Selection of process parameters for producing high quality defatted sesame flour at pilot scale

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Abstract The present work was undertaken to study the effect of pearling duration, soaking time, steaming duration and drying temperature on the quality of sesame seeds and mechanically extracted partially defatted sesame cake. On the basis of quality attributes i.e. high protein, low crude fibre, low residual oil and low oxalic acid, the optimum process parameters were selected. The combination of 20 min of pearling duration, 15 min of soaking, 15 min of steaming at 100 kPa pressure and drying at 50 °C yielded high quality partially defatted protein rich sesame flour as compared to untreated defatted sesame flour. The developed high quality partially defatted protein rich sesame flour may be used in various food applications as a vital ingredient to increase the nutritional significance of the prepared foodstuffs.

Keywords Sesame · Protein · Dehulling · Defatted cake · Oxalic acid

Introduction

Sesame (*Sesamum indicum* L.) is an important oilseed crop being cultivated in the tropics and the temperate zone of the world. Myanmar is a major producer of sesame followed by India, China, Ethiopia and Nigeria (FAOSTAT 2011). Sesame seeds are rich in protein, oil, crude fibre and carbohydrates (Obiajunwa et al. 2005). Sesame seed contains 50 % oil which is highly resistant to oxidation and 25 % protein which has unique balance of essential amino acids and minerals (Johnson et al. 1979). It is also consumed for its medicinal qualities. Among all the oilseed proteins, sesame protein is the most nutritious as it is a rich source of methionine (sulphur

containing amino acid) (Narsinga Rao 1985; Smith 1971) and tryptophan (Johnson et al. 1979). Because of its greater and varied utility, it is considered as the “Queen of oilseeds”. Dehulled sesame seeds are used in baked products viz. cake, hamburger, buns, cookies, confectionery purposes and many snack foods (Nagaraj 2009). Looking into the shortage of edible proteins due to increasing trend of population, diversification of oilseeds and their byproducts for food purpose is essential to meet the protein demand (Parpia 1991). Defatted meals of oilseeds contain various antinutritional components such as oligosaccharides, trypsin inhibitors, phytic acid and tannins that render low protein solubility, which could limit its food applications. A number of treatments viz. hydrothermal, soaking, fermentation, coagulation and germination can be performed on oilseeds to remove these antinutritional compounds for improving nutritional quality and techno-functional properties of the resulting defatted meal (Nagaraj 2009).

The antinutritional constituent i.e. oxalic acid is mostly concentrated in sesame seed coat/hull (Prakash and Nandi 1978) and was significantly reduced after removal of hull/fibre (Narsinga Rao 1985). Dehulling of oilseeds helps in producing superior quality edible cake/meal (Nagaraj 2009; Johnson et al. 1979; Sastry et al. 1969). Thus, dehulling is a widely accepted practice prior to the consumption of sesame. Both dry and wet methods like roasting, soaking, boiling and pressure cooking are also considered good for eliminating heat labile antinutritional factors present in oilseeds. Heating the oilseeds improves oil extraction. At around 10 % moisture, the oil in the cells tries to diffuse out of the cells, making it more efficiently extractable. In view of this, oilseeds are normally cooked at 10–12 % moisture content at about 90 °C for 15–20 min and anti-nutrients if any, also get detoxified. Thus, the quality of oil as well as oilcakes improves (Nagaraj 2009). Technologies, processes and protocols available for the production of defatted flour, concentrates, isolates and other value added products utilize the protein extracts using chemicals & solvents, which are complex and expensive processes.

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Fig. 1 Effect of steaming pressure on residual oil of defatted cake (Bars with similar letter do not differ significantly ($p \leq 0.05$) for each pass)

Traditionally, sesame seed is soaked for 10–12 h either in water or alkaline solutions and then dehulled by vigorous stirring and floatation (Inyang and Ekanem 1996). Ramchandra et al. (1970) also reported a lye treatment process for dehulling of sesame seeds. Sesame seeds were treated with hot lye solution and thoroughly washed with excess water. This method consumes more time and the subsequent slurry may become more viscous and difficult to handle (Sastry et al. 1969). Moreover, the odor of alkaline solution persists and it also affects the final quality of the resulting cake and may render it non-edible. In the process of extraction of sesame oil by mechanical press, semi defatted sesame cake with about 50 % of protein and high calcium (1,500 mg/100 g) is obtained (Arriel et al. 2006). Sesame cake is also rich source of crude fiber (10.8 g/100 g) (Mohdaly et al. 2011). There is a growing interest in the quality evaluation of the residues generated by food processing industries (Stojceska et al. 2008). Thus, the objective of the present investigation is to select the optimum process parameters for producing high quality partially defatted sesame flour by studying the effect of different treatments such as pearling, soaking, steaming and drying on the quality of sesame seeds and the partially defatted cake.

Materials and methods

Preparation of raw material

Light brown sesame variety *Gujarat til – 1* was procured from local market. The seeds were cleaned and graded using air screen cleaner (CIAE, Bhopal) with 1 & 2 mm screen size. The experiment was performed in triplicate with 25 kg batch.

Pearling

The cleaned seeds (adjusted to 10 ± 0.5 % moisture) were pearled using multi crop pearler (Capacity-35 kg; Mathesis Engineers Pvt. Ltd., Hyderabad, India) in order to reduce the processing time. The pearler consists of six abrasive discs spaced apart 10 cm on the main shaft. The revolving speed of the main shaft was 1,440 rpm with 5 hp motor. The effect of different pearling duration (10, 20 & 30 min) on thousand grain weight, crude fibre, oxalic acid and protein content of seed was studied. After each treatment, pearled seeds were visually examined for oozing of oil, if any.

Soaking of seeds

On the basis of quality of pearled seeds i.e. low crude fibre, low oxalic acid and no oozing of oil, the best pearling conditions were selected and these pearled seeds were soaked in water for four different durations (10, 15, 30 & 45 min) under ambient condition (28 ± 2 °C temperature and 65 ± 3 % relative humidity). At the end of specified period of soaking, the seeds were vigorously stirred with hand. The low weight hull components were floated due to stirring. Then, this hull component was separated and dried in oven at 102 ± 1 °C till the attainment of constant weight. The hullability (%) was calculated by dividing the weight of hull removed by the total weight of hull (Barnwal et al. 2010). On the basis of maximum hullability, the optimum soaking time was selected for further experimentation.

Table 1 Effect of pearling duration on quality characteristics of sesame seeds

Parameter	Pearling duration, min				Overall effect ($p \leq 0.05$)
	0	10	20	30	
1,000 grain wt (g)	2.7 ± 0.13^a	2.6 ± 0.03^b	2.4 ± 0.14^c	2.3 ± 0.22^d	Significant
Crude fibre (%)	6.5 ± 0.24^a	4.6 ± 0.91^b	3.2 ± 0.35^b	3.1 ± 0.02^b	Significant
Oxalic acid (%)	2.2 ± 0.02^a	1.2 ± 0.05^b	0.65 ± 0.035^c	0.63 ± 0.011^d	Significant
Protein (%)	22.3 ± 0.41^a	22.9 ± 0.32^b	23.5 ± 0.61^c	23.9 ± 0.55^d	Significant
Oozing of oil	–	No	No	Yes	–

Fig. 2 Effect of soaking time on hullability (%) of pearled sesame seeds (bars with similar letter do not differ significantly ($p \leq 0.05$))

Steaming

After draining the excess water, the partially dehulled sesame seeds were steamed in order to expand the oil globules and break the nexus between oil globules and surrounding protein matrices (Warra 2011). Trials were undertaken at varied steam pressure (50, 100 and 150 kPa) and steaming time of 15 min. By analyzing the quality of resulting meal, it was inferred that residual oil got decreased with the increase in steam pressure (Fig. 1). But, pressure above 100 kPa resulted into meal having cooked/burnt flavor. Thus, on the basis of these observations, steam pressure of 100 kPa was found best and thus fixed during actual experiment. The effect of steaming duration (5, 10, 15 & 20 min) on quality of the sesame seeds and its resulting oilcake was studied. The steam treated seeds were mechanically dried at 50 °C up to 10 ± 1 % moisture content and then, oil was extracted using mechanical extractor (Capacity - 40 kg/h, 5 hp, 160 rpm; Goyal Expeller Industries, Ludhiana) to get partially defatted cake (Warra 2011).

Drying of defatted cake

Resulting oilcake was further dried for a period of 4 h to study the effect of various drying temperatures (40, 50, 60 & 70 °C)

on the quality characteristics of prepared oilcake. The oilcake was pulverized using mini mill (INALSA, Tuareg Pvt. Ltd., India). The prepared flour was packed in polyethylene bags (75 μ m) and stored at refrigerated conditions till further use. The partially defatted sesame flour produced without using any treatment was considered as control.

Quality evaluation of seeds, defatted cake and flour

Moisture content was determined by digital moisture meter (MA150, Sartorius, Germany) using standard procedure (AOAC 2000). Crude protein, crude fibre, oxalic acid, oil and ash content were determined using standard procedures (Ranganna 2000) on 'as is' basis. The hunter color values (L = lightness, a = redness/greenness & b = yellowness/blueness) were measured using Hunter's colorimeter (Mini Scan XE Plus Hunter Associates Lab inc., Reston, Virginia, USA) and the total color difference was calculated (Fernande et al. 2011). For color determination, samples were filled in the circular (6.25 cm diameter) glass cell provided with the instrument.

Statistical analysis

Duncan's multiple range test (DMRT) was used to show significant differences in mean values of the measured parameters (Ananthan et al. 2012). The analysis of variance test (ANOVA) was carried out using SPSS 7.5 software and statistical procedures described by Gomez and Gomez (1984) to examine the overall effect of various treatments on the quality of the sesame seeds, defatted oilcake and flour.

Results and discussion

Effect of pearling

There was significant effect of pearling duration on the measured quality characteristics of sesame seeds (Table 1). There

Table 2 Effect of steaming duration on quality of partially dehulled sesame seeds (db)

Parameter	Steaming time, minutes					Overall effect ($p \leq 0.05$)
	0	5	10	15	20	
Moisture (% w.b.)	11.3 ± 0.34^a	13.4 ± 0.59^b	14.2 ± 0.71^b	16.4 ± 0.98^c	17.5 ± 0.91^c	Significant
Protein (%)	26.2 ± 0.52^a	25.5 ± 0.74^a	25.2 ± 1.21^{ab}	24.9 ± 1.21^{ab}	23.1 ± 0.71^b	Not significant
Fat (%)	55.2 ± 0.74^a	53.8 ± 0.72^{ab}	53.2 ± 0.93^{ab}	52.7 ± 1.29^b	51.9 ± 0.42^b	Significant
Crude fibre (%)	2.8 ± 0.04^a	2.2 ± 0.57^b	1.8 ± 0.21^b	1.5 ± 0.03^b	1.4 ± 0.06^b	Not significant
Oxalic acid (%)	0.73 ± 0.04^a	0.62 ± 0.011^b	0.66 ± 0.064^b	0.42 ± 0.018^c	0.41 ± 0.028^c	Significant

Table 3 Effect of steaming duration on quality parameters of defatted cake

Parameter	Steaming time, min					Overall effect ($p \leq 0.05$)
	0	5	10	15	20	
Moisture (% w.b.)	9.8±0.62 ^a	9.8±0.83 ^a	9.6±0.58 ^a	9.3±0.35 ^a	9.7±0.79 ^a	Non significant
Protein (%)	35.8±1.15 ^a	40.6±1.72 ^b	42.5±1.57 ^b	47.3±0.88 ^c	48.2±1.63 ^c	Significant
Residual oil (%)	15.5±0.50 ^a	13.3±0.55 ^{ab}	12.1±0.62 ^{bc}	9.8±0.48 ^{cd}	8.6±0.55 ^d	Significant
Crude fibre (%)	3.6±0.42 ^a	3.2±0.49 ^a	3.2±0.261 ^a	3.2±0.24 ^a	3.1±0.65 ^a	Non significant
Oxalic acid (%)	0.82±0.09 ^a	0.72±0.062 ^b	0.69±0.028 ^c	0.46±0.013 ^d	0.43±0.011 ^d	Significant

was a decrease in 1,000 grain weight, crude fibre and oxalic acid content with increase in pearling duration. The decrease in crude fibre and oxalic acid due to pearling proved that these components are mostly concentrated in the hull. Johnson et al. (1979) also reported that the removal of hull resulted into reduction of crude fibre and oxalic acid in the sesame seed.

Though there was a decrease in crude fibre and oxalic acid with the increase in pearling duration, oil from 30 min pearled sesame seeds started to ooze out. This stage was not conforming to the aim of our study. Therefore, 20 min was selected as optimum pearling duration to get the good quality pearled sesame seed having lesser crude fibre and oxalic acid.

Effect of soaking on hullability

The average hull content of sesame seed was 15.3 %. From Fig. 2, it is observed that the percent hullability was increased with the increase in soaking duration. But, there was no significant increase in hullability after 15 min of soaking. At 10 min of soaking, only 24.7 % hullability was observed. Hence, 15 min was considered as the optimum soaking time to remove hull from the sesame seeds. Sastry et al. (1969) also studied the wet dehulling of sesame seeds and observed efficient dehulling with water. However, the same author also used the alkaline solution for dehulling, but it lead to thick slurry that was difficult to handle.

Effect of steaming

From Table 2, it was observed that all the measured quality parameters were decreasing with increase of the steaming duration. Protein content of the seeds did not affected significantly. Sastry et al. (1974) also observed that heat treatment of the sesame seeds did not affect the protein significantly. During steaming treatment, the moisture is absorbed by seed and thus weight of the seed is increased. As the parameters were determined on 'as is' basis, therefore, this increase in weight might lead to the proportionate decrease in the oxalic acid, fat and other measured parameters. The steamed sesame seed samples

mentioned in Table 2 were dried and fed into the oil expeller for two passes and the residual oil and other quality parameters of defatted cake were determined (Table 3). From Fig. 3 & Table 3, it is plausible that residual oil in cake and oxalic acid decreased significantly ($p \leq 0.05$) with increase in steaming duration and protein content increased significantly. This may be due to the fact that steaming leads to the expansion of the oil globules and due to breakage of nexus between oil globules and protein matrix, the oil in the cells tried to diffuse out of the cells, making it more efficiently extractable (Nagaraj 2009). However, there was no significant ($p \leq 0.05$) change in residual oil and protein content of cake after 15 min of steaming. Hence, on the basis of less residual oil and more protein content, 15 min steaming was selected as an optimum steaming duration for the production of good quality defatted sesame cake. The defatted cake obtained in the present study was better in terms of high protein, low crude fibre and low oxalic acid as compared to the expeller pressed and alcohol/hexane extracted sesame oilcake produced by Weiss (2000). Sastry et al. (1974) studied the effect of heat treatment on the protein quality of sesame meal and reported that heat treatment did not affect the amount of total protein. However, heat treatment for a prolonged period (60 min) caused significant decrease in the protein quality.

Fig. 3 Effect of steaming duration on residual oil of defatted cake (Bars with similar letter do not differ significantly ($p \leq 0.05$) for each pass)

Table 4 Effect of drying temperature on quality of defatted sesame cake

Parameter	Drying temperature, °C				Overall effect ($p \leq 0.05$)
	40	50	60	70	
Moisture (% w.b)	7.1±0.32 ^a	5.6±0.35 ^b	5.1±0.58 ^b	4.7±0.39 ^b	Significant
Protein (%)	47.9±0.97 ^a	47.5±0.68 ^a	47.05±0.42 ^a	47.7±0.63 ^a	Non significant
Fat (%)	9.8±0.53 ^a	9.3±0.73 ^a	9.2±0.43 ^a	9.0±0.24 ^a	Non significant
Crude fibre (%)	3.2±0.51 ^a	3.2±0.62 ^a	3.2±0.55 ^a	3.2±0.63 ^a	Non significant
Oxalic acid (%)	0.45±0.045 ^a	0.43±0.013 ^a	0.42±0.016 ^a	0.42±0.112 ^a	Non significant
Hunter L value	60.6±0.13 ^a	59.8±0.52 ^a	57.8±0.92 ^b	53.8±0.47 ^c	Significant
Hunter a value	5.2±0.11 ^a	5.8±0.47 ^a	6.3±0.07 ^b	6.4±0.05 ^b	Significant
Hunter b value	16.2±0.77 ^a	17.4±0.17 ^a	20.8±0.76 ^b	21.7±0.59 ^b	Significant
Color difference	62.9±0.33 ^a	62.6±0.58 ^a	61.8±1.12 ^a	58.3±0.66 ^b	Significant

Effect of drying temperature

The oilcake produced using the above optimum process conditions was dried and the effect of different drying temperature on the quality of defatted sesame cake was studied (Table 4). The moisture content of the oilcake decreased with the increase of the drying temperature. No significant effect of drying temperature was observed on the protein, fat, crude fibre and oxalic acid content. There was a significant decrease in lightness (L) value and increase in redness (a) and yellowness (b) value. However, difference in hunter colour parameters (L, a, b) of the cake dried at 40 and 50 °C was not significant. The moisture content (5.6 %) in the cake dried at 50 °C was significantly lower (7.1 %) as compared to cake dried at 40 °C. The lower moisture in the cake will facilitate extended shelf-life. Drying

temperature above 50 °C resulted darker cake as indicated by colour values (Table 4). Thus, 50 °C temperature was considered as an optimum drying temperature to get good quality partially defatted sesame flour.

Proximate analysis

On the basis of the whole experiment, the process diagram showing optimum parameters to get high quality partially defatted sesame flour (PDSF) at pilot scale is given in Fig. 4. The proximate composition of the prepared partially defatted sesame flour was determined and compared (Table 5) with sesame seeds and its defatted flour (control). There was a significant difference in all the parameters (protein, oil, ash, crude fibre, oxalic acid and average particle size) for the raw seeds, untreated and treated partially defatted sesame flour. The treated PDSF had higher protein (50.5 %) and lower crude fiber

Fig. 4 Typical process flow chart for the production of protein rich defatted sesame flour at pilot scale**Table 5** Proximate composition of raw sesame seed and prepared partially defatted flour

Parameters	Materials		
	Raw sesame seeds	Untreated PDSF (Control)	Treated PDSF*
Moisture content (% w.b)	4.8±0.24 ^a	8.1±0.52 ^b	5.6±0.39 ^c
Protein (%)	22.3±0.82 ^a	33.7±2.06 ^b	50.5±1.08 ^c
Fat (%)	52.7±1.49 ^a	12.3±0.84 ^b	9.3±0.58 ^c
Ash content (%)	4.4±0.20 ^a	2.8±0.44 ^b	3.6±0.22 ^c
Crude fiber (%)	6.5±0.24 ^a	5.3±0.29 ^b	3.2±0.33 ^c
Oxalic acid (%)	2.2±0.17 ^a	1.9±0.036 ^b	0.43±0.028 ^c
Average particle size (mm)	3.5±0.22 ^a	0.41±0.051 ^b	0.29±0.021 ^c

*Partially defatted sesame flour (PDSF) produced using selected optimum parameters in this work

^{a,b,c} used in the table show the statistical significance of the each quality parameter measured

(3.2 %), oxalic acid (0.43 %) and average particle size (0.29 mm) as compared to control (Table 5). Significant decrease in the antinutritional component i.e. oxalic acid content is observed in treated PDSF. This may be due to the effect of pearling and removal of hull which contains oxalic acid. Toma and Tabekhia (1979) also reported that decortication of sesame seeds can remove most of oxalic acid. The significant difference in residual oil content of treated (9.3 %) and untreated PDSF (12.3 %) sample may be due to the effect of steaming which resulted in more oil extraction from the treated seeds. The absence of steam treatment and presence of hulls might result higher particle size (0.41 mm) of control PDSF than the treated PDSF (0.29 mm). Other measured quality parameters were also improved in the treated PDSF as compared to the untreated samples.

Conclusion

The study revealed that protein rich flour can be prepared from sesame seeds by employing pearling, soaking, steaming, oil expelling and drying treatments. The optimum combination of 20 min pearling, 15 min soaking, 15 min steaming at 100 kPa steam pressure and drying at 50 °C yielded protein rich flour with lower anti-nutritional component. The results of the present study will be useful in the development of protein rich flour from sesame seeds with less residual oil, crude fibre and oxalic acid. The produced flour may be used as protein supplement for human consumption. However, further research in this direction is needed to develop different food formulations containing defatted sesame flour.

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