Technical

Soybean Oil Quality as Influenced by Planting Site and Variety

W.S. CHU and **V.L. SHELDON**[1], Department of Agriculture, Western Illinois University, Macomb, Illinois 61455

ABSTRACT

Seven soybean genotypes were grown in various locations in Illinois and Missouri. Crude oils were analyzed for fatty acid composition, total phospholipid, free fatty acids, iron and peroxide value. Of the seven varieties examined, William's beans showed significant differences in total oil, protein, and fatty acid composition relative to planting sites. Evidence was obtained that crude oil from beans grown on irrigated land were higher in polyunsaturated fatty acids and lower in iron contents compared to those grown on nonirrigated land.

INTRODUCTION

Many factors contribute to the quality of whole soybeans and the oil and meal products derived from them. It is generally accepted, however, that linolenic acid content of the oil is responsible for flavor problems that restrict its acceptance for use in cooking and frying (1,2). Efforts to remove linolenate ester by partial hydrogenation and breeding have been only partially successful (3,4,5).

Recent studies indicate that flavor problems associated with the meal may well be caused by enzymatic oxidation of polyunsaturated acid within the bean (6,7). Studies also indicate that levels of lipoxygenases of soybean varieties are variable and may be under genetic control (7,8).

Relative little is known of the environmental and varietal factors governing the composition of whole soybeans (9,10,11,12). A more complete understanding could lead to varieties having not only higher oil and protein contents but improved end products as well. This study was undertaken to determine the chemical composition of soybeans and crude oils from seven genotypes and to study the effects of planting site and environmental factors on the quality of crude oils.

EXPERIMENTAL PROCEDURES

Seed

Seeds of Williams 50, 51, 52; Amsoy 35, 48; Corsoy 38, 39; Butler 43, 44 varieties were obtained from the Illinois Crop Improvement Association, Inc., Urbana, Illinois. Williams 24, 26, 28, 30, 31, 32, 34; Northrup-King 25, 27, and Mitchell 29 and 33 were obtained from the University of Missouri, Columbia, Missouri. Seed of Williams 21, and Butler 11 were grown at Western Illinois University, Macomb, Illinois. Amsoy 3 and Corsoy 13 were obtained from the University of Minnesota, St. Paul, Minnesota.

Oil Extraction

The soybean seeds were equilibrated to 12% moisture, cracked, dehulled and flaked in the milling apparatus at the USDA Northern Regional Research Center, Peoria, Illinois. The flaked soybeans were extracted three times with petroleum ether at room temperature. The solvent was removed under nitrogen with a rotary evaporator. The solvent-free oil (about 15% yeild) was held at -20 C until analyzed.

Fatty Acid Composition

Palmitic, stearic, oleic, linoleic and linolenic acids were determined by gas liquid chromatography. Methyl esters were prepared from 0.4-0.6 grams of crude soybean oil by the AOCS method (13) and injected into a Varian series 3700 gas chromatograph. A 0.25 in x 6.0 f stainless steel column packed with 10% EGSS-x on 100:120 mesh gas chrom P was used with a nitrogen flow rate of 30 ml/min. The injection port and detector temperature was 320 C. The column temperature was operated at 185 C.

Phospholipid Composition

Polar phospholipids were quantitatively separated from the neutral lipid by means of the solvent partition method described by James et al. (14) with modification by List (15). A 2-funnel, 4-withdrawal counter-current distribution was used.

Other Procedures

The crude soybean oils were analyzed for oil content, total phospholipid content, free fatty acid (FFA), peroxide value, and protein by AOCS methods (13). Iron was determined on hand-ground beans and measured by atomic absorption as described by List et al. (16).

RESULTS AND DISCUSSION

The diversity of the fatty acid composition is shown in Table I. In the crude oils from the Williams variety, the palmitic acid values ranged from 10.6% in northern Illinois to 12.7% at Novelty, Missouri; the stearic acid values increased from 3.8% in northern Illinois to 6.3% at Columbia, Missouri; and the oleic acid values from 20.0% in northern Illinois to 25.8% at Columbia. In the same samples, these increases were accompanied by significant decreases in both linolenic and linoleic acids. The fatty acid composition of Amsoy, Butler, and Corsoy varieties shows similar, but less significant differences.

The increase of linoleic and linolenic acids and the accompanying decrease in oleic acid (17,18) appears to be more marked in each of the varieties as the planting sites are farther north. The largest change in composition appears to be in the Corsoy variety.

If the eleven sites where Williams soybeans were grown are divided into two groups – 4 from Illinois (IL) and 7 from Missouri (MO) – the mean chemical composition varies significantly, as shown in Table II. The Williams soybeans from Illinois are higher in crude oil content and lower in crude protein than those grown in Missouri. The inverse relationship between these two constituents is also

[1]Research assistant and professor of agriculture, respectively.

TABLE I

The Fatty Acid Composition of Crude Soybean Oils According to Planting Location and Variety

Sample	Planting location	Palmitic	Stearic	Oleic	Linoleic	Linolenic
		Fatty acid composition (%)				
		WILLIAMS				
26	Missouri-Columbia	11.2	6.3	25.8	50.7	6.1
32	Missouri-Blackburn	12.2	5.1	25.1	51.3	6.3
24	Missouri-Rutledge[a]	12.3	4.9	25.1	51.3	6.3
31	Missouri-Novelty	12.7	4.8	23.4	51.7	7.4
30	Missouri-Spickard	12.1	4.7	24.3	52.1	6.9
28	Missouri-Rutledge	11.7	4.6	24.2	52.5	6.9
34	Missouri-Columbia[b]	12.5	4.7	22.7	52.8	7.3
50	Illinois-Southern	11.4	4.2	24.3	53.3	6.7
51	Illinois-Central	11.6	4.1	22.9	54.1	7.2
21	Illinois-Macomb	11.6	4.2	22.5	54.6	7.1
52	Illinois-Northern	10.6	3.8	20.0	57.3	8.3
		AMSOY				
48	Illinois-Southern	15.2	5.0	23.1	48.6	8.1
35	Illinois-Central	11.0	4.5	26.1	50.1	8.2
3	Minnesota-Central	12.1	3.7	21.6	52.8	9.8
		BUTLER				
43	Illinois-Southern	11.9	4.5	21.4	54.5	7.7
44	Illinois-Central	11.8	4.8	18.8	56.2	8.5
		CORSOY				
38	Illinois-Central	12.1	4.0	24.1	52.6	7.2
39	Illinois-Northern	12.4	3.7	18.7	59.4	5.8

[a]Same as No. 28 except soil treated with 320 lbs/acre K_2O.
[b]Same as No. 26 except irrigated.

TABLE II

Comparison of Crude Oils from Williams Soybeans Grown in Missouri and Illinois[a]

Constituent	Planting site location: Missouri	Illinois
Oleic acid (%)	24.4 ± .40	22.4 ± .90
Linoleic acid (%)	51.8 ± .28	54.8 ± .87
Linolenic acid (%)	6.7 ± .20	7.3 ± .34
Crude oil (%)	22.7 ± .29	24.2 ± .70
Crude Protein (%)	44.3 ± .48	41.9 ± .076
Total phospholipids (%)	1.20 ± .067	1.10 ± .065
Iron (PPM)	0.4 ± .082	0.2 ± .12

[a]Mean values with standard error of the mean.

evident. These results are in agreement with Howell and Collins (17).

Of the many factors in any plant growth environment that may affect the metabolism and composition, soil conditions present themselves for first consideration. That an ample supply of water, for example, may be important is illustrated by the data presented in Table III. Mitchell and Williams varieties are grown at the same planting site with normal rainfall and with irrigation. Here again the decrease of oleic acids is accompanied by a concurrent increase in linoleic and linolenic acids. Such a change in the soil moisture status may simply be one of supplying adequate water, but also it could cause a change in the nutrient status within the soil or in the soil aeration. Iron content varied most among the chemical components studied. Since iron is an oxidation catalyst, soybean strains and environmental factors that produce low iron content are obviously important.

The diversity of crude soybean oils from different varieties grown at different locations is also illustrated by the phospholipid, free fatty acid, peroxide, iron, oil and protein values shown in Table IV. The greatest range in values occurred in the crude oils from the Williams variety. The iron content again varied most among all the chemical components studied. Those crude oils with the higher iron contents might have increased oxidation (18).

The phospholipid content of crude soybean oil is important for a number of reasons. For the processor who degums the oil and processes lecithin, development of varieties with a high phospholipid content would be desirable. On the other hand, many processors refine the crude oil directly. Here strains with a low phosphatide content would be desirable because such oils would emul-

TABLE III

The Effect of Irrigation on the Chemical Composition of Crude Oils from Mitchell and Williams Soybeans

Chemical constituent	Mitchell: Normal	Mitchell: Irrigated	Williams: Normal	Williams: Irrigated
Palmitic acid (%)	13.3	12.4	11.2	12.5
Stearic acid (%)	5.7	7.45	6.3	4.7
Oleic acid (%)	24.4	21.5	25.8	22.7
Linoleic acid (%)	49.6	53.8	50.7	52.8
Linolenic acid (%)	7.0	7.7	6.1	7.3
Crude oil (%)	22.8	25.1	23.5	22.5
Iron (PPM)	0.6	0.1	0.7	0.1

TABLE IV

Diversity of Chemical Composition of Soybean Varieties

Variety	TLP (%)	FFA (%)	PV (meq/kg)	Iron (ppm)	Oil (%)	Iodine Value[a]
Williams						
Maximum	1.30	.4	2.1	.7	26.2	138.2
Minimum	0.80	.2	1.5	0	21.6	126.0
Northrup-King						
Maximum	1.40	.5	1.7	.3	26.2	126.5
Minimum	.80	.3	1.1	.2	22.8	123.5
Mitchell						
Maximum	1.20	.3	2.1	.6	25.1	131.8
Minimum	.80	.3	1.6	.1	22.8	125.2
Amsoy						
Maximum	1.50	.4	1.6	.7	25.7	135.7
Minimum	1.00	.3	1.6	0	21.8	125.2
Butler						
Maximum	1.20	.3	2.1	.5	23.0	135.8
Minimum	1.00	.2	1.3	.1	22.2	132.4
Corsoy						
Maximum	1.60	.4	1.7	.6	25.9	134.1
Minimum	1.00	.3	1.3	0	23.7	130.5
Beeson						
Maximum	1.30	.4	1.7	.5	23.8	134.4
Minimum	1.10	.3	1.0	0	21.9	133.0

[a]Calculated values.

sify less neutral oil in the soap stock during caustic refining. A further impetus for development of low phosphatide oils stems from the possible extension of steam refining into soybean processing. Oils with a high phosphatide content are known to be more difficult to steam refine. Development of low phosphatide oils would also be desirable if crude oil is to be stored in bulk for extended periods of time. Crude soybean oil is apt to deposit sludge in the bottom of storage tanks, tank cars, barges or tankers if stored for extended periods.

That a variation in the chemical composition of crude oils from the same soybean variety can occur is of utmost significance. Divergence in crude oil composition as the plants are grown on a wide variety of soils under different climatic regimens evokes renewed efforts to define more specifically the causes for these effects. Biosynthesis of oil by the soybean plant ultimately depends upon the enzymes that are activated by the nutrients coming from the soil and the climatic forces which created them. The economic importance to both the grower and the processor would seemingly dictate indepth studies of the causes for divergence of soybean oil quality.

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