Sesame: Current Knowledge of Composition and Use[1]

C.K. LYON Western Regional Research Laboratory,[2]
Berkeley, California

ABSTRACT

Because of its good taste and outstanding stability, sesame oil has long been one of the most desirable edible vegetable oils. Sesame meal is a valuable supplement for food and feeds because of the high methionine content of its protein relative to other oilseed proteins. Production of sesame seed in the U.S. has been small but is expected to increase with success in the development of nonshattering varieties. Current information on the composition, properties, processing and use of sesame is discussed.

INTRODUCTION

Sesame, which has been under cultivation in India for as long as rice has, has been called the "queen of the oilseed crops" because of the high yield of oil obtained and the good qualities of the seed, oil and meal (1). Sesame seed is used extensively in baked goods and confectionery products. The oil has a mild, pleasant taste and is a natural salad oil requiring little or no winterizing. It is particularly stable because of its content of natural antioxidants. It is used as a cooking oil, in shortenings and margarine, as a soap fat, in pharmaceuticals and as a synergist for insecticides. The meal has a high protein content and a favorable balance of amino acids for use in feeds and food. Reviews were published on the oil in 1951 (2), on the composition of the seed in 1964 (3), and on the natural antioxidants and related compounds in sesame oil in 1964 (4).

Production of sesame seed by the major producing countries (5) is listed in Table I. World production is about 3.5 billion lb. Most of the seed is used in the countries where it is produced, less than 5% being exported. Production is negligible in the U.S. Development of sesame as a successful crop in this country has been retarded by its characteristics of uneven ripening and shattering, or dropping of the seed from its pods. As a result more costly harvesting methods are required. Much work has been done on the development of nonshattering or semishattering varieties (46,47) which could be harvested more economically. Sesame may be grown in the southern and western parts of the U.S. where cotton is now grown.

During the last decade, imports of sesame seed by the U.S. (largely for baked goods and confectionery products) have increased from 24-40 million lb. (6,7) and disappearance of the oil in the U.S. has doubled to 2 million lb. (8). During this time cost of the oil has varied from 33-40c/lb. and is now 39c/lb. (6,9).

The valuable components of sesame seed are the oil and protein and the contents of these have been determined for several varieties of sesame which were grown in the southern and southwestern parts of the U.S. (10). Oil contents varied from 45-63% and averaged 54%. Protein contents varied from 17-32% and averaged 26%. The average protein content of the oil-free meals was 57%.

SESAME OIL

The properties of sesame oil as listed in the Official and Tentative Methods of the AOCS are as follows: sp. grav. 25/25 C, 0.918-0.926; refract. index 25 C, 1.472-1.474; iodine value, 104-118; saponification value, 187-193; unsaponificable matter (%), <1.8; titer (C), 20-25; saturated acids (%), 12-15; unsaturated acids (%), 80-87. The unsaponifiable material includes some unusual and important compounds which will be discussed in detail later.

The fatty acid content of sesame oil is shown in Table II. These are all recent values as determined by gas liquid chromatography. The range of values listed in the first column was presented by the Instrumental Techniques Committee of the AOCS to the Codex Alimentarius Commission of the Food and Agriculture and World Health Organizations of the United Nations in 1968 (11). The major fatty acids are oleic and linoleic acids which occur in about equal amounts. There is 7-12% of palmitic and 3.5-6% of stearic acid. The content of linolenic acid is less than 1%. In the next column is listed the composition of a typical sesame oil as reported by workers at the Tata Oil Mills in Bombay (12). There is about 40% each of oleic and linoleic acids. The contents of all the acids fall within the Codex ranges. The fatty acid contents reported for oils from different countries are indicated in the next several columns. Most of the acid contents are close to the Codex values, but the palmitic acid contents of some of the Indian oils were significantly higher. In the first two Indian oils, low contents of C_{17} and C_{24} acids were reported (13). H.P. Kaufmann and Mankel also reported the presence of 0.2-0.3% of C_{17} acids in sesame oil (14).

The grouping of these fatty acids in the triglycerides of sesame oil has been investigated. Kartha (15) found that oil from a brown seed variety contained no trisaturated glycerides, 6 mole % monounsaturated glycerides, 36 mole % di-unsaturated glycerides and 58 mole % tri-unsaturated glycerides. These values were within 1 mole % of those calculated for a restricted random distribution based on the fatty acid composition of the oil. The glyceride distribution of a white seed variety differed by several mole % from the calculated values, which shows, according to Kartha, a high

TABLE I

Major Producers of Sesame Seed

Region	Country	1968 Production, million lb.
Asia	India	914
	China	805
	Burma	184
	Turkey	110
	Pakistan	88
	Thailand	51
	Iraq	27
	Regional Total	2285
North South and Central America	Mexico	474
	Venezuela	168
	Columbia	27
	Nicaragua	13
	U.S.A.	1
	Regional Total	709
Africa	Sudan	269
	Ethiopia	79
	Uganda	44
	Central African Republic	35
	Upper Volta	35
	Regional Total	579
Europe	Greece	13
	Regional Total	17
	World Total	3590

[1]Presented at the AOCS Meeting, Atlantic City, October 1971.
[2]W. Market. Nutr. Res. Div., ARS, USDA.

TABLE II

Per Cent of Fatty Acids in Sesame Oil

Fatty acid	Codex 1968 range (11),%	1968 Tata (12), %	India			U.S.A.		Japan	Denmark
			(13) %	(13) %	(14) %	(14) %	(14) %	(14) %	(14) %
< 14	< 0.5	0.4	---	---	---	---	---	---	0.2
14:0	< 0.5	0.2	0.02	0.02	0.1	---	---	---	0.1
16:0	7.0-12	11.7	14.6	15.0	17.0	9.2	9.8	9.5	11.4
16:1	< 0.5	0.2	0.3	0.3	0.2	0.1	trace	trace	0.2
17:0	---	---	0.1	0.1	---	---	---	---	---
17:1	---	---	0.04	0.05	---	---	---	---	---
18:0	3.5-6.0	5.2	6.5	5.5	10.0	5.8	2.9	6.1	6.2
18:1	35-50	41.4	42.9	40.8	33.8	38.2	45.2	38.9	41.4
18:2	35-50	39.4	33.3	34.7	37.6	45.6	41.5	44.4	39.5
18:3	< 1.0	0.4	0.4	1.0	< 1.0	< 0.6	---	< 0.6	< 0.6
20:0	< 1.0	0.4	1.0	2.1	0.3	0.4	0.5	0.5	0.4
20:1	< 0.5	0.1	0.3	0.4	< 1.0	< 0.6	---	< 0.6	< 0.6
22:0	< 1.0	0.6	0.3	0.1	---	---	---	---	---
24:0	---	---	0.3	0.1	---	---	---	---	---

order compositeness of the white seed oil. In some earlier work (16), the triglycerides of sesame oil were reported to contain the following combinations of fatty acids: 39 mole % (1 oleic + 2 linoleic), 37 mole % (1 saturated + 1 oleic + 1 linoleic), 15 mole % (2 oleic + 1 linoleic), 4 mole % (1 saturated + 2 linoleic), 3 mole % (2 saturated + 1 oleic), 1 mole % (2 saturated + 1 linoleic) and 1 mole % (3 linoleic). A procedure has been reported (17) for detecting sesame oil in mixtures with some other oils by estimating the distribution of triglycerides with thin layer chromatography.

Minor Components of Sesame Oil

Many of the special properties of sesame oil are due to the presence of 0.4-1.1% sesamin, 0.3-0.6% sesamolin and traces of sesamol in the oil (4,18). As shown in Figure 1, sesamin and sesamolin have the same 2,7-dioxabicyclo-(3,3,0)-octane nucleus and both have two 3,4-methylene dioxyphenyl substituents. In sesamin these are attached directly to the nucleus, while in sesamolin one is attached directly and the other through a connecting oxygen atom. Sesamol is the free 3,4-methylenedioxyphenol. Thus sesamolin is an acetal-type derivative of sesamol. The absolute configurations of sesamin and two other sterioisomers are known (4).

The superior oxidative stability of sesame oil relative to other oils is largely due to sesamol, which is usually present in traces but may be released from sesamolin by hydrogenation, by acid or acid bleaching earths or other conditions of processing or storage (2,4,18). Sesamol may also be removed by some bleaching earths or by deodorization (2,4,19). The effectiveness of sesamol as an antioxidant on the keeping quality of lard has been reported (20). It was

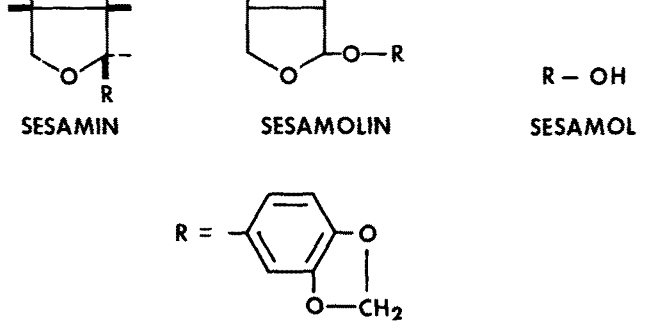

FIG. 1. Structures of Sesamin, Sesamolin and Sesamol.

more effective than butylated hydroxytoluene (BHT), butylated hydroxyanisole (BHA) and several other antioxidants and was surpassed only by propyl gallate. In a more recent study of antioxidants (21), the induction period for autoxidation of methyl octadecadienoates, in the presence of 0.01% of various antioxidants, was estimated by measuring the time for pick-up of a certain weight of oxygen, as indicated in Table III. In the natural *cis*, *cis*-linoleate, sesamol was more effective than BHT or BHA and was surpassed only by propyl gallate. Sesamol was not effective in the *trans*, *trans*-ester. In the conjugated ester, BHT, BHA and sesamol were equally effective and were more effective than propyl gallate.

During World War II it was discovered that sesame oil (22) had a synergistic effect with pyrethrum and some other insecticides. About 5% sesame oil was used in the "aerosol bombs" of that time (23) and this permitted a 50% reduction in the requirement for pyrethrum. It was soon found that sesamin was active as a synergist and that its activity came from the methylenedioxyphenyl groups (24). A number of synthetic synergists containing this group were developed. Later it was discovered (25) that sesamolin, with its methylenedioxyphenoxy group, was five times as active as sesamin and therefore responsible for a majority of the activity in sesame oil. This led to the development of another series of synthetic synergists. Sesamol, the free methylenedioxyphenol, was found to be inactive.

Sesame oil may be readily detected in mixtures with other oils by tests for sesamol, sesamolin and sesamin. For this reason it has been used in some countries as a marker in margarine and other hydrogenated oils. The analyses by the Villavecchia and other color tests, by UV spectrometry and by thin layer chromatography have been thoroughly reviewed (4,2). A procedure has been reported recently (26) for the determination of sesamol and related methylenedioxypenyl compounds by fluorescence and phosphorescence which are much more sensitive than the colorimetric procedures.

The sterols and triterpenes in sesame oil have been separated and identified using thin layer and gas liquid chromatography (27). The 0.19% of sterols are the usual plant sterols and are, in order of decreasing concentration, β-sitosterol, campesterol and stigmasterol. The 0.03% of triterpenes includes at least six compounds, three of which were identified as cycloartenol, 24-methylenecycloartanol and α-amyrin.

The presence of 0.02-0.05% tocopherol in sesame oil (2,38) has been reported. The accuracy of these values has been questioned since free sesamol interferes with the analyses.

Sesame oil contains a very small amount, 0.03-0.13%, of

TABLE III

Induction Period (hr) for Autoxidation of Methyl Octadecadienoates

Antioxidant, 0.01%	*cis*-9,*cis*-12, hr	*trans*-9,*trans*-12, hr	Conjugated, hr
None	35	52	16
Sesamol	320	55	190
Propyl gallate	560	220	110
Butylated hydroxytoluene	290	170	190
Butylated hydroxyanisole	200	260	190
D[a]	200	130	68
L-thyroxine	120	140	17
NDGA[b]	70	320	40
α-Tocopherol	45	75	44

[a]4,4'-Dihydroxy-3,5,3',5'tetra-tert-butyl-diphenylmethane.
[b]Nordihydroguaiaretic acid.

phosphatides (3).

The pigments in the oil have been investigated spectrophotometrically (28) and Pheophytin A (λ_{max} 665-670 mμ) was found to predominate markedly over Pheophytin B (λ_{max} 655 mμ).

Sesame oil has a pleasant odor and taste and attempts have been made to identify the components responsible for this (29,30). The aroma material was obtained by steam distillation and separated into different fractions. The main components of the characteristic aroma, which seemed to be in the carbonyl and phenolic fractions, were separated and identified using gas liquid chromatography. Most of these were C_5-C_9 straight chain aldehydes or aldehyde or ketone derivatives of furan or pyrrole. Acetylpyrazine was claimed to have a popcorn odor that contributes to the odor of the sesame oil. A moderate amount of hydrogen sulfide was also found.

SESAME PROTEIN

Oil-free sesame meal contains almost 60% of protein which is valued in feeds and food because of its high methionine content. In Table IV the essential amino acid content of sesame protein is compared with the reference pattern of essential amino acid requirements of the Food and Agriculture Organization (UN). The ranges of values in this study (31) are from five varieties of sesame from the U.S., Mexico and Brazil. For a vegetable protein, sesame has a particularly high content of methionine, 2.5-4.0% and total sulfur-containing amino acids, 3.8-5.5%. It is deficient only in lysine and somewhat in isoleucine.

In a recent rat feeding study (31), illustrated in Table V, the effect of fortification on the nutritive value (relative to casein) of sesame meal was demonstrated. Sesame alone had a protein nutritive value of 47%. Fortification with 0.2% lysine raised this to 94%, while fortification with 0.2% lysine + 0.1% isoleucine + 0.1% methionine raised it to 102%. The protein nutritive value of a 1:1 mixture of sesame and soybean protein was about the same as that of casein. Soybean protein has an abundance of lysine but is deficient in methionine. In poultry feeds, supplementation of sesame meal with 0.4-0.5% lysine, or with soybean meal, was found to be necessary for maximum growth and feed efficiency (32).

In related studies (33,34), in which rats were fed a 10% protein ration for 4 weeks, fortification of sesame protein with lysine to a level of 4.2%, the level in the FAO Reference Protein, raised the protein efficiency ratio (PER) from 1.70 to 2.14. Fortification with lysine to a level of 8.2%, the level in casein, raised the PER to 2.91. The PER is the weight gain per weight of protein fed and is about 2.5 for casein. It was also demonstrated that incorporation of 25% of sesame meal raised the PER of a 2:1 mixture of peanut and bengal gram protein from 1.79 to 2.03. In human feeding tests (35a), the sesame-peanut-bengal gram protein mixture, which is somewhat deficient in lysine, was nearly as effective as skim milk in controlling the clinical manifestations or protein malnutrition but was inferior to skim milk with regard to serum albumin regeneration.

High protein, vegetable mixtures for human feeding, containing 35% sesame flour, were developed (35b) by the Institute of Nutrition of Central America and Panama (INCAP). These low-cost mixtures were readily accepted and well tolerated as the chief protein source of needy populations. In later mixtures, developed by INCAP, sesame was replaced by cottonseed flour which was less costly and more readily available in the area.

Availability of the amino acids in sesame is affected by the processing methods used on the seed (36). The effect of three treatments is shown in Table VI. In the first, part of the oil was removed by prepressing and the remainder by solvent extraction. In the second, oil was extracted in an expeller at high pressure and temperature, under conditions similar to those used commercially. The third sample was prepressed and extracted like the first, but was then moistened and heated for 1 hr at 121 C. Enzyme digestibility was affected very little, but methionine availability was increased by heat treatment. In the sample that was heated after oil extraction it was 2.33%, close to an average literature value. Lysine availability was not affected consistently by heat treatment and in all cases was less than

TABLE IV

Essential Amino Acid Content of Sesame Protein

Amino acid	Sesame (5 varieties), g/16 g N		FAO Reference, g/16 g N
Arginine	12.0-13.0		2.0
Histidine	2.4- 2.8		2.4
Isoleucine	3.3- 3.6		4.2
Leucine	6.5- 7.0		4.8
Lysine	2.5- 3.0	<	4.2
Methionine	2.5- 4.0	>	2.2
Methionine + cystine	3.8- 5.5	<	4.2
Phenylalanine	4.2- 4.5		2.8
Threonine	3.4- 3.8		2.6
Tryptophan	2.0- 2.4		1.4
Valine	4.2- 4.4		4.2

TABLE V

Relative Nutritive Value

Protein	Protein nutritive value,[a] %
Mexican sesame	47
+ 0.2% lysine	94
+ 0.2% lysine + 1.1% methionine	93
+ 0.2% lysine + 0.1% methionine + 0.1% isoleucine	102
Mexican sesame + soybean 1:1	99

[a]Weight gain x 100 per weight gain of rats fed casein (31).

TABLE VI

Availability of Amino Acids in Sesame Meal

Meal preparation	Enzyme digestibility,[a] % soluble N	Available methionine,[b] g/16 g N	Available lysine,[b] g/16 g N
Prepressed; then extracted	90	1.85	1.08
High temperature expeller	87	2.17	0.84
Prepressed; extracted; then heated (50% H_2O) 1 hr at 121 C	92	2.33	1.04
Average literature value		2.34	2.71

[a]Pepsin; then pancreatin.

[b]Microbiological assay after enzyme digestion.

50% of an average literature value for lysine content.

Minor Components of Sesame Meal

Information on carbohydrates, vitamins and some other minor components may be found in earlier reports 3,37,41).

Sesame meal contains 1.0-1.3% as P of phytic acid (37,38) which can cause problems when the meal is used in chicken feed. Phytic acid binds zinc, and the chickens may show signs of Zn deficiency such as leg deformities and poor growth (38,39). It was found that the problem could be avoided by adding 60 ppm Zn or by autoclaving the meal for 4 hr. Phytic acid is also present in other common oilseed meals.

The flavor substances of broiled sesame seed have been investigated (40) and were found to contain H_2S and other S compounds. Heating a model system of cystine + glucose yielded a polymer of thioglycolaldehyde which was claimed to have the flavor of broiled sesame seed.

An unusual feature of sesame is that it contains 1-2% of oxalic acid (37). Associated with it as the salt is 2-3% of calcium. It occurs in the outer layer of the thin hull and practically all of it can be removed by decortication. For feed use it is not necessary to remove this outer layer. But to obtain a glossy, non bitter, low-fiber product for some food uses, it is desirable to remove the oxalate-containing hull. This is readily done before conventional (41) processing by several decorticating techniques, including treatment with alkali or water, followed by separation on a screen (42,43) or in a salt solution which has a density between those of the hulls and the kernels (37). Oxalic acid may be removed from sesame meal by treating it with hydrogen peroxide at pH 9.5 (44).

Other procedures have been developed for obtaining high protein material, suitable for food use, from sesame meal. Solvent-extracted meal has been screened (37) or air-classified to yield high protein and high fiber fractions. Preliminary work has been done in this laboratory on the isolation of high protein material from the suspension obtained by milling sesame seed under hexane. A process has been patented recently (45) for extraction of the oil from crushed sesame seed with a hot calcium hydroxide solution. The alkaline solution dissolves a considerable part of the protein. When it is acidified to the isolectric point, a high grade protein is precipitated. This is centrifuged out and then the oil is separated from the water.

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