Food Chemistry **18** (1985) 35–45

Chemical Composition and Nutritional Quality of Tehineh (Sesame Butter)

Wajih N. Sawaya, Muhammad Ayaz, Jehangir K. Khalil & Abdallah F. Al-Shalhat

Regional Agriculture and Water Research Center, Ministry of Agriculture and Water, PO Box 17285, Riyadh, Saudi Arabia 11484

(Received: 5 February, 1985)

ABSTRACT

The chemical composition and nutritional quality of tehineh, a paste of dehulled roasted sesame seeds, from Saudi Arabia and other countries, were studied. Results showed 24·7% protein, 58·9% fat, 2·3% fiber, 3·0% ash and < 1·0% moisture. The tehineh contained relatively high amounts (mg/100 g) of P (692), Mg (362), Fe (7·19), Cu (1·96), Mn (1·46) and Zn (7·82) and low amounts of Ca (61) and Se (0·05). Gas–liquid chromatography (GLC) analysis of the oil revealed percentages of 42·4 for oleic, 39·7 for linoleic, 9·8 for palmitic and 6·4 for stearic acid. Lysine was the only limiting amino acid with a chemical score of 64, while the sulphur-containing amino acids (methionine + cystine) and tryptophan were present in amounts exceeding the requirement of the FAO/WHO (1973) reference protein. The in vitro *protein digestibility (IVPD) value of 83·3% and the calculated protein efficiency ratio (C-PER), 2·14, were slightly higher than those of sesame seeds and both values were lower than the IVPD and C-PER of 90·0% and 2·50, respectively, for ANRC casein.*

INTRODUCTION

Sesame is considered to be one of the first oil seed crops ever grown, archeological evidence indicating that it was cultivated in Syria and the civilization of Babylonia around 3000 BC (Johnson *et al.*, 1979).

At present, sesame is grown primarily in tropical and subtropical areas of the world and has lately been adapted to semi-arid regions. The annual world production for 1982 was estimated to be 1 870 000 tons, with India, China and Sudan being the major world producers (FAO, 1982).

Sesame seeds contain about 50 % oil, which is highly stable, and about 25 % protein, which is rich in the sulphur-containing amino acids methionine and cystine. Sesame is primarily grown for its oil content with the oil-free meal traditionally being used for animal feed. Restriction on the use of the meal for human consumption resides in the high oxalic acid, calcium and selenium contents of the hull, as well as the meal's intense bitter taste. When dehulled, sesame seeds are sweet and oleagenous and are used directly in different types of food in various parts of the world (Johnson *et al.*, 1979).

In the Middle East, dehulled sesame seeds are mainly utilized in the production of tehineh (a peanut butter counterpart), which is made from a paste of dehulled roasted sesame seeds, and halaweh (Halva), a sweet made up of tehineh, sugar, citric acid and *Saponaria officinalis* root extract. All tehineh products are commercially produced in specialized factories which exist in many countries of the Middle East and North Africa. In Saudi Arabia alone, there are ten factories which produce tehineh and halaweh, some being equipped with the most up-to-date production lines and being completely automated. However, all the sesame utilized in the production of halaweh and tehineh in Saudi Arabia is imported, mainly from Sudan, Ethiopia and India (Anon., 1982).

The popularity of tehineh among the people of the Middle East is evidenced by its use in several popular foods in the region. It is usually mixed with cooked chickpeas and the product is called 'Hommes tehineh' or mixed with eggplants to obtain 'Baba gannouj', which are very popular dishes in Middle eastern areas, and it is also mixed with legumes and fresh green vegetables in a salad form. Tehineh is also added to some types of bread and bakery products and is used as a sauce for fish and meat and is a major constituent of halaweh ($\simeq 50\%$) and other sweets, pastries and snack foods. Information on the nutritive value of tehineh is scarce except for a report by Pellett & Shadarevian (1970) on the chemical composition and amino acid contents of tehineh from Lebanon.

The objective of the present investigation was to study the chemical composition and nutritional characteristics of tehineh produced in the Kingdom of Saudi Arabia and of samples imported from Lebanon and Tunisia.

MATERIALS AND METHODS

Manufacture of tehineh

All tehineh products marketed are prepared in specialized factories. The methods used vary from factory to factory; however, the basic principles followed for the preparation of tehineh are the same, be the method the old conventional one or the newly automated one. Sesame seeds (white variety) are cleaned, sieved and dehulled, either by soaking in water and then passing them through a peeler or by steam injection and hot air blowing. The seeds are then dried and passed through a roaster (90–100 °C) (either steam heated jacketed tunnels with mixers or an electrically heated tunnel) for a few minutes. The roasted sesame seeds (light yellowish brown) are then ground, either by stone mills or by high speed automatic mills, to a viscous paste which is then filled into various size containers (mostly plastic) and marketed as tehineh.

Collection of samples

Samples ($5 \times 0{\cdot}5$ kg per factory) were collected from ten factories in Saudi Arabia. Two additional samples, imported from Lebanon and Tunisia, were bought at a local market. All samples collected were packaged in plastic containers and kept at room temperature—the usual method of storage—for further analyses. All analyses were carried out in triplicate on one sample from each factory and on samples collected from the market, representing a homogeneous mixture of $5 \times 0{\cdot}5$ kg.

Proximate analyses

Proximate analyses, for crude fat, crude fiber, crude protein ($N \times 6{\cdot}25$), moisture and ash, were carried out according to procedures outlined in AOAC (1980).

Minerals

For the determination of mineral elements (sodium, potassium, calcium, magnesium, phosphorus, iron, copper, zinc and manganese) the ash was dissolved in 20% HCl. The final diluted solution for calcium and magnesium contained 1% lanthanum to overcome interference, especially by phosphates. All minerals except sodium, potassium and phosphorus were determined with an atomic absorption spectrophotometer (Perkin-Elmer, Model 603). Sodium and potassium were determined with a flame photometer (Beckman, Klina Flame). Phosphorus was determined spectrophotometrically using the procedure of Watanabe & Olsen (1965).

For the determination of selenium, 5 g of each of the samples were wet-ashed, using a mixture of 3:1 nitric + perchloric acids, and the residue obtained was taken up in 5 ml of 25% v/v hydrochloric acid followed by further evaporation to almost dryness. The residue was then diluted with deionized water and the selenium content was determined colorimetrically by the diaminobenzidine method according to the procedure of Hoste and Gillis, as described by Allen (1974).

Isolation and identification of fatty acids

Tehineh was extracted for 8 h with petroleum ether in a Soxhlet extractor. After extraction, the solvent was removed by a rotary evaporator under pressure and the oil flushed with nitrogen. Fatty acids were determined in the oil as their methyl esters by gas–liquid chromatography. For the preparation of methyl esters, 2 g of the oil was refluxed with 15 ml 14% BF_3-MeOH and 5 ml benzene (AOCS, 1974). After extraction with diethyl ether, the extract was dried with anhydrous sodium sulphate and evaporated to dryness under reduced pressure. Quantitative analysis of the methyl esters was performed with a gas–liquid chromatograph (Varian 6000) equipped with a hydrogen flame ionization detector. Fatty acid methyl esters of chain length $C_{8:0}$ to $C_{22:0}$ were analyzed using a 3 mm × 4 m stainless steel column packed with 10% SP-2330 on 100–120 mesh Chromosorb WAW. Column temperature was programmed from 130 to 175 °C at 11·3 °C/min, 175 to 200 °C at 1·8 °C/min and 200 to 205 °C at 1·0 °C/min. The flow rate of the carrier gas, nitrogen, was 4·0 ml/min, with flow rates at 40 and 200 ml/min for hydrogen and air, respectively. Peaks were identified by comparing their retention times with those of authentic standards and peak areas were integrated by a computing integrator (Vista 401). The fatty acid profile was quantitated according to procedures outlined in AOCS (1977).

Amino acid analysis

Samples of tehineh containing 5 mg protein were hydrolyzed with 6 N HCl for 24 h at 110 °C (Moore & Stein, 1963). Cystine was determined, as cysteic acid, by performic acid treatment of the sample and then hydrolyzing as described above (Moore, 1963). Tryptophan was released by alkaline hydrolysis with NaOH (Hugli & Moore, 1972). All the hydrolysates were analyzed with a Beckman Model 119 CL amino acid analyser.

Chemical score

The chemical score was calculated by dividing the contents of the essential amino acids in tehineh protein by the amounts of the same amino acids in the FAO/WHO reference protein (FAO/WHO, 1973).

In vitro protein digestibility (IVPD) and calculated protein efficiency ratio (C-PER)

The IVPD of tehineh was determined by the multienzyme digestive procedure of Hsu *et al.* (1977) with the modifications suggested by Satterlee *et al.* (1979). The C-PER was calculated from the data on essential amino acids and IVPD according to the procedure of Satterlee *et al.* (1979).

RESULTS AND DISCUSSION

The proximate composition of tehineh (Table 1) shows high percentages of fat (58·9 %) and protein (24·7 %), low percentages of crude fiber (2·3 %) and moisture (< 1·0 %) and substantial levels of ash (3·0 %). These values are more or less comparable with those reported by Pellet & Shadarevian (1970) for the tehineh of Lebanon with only minor differences. The results are also in agreement with those reported by Johnson *et al.* (1979) for the proximate composition of dehulled sesame seeds of the Sudanese white variety, but contain relatively higher levels of protein and fat, and lower levels of ash, compared with the values reported by Watt & Merrill (1963) for decorticated sesame seeds. Since it is known that compositional differences exist among the different varieties of sesame seeds, and even among the same varieties grown in different countries (Johnson *et al.*, 1979), and since sesame seeds imported to Saudi Arabia, although mostly of the white variety, are not confined to one region, variation in the proximate composition of tehineh produced in different countries is not unexpected.

TABLE 1
Chemical Composition of Tehineh

Nutrient	*Concentration*[a]
Moisture (%)	0·7 ± 0·42
Crude protein (%)	24·7 ± 1·70
Crude fat (%)	58·9 ± 2·54
Crude fiber (%)	2·3 ± 0·21
Ash (%)	3·0 ± 0·18
Na (mg %)	251 ± 77·23
K (mg %)	354 ± 44·10
Ca (mg %)	61 ± 27·01
P (mg %)	692 ± 71·36
Mg (mg %)	362 ± 40·87
Fe (mg %)	7·19 ± 0·49
Zn (mg %)	7·82 ± 0·68
Cu (mg %)	1·96 ± 0·24
Mn (mg %)	1·46 ± 0·17
Se (mg %)	0·05 ± 0·01

[a] Mean of forty determinations ± standard deviation on fresh weight basis.

Mineral contents

The mineral contents of tehineh (Table 1) show relatively lower levels of Ca, P and Fe compared with the values reported by Pellet & Shadarevian (1970) for Lebanese tehineh (Ca, 100 mg/100 g; P, 840 mg/100 g; Fe, 9·0 mg/100 g). No data are available on the contents of other minerals in tehineh. However, data for the mineral composition of sesame seeds is already established (Watt & Merrill, 1963; Johnson *et al.*, 1979; Deosthale, 1981). When compared with sesame seeds, the Ca content of tehineh is very low, which is mainly due to dehulling of seeds since the hull contains usually over 80 % of the Ca (Johnson *et al.*, 1979). The contents of P and Mg are also lower in tehineh (P, 692 mg/100 g; Mg, 362 mg/100 g) than in sesame seeds (P, 872 mg/100 g; Mg, 521 mg/100) while those of the microelements Cu, Mn and Zn are comparable. The selenium content of tehineh was relatively low ($\simeq$0·05 mg/100 g) compared with the values reported by Brito & Nunez (1982) for other sesame seed varieties. Selenium ingestion for a long period could be toxic if it exceeds a daily intake of 5 ppm (FNB/NRC, 1976). However, the levels of selenium detected in tehineh were relatively low.

In general, the data presented here show that tehineh is a rich source of inorganic nutrients. A hundred grams of tehineh can furnish approximately 7·6% Ca, 86·5% P, >100% Mg, 52·1% Zn, 72% Fe, 65–98% Cu and 29–58% Mn in terms of the Recommended Dietary Allowances (RDAs), or suggested safe and adequate daily intake of the Food and Nutrition Board (NRC/NAS, 1980), for adults.

Fatty acid composition

The fatty acid profile of tehineh oil is presented in Table 2. The oil is highly unsaturated (≃82%), with oleic (42·4%) and linoleic (39·7%) acids being the two major unsaturated fatty acids present. Among the saturated fatty acids, palmitic (9·8%) and stearic (6·4%) were predominant. Altogether, oleic, linoleic, palmitic and stearic acids constituted over 98% of the total tehineh fatty acids. In comparison with data in the literature, the tehineh oil fatty acid profile is similar to that of sesame seed oil of non-domestic sesame seed varieties grown at Shamleat in Sudan, as reported by El-Tinay *et al.* in 1976 (Swern, 1979) but differs slightly from that reported by Archer *et al.* (Anon., 1961) where linoleic acid (43%) was reported to be higher than oleic acid (40%). Minor differences among the fatty acid compositions of sesame seed oils in different sesame varieties and for different locations exist and are already documented (Brar, 1982).

TABLE 2
Fatty Acid Composition[a] of Tehineh

Fatty acid[b]	*(g/100 g)*
Palmitic $C_{16:0}$	9·8 ± 0·15
Palmitoleic $C_{16:1}$	0·1 ± 0·01
Heptadecanoic $C_{17:0}$	0·1 ± 0·014
Stearic $C_{18:0}$	6·4 ± 0·34
Oleic $C_{18:1}$	42·4 ± 1·0
Linoleic $C_{18:2}$	39·7 ± 0·53
Linolenic $C_{18:3}$	0·4 ± 0·42
Arachidic $C_{20:0}$	0·5 ± 0·01
Behenic $C_{22:0}$	0·2 ± 0·03

[a] Mean of five determinations ± standard deviation.
[b] $C_{19:0}$, $C_{21:0}$, $C_{23:0}$ were detected in trace amounts (<0·1%).

Nutritive value

Table 3 shows the amino acid composition of tehineh. The amino acid profile of tehineh indicated that lysine (3·51 g/100 g protein) was the first limiting amino acid with a chemical score of 64 for the protein. Tehineh protein contained high levels of tryptophan (1·36 g/100 g protein) and the sulphur-containing amino acids, methionine and cystine (4·70 g/100 g protein), which are usually limiting in many foods. Isoleucine, which was

TABLE 3
Amino Acid Composition[a] (g/100 g Protein), *In Vitro* Protein Digestibility[b] (IVPD) and Calculated Protein Efficiency Ratio[c] (C-PER) of Tehineh

Amino acid	*Concentration*	*FAO/WHO reference protein*
Threonine	4·04 ± 0·18	4·0
Valine	5·22 ± 0·30	5·0
Isoleucine	4·36 ± 0·24	4·0
Leucine	7·81 ± 0·43	7·0
Tyrosine (T)	3·22 ± 0·23	—
Phenylalanine (P)	5·10 ± 0·31	—
T + P	8·32 ± 0·47	6·0
Lysine	3·51 ± 0·17	5·5
Methionine (M)	2·47 ± 0·36	—
Cystine (C)	2·23 ± 0·28	—
M + C	4·70 ± 0·43	3·5
Tryptophan	1·36 ± 0·05	1·0
Aspartic acid	9·0 ± 0·44	—
Serine	5·09 ± 0·26	—
Glutamic acid	21·4 ± 1·87	—
Proline	3·42 ± 0·46	—
Glycine	5·50 ± 0·31	—
Alanine	5·24 ± 0·22	—
Histidine	2·75 ± 0·14	—
Arginine	14·1 ± 1·16	—
Chemical score	64	
IVPD (%)	83·3 ± 0·74	
C-PER	2·14 ± 0·04	

[a] Mean of nine determinations ± standard deviation.
[b] Mean of twenty determinations ± standard deviation.
[c] Mean of six determinations ± standard deviation.

reported by Johnson *et al.* (1979) to be the only other deficient essential amino acid in sesame seeds after lysine, was not found to be deficient in tehineh protein in the present study and, in fact, exceeded the FAO/WHO (1973) reference protein requirements. In comparison with the amino acid composition of sesame seed protein, the amino acid profile of tehineh protein conformed to the same pattern as that of sesame protein where lysine is usually reported to be the first limiting amino acid. However, the content of lysine in tehineh protein is higher than the values of 2·5–3·0 g/16 g N reported by Lyman *et al.* (1956), but comparable with those reported by other investigators (Johnson *et al.*, 1979; Brito & Nunez, 1982). Such variations might probably be due to varietal differences as well as to the effect of dehulling of seeds which leads to the improvement of the nutritional quality of sesame seed proteins (Johnson *et al.*, 1979).

The IVPD (83·3%) and C-PER (2·14) of tehineh were lower than those of the Animal Nutrition Research Council (ANRC) casein (Table 3). However, the IVPD of tehineh was slightly higher than the average digestibility value of sesame seeds (81·7%) while the C-PER was relatively much higher than the PER (1·77) of sesame seeds, as reported by the FAO (1970).

In conclusion, tehineh might be considered a highly nutritive food which could be used in various combinations with different types of food. Due to its high contents of sulphur-containing amino acids, it could be used as a food adjunct for improving the nutritional quality of diets based on legumes which are usually deficient in the sulphur-containing amino acids. The relatively high values for IVPD and C-PER indicate that tehineh is easily digestible and has a good nutritive value. Since tehineh is made from dehulled sesame seeds, most of the oxalates (2–3%) which chelate Ca are removed by dehulling.

REFERENCES

Allen, S. E. (Ed.) (1974). *Chemical analysis of ecological materials*. John Wiley & Sons, New York, pp. 330–7.

Anon (1961). *Composition and constants of natural fats and oils by gas-liquid chromatography*. Chart published by Archer-Daniels-Midland, Minneapolis, MN.

Anon (1982). *Foreign Trade Statistics*. Ministry of Finance and National Economy, Central Department of Statistics, Saudi Arabia.

AOAC (1980). *Official methods of Analysis* (13th edn), Association of Official Analytical Chemists, Washington, DC.

AOCS (1974). *Official and tentative methods*, Vol. 1, Method Ce 2-66, American Oil Chemists Society, Champaign, IL.

AOCS (1977). *Official methods of analysis*. (4th edn), Method Ce 1-62, American Oil Chemists Society, Champaign, IL.

Brar, G. S. (1982). Variations and correlations in oil content and fatty acid composition of sesame *Sesamum indicum*. *Indian J. Agric. Sci.*, **52**(7), 434–9.

Brito, O. J. & Nunez, N. (1982). Evaluation of sesame flour as a complementary protein source for combinations with soy and corn flour. *J. Food Sci.*, **47**, 457–60.

Deosthale, Y. G. (1981). Trace element composition of common oilseeds. *J. Am. Oil Chem. Soc.*, **58**, 988–90.

FAO (1970). *Amino acid content of foods and biological data on proteins*. FAO Food and Nutrition Series, No. 21. FAO Nutritional Studies, No. 24, Rome, Italy, 144.

FAO (1982). *FAO production yearbook*, Vol. 36, FAO Statistics Series, No. 47, Rome, Italy.

FAO/WHO (1973). *Energy and protein requirements*. FAO Nutritional Meeting. Report Series No. 52. WHO Tech. Report Series, No. 522, Food and Agriculture Organization of the United Nations, Rome, Italy.

FNB/NRC (1976). *Selenium and health*. Food and Nutrition Board, National Research Council, National Academy of Sciences, Washington, DC.

Hsu, H. W., Vavak, D. L., Satterlee, L. D. & Miller, G. A. (1977). A multienzyme technique for estimating protein digestibility. *J. Food Sci.*, **42**, 1269–73.

Hugli, T. E. & Moore, S. (1972). Determination of tryptophan content of proteins by ion exchange chromatography of alkaline hydrolysates. *J. Biol. Chem.*, **247**, 2828–34.

Johnson, L. A., Suleiman, T. M. & Lusas, E. W. (1979). Sesame protein: A review and prospectus. *J. Am. Oil Chem. Soc.*, **56**, 463–8.

Lyman, C. M., Kui, K. A. & Hale, F. (1956). Essential amino acid content of feeds. *J. Agric. Food Chem.*, **4**, 1008–10.

Moore, S. (1963). On the determination of cystine as cysteic acid. *J. Biol. Chem.*, **238**, 235–7.

Moore, S. & Stein, W. M. (1963). Chromatographic determination of amino acids by the use of automatic recording equipment. *Methods in Enzymology*, **6**, 819–31.

NRC/NAS (1980). *Recommended dietary allowances* (8th edn), Food and Nutrition Board, National Research Council, National Academy of Sciences, Washington, DC.

Pellet, P. L. & Shadarevian, S. (1970). *Food composition tables for use in the Middle East* (2nd edn), American University of Beirut, Heidelberg Press, Beirut, Lebanon.

Satterlee, L. D., Marshall, H. F. & Tennyson, J. M. (1979). Measuring protein quality. *J. Am. Oil Chem. Soc.*, **56**, 103–9.

Swern, D. (Ed.) (1979). *Bailey's industrial oil and fat products* (4th edn), Vol. 1, John Wiley & Sons, New York, pp. 387–91.
Watanabe, F. S. & Olsen, S. (1965). Test of an ascorbic acid method for determining phosphorus in water and $NaHCO_3$ extracts from soil. *Soil Sci. Soc. Am. Proc.*, **29**, 677–8.
Watt, B. K. & Merrill, A. L. (1963). *Composition of foods, raw, processed and prepared.* Agricultural Handbook No. 8, US Department of Agriculture, Washington DC.