{c}	0.73 ± 0.11^{bc}
	SSC	0.35 ± 0.00^{c}	0.41 ± 0.0^{b}	15.33 ± 2.88^{c}	2.2 ± 0.00^{g}	2.12 ± 0.00^{d}	1 ± 0.00^{d}
Ojha	WSS	0.56 ± 0.00^{h}	0.65 ± 0.00^{e}	13.7 ± 1.66^{b}	1.63 ± 0.15^{f}	2.03 ± 0.05^{d}	0.56 ± 0.05^{b}
	SSF	0.57 ± 0.00^{h}	0.96 ± 0.00^{g}	40.66 ± 0.57^{e}	0.86 ± 0.05^{a}	1.34 ± 0.05^{c}	0.60 ± 0.2^{b}
	SSC	0.277 ± 0.00^{a}	0.363 ± 0.0^{a}	23.43 ± 0.25^{c}	1.55 ± 0.00^{ef}	2.35 ± 0.05^{e}	2.07 ± 0.11^{g}

WSS: Whole sesame seeds; SSF: Sesame seed flour; SSC: Sesame seed cake. Mean±Standard deviation in column having same superscript do not differ significantly at $p<0.01$

Acknowledgment

The authors are grateful to the University of Allahabad for providing the necessary facilities for the research work.

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