Fatty Acid Variation in Seed Oil Among *Ocimum* Species

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ABSTRACT: Content, fatty acid composition, and glyceride profile of oil from seeds of seven basil (*Ocimum* sp.) chemotypes were determined. The species studied included *O. basilicum, O. canum, O. gratissimum,* and *O. sanctum.* The oil content ranged from 18 to 26%, with triglycerides comprising between 94 and 98% of extracted neutral lipids. The major acylated fatty acids were linolenic (43.8–64.8%), linoleic (17.8–31.3%), oleic (8.5–13.3%), and palmitic acid (6.1–11.0%). Linolenic acid was similar among the four *O. basilicum* chemotypes (57–62%), highest in *O. canum* (65%), and lowest in *O. sanctum* (44%). Basil seed oil appears suitable as an edible oil or can be used for industrial purposes, and could be processed in the same way as linseed oil. Preliminary calculations estimate that a hectare of basil could produce from 300 to 400 kg of seed oil.
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KEY WORDS: Basil, edible oil, fatty acids, Lamiaceae, linolenic acid, linseed oil, *Ocimum, O. basilicum, O. canum, O. gratissimum, O. sanctum,* seed oil.

The genus *Ocimum* (Lamiaceae), collectively called basil, has long been acclaimed for its diversity as a source of essential oils, its flavor and delicacy as a spice, and its beauty and fragrance as an ornamental (1). *Ocimum* comprises between 50 to 150 species of herbs and shrubs from the tropical regions of Asia, Africa, and Central and South America (2,3). Basil is extensively used by the perfume, pharmacy, and food industries for its natural aroma and flavor (4). In spite of this popularity, little recent work has examined seed oil composition in *Ocimum* species (5), although its essential oil content has been widely analyzed (6–12). In this study, we examined seed oil of four *Ocimum* species, including seven different chemotypes. The species studied included *O. basilicum, O. canum, O. gratissimum,* and *O. sanctum.*

MATERIALS AND METHODS

Mature dry seeds of seven basil chemotypes: citral, linalool, methyl chavicol, and methyl cinnamate (*O. basilicum*); camphor (*O. canum*); eugenol (*O. sanctum*); and geraniol (*O. gratissimum*), from our breeding lines at Purdue University, were washed and finely ground in a mortar. The oil from the resulting flour was extracted in a Butt-type apparatus by following AOCS recommendations (13). The extract was concentrated under a stream of dry nitrogen or argon for quantitative determination of the oil content. Transesterification of acylated fatty acids was carried out with 2.0 N sodium hydroxide in dry methanol (14). Preliminary analysis of the methyl esters by thin-layer chromatography (TLC) did not reveal fatty acids with unusual functionality, such as epoxy groups. Iodine values (Hanus method) and saponification values were both measured according to AOAC (15,16). Refractive indices were measured at 20°C with a Bausch and Lomb (Rochester, NY) refractometer, coupled with a Forma Scientific controlled temperature bath and circulator (model 2067; Forma Scientific, Marietta, OH). The gas-chromatographic analysis of the methyl esters were carried out with a Varian (Walnut Creek, CA) model 3700 gas chromatograph, fitted with a flame-ionization detector and a Hewlett-Packard model 3396 series II integrator (Palo Alto, CA). A capillary column (30 m × 0.32 mm i.d., 0.20-mm film thickness, SP 2330; Supelco, Bellefonte, PA) was used. The injector and detector temperatures were maintained at 220°C and the column temperature was at 185°C. Sample volumes of 0.2 μL in dichloromethane were injected with a split ratio of 100:1, with helium as the carrier gas at a linear velocity of 20.0 cms^{-1}. Peaks were identified with appropriate standards (Sigma, St. Louis, MO), and by gas chromatography/mass spectrometry analysis with a Finnigan (San Jose, CA) gas chromatograph, model 9610, and mass spectrometer, model 4000, hooked on-line to a Data General Nova/4 data processing system. Glyceride composition was determined with a Hewlett-Packard model 5890 Series II gas chromatograph, equipped with a flame-ionization detector and connected to a computer with a Hewlett-Packard ChemStation. Sample volumes of 0.3 μL in decane were injected on a DB-1 capillary column (10 m × 0.25 mm i.d., 0.10-μm film thickness; J&W, Folsom, CA) by the "on-column" technique. Detector temperature was set at 355°C; the oven temperature was programmed from 200 to 250°C at 10°C min^{-1}, and then up to 350°C at 5°C min^{-1}, and held for 10 min at this temperature. Homogeneous triglycerides were used as standards (Nu-Chek-Prep, Elysian, MN).

RESULTS AND DISCUSSION

The oil content in the seeds of the plants averaged 21%, from 18% in the camphor chemotype (*O. canum*), up to 26% in the linalool chemotype (*O. basilicum*) (Table 1). While the oil

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TABLE 1
Analytical Values and Glyceride Content of Oil from Seeds of Different *Ocimum* Chemotypes and Linseed

Chemotype	Oil content (% w/w)[a]	Refractive index (n_D^{20})	Saponification value	Iodine value	Class[b]			Carbon number[c] (%)		
					MAG (%)	DAG (%)	RAG (%)	50	52	54
O. basilicum										
Citral	20	1.481	199	198	2	2	96	2	16	82
Linalool	26	1.480	200	198	1	1	98	1	18	81
Methyl chavicol	21	1.479	200	184	1	1	98	1	20	78
Methyl cinnamate	24	1.479	200	190	3	2	95	1	20	78
O. canum										
Camphor	18	1.472	—	200	1	2	97	1	15	84
O. gratissimum										
Geraniol	20	1.460	194	178	1	1	98	3	23	74
O. sanctum										
Eugenol	22	1.477	191	172	3	3	94	3	27	70
Average for all basils	22	1.475			2	2	96	2	20	78
Linseed[d]	32–43	1.477–1.482[e]	192	180	—	—	—	—	—	—

[a]Percentages of the seed on dry weight basis.
[b]TAG, triacylglycerols; DAG, diacylglycerols; MAG, monoacylglycerols.
[c]The carbon number is relative to TAG.
[d]Reference 26.
[e]Reference 27.

content of these basils is lower than that found in many commercial oil plants such as rapeseed (*Brassica napus* L., 38–44%) or linseed (*Linum usitatissimum* L., 32–43%), the actual physicochemical and fatty acid profiles approached that of linseed oil. The refractive indices (1.472–1.481), saponification (191–200), and iodine values (172–200, Hanus) were all characteristic of a highly unsaturated oil. The oils were high in triacylglycerols (TAG), averaging 96% among all basils, while the total for both mono- and diacylglycerols reached only 2% each (Table 1). The main TAG had, in all cases, a carbon number (CN) of 54 (70–84%), with lesser amounts of CN 52 (15–27%) and 50 (1–3%). In addition, traces (less than 1%) of TAG with CN 48 and 56 were detected.

The high proportion of unsaturated fatty acids averaged 89%, with the major fatty acids being linolenic acid (43.8–64.8%) and linoleic acid (18.3–31.3%), along with lesser amounts of oleic acid (8.5–13.3%). The most abundant saturated acids included palmitic acid (6.1–11.0%) and stearic acid (2.0–4.0%) (Table 2). These results emphasize important differences in the relative ratios of linoleic to linolenic acids in basil seed oils, and compare similarly to most literature values, which extend from 5 to 15% for oleic acid, 14 to 66% for linoleic acid, and 16 to 65% for linolenic acid (17–24). There appears to be an inversion in the relative amounts of linoleic and linolenic acids among some species, inversions which are in agreement with the reported iodine values, ranging from 169 to 196.

Oil composition from seeds of the methyl cinnamate

TABLE 2
Fatty Acid Composition of Oil from Seeds of Different *Ocimum* Chemotypes[a] and Linseed

Chemotype	Composition (mol%)						
	16:0	16:1	18:0	18:1	18:2	18:3	20:0
O. basilicum							
Citral	6.8	0.3	2.2	9.7	18.3	62.5	0.2
Linalool	7.4	0.2	2.0	8.7	21.7	60.0	trace[b]
Methyl chavicol	8.8	0.2	2.8	9.5	21.3	57.4	trace
Methyl cinnamate	7.8	0.2	2.4	11.6	20.6	57.4	trace
O. canum							
Camphor	6.1	0.2	2.3	8.5	17.8	64.8	0.2
O. gratissimum							
Geraniol	10.0	0.3	2.1	8.6	31.3	47.4	0.2
O. sanctum							
Eugenol	11.0	0.2	4.0	13.3	26.8	43.8	0.2
Average for all basils	8.3	0.3	2.5	10.0	22.5	56.2	0.1
Linseed[c]	6	—	4	22	16	52	—

[a]Values are means of four replicate analyses. The percentages represent the sum of all the isomers with the same number of carbon atoms and unsaturations.
[b]Trace values are lower than 0.1%.
[c]Average values. Patterson, H.B.W. Handling and Storage of Oilseeds, Oils, Fats and Meal, Elsevier Applied Science, London, 1989 pp. 112–113.

chemotype were collected at different times of seed maturity and separated by maturity. No differences between seed location and flower spike position were found. However, there appeared to be a slight increase in oil yield with seed age.

Based upon basil seed yield in *O. basilicum*, which averaged, in 1995, 125 g per plant, we estimate that about 300 to 400 kg of oil per hectare could potentially be obtained, depending on the cropping system and seed harvest efficiency. This oil yield compares favorably to that of linseed oil, which averages around 550 kg/ha in North America (325 kg/ha, on a world basis) (25).

The genus *Ocimum* contains seed oils that are not only edible, but whose high ω-3 fatty acid content makes it suitable for use by the petroleum, paint, and varnish industries, and in the manufacture of printing inks and soaps, as with linseed oil. Because the oil content is highest with mature seeds, plants can be harvested at the stage of maximum seed yield, which is usually 20–25 d after full bloom.

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