The Occurrence of Ricinoleic Acid in *Linum* Seed Oils

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ABSTRACT

Thirty-one *Linum* species, representing each of the 5 taxonomic sections of the genus, were analyzed for fatty acid composition of the seed oils. Linolenic acid was the major component of the seed oil of species from the sections *Linum* and *Dasylinum,* whereas linoleic acid predominated in those from the sections *Syllinum, Linastrum* and *Cathartolinum.* All 5 species tested from the section *Syllinum* contained ricinoleic acid as a minor component, ranging between 3% and 8% of total fatty acids. Ricinoleic acid was not present in any other species analyzed. An unidentified fatty acid was present as a minor component in species from the sections *Linum* and *Dasylinum* but absent in species from other sections of the genus.

INTRODUCTION

Ricinoleic acid (12-D-hydroxy-*cis*-9-octadecenoic acid) is the principal component of the oil from castor bean, *Ricinis communis,* and is of commercial importance because of the industrial uses of its pyrolytic degradation products, e.g., sebacic acid and capryl alcohol (1). Although castor oil contains up to 90% ricinoleic acid, this fatty acid is only rarely a component of seed oils and, when present, is usually in much smaller proportions than the more common saturated, monoenoic and C18 polyenoic fatty acids. The presence of ricinoleic acid in the genus *Linum* was identified by Kleiman and Spencer (2), who reported that seeds of *Linum mucronatum* collected in Turkey contained 15% ricinoleic acid. Previous extensive surveys of fatty acid composition in this genus (3,4), although including samples of *L. mucronatum* and several closely related species, had not identified ricinoleic acid as a component of the seed oil. The occurrence of only 1 accession from a single species possessing the biosynthetic pathway necessary for the production of ricinoleic acid would seem unlikely. An alternative explanation could be that the earlier surveys did not adequately test for this unusual fatty acid. Therefore, the aim of this study was to analyze the seed oil of all available *Linum* species to identify those species containing ricinoleic acid and to determine if a taxonomic relationship existed for this character.

EXPERIMENTAL PROCEDURES

Seeds of 31 *Linum* species representing all 5 sections of the genus were obtained from various sources. The taxonomic distribution of these accessions is presented in Table I. A total of 169 accessions were analyzed, including a sample of the *L. mucronatum* genotype (CPI 82684) found to contain ricinoleic acid by Kleiman and Spencer (2). Analyses for fatty acid composition were performed directly on samples of the introduced seed, ranging from 20-200 seeds, depending on size and availability. The oil in the samples was transmethylated without prior extraction, by using the method of Welch (5). Fatty acid methyl esters were analyzed by gas chromatography (GC) using a Varian Model 3700 gas chromatograph equipped with a hydrogen flame ionization detector (FID). The stainless-steel column (length 360 cm, internal diameter 2 mm) was packed with Silar 10C (10%) on Gas Chrom Q. The oven, injector and detector temperatures were 210 C, 280 C and 280 C, and nitrogen was used as the carrier gas. Percentages of fatty acid methyl esters were calculated by a Varian CDS 111C Data System with reference to standard mixtures (Applied Science, State College, PA) measured on the same column, under identical conditions.

RESULTS AND DISCUSSION

The fatty acid compositions of *Linum* seed oils are presented in Table I. Palmitic and stearic acid were minor components in all species, averaging 8% and 3% of total fatty acids, with no significant differences between taxonomic sections. However, taxonomic relationships were evident for the principal fatty acids, e.g., oleic, linoleic and linolenic acids. In species from the sections *Linastrum, Cathartolinum* and *Syllinum,* linoleic acid was the major component, ranging from 46% to 82%. Oleic acid varied between 8% and 24%, and linolenic acid between 3% and 28% in these species. In contrast, the major component of species from the sections *Linum* and *Dasylinum* was linolenic acid ranging from 38% to 57%, with ca. equal proportions of oleic (12-23%) and linoleic acid (15-32%). *L. leonii* was the single exception to this pattern, having a high concentration of linoleic acid (44%) with equal amounts of oleic and linolenic acids (24%). The results for these fatty acids generally agree with those of previous studies (3,4).

An unknown fatty acid was detected in all species from sections *Linum* and *Dasylinum,* with the exception of *L. marginale.* The methyl ester of this fatty acid had an equivalent chain length (ECL) of 27.2 under the chromatographic conditions employed in this study. It could not be identified by reference to available fatty acid methyl esters, including those of 20:0, 20:1, 22:0, 24:0 and 24:1 and hence could not be precisely quantified. However, it accounted for between 1% and 8% of the total chromatogram peak area. This compound was not detected in any species from other sections of the genus and has not been previously reported in the literature.

Ricinoleic acid was present as a minor component of all 5 species tested in the section *Syllinum,* ranging from 3% to 8% of total fatty acids, whereas no species from the remainder of the genus contained any detectable level. Although one of the *L. mucronatum* accessions analyzed (CPI 82684) had been reported to contain ricinoleic acid (2), previous analyzes of other species from this section had failed to detect this fatty acid (3,4). This could be caused by the fact that under the chromatographic conditions normally used to analyze fatty acid methyl esters of seed oils, ricinoleic acid has a retention time ca. 4 times that of linolenic acid. Thus, in previous studies that were not specifically searching for ricinoleic acid, the chromatographic analysis may have been terminated before the elution of this compound. Such an explanation could also account for the previous failure to detect the unidentified fatty acid observed in the present study.

The concentration of ricinoleic acid in these *Linum* species is too low to be of direct economic importance,

TABLE I

Fatty Acid Composition of *Linum* Seed Oils

Species[a]	Fatty acid composition (%)						
	Palmitic	Stearic	Oleic	Linoleic	Linolenic	Ricinoleic	Unknown[b]
Section *Linum*							
L. usitatissimum (7)	9.3	2.1	17.2	19.1	52.2	–	+
L. angustifolium (4)	11.1	3.5	17.9	14.5	53.0	–	+
L. bienne (11)	11.6	4.4	16.9	14.7	52.5	–	+
L. grandiflorum var. rubrum (10)	9.7	3.8	21.5	18.6	46.4	–	++
L. marginale (41)	6.5	2.0	15.5	19.0	57.1	–	–
L. perenne (6)	7.5	2.2	22.5	28.1	39.8	–	++
L. alpinum (6)	7.7	2.3	20.5	27.9	41.7	–	++
L. extraaxillare (1)	7.3	2.0	12.1	28.0	50.7	–	+
L. anglicum (3)	7.0	2.4	14.3	26.0	50.5	–	+
L. austriacum (13)	7.7	3.0	21.5	28.6	39.2	–	++
L. leonii (2)	6.4	1.9	24.3	43.7	23.8	–	+
L. lewisii (1)	7.7	2.3	20.1	25.4	44.4	–	+
L. altaicum (1)	8.6	2.4	22.6	24.3	42.2	–	+
L. mexicanum (1)	8.7	2.3	20.7	28.1	40.3	–	+
L. narbonense (1)	6.6	1.8	22.0	32.2	37.5	–	+
Section *Dasylinum*							
L. hirsutum (2)	6.6	1.8	19.4	27.4	45.0	–	+
L. viscosum (2)	7.2	1.1	13.4	28.2	50.2	–	+
Section *Cathartolinum*							
L. catharticum (5)	7.6	2.8	13.2	64.3	12.1	–	–
Section *Linastrum*							
L. maritimum (3)	11.0	3.0	13.8	46.1	26.1	–	–
L. strictum (3)	8.9	3.1	7.6	52.9	27.6	–	–
L. rigidum (1)	7.7	1.3	8.1	62.1	20.8	–	–
L. sulcatum (1)	7.9	2.5	12.5	68.7	8.5	–	–
L. imbricatum (1)	8.9	2.5	6.6	75.4	6.5	–	–
L. lundelli (1)	8.4	2.4	8.9	74.6	5.7	–	–
L. tenuifolium (6)	5.0	2.1	8.0	81.5	3.6	–	–
L. salsoloides (3)	5.9	2.7	9.6	78.5	3.4	–	–
Section *Syllinum*							
L. flavum (8)	7.7	3.7	23.8	47.6	12.6	4.5	–
L. arboreum (2)	6.5	2.9	23.1	50.9	13.6	3.1	–
L. dolomiticum (1)	5.9	2.8	17.8	53.3	16.5	3.6	–
L. campanulatum (2)	5.3	2.3	21.8	51.2	16.4	3.2	–
L. mucronatum (2)	7.2	3.0	20.9	60.8	3.2	5.1	–

Symbols: – = absent. + = less than 5% of total peak area. ++ = greater than 5% of total peak area.

[a]Number in parentheses indicates number of accessions analyzed for each species.

[b]Unidentified fatty acid methyl ester with ECL of 27.2 (see text).

particularly in view of the small seed size and low oil contents of these wild species (3). However the occurrence of ricinoleic acid is of significance for two reasons. First, its confinement to species of only 1 section of the genus, adds further support to the suggestion that fatty acid composition is a useful taxonomic discriminator in this genus (6). The section *Syllinum* is morphologically quite distinct from other sections of the genus, being far more broad-leaved and prostrate in habit. Thus, their unique ability to produce ricinoleic acid in seed oils further supports the separation of these species into a separate section. A wider survey of oil composition in other species of the section *Syllinum* should be undertaken to verify this proposition.

Second, the presence of ricinoleic acid in wild *Linum* species is of consequence to their use as a genetic resource in flax breeding. Suggestions have been made that wild *Linum* species, including those of section *Syllinum*, having low levels of linolenic acid in their seed oils, offer the potential to reduce the concentration of this fatty acid in flax *(L. usitatissimum)* through interspecific hybridization (3,7). Such a reduction is being sought in order to convert linseed oil into an edible oil. Since ricinoleic acid would be an undesirable component in an edible oil, selection against its production in any hybrid involving a species from the section *Syllinum* would be necessary. Thus, to concentrate such hybridization attempts on those low-linolenic acid *Linum* species not containing ricinoleic acid, that is, on species from the sections *Linastrum* and *Cathartolinum*, appears preferable.

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