SORGHUM AND PEARL MILLET LIPIDS[1]

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ABSTRACT

The grain of *Sorghum bicolor* and *Pennisetum typhoides* (pearl millet) contains about 3.5 and 5.5% ether-extractable material, respectively. The lipids are concentrated in the germ. Sorghum germ oil is similar to corn oil in fatty acid composition and other properties. Pearl millet oil appears to contain more saturated fatty acids than corn and sorghum oil. Information on sorghum and especially pearl millet lipids is limited.

Sorghum and millets are important food crops in many areas of Asia, Africa and Latin America, ranking fourth or fifth in worldwide total grain production. Small farmers in many of the lesser developed countries and in areas where rainfall distribution or quantity is extremely limited grow and consume sorghum and millets. They produce low yields of grain under marginal circumstances, which is the reason for their evolution in semiarid areas.

Sorghum is a major crop in the United States and Latin America. In the United States and Argentina, sorghum is used primarily as animal feed, either directly or mixed with appropriate supplements and processed into complete rations for poultry, swine, cattle, sheep, goats, and other animals.

Several kinds of millets exist, and the literature is often confusing about which is being discussed. In the early literature, especially British, sorghum was often referred to as the "great millet," which caused further confusion. Caution must be used in interpreting the genus and species of millet discussed in an article because authors frequently use the common names and the names vary considerably throughout the world. Table I, therefore, lists some widely used millets by their

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common and scientific names. In this paper, the term "millet" will refer to pearl millet.

In the southeastern United States, pearl millets (*Pennisetum typhoides*) are grown primarily for forage. None are grown for grain at present in the United States. In this country, in eastern Colorado and adjacent areas primarily, proso or hog millet (*Panicum miliaceum*) is grown for forage and grain, and some is used in food products chiefly as whole or pearled millet. Foxtail or Italian millet (*Setaria italica*) also has been grown in the United States, chiefly as a forage crop.

Both proso and foxtail millets are widely cultivated in China and used for food. *Eleusine coracana* is grown in certain areas of Africa and India where it is called finger millet or ragi. Japanese barnyard millet (*Echinochloa crusgalli*) is produced chiefly in Japan.

OIL CONTENT

Several authors have reported the composition of the grain from sorghum and various millets (1–8); Table II is a composite of the data. The data for foxtail, Japanese and proso millets are on grain with hulls (covered caryopsis), and data for sorghum, corn and pearl millet concern whole grain without hulls (naked caryopsis). In general, the mean oil content approaches 5.5% for the millets and 4.5% and 3.5% for corn and sorghum, respectively. Pearl millet kernels are about one-fourth the size of sorghum and appear to have a much larger proportion of germ to endosperm than either corn or sorghum has.

The oil of sorghum and millet is concentrated in the germ, pericarp, and aleurone layer, as it is in other cereal grains, especially corn. In whole sorghum grain with a mean oil content of 3.6%, the oil content of hand-dissected endosperm, germ and bran fractions is 0.6, 28.1, and 4.9%, respectively (9). The germ contains more than 70% of the oil in the sorghum kernel. The bran contains 11% of the oil, but it contains a high proportion of wax. Comparable data are not available for pearl millet grain. Obtaining free germ from the pearl millet caryopsis is nearly impossible.

Table III displays information on the composition of the major fatty acids in sorghum, corn, and pearl millet oils from grain samples grown in 1976 under similar conditions at Lubbock, TX. These data confirm that pearl millet oil tends to be higher in palmitic and stearic acids and lower in oleic acid than oil from sorghum and corn. Additional data comparing sorghum and millet oil composition is presented in Table IV. Environmental conditions during

TABLE I
Names of Important Millets

Scientific Name	Common Names
Pennisetum typhoides	Pearl, cattail, bulrush, bajra, cumbo, sajja
Panicum miliaceum	Proso, hog, hershey
Setaria italica	Foxtail, Italian
Echinochloa crusgalli	Japanese, barnyard
Eleusine coracana	Finger millet, ragi

maturation of grain affect fatty acid composition. This must be considered in interpreting the data in Table IV, since the sorghum grains were commercial hybrids grown under varying conditions and the pearl millet samples were grown at one location in a nursery. Even so, pearl millet oil contains significantly more saturated fatty acids than does sorghum oil.

Sorghum oil can be produced in large quantities as a coproduct of wet milling, but it is not available now because wet milling of sorghum was discontinued several years ago. After extraction and purification, sorghum oil had essentially the same properties as corn oil. The physical properties of sorghum oil are presented in Table V. Kummerow (12) found that 14 different varieties of sorghum, grown under similar conditions, contained approximately 0.5% wax

TABLE II
Comparison of Ether-Extracted Material of Several Millets, Sorghum and Corn

Grains	N[a]	Extract[b] Mean	Extract[b] Min.	Extract[b] Max.
Sorghum[c]	633	3.3	1.4	5.8
Sorghum[d]	234	3.4	2.0	5.3
Pearl millet[e]	14	5.1	4.1	5.6
Pearl millet[e]	167	5.4	2.8	8.0
Pearl millet[f]	40	5.6	4.3	7.1
Pearl millet[e]	35	6.2	4.2	7.4
Foxtail millet[c]	6	4.8	4.6	5.0
Japanese millet[c]	6	5.8	5.5	6.3
Proso millet[c]	20	4.2	3.8	4.9
Corn, dent[c]	1,825	4.5	2.2	7.0

[a]N = Number of samples.
[b]Expressed as percent of oven dry weight.
[c]Data from Miller (1).
[d]L. W. Rooney. Unpublished data.
[e]Data from literature (2–8).
[f]Unpublished data from R. D. Galyean, Texas Tech. Univ., Lubbock, TX.

TABLE III
Fatty Acid Composition[a] of Sorghum, Corn, and Pearl Millet Oils

Component	Corn (%)	Sorghum (%)	Pearl Millet (%)
Ether extract %	4.5	3.4	5.6
Palmitic	12.7	14.3	19.0
Stearic	2.6	2.1	5.0
Arachidic	0.4	0.2	0.5
Palmitoleic	0.4	1.0	0.6
Oleic	26.0	31.0	25.0
Linoleic	56.3	49.0	46.0
Linolenic	1.6	2.7	3.2

[a]Expressed as percent of total.

and 2.5% oil, which was approximately 50 times the wax content and two-thirds the oil content of corn. Wax yield varied among varieties as much as 58% and oil yield varied as much as 20%. The oils varied in color from light green to amber, depending on the pigments in the sorghum variety. Pearl millet oil has not been extracted commercially.

Baldwin and Sniegowski (15) compared the fatty-acid composition of the lipids in the main fractions (germ, starch, gluten, and fiber) obtained in wet-milling sorghum grain. Germ lipids were the most unsaturated and contained the smallest amounts of free fatty acids and unsaponifiable material. Starch lipids were 70–90% free fatty acids; palmitic acid was most prevalent. Gluten and fiber lipids from wet milling of sorghum contained up to 32% unsaponifiables and approximately 20% free fatty acids. The fractions from wet-milled corn had similar compositions but were lower in unsaponifiable material. Bidwell and associates (16) hand-dissected bran and germ from grain sorghum and corn. Sorghum grain bran contained almost eight times more ether-soluble material than corn bran. The germ lipids did not differ. The sorghum grain endosperm,

TABLE IV
Fatty Acid Composition[a] of Lipids from Sorghum and Millet

Grain	N[b]	Palmitic	Stearic	Oleic	Linoleic	Linolenic
Sorghum[c]	22					
Mean		12	1	34	50	3
Range		10–14	0.2–1.0	28–42	42–56	1–5
Pearl millet[d]	65					
Mean		20	4	26	45	4
Range		18–25	2–8	20–31	40–52	2–5

[a]Expressed as percent of total.
[b]N = number of samples.
[c]Data from Freeman and Bocan (2).
[d]Data from Jellum and Powell (10).

TABLE V
Properties of Sorghum Oil[a]

Property or Component	Value Reported		
	Kummerow (12)	Kummerow (13)	Bertoni (14)
Color	...	Lt. amber-green	...
Refractive index (25° C)	1.4718	1.4695	1.4720
Unsaponifiable matter (%)	1.88	2.51	2.83
Acid value	3.14	...	18.9
Saponification value	181.0	...	189.5
Iodine value	119.0	120.8	121.2
Thiocyanogen value	76.7	81.5	...
Acetyl value	16.7	...	...
Neutralization equivalent	...	278.8	...

[a]Source: Wall and Blessin (11).

bran, and germ contained 0.7, 6.8, and 31.5% ether extract, respectively. The unsaponifiable fraction contained high molecular-weight alcohols and small quantities of wax.

FREE AND BOUND LIPIDS

We extracted the free and bound (polar) lipids from corn, wheat, and sorghum with petroleum ether in a soxhlet and then with water-saturated *N*-butanol at room temperature (Table VI). Wheat contains considerably more bound or polar lipids than either corn or sorghum, which contain similar quantities. Whole grain of 17 common sorghum varieties contains 2.66–3.97% free lipids ($\overline{X} = 3.24$); 0.1–0.30% ($\overline{X} = 0.2$) additional lipids (bound) were extracted from the ether-extracted residue with water-saturated *N*-butanol at room temperature. Thin-layer chromatography shows that the free and bound lipid extracts from the different varieties have similar components. The free lipid fraction consists of hydrocarbons, triglycerides, monoglycerides and diglycerides, free fatty acids and some polar lipids. The bound lipid fraction contains lecithin, lysolecithin, and other components but no free fatty acids.[3]

According to Boissy and Perles (17), the major components of the bound lipid fraction extracted from sorghum grain with methanol-chloroform are phospholipids. The phospholipids represent about 5% of the total lipids with about a 1:1 distribution between the lecithin and cephalin fractions. Thin-layer chromatography of the cephalin fraction shows phosphatidylethanolamine, phosphatidylserine, and an inositol phosphatide. Badi and colleagues (18) fractionated the free and bound lipids of wheat, sorghum, and pearl millet with thin-layer chromatography and reported that pearl millet lipids were similar to those of sorghum. No data were presented on relative quantities of each fraction.

CAROTENOIDS

Blessin and co-workers investigated the carotenoids of corn and sorghum grain (19,20). The common varieties of sorghum grain contain only a trace of carotenoids, compared with 25–30 ppm for yellow corn. However, by using African yellow-endosperm varieties in sorghum breeding programs, yellow-

[3]L. W. Rooney. Unpublished data.

TABLE VI
Free and Bound Lipids[a] of Ground Sorghum, Corn, and Wheat[b]

	No. of Replications	Free (%)	Bound (%)
Wheat	6	1.90 ± 0.19	0.84 ± 0.20
Corn	6	4.25 ± 0.20	0.14 ± 0.10
Sorghum	6	3.16 ± 0.17	0.19 ± 0.04

[a]14% moisture basis.
[b]Extracted with petroleum ether followed by water-saturated *N*-butanol.

endosperm sorghum types have been developed that contain 5 or more ppm of carotenoids. The major carotenoids in sorghum grain are lutein, zeaxanthin and β-carotene. In addition to those compounds, corn contains cryptoxanthin, hydroxy-α-carotene and α-carotene. Sorghum grain does not contain the latter compounds. Fifty percent of the carotenoids of yellow-endosperm sorghum grain may be lost through exposure to the sun. After the grain is physiologically mature, carotenes and xanthophylls decrease continuously with no preferential loss of individual carotenoids. Yellow-endosperm sorghums are now commonly grown, but the carotenoid pigment content is low. The carotenoid pigment content of pearl millet is similar to that of nonyellow endosperm sorghums. Most yellow endosperm cultivars of pearl millet should have increased levels of carotenoids.

WAXES OF SORGHUM

The composition and properties of the carnauba-like wax from sorghum have been studied extensively (21–24). Bunger and Kummerow (21) compared the wax from four varieties of sorghum grain with carnauba wax. Sorghum grain wax contained a lower percentage of esters and unsaponifiables than carnauba and a hydrocarbon that was absent from carnauba. A more extensive study (23) showed 46% alcohols, 49% esters, and 5% paraffins in grain wax and 80% esters, 12% alcohols, 1% paraffins, 4% resins, and 3% lactones in carnauba wax. These studies indicate that sorghum grain wax might substitute for carnauba waxes if some of the alcohol fraction were removed.

Seitz (24) extracted the wax from sorghum varieties by using hot benzene for 30 sec. The wax contained 4–5% hydrocarbons, 46–50% wax esters, 40–45% alcohols and about 8% of other lipid components. The hydrocarbon fraction was a complex mixture including n-alkanes (C_{23}–C_{31}) and squalene. The fatty alcohol fraction was composed of saturated, even chain, primary alcohols, C_{22}–C_{30}, with C_{28} and C_{30} predominating. The wax content of several sorghum varieties was similar.

Little basic information is available on the composition of sorghum and millet lipids; less is available regarding their function. Rancidity of pearl millet products can be a problem, but traditional villages usually avoid it by grinding grain sufficient only for a short time. Because the small, variable kernel size of pearl millet precludes effective degermination, the shelf life of its milled products must be considered in development of large-scale central processing plants.

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