Oil and Minor Components of Sesame (*Sesamum indicum* L.) Strains

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Oil and minor components of sesamin and sesamolin were studied in 42 strains of *Sesamum indicum* L. The oil contents of the seed ranged from 43.4 to 58.8% and varied inversely with the percentage of hull (r = −0.804, significant at the 1% level). The hull percentage was used as a criterion to predict oil content. The percentage of sesamin in the oil ranged from 0.07 to 0.61% and that of sesamolin from 0.02 to 0.48%. There was a significant positive correlation between the oil content of the seed and the sesamin content of the oil (r = 0.608, significant at the 1% level); no correlation was found between the oil and sesamolin contents.

The average oil content found for the white-seeded strains was 55.0% and for the black-seeded strains 47.8%, the difference of 7.2% being significant at the 1% level. The white- and black-seed strains also differed significantly in sesamin content, but not in sesamolin content.

KEY WORDS: Hull percentage, oil, seed color, seed weight, sesamin, sesamolin, *Sesamum indicum* L., strain, variability.

Sesame (*Sesamum indicum* L.) is one of the world's most important oil seed crops. Not only is it a source of edible oil, the seed itself provides a nutritious food for humans.

One excellent characteristic of sesame oil is its resistance to oxidative deterioration. Its remarkable stability has been suggested to be due to the presence of the endogenous antioxidants, sesaminol and sesamol, together with tocopherol. Sesaminol is produced from sesamolin, a minor component of sesame oil, by intermolecular transformation during the industrial bleaching process of unroasted sesame oil. Sesamol is liberated from sesamolin during the frying process (1,2). In contrast, sesamin, another minor component of sesame oil, gives an epi-sesamin during the bleaching process, and it also has been reported to enhance the activities of pyrethrin insecticides synergistically (3,4).

The major objectives of sesame plant breeding at present are to increase the seed oil content and the contents of its minor components, as well as to improve the quality of both the seed and its oil.

Beroza and Kinman (5) reported considerable variations in the percentages of each of the minor components of the sesame oils extracted from 33 strains of *Sesamum* grown in Texas, U.S.A. Their values ranged from 0.340 to 1.130% for sesamin, and from 0.131 to 0.589% for sesamolin; and there were traces of sesamol in the oils. Using 14 Japanese domestic strains, Fukuda *et al.* (6) found that the content of sesamin ranged from 0.155 to 0.885%, and that of sesamolin from 0.124 to 0.477%.

We have investigated the variability of sesame oil contents and that of the contents of its minor components in different strains of *Sesamum* in order to determine the relation between the oil content and the content of its minor components, as well as their relationships to seed characteristics. Information about these relationships should prove valuable for making genetic improvements in sesame seed and, should provide a basis for nutritional evaluations of sesame meal.

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MATERIALS AND METHODS

Samples. Seeds from 42 strains of *Sesamum* that had been grown in 1986 at two locations, the Experiment Stations of Nagoya University and Kahoku Oil Production Company, were used.

These strains, all being the dehiscent type, were obtained from Toyama University and Takemoto Oil and Fat Company. Those from the latter included strains that had originated in China, Colombia, Mexico, Afghanistan, and Vietnam. The strains provided a wide range of types that differed in height, degree of branching, maturity, and other agronomic characteristics.

Cultural conditions. Seeds were sown in rows 50 cm apart in May. Plants were thinned when they were 10 to 15 cm tall, leaving a distance of 15 cm between plants. Individual plants were harvested when the lower capsule turned light yellow.

Seed samples obtained from each strain at each location were carefully cleaned to remove all foreign materials. Immature seeds were discarded by hand picking. Seed samples were classified by color: white [15 samples], brown [12 samples], black [11 samples], and yellow [2 samples].

Analyses. The oil content was determined twice, by comparing the weight of approximately 5-g seed samples before and after oil removal by Soxhlet extraction with petroleum ether for 8 hr.

The sesamin and sesamolin contents of the oils were analyzed with a Shimazu Model 190 HPLC equipped with a stainless-steel column (4.6 mm i.d. × 25 cm) packed with Develosil ODS (Nomura Chemical Co., Ltd., Japan). The chromatograph was operated with a mobile phase (70% methanol) at a flow rate of 3 mL/min. The amount of each compound present was determined by the peak height at 290 nm. Sesamin and sesamolin were purified as reported previously (7). Their purities were confirmed by mass spectrometry and proton nuclear magnetic resonance (^{1}H-NMR).

Removal of the hull. Good quality sesame seeds were soaked in water for 5 min at room temperature with occasional shaking. The wet seeds were drained on gauze, then mildly rubbed with the gauze to remove the loosened hull. Seed weight was taken to be the average weight of 3 samples of 100 seeds each.

RESULTS

The oil content and the contents of minor components in oil. Chemical and grain characteristic data for the 42 sesame strains grown at two locations are given in Table 1. The oil content of the seed varied from 43.4 to 58.8%, the average being 52.7% and the standard deviation 3.9%. The magnitude and range of the values obtained for the oil were similar to those reported by Yermanos *et al.* (8). The highest value for oil content was for a sample from a white-seeded strain that had a relatively low seed weight

TABLE 1

The Seed Oil Content and the Contents of Minor Components in Oil for 42 Strains of *Sesamum indicum* L.

	Oil (%)	Sesamin (% in oil)	Sesamolin (% in oil)	100 Seed weight (mg)	Hull[a] (%)
Mean	52.7	0.36	0.27	279.8	9.1
Range	43.4-58.8	0.07-0.61	0.02-0.48	218.7-390.9	3.5-23.2
SD[b]	3.9	0.16	0.13	42.8	4.7
CV[c]	7.4	44.2	47.5	15.3	51.1

[a] Ratio of the hull to the whole seed by weight.
[b] Standard deviation.
[c] Coefficient of variation.

TABLE 2

Effect of the Seed Color Types on the Seed Oil Content and the Contents of Minor Components in Oil of *Sesamum indicum* L.

	Seed color type		
	White	Brown	Black
Number of samples	15	12	11
Oil (%)			
Mean	55.0 a[a]	54.2 a	47.8 b
Range	51.8-58.8	50.5-56.5	43.4-51.1
CV[b]	3.7	3.4	5.9
Sesamin (% in oil)			
Mean	0.44 a	0.36 a*	0.24 b*
Range	0.12-0.61	0.11-0.61	0.07-0.40
CV	36.7	38.8	39.0
Sesamolin (% in oil)			
Mean	0.25 a	0.30 a	0.27 a
Range	0.02-0.48	0.13-0.42	0.13-0.40
CV	73.3	33.4	27.1
100 seed weight (mg)			
Mean	274.5 a	295.0 a	280.3 a
Range	228.8-390.9	218.7-346.3	232.5-351.9
CV	12.8	18.8	12.9
Hull[c] (%)			
Mean	6.2 c	8.0 b	14.4 a
Range	3.5-8.3	6.1-9.5	6.7-23.2
CV	25.5	12.4	39.3

[a] Mean values on each row followed by the same letter do not differ significantly at the 1% level.
[b] Coefficient of variation.
[c] Ratio of the hull to the whole seed by weight.
*The content of sesamin in oil in brown- and black-seeded strains differs significantly only at the 5% level.

of 247.0 mg and a low hull percentage of 3.5. The lowest value was for a sample from a black-seeded strain that had a relatively low seed weight of 257.1 mg and a high hull percentage of 23.2.

The sesamin content of the oil ranged from 0.07 to 0.61%, averaging 0.36% with a standard deviation of 0.16%; whereas, the sesamolin content ranged from 0.02 to 0.48%, averaging 0.27% with a standard deviation of 0.13%. The respective coefficients of variation for sesamin and sesamolin were 44.2% and 47.5%. The magnitude of these values were higher than those reported by Beroza and Kinman (5) and by Fukuda *et al.* (6). The highest sesamin value was for a sample from a white-seeded strain having a high oil content of 55.5%. The lowest value was for a sample from a black-seeded strain having a low oil content of 44.6%. The highest and the lowest values, respectively, for sesamolin were found in samples from the white-seeded strain. The respective oil contents for the highest and the lowest sample were 54.8% and 53.9%. The lowest sesamolin value was quite lower than the range of values published previously (5,6).

Relation of the content of seed oil to the minor oil components in oil and their relationship to seed characteristics. The contents of the sesame oil and its minor components are given for three seed color types in Table 2. White-seeded strains averaged 55.0% oil, and black-seeded strains 47.8%; the difference of 7.2% was significant at the 1% level. A previous report (9), that the oil content of black-seeded strains is lower than that of white-seeded strains, is confirmed by these results. There were no significant differences in oil content between the means for the white- and brown-seeded strains.

There was a significant difference in sesamin content between black- and white-seeded strains. Seeds of white-seeded strains averaged 0.44% sesamin in their oil with a range of 0.12 to 0.61%; whereas, those of black-seeded strains averaged 0.24% sesamin in their oil with a range of 0.07 to 0.40%. No significant difference in sesamin content was found between the means of white- and brown-seeded strains. The data for sesamolin showed there was no consistent difference among the color types. Seeds from the white-seeded strain contained an average of 0.25% sesamolin in their oil with a range of 0.02 to 0.48%. Seeds of black-seeded strains contained an average of 0.27% sesamolin with a range of 0.13 to 0.40%. The coefficient of variation for the sesamolin from white-seeded strains was 73.3% and from black-seeded strains 27.1%. There was less variation in the percentage of sesamolin in black-seeded than in white-seeded strains.

The coefficients of correlation among sesame oil, and minor components and grain characteristics are presented in Table 3. White-seeded strains showed a highly significant negative correlation between seed weight and oil content. For black-seeded strains, however, seeds of heavy weight had a greater oil content, but there was no significant difference; this may be due to small sample size. The oil contents of the seeds were negatively correlated with the percentage of hull, higher oil contents being found for low percentages of hull. The coefficients of correlation were much greater for black-seeded than for white-seeded strains. Similar observations have also been reported by Yermanos *et al.* (10) and by Knowles (11) in their studies of safflower varieties. The sesamin content was positively and significantly correlated with the oil content. For black-seeded strains, the coefficient is 0.630 (significant at the 5% level) and for white-seeded strains 0.517 (significant at the 5% level). The sesamolin content of the black-seeded strains showed a positive correlation with oil content, but there was no significant difference; this may also be due to small sample size. For black- and brown-seeded strains, the sesamin and sesamolin contents were

TABLE 3

Simple Correlations Among the Seed Oil Content, the Contents of Minor Components in Oil and Seed Characteristics of *Sesamum indicum* L.

Correlation between	Calculated r			
	White (15)[a]	Brown (12)	Black (11)	Whole (42)
Seed weight and hull percentage[b]	0.573[c]	0.764[d]	−0.574[c]	−0.031
Seed weight and oil content	−0.604[d]	−0.033	0.394	−0.113
Hull percentage and oil content	−0.566[c]	0.047	−0.834[d]	−0.804[d]
Oil content and sesamin content	0.517[c]	−0.334	0.630[c]	0.608[d]
Oil content and sesamolin content	−0.101	−0.397	0.492	−0.008
Sesamin content and sesamolin content	0.386	0.903[d]	0.778[d]	0.403[d]

[a]Number of samples analyzed given in parentheses.
[b]Ratio of the hull to the whole seed by weight.
[c]Significant at the 5% level.
[d]Significant at the 1% level.

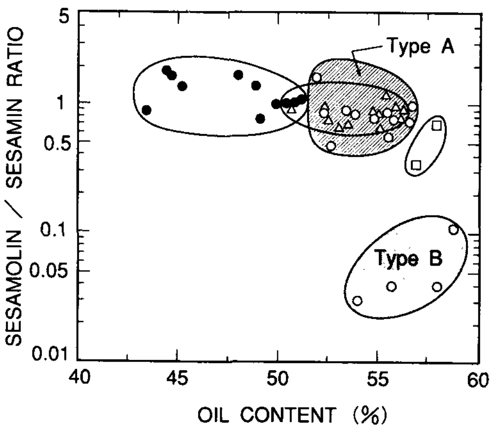

FIG. 1. Relationship of the ratios of sesamolin content to sesamin content and to the oil content in different strains. ○, White-seeded strain; △, Brown-seeded strain; ●, Black-seeded strain; □, Yellow-seeded strain.

significantly and positively correlated in the seed oil content; but, for white-seeded strains there was no significant correlation.

The relationship between the ratio of sesamolin to sesamin and the oil content of *Sesamum* strains with different seed color types is shown in Figure 1. The four seed color types were characterized as follows: White-seeded strains were of two types: one (Type A) has a relatively high ratio of sesamolin to sesamin and a high oil content, and the other (Type B) a markedly low ratio of sesamolin to sesamin (due to the radically low sesamolin content) and a high oil content. Brown-seeded strains formed a cluster similar to that of white-seeded strains identified as Type A; but, they showed a relatively constant ratio of sesamolin to sesamin for every oil content. Black-seeded strains had a high ratio of sesamolin to sesamin (due to the low sesamin content) and a low oil content. Yellow-seeded strains had a low ratio of sesamolin to sesamin and a high oil content.

DISCUSSION

Results of our study on the oil and sesamolin contents of different strains of sesame seeds indicate that there is considerable quantitative variability in both traits. No strains were found to have a very high oil content or a markedly high sesamolin content, which would increase the quality of both the seed and oil. White-seeded strains that were identified as Type B had undesirable sesamolin contents that might decrease the stability of their edible oil. These strains are of more genetic and physiological curiosities than potential sources of germplasm because the role of sesamolin and sesamin in the seed is unknown.

Knowledge about the characteristics of seed is important for breeding purposes. It might indicate a cause-and-effect relationship, pleiotropy, or linkage of characteristics, and such knowledge could be used to screen strains with high oil contents as well as strains that produce oil of high quality. Unfortunately, our information on the association of chemical components with each other as well as with morphological seed characteristics is limited.

We found a valid association between seed color types and the oil content of the seed. Strains that had light-colored seed coats tended to have higher oil contents. The difference in oil contents among strains of the three main seed coat colors primarily was a function of seed size. Black-seeded strains had a higher percentage of hull than did the white- or brown-seeded strains. Therefore, oil content, as determined as a percentage of the entire grain, is affected cumulatively by differences in seed weight and hull thickness as is the actual oil content of the seed.

We found a significant negative correlation between the oil values and the percentage of hull for both the white- and black-seeded strains. This means that the percentage of hull in combination with seed color type can be used as a criterion of oil content.

The relationship between seed color types and sesamin content is a direct one. Strains with white seed coat colors tended to have higher sesamin contents. The differences in sesamin content among the different colored strains are attributable to the oil content. The oil and sesamin contents showed a significant positive correlation in both the white- and black-seeded strains. The higher oil content, found for white-seeded strains, therefore, was related to the higher sesamin content.

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