The Composition of Safflower Seed

T. H. APPLEWHITE, Western Regional Research Laboratory,[1] Albany, California

Abstract

Safflower has some interesting variations in composition. Current commercial seed types have about 40% hull, 37% oil, and 23% meal. Varities also exist with from 59–18% hull and inversely varying oil and meal percentages. The fatty acid composition of the linoleic acid type oils is quite constant at about 78% linoleic, 11% oleic, 3% stearic, 6% palmitic. Experimental types have been described with about 45% oleic: 45% linoleic, 80% oleic: 10% linoleic, and with 10% stearic. Compositional data are reviewed with particular attention to major and minor constituents (especially linolenic acid) that influence safflower use.

In his historical account on safflower, Kneeland (1) outlined the development of the present commercial types of seed. He also indicated the possibilities for the development of new seed types through breeding. General material on composition of commercial varieties was summarized in 1959 by Purdy et al. (2), but since that time most authors have dealt mainly with specific areas of safflower composition. This paper attempts to gather the recent available compositional information on commercial and experimental safflower varieties and thus provide a comprehensive view of the whole subject.

Commercial seeds differ grossly from some experimental types. Most of the commercial types have thick, white hulls. Many experimental types have thin, dark or striped hulls. The white-hulled commericial varieties have gross composition as follows: hull 33.5–44.5%, kernel 55.5–64.4% and oil 36.0–43.0% (3,4). Experimental, thin-hulled varieties high in linoleic acid have been described as follows: hull 18.4–30.1%, kernel 66.4–81.3%, and oil 39.5–49.6% (3,5). Hull 54.4%, kernel 42.9%, and oil 21.6% (3) or 25.4% (6) have been found in some high oleic types first described by Horowitz and Winter (7). Types high in stearic acid have hull 48.4%, kernel 51.0%, and oil 26.7% (3).

Hulls make up a large part of safflower seed, but they do not contribute proportionate value. Available data on hull composition are shown in Table I. The large amount of fiber in the commerical hulls lowers market value of the hulls and of whole safflower meal. The higher protein and lower fiber content of the experimental, high linoleic types may be plus factors in future crops.

Hull-free safflower kernels from experimental and commercial seed have quite similar gross composition; meal ranges from 32.2–47.0% and oil from 53.0–67.1% (3,4,5,8). Because all the high linoleic types are relatively high in oil, development of commercial thin-hulled varieties will greatly increase oil yield per acre. Even the experimental high oleic and stearic types that have relatively poor gross oil contents have good oil proportion (51.5 and 52%). Thus, it seems plausible that breeders will eventually produce commercial crops by introducing lower hull content into these varieties as well.

Perhaps the most important feature of an oilseed is its fatty acid composition. In Table II, some results of fatty acid analyses of the various experimental safflower oils are presented. The composition of the high linoleic oils is essentially indistinguishable from that of the normal commercial oils (Table III). Note, however, that the nonsaponifiable values (Table II) are somewhat uncertain because the samples were very small. The fatty acids, however, were determined, for the most part, by GLC on the esters and are quite reliable. The other experimental results are most interesting. Horowitz and Winter (7) first described the high oleic types. Since then, Knowles and co-workers (6,9) have found both the high oleic and intermediate types. They also have described the high stearic types. The high stearic types with only about 10% stearic acid are interesting genetically, but probably will have limited utility. However, the high oleic types appear to be an excellent source of oleic acid if and when the seed is commercialized. Commercialization may be relatively soon. Knowles (11) plans an early release of one high oleic seed variety for breeding and increase. He indicates, however, that even this seed is at least two years from commerical production.

The remainder of this review will be concerned only with commerical safflower oil. In Table III selected fatty acid analytical data are shown for such oils. The data on the first two lines, obtained by classical methods, are included for comparison with the remainder of the results which were determined by GLC techniques. The good agreement in the first four columns deserves comment. For the most part the ranges are narrow and show the quite uniform occurrence of the major acids in ordinary safflower oil. There seems to be little question that the high linoleic types always contain between 75 and 80% of that acid, and that the other fatty acids fall in narrow ranges as well.

The glyceride structure of safflower oil has been determined a number of times by a number of methods (8,19–24). Opinions reported in the literature conflict as to the glyceride distribution. The most convincing study is that of Scholfield and Dutton (23). By countercurrent distribution techniques they

[1] W. Utiliz. Res. Dev. Div., ARS, USDA.

TABLE I
Safflower Hull Composition (%)

Seed type	Protein	Fiber	Ash	Nitrogen-free extract	Fat	Reference
Commercial	3.8–5.0	57.9–62.4	1.2–3.4	22.4–28.3	1.2–3.8	3
	2.9	....	2.1	....	1.7	8
	3.1	....	....	....	....	4
Experimental						
High linoleic	6.3–10.1	44.3–54.0	3.5–5.8	23.9–32.4	2.6–6.8	3
Intermediate	4.0	62.2	1.0	24.0	2.4	3
High oleic	5.2	63.9	0.9	20.6	2.5	3
High stearic	3.1	65.8	0.9	22.1	1.6	3

TABLE II
Experimental Safflower Seed Oils Composition (%)

Seed type	Palmitic	Stearic	Oleic	Linoleic	Misc.	Nonsap.	Reference
High linoleic	6.0–6.8	2.1–2.9	9.8–12.7	77.5–81.0	0.2–0.8	0.8–1.4	10
Intermediate	5.0–5.5	1.2–1.4	45.1–47.3	46.5–48.2	(0.8)	(1.3)	9 (10)
High oleic	4–8	4–8	74–79	11–19	.....		7
	4.5	(1.2)	86.8	8.7	(0.5)	(2.3)	6 (10)
High stearic	6.2	9.5	11.9	71.0	1.4	2.1	10

TABLE III
Commercial Safflower Oil Composition (%)

Method	Palmitic	Stearic	Oleic	Linoleic	Misc.	Nonsap.	Reference
UV, IV, Cryst.	6.3	3.1	13.2	76.0	0.2	1.2	12
Dist., IV, UV	4.1–5.1	5.4–6.5	7.1–7.5	78.5–80.0	2.4–3.0	....	13
GLC	11	11	13	76.0	....	....	14
	7.1–7.5	2.5–2.8	12.2–13.6	76.1–78.3	....	....	15
	6.2	3.1	10.9	79.8	tr.	....	16
	7.9	2.7	14.8	74.1	0.5	....	17
	6.7	2.7	12.9	77.5	0.06	0.5	18
	6.4–7.0	2.4–2.8	9.7–13.1	76.9–80.5	0.2–0.8	0.9–1.6	10

found that safflower oil glycerides follow a random distribution pattern. Their observations on the oil seemed well substantiated when they demonstrated that the patterns for natural glycerides and randomized (base-catalysis) glycerides were identical.

Processors and users are also interested in minor constituents—the odds and ends that make an oil better or worse depending on one's point of view. The literature contains some data on various minor components of safflower oil. Purdy et al. (2) mentioned 0.5–0.6% nonsaponifiables in usual commercial oil. Ibrahim et al. (18) reported 0.41–0.57% and Eisner and Firestone (25) noted 0.87–1.26% nonsaponifiables. The lower values were probably from prepress oils and the higher from solvent extracted oils. Phospholipid data on safflower are scarce. Purdy et al. (2) stated that solvent extracted oil has about 2% gums (presumably containing the phospholipids). The only published data available are those of McKillican and Sims (26) who reported 1.1% phospholipids in safflower seed oil 40 days after flowering. Kuksis (27) studied hydrocarbons in oils and found 0.01% in refined safflower oil. He suggests considerable losses occur during refining. Ibrahim and coworkers (18,28) noted 0.004–0.007% squalene. Total sterol figures were determined in maturity studies (26), but the results seem unreasonably high. The value of 0.36% sterols recently published by Kiribuchi et al. (29) seems more reasonable and is in line with the nonsaponifiable percentages usually found. Eisner and Firestone (25) did not give a figure for total sterols, but they did determine the percentage of various sterols therein: γ-sitosterol 8.2–8.7%, stigmasterol 3.5–4.7%, β-sitosterol 52.9–59.9%, and unknowns 26.7–35.4%. These authors also suggested that the pattern of sterol composition in various vegetable oils can be used for checking on adulteration. Minor constituents of safflower do not offer particular processing or other utilization problems, and the sterols do not seem to offer much in the way of potential recoverable value.

Color should be mentioned here. Safflower oil is normally pale. The maximum Gardner value listed in ASTM specifications is 12, and after heat bleach is 5. Purdy and co-workers (2) note that normal values are below 4. The color present is probably associated with the carotenes or unknown pigments in the oil. The only report on safflower carotenes is that of Baszynski (30). He found 12.6 mg/liter β-carotene and noted this was among the higher values in seed oils he examined. However, color is not a problem in processing or using commercial safflower oils.

TABLE IV
Tocopherols in Safflower Oil

Oil type	Tocopherol	μg/g	Reference
Crude	Total	283–920	31
Refined	α	370	32
Refined	Total	248–492	33
	α	226–426	
Crude	Total	311–453	
	α	290–411	
Crude	Total	870–910	34
	α	405–495	
	β	....	
	γ	160–234	
	δ	200–259	
....	Total	319–750	35

Tocopherols affect oil stability and nutrition. Table IV lists data on safflower oil tocopherols determined for the most part by the Emmerie-Engle procedure. Different separation procedures were employed, however, some of them quite complex. Unfortunately, it is difficult to establish actual values because of the spread of the data. Kneeland (36) has found tocopherol ranges of 500–700 μg/g in over 20 commercial oil samples also by a modified Emmerie-Engle method. In the most recent paper, Rao et al. (34) used a single-step TLC separation followed by elution and an Emmerie-Engle measurement. Their control mixture results were quite convincing; recoveries of tocopherols added to safflower oil were 94–96%. Data on GLC determination of safflower tocopherols are not now available; however, the method has been applied to other tocopherol mixtures and should be equally applicable to this problem.

Because more and more attention is being devoted to minor constituents in fats and oils, some data from the literature on minor fatty acids of safflower oil are assembled in Table V. The most complete analyses of saturated and unsaturated acids are those of Kuemmel (37). Saturated acids are not extraordinary and do not pose processing or utilization problems. Although Kuemmel (37) has given the most complete analysis and has established the posi-

TABLE V
Minor Fatty Acids of Safflower Oil

Fatty acid	Per cent					
	Ref. 12	Ref. 13	Ref. 16	Ref. 17	Ref. 18	Ref. 37
12:0	....	....	tr.	...	....	<0.01
14:0	tr.	0–0.4	tr.	0.3	0.07	0.12
16:0	6.3	4.1–5.1	6.2	7.9	6.7	6.5
18:0	3.1	5.4–6.5	3.1	2.7	2.5	2.9
20:0	0.2	0.5–1.0	tr.	0.2	0.5	0.36
22:0	....	0.5–1.2	....	....	....	0.22
24:0	....	....	....	....	....	0.14
16:1	....	0.01–0.02	tr.	....	....	0.06
18:1	....	7.1–7.5	10.9	....	12.9	13.8 (Δ 9)
20:1	....	0.3	tr. ?	....	0.5	0.27 (Δ 11)
22:1	....	0.2–0.9	....	....	....	0.03 (Δ 13)
24:1	....	....	....	....	....	0.10 (Δ 15)
18:3	....	0.1 (conj.)	....	....	0	tr. ?

tions of the double bonds in the various monoenes, he did not clearly identify linolenic acid. The question of linolenic acid content in safflower oil deserves special comment. Because this acid oxidizes readily and has been implicated in vegetable oil color and odor problems, it is usually considered undesirable. A most careful search for linolenic acid in safflower oil was made by Ibrahim and co-workers (18). They used both polar and nonpolar stationary phases in their GLC analyses of the mixed esters and their data can be interpreted to indicate that linolenate is completely absent. A peak conceivably containing linolenate was observed on the polar column. When the same sample was then examined on the nonpolar column only eicosenoate and not linolenate was observed. A possible clue to earlier reports of linolenic acid is contained in Craig's results (13). The conjugated triene observed by him probably arises from autoxidation of linoleic.

As a closing note, many of us are now being exposed more and more to safflower oil in our daily lives. It is comforting to know that Goodman recently pointed out (38) that, among its many other attributes, safflower oil also is nonallergenic.

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