Effect of Dehulling and Heat Processing on Nutritional Value of Sesame Proteins

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ABSTRACT

Processing of edible sesame flour involves use of hot lye treatment of the seed for dehulling followed by drying, screw pressing, and solvent extraction. The effect of such processing on protein quality, especially lysine availability has been studied. The enzymatic digestibility of protein is improved as a result of dehulling, and lysine present in the flour exhibits remarkable stability to heat treatment, the maximum losses being less than 15% even under drastic conditions of heat treatment of the flour (1 kg/cm^2 for 60 min). Supplementation of the flour with lysine at an optimal level of 1.25 g L-lysine HCl/100 g flour enhances the nutritive value of protein, making it comparable to that of milk powder.

INTRODUCTION

The importance of utilizing oilseed meals as supplementary protein sources for human consumption has received considerable attention in recent years. India is one of the major oilseed producing countries in the world and has the largest production of peanuts (5 million tons) and sesame seeds (0.5 million tons). A major portion of this production, ca. 80% is utilized for oil extraction and the rest for edible uses in traditional foods. Between the two oilseeds, sesame has special significance as a rich source of sulphur containing amino acids, particularly methionine; both have however, marginal levels of the essential amino acid lysine, which is highly susceptible to heat damage during processing.

Earlier investigations carried out in this laboratory indicated that the primary factor which limits the extended use of sesame meal for human consumption is the presence of hull, which contributes to color, bitterness, and high oxalate and fiber content and that dehulling was, therefore, essential to improve its quality. This was accomplished by contacting the seed with a weak lye solution under optimal conditions (1, 2). The dehulled seed and the defatted meal obtained from it were found to be superior to the original black seed, and the cake obtained from it was found to be superior with respect to acceptability and nutritional quality. It also was observed that heat treatment inherent to the expeller operation had a beneficial effect upon the nutritive value of sesame protein as assessed by the protein efficiency ratio (PER) values of sesame flours obtained by direct solvent extraction and screw pressing followed by solvent extraction.

The effect of processing sesame seed upon protein quality with special reference to the loss or unavailability of lysine has been studied by others (3-5). Commercial samples of screw pressed sesame cake were, in general, found to contain significantly lower amounts of available lysine, indicating damage to protein quality under normal expelling conditions; the meals also gave lower growth rates and PER in biological tests with rats and chicks. Since results obtained in our work (1) had shown that heat treatment was beneficial in improving the nutritional quality of sesame protein, it was of interest to study the effect of such processing, namely dehulling and heat treatment, upon the available lysine content of the protein and its dispersibility and enzymatic digestibility. The effect of supplementing edible sesame flour with lysine upon the nutritive value of protein also has been studied.

EXPERIMENTAL PROCEDURES

Sesame Flour Samples

S: Cleaned, commercial black sesame seed was flaked to 0.1 mm thickness in a twin flaking roll and exhaustively solvent extracted using hexane. The extracted meal was air dried at room temperature for 24 hr and finally dried in a vacuum shelf drier for 4 hr to remove the solvent.

S-1: Black sesame seed was dehulled by wet dehulling process involving the use of lye (0.6% NaOH) at 86 C for 1 min (1). The dehulled seed was dried mechanically in a current of hot air in a through-flow drier at 60 C for 2 hr. It was flaked, solvent extracted, and the defatted meal prepared as above.

S-2: S-1 was subjected to heat treatment. It was spread in a stainless steel tray to 0.5 cm thickness and covered with another tray to minimize moistening with condensed steam and autoclaved at 1 kg/cm^2 (120 C) for 15 min. The autoclaved sample was free flowing, though there was a slight increase in moisture content (moisture increase during autoclaving was only 5%). It was air dried.

S-3, S-4, and S-5: These samples were prepared by autoclaving S-1 for 30, 45, and 60 min, respectively, under conditions similar to S-2. The maximum moisture level attained after autoclaving in the case of S-5 was found to be 11.3%.

S-6: The dehulled seed was cooked in a 2 ft high stack cooker of an expeller for 20 min at a temperature of 80-95 C (moisture increase during cooking was from initial 5-9%) and expeller pressed. Two successive pressings were done to get a cake containing ca. 10% fat. The cake was ground coarsely to 16 mesh size, extracted with hexane, and dried as in the case of S.

S-7, S-8, S-9, and S-10: These samples were prepared by autoclaving S-6 for 15, 30, 45, and 60 min, respectively, under conditions given earlier; the moisture increase during autoclaving was not appreciable, the final moisture content in the case of S-10 being ca. 11.0%. All the samples were ground to pass through 60 mesh screen and taken for analysis.

Analytical Procedures

Total lysine: Total lysine content of the samples was

TABLE I

Effect of Heat Processing upon the Available Lysine Content in Sesame Protein

Sample and method of processing		Protein content N x 6.25	Total lysine M. assay g/16g N	Chemically available lysine g/16 g N	Loss of available lysine %
S	Original, defatted	38.90	2.36	2.39	—
S-1:	Dehulled, defatted	52.05	2.30	2.28	—
S-2:	S-1 autoclaved 15 min.		2.28	2.29	—
S-3:	S-1 autoclaved 30 min		2.29	2.25	1.32
S-4:	S-1 autoclaved 45 min		2.34	2.19	3.95
S-5:	S-1 autoclaved 60 min		2.30	2.09	8.33
S-6:	Dehulled, screw pressed and defatted	54.40	2.36	2.20	3.51
S-7:	S-6 autoclaved 15 min		2.34	2.28	—
S-8:	S-6 autoclaved 30 min		2.40	2.20	3.51
S-9:	S-6 autoclaved 45 min		2.40	2.10	7.90
S-10:	S-6 autoclaved 60 min		2.34	1.99	8.74

determined by microbiological assay procedure using *Leuconostoc mesenteroids* P-60 organism (6), and the value was expressed as g/16 g N.

Available lysine: This was determined by the corrected straight acid procedure of Carpenter based upon the chemical reaction of lysine with fluorodinitrobenzene and expressed as g/16 g N (7).

Protein dispersibility: The dispersibility of protein was determined using both water at pH 7.2 and 0.02 N NaOH solution as solvents in the following manner: 2 g sample was taken in a conical flask, 60 ml distilled water added and the pH adjusted to 7.2 with 1 N NaOH. The flask was shaken for 30 min and the contents centrifuged for 15 min at 2000 rpm. A second extraction was made using 40 ml water at pH 7.2. The supernatants were combined, made up to 100 ml, and an aliquot was taken for nitrogen estimation. For determining the protein dispersibility in 0.02 N NaOH solution, the sample (2 g) was shaken for 2 hr with 100 ml of the solvent and centrifuged at 2000 rpm for 15 min (8). An aliquot of the supernatant was taken for nitrogen estimation. The percentage of the total nitrogen extracted under these conditions was expressed as the protein dispersibility in the respective solvents.

Protein digestibility: The enzymatic digestibility of the protein in a selected number of sesame flour samples was determined by the pepsin-pancreatin procedure described by Villegas, et al. (5). Controls without enzymes also were included in each case. In addition, the digests were examined for the presence of any protein intermediary products stable to enzyme attack by the trichloroacetic acid (TCA) precipitation method of Birk and Bondi (9). For this the enzymatic digests were treated with an equal volume of 10% TCA to precipitate the undigested protein, centrifuged, and the nitrogen determined in the supernatant.

Animal experiments: The PER and the net protein utilization (NPU) of the protein in selected sesame flour samples were determined according to the standard procedures (10).

RESULTS AND DISCUSSION

Total lysine: Values given in Table I indicate that the total lysine content in the different sesame flour samples ranged from 2.28-2.40 g, and these are comparable to the literature values for sesame protein.

Lysine availability: In a number of foodstuffs, the lowering of nutritional value of protein is brought about by a loss or unavailability of essential amino acids, particularly lysine which is highly susceptible to heat damage. The adverse effects of heat upon the lysine availability in peanut, cottonseed, soybean, and sunflower seed during processing have been reported (11-15). Data on the effect of dehulling and heat processing of sesame seed upon the total and available lysine contents of the proteins are presented in Table I. As evident from the results, the total, as well as the available lysine values of protein in the original sample (S), was nearly the same (2.36 and 2.39 g, respectively); the dehulled sample (S-1) gave slightly lower values of 2.30 and 2.28 g, respectively. This agrees with the data of Carter, et al., (3) who got nearly the same value for available lysine in the original and dehulled sesame samples.

Prepressed and solvent extracted sesame flour (S-6) prepared from dehulled seeds showed a small decrease in the available lysine content (2.2 g), while the total lysine content was unaffected (2.36 g). Heat treatment (autoclav-

TABLE II

Effect of Dehulling and Heat Processing upon the Dispersibility of Sesame Protein in Water and Sodium Hydroxide Solution

Sample		Protein %	Dispersibility of protein g/100 g total protein: Water at pH 7.2	Dispersibility of protein g/100 g total protein: 0.02N[a] NaOH
S:	Original, defatted	38.9	21.1	92.7
S-1:	Dehulled, defatted	52.1	14.4	90.1
S-2:	S-1 autoclaved 15 min	51.9	11.0	78.5
S-5:	S-1 autoclaved 60 min	51.9	8.5	55.0
S-6:	Dehulled, screw pressed and defatted	54.4	11.2	81.6
S-7:	S-6 autoclaved 15 min	54.4	10.6	74.4
S-10:	S-6 autoclaved 60 min	54.4	7.8	46.3

[a] Final pH value of dispersion was 11.5.

TABLE III

Enzymatic Digestibility of Protein in Sesame Flour

Sample		Digestibility (soluble N/total N x 100)		TCA[a] extract % N	
		Without enzyme	With enzyme	Without enzyme	With enzyme
S:	Original, defatted	21.8	66.0	21.0	63.0
S-1:	Dehulled, defatted	20.7	81.4	20.0	81.0
S-6:	Dehulled, screw pressed and defatted	16.8	70.4	16.0	70.4

[a]TCA = trichloroacetic acid.

ing) of the direct solvent extracted sesame flour from dehulled seeds (S-1) at 120 C for 15, 30, 45 min (S-2, S-3, and S-4), respectively, did not lower the values for available lysine content appreciably (range 2.28-2.19 g); the samples heated for 60 min (S-5), however, gave a value of 2.09 g corresponding to a loss of ca. 8% in available lysine. Similarly, heat treatment of the prepress solvent extracted flour (S-6) for 15 and 30 min (S-7 and S-8) showed no appreciable loss in available lysine, the values being 2.28 and 2.20 g, respectively. However, longer heat treatment for 45 and 60 min (S-9 and S-10) lowered the value to 2.10 and 1.99 g respectively from the initial value of 2.28 g, the losses being 8 and 13%. Thus, under the processing conditions employed in the present study, heat damage to lysine in sesame flour was not appreciable, the maximum loss being less than 15% even under extreme conditions of heat processing. This could be due to the fact that the moisture content of the samples during autoclaving did not exceed 11%.

Protein dispersibility: Data given in Table II show that the dehulled sesame flour obtained by either direct solvent extraction (S-1) or prepressing and solvent extraction (S-6) possessed lowered protein dispersibilities of 14.4 and 11.2%, respectively, compared to 21.1% of the original sesame flour. This lowering could be due to denaturation of the protein during the hot lye treatment given to the seed for dehulling. Autoclaving of the above samples at 120 C for 15 and 60 min (S-2, S-5 and S-7, S-10) lowered the protein dispersibilities further to 11.8-7.8%. A similar trend was seen in the case of dispersibility studies with 0.02 N NaOH as solvent, wherein the final pH value of the dispersion was 11.5. The protein dispersibilities in the weak alkali ranged from 46-92% compared to 8-21% in water at pH 7.2.

Protein digestibility: Data given in Table III show that the enzymatic protein digestibility value of the original sesame flour (S) was 66% compared to 81.4% in the case of dehulled sesame flour (S-1), indicating that the presence of hulls and hull constituents lowers the in vitro digestibility of proteins. When dehulled sesame seed was expeller pressed and solvent extracted (S-6), the digestibility value decreased from 81.4-70.4%. This reduction presumably is due to the heat denaturation of protein during expeller pressing. The TCA soluble fraction of the enzymatic digests contained practically all of the nitrogen present in the enzymatic digest. This would indicate that no enzymatically resistant protein fractions were present in edible sesame flour and that dehulling of the seed improves the digestibility of the protein.

Nutrition studies: The chemical score of sesame protein based upon the amino acid pattern of egg as reference protein (A:E ratio) is 63, the primary deficiency in the protein being lysine (16). Expeller pressed sesame cake from undehulled sesame seed has been reported to give a value of 55 for the NPU value. Fortification of this flour with lysine, corresponding to levels present in milk protein (8.2%), had been shown to increase the PER and NPU values significantly; while at a lower level of lysine supplementation, corresponding to that of Food and Agriculture Organization reference protein (4.4 g), there was no improvement in protein quality (17).

Data upon PER values for protein obtained on rats fed on edible sesame flour prepared from prepress solvent extraction of dehulled seeds is given in Table IV. The effect of supplementation of the flour with L-lysine HCl at levels of 1.25 g and 2.50 g/100 g flour upon the nutritive value of protein also has been studied. At the lower levels of supplementation (1.25 g), the lysine content of sesame protein would increase from 2.4-4.4 g/100 g protein, and this was found adequate to correct the lysine deficiency (A:E ratio). At the higher level of supplementation (2.5 g), the lysine content would increase to 6.4 g/100 g protein corresponding to the level present in egg protein. Rats fed on edible sesame flour diet gained a body wt of 36.9 g in 4 weeks and gave a PER value of 1.80. Supplementation of the flour at an optimal level of 1.25 g L-lysine HCl nearly doubled the average gain in wt from 36.9 to 71.5 g and increased the PER from 1.80 to 2.88, the values comparing favorably with milk powder which promoted a wt gain of 67 g and gave a PER value of 3.08. Supplementation of sesame flour with lysine at a higher level (2.5 g) did not show any further improvement in the wt gains and PER,

TABLE IV

Effect of *Lysine* Supplementation upon the Nutritive Value of Dehulled Sesame Flour

Group	Source of protein in diet	Level of protein %	Gain in wt, g	Food intake g	PER[a]
A	S-6: Dehulled, screw pressed and defatted	10.05	36.9	205	1.80
B	S-6 + 1.25% L-lysine HCl	10.40	71.5	238	2.88
C	S-6 + 2.50% L-lysine HCl	10.65	71.6	237	2.85
D	Skim milk powder	9.53	67.0	228	3.08

[a]Eight male rats in each group, 4 weeks duration, standard error of the individual means ± 0.062 (21. degrees of freedom). PER = protein efficiency ratio. Test of significance: B∿C not significant at 5% level, A is significantly lower, and D higher than the rest.

TABLE V

Net Protein Utilization (NPU) Studies upon Sesame Protein

Group	Source of protein in diet	Level of protein %	Average initial wt, g	Average gain in wt, g	Body N		Average N intake		NPU[a]
					Non protein group	Test protein group	Non protein group	Test protein group	
A	S-1: Dehulled, defatted flour	10.56	65.9	18.6	1.4	2.40	1.28	1.77	67
B	S-2: S-1 autoclaved 15 min.	10.60	66.0	19.1	1.4	2.48	1.28	1.85	69
C	S-2 + 1.25% L-lysine HCl	10.68	66.0	28.8	1.4	2.78	1.28	1.77	89

[a]Eight male rats in each group, 10 days duration, standard error of the individual means ± 2.5 (12 degrees of freedom). Test of significance: A ∿ B not significant, $\left.\begin{matrix} A \sim C \\ A \sim C \end{matrix}\right\}$ highly significant at 0.1% level.

the values being 71.6 g and 2.85 respectively.

With a view to finding out whether there was any true improvement in the utilization of sesame protein as a result of heat treatment, NPU assay was carried out on growing rats using samples of direct solvent extracted sesame flour (S-1) and the same flour autoclaved for a period of 15 min at 1 kg/cm^2 (S-2). The effect of lysine supplementation of the flour (S-2) at an optimal level (1.25 g L-lysine HCl/100 g flour) on the NPU also was determined. The data are presented in Table V. There was no significant difference between the NPU values of the two sesame flours (S-1 and S-2), the values being 67 and 68 respectively. This result shows that, even though there is no improvement in the biological utilization of protein, there has been no damage to protein quality. The significant increase in the NPU value of the lysine fortified flour to 89 also confirms that the lysine originally present in the direct solvent extracted, as well as autoclaved, sesame flours is fully available for growth of rats.

The different experiments reported in the present study indicate: (A) dehulling of sesame seed is essential to upgrade meal quality; (B) heat treatment during dehulling, as well as subsequent processing of the flour, does not lower the available lysine content; (C) the lysine present in sesame protein exhibits remarkable stability even under severe conditions of heat treatment; (D) the enzymatic digestibility of protein is improved by dehulling; and (E) supplementation of the flour with L-lysine HCl at an optimal level of 1.25 g/100 g flour enhances nutritive value of the proteins making them comparable to that of skim milk powder.

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