Quality of Soybeans and Their Crude Oils in Saudi Arabia

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Fourteen locally grown soybean varieties and their extracted crude oils were evaluated and analyzed for characteristics and compositions. Caribe, followed by SH-1274 soybeans, were the best in terms of soundness and freedom from foreign material, while others were heat-damaged to a different extent. The seeds of different varieties contained from 40.57 to 47.60% protein and from 15.84 to 21.35% oil, with Caribe soybeans being the highest in protein and the lowest in oil content.

The ranges of the physicochemical characteristics of crude oils were as follows: specific gravity (25°C), 0.9069–0.9231; refractive index (25°C), 1.4726–1.4742; free fatty acid as oleic, 0.07–0.32%; peroxide value, 1.90–5.40 meg/kg; iodine value, 117.02–124.97; saponification number, 187.13–194.97; unsaponifiable matter, 0.55–0.95%. Phosphorus, calcium, magnesium and iron were found as 149.8-602.2, < 1–18, 2–24 and < 1–4 ppm, respectively. Gas liquid chromatography detected eight fatty acids (C14, 16, 18, 18:1, 18:2, 18:3, 20 and 22) present in crude oils. The level of each differed among varieties but remained within the usual ranges.

Soybeans are an important world crop grown in many countries, but mainly in the United States, Brazil, China and Argentina. They now dominate the world vegetable protein and oil markets due to favorable agronomic characteristics and high quality oil and protein products, as well as to plentiful and dependable supply at a competitive price (1). The world's production of soybeans and soybean oils in 1987 are expected to reach 98.78 and 14.09 million metric tons, respectively (2).

The chemical composition of soybeans and soybean oils are affected by factors such as climatic conditions, fertility and varietal differences (3-6). The oil and protein contents may range from 14 to 24% and from 30 to 50%, respectively (7). Other constituents like cellulose and hemicellulose, sugars, crude fiber and ash are also present in the amounts of 17, 7, 5 and 6%, respectively (8). The ranges of physicochemical characteristics of crude soybean oils are approximately as follows: iodine value, 120-141; saponification value, 189-195; refractive index, (25°C) 1.470-1.476; specific gravity, (25 C), 0.917-0.921; unsaponifable matter not over 1.5% (9). Unsaturated fatty acids, mainly C18:1, 18:2 and 18:3, represent more than 80% of the total fatty acids in crude soybean oil (6,10). However, the latter authors reported other fatty acids such as C16, 18 and traces of C12, 14 and 16:1.

Saudi Arabia is not an oilseed producer. It depends totally on imports for oilseeds and crude vegetable oils. The Kingdom's 1985 import statistics indicated a value of more than SR 90 million of imported soybeans and soybean products, and the value is expected to increase in the future (11). Therefore, many soybean-growing experiments have been conducted in different areas of the country (12-21). However, the reported data was on agronomic characteristics such as yield amount, days of flowering, plant height, days of maturity, branches per plant, nodes per plant, etc. Neither the grade evaluation of locally grown soybeans nor the quality of their oils has been investigated. The quantity and quality of soybean oils can be affected by climatic conditions (6,22,23), which are known to be different in Saudi Arabia. Fourteen soybean varieties successfully grown by the Department of Plant Production, College of Agriculture, King Saud University during the summer of 1985, were evaluated for grade of soybeans and the physicochemical characteristics of their crude oils.

EXPERIMENTAL PROCEDURES

Seed evaluation. The soybeans were obtained from the experimental station of the College of Agriculture, King Saud University. The 14 varieties used in this study were grown in May and harvested in October 1985. The percentages of moisture, damaged kernels, splits, foreign material and brown and black soybeans and/or bicolored soybeans in yellow and green soybeans were calculated. The varieties were then graded according to grade requirements (24). The weight and volume of 100 seeds was also determined.

Sample preparation and analysis. The soybeans were milled to pass through a one-mm sieve with Ultra-centrifugal mill, Resh type ZM1, No.140. Oil, protein (NX6.25) and ash were determined according to AOAC (25).

Oil extraction and analysis. Soybean oils were extracted by petroleum ether (40-60°C) using a Soxhlet extractor. The oils were then analyzed for specific gravity, refractive index, free fatty acids, iodine value, peroxide value, saponification value and unsaponifiable matter by the standard methods (26). After wet ashing (25), magnesium and iron were determined by an IL 251 atomic absorption spectrophotometer; calcium was determined by an 1100 B Perkin Elmer atomic absorption spectrophotometer. Total phosphorus was determined separately by a modification of the molybdenum blue method recently reported by Abu-Lehia (27) after wet digestion with a mixture of concentrated sulfuric and nitric acids.

GLC analysis. The fatty acid composition of extracted soybean oils was determined by gas chromatography according to the procedure of Metcalfe et al. (28). Fatty acid methyl esters (FAME) were identified on a 3700 gas chromatograph (Varian) with a flame ionization detector (FID) at 250 C. The hydrogen, air and nitrogen flow rates were 30, 300 and 40 ml/min, respectively. A one-μl sample was injected on a 200-cm × 6.25-mm column which was packed with 15% ov-275 on 80/100 chromosorb WAW. The temperature of the injection and column was 150 C. A comparison between relative retention times of the peaks of the samples and those of the standards, run on the same column under the same conditions, was made for identification.

RESULTS AND DISCUSSION

Evaluation of soybeans. The value of oilseeds is usually determined either on the basis of general quality of the seeds or on the basis of yield and quality of the oil extracted

TABLE 1

Evaluation of Soybeans Upon the Basis of Their Soundness and Freedom of Foreign Material

Varieties	Color	Volume of 100 kernels (ml)[a]	Wt of 100 kernels (g)	Moisture (%)	Splits (%)	Damaged kernels (%)	Foreign material (%)	Different colored soybeans
Cabrillo	Yellow	13.00	15.30	7.10	1.6	4.2	–	–
Rillito	G. Yellow	13.50	15.50	7.08	2.5	2.9	–	–
Jupiter	Green	15.00	18.03	7.24	4.3	0.2	–	2.7 (brown)
Caribe	Black	10.50	12.45	7.68	0.8	0.7	0.3	–
Improved Pelican	Yellow	13.00	15.34	5.63	0.9	13.9	–	–
Braxton	Yellow	13.00	15.01	5.90	1.3	20.2	0.1	–
Davis	Yellow	14.00	16.01	5.80	3.0	6.0	–	–
DB-1601	Yellow	13.50	15.06	5.13	0.7	8.6	–	–
Duocrop	Yellow	12.00	14.00	5.17	0.5	19.6	–	–
EGSY 19-7	Yellow	12.80	14.69	5.67	0.7	19.2	–	–
IBP 185-77	Yellow	12.00	14.36	5.70	1.2	13.0	–	8.2 (green)
Jupiter-R	Yellow	13.00	15.60	5.27	1.6	6.4	0.1	–
PK-308	Yellow	12.90	15.23	5.40	0.9	12.0	–	3.1 (green)
SH-1274	Yellow	13.00	15.52	5.73	3.5	2.6	–	–

[a] Water.

from them (9). The soybean varieties investigated in this study were evaluated on the basis of soundness and freedom from foreign material (Table 1). Generally, all varieties were low in moisture content and rarely free of foreign material, including brown or black soybeans in yellow or green soybeans. The broken or split beans were present in very low amounts. However, some varieties, mainly Braxton, Duocrop and EGSY 19-7 soybeans, were badly damaged, while Caribe soybeans (black beans) were almost unaffected though all were grown under the same climatic conditions. The summer in Saudi Arabia is usually hot and dry. The average temperatures and relative humidities during the months of planting of the soybean varieties are shown in Table 2. These climate conditions were severe enough to cause considerable damage to the seeds. The split and damaged beans are of concern to soybean processors because of their effect on the quality of extracted crude oils, mainly higher free fatty acids, higher iron, and higher peroxide values than those from whole and sound beans (29-31).

The soybean varieties were compared with grade requirements set by the U.S. Department of Agriculture (24). Grading was based on soundness and freedom from foreign material, and on the presence of different colored soybeans in yellow or green soybeans. The black color of Caribe is not taken into consideration during grading; therefore, it cannot be graded as a No. 1 yellow soybean according to the U.S. standard. The grades are shown in Table 3. Caribe and SH-1274 met the requirements for grade No. 1 and grade No. 2, respectively. However, the high percentage of damaged kernels lowered the grade of other varieties. Improved Pelican, Braxton, DB-1601, Duocrop, EGSY 91-7, IPB 185-77 and PK-308 soybeans did not meet the requirements for any of the four known grades of soybeans. Weight criteria of the minimum test weight (lb/bu) was not taken into account because of the small sample size obtained for the study. However, the weight and volume of one hundred kernels are reported in Table 1. Jupiter beans were the heaviest, and Caribe beans were the lightest.

Approximate composition. Table 4 shows the percentages of oil, protein and ash in soybeans. The values are within the ranges for most soybeans (7,8). Caribe soybean was the highest in protein and the lowest in oil content. Most soy-

TABLE 2

Average Temperatures and Relative Humidities During Months of Planting of Soybean Varieties[a]

	Temperature (°C)[b]		Relative humidity (%)[c]	
Month	MAX	MIN	MAX	MIN
May	38.8	20.7	54.8	21.4
June	41.6	21.8	29.3	13.6
July	42.9	21.8	31.9	14.6
August	43.5	21.7	30.5	15.4
September	40.1	18.3	35.4	17.0
October	35.6	13.0	55.0	18.4

[a] Data was reported by the weather station of the Agricultural Experimental Station, College of Agriculture, King Saud University.
[b] The highest temperatures reported during May, June, July, August, September and October were 43, 44, 45.5, 42 and 39.5°C, respectively.
[c] The lowest relative humidities during May, June, July, August, September, and October were 12, 12, 13, 13, 14 and 13%, respectively.

TABLE 3

Final Grading of Soybean Varieties Based on Standard Grade Requirements in Table 1

Variety	Grade No.[a]
Cabrillo	3
Rillito	3
Jupiter	3
Caribe	1[a]
Improved Pelican	SG[b]
Braxton	SG
Davis	4
DB-1601	SG
Duocrop	SG
EGSY 91-7	SG
IPB 185-77	SG
Jupiter-R	4
PK-308	SG
SH-1274	2

[a] Color not considered. Caribe is not graded a No. 1 yellow soybean but graded No. 1 based on soundness and freedom of foreign material.
[b] Sample grade indicates the soybeans which do not meet the requirements for any of the four grades from No. 1 to No. 4.

beans lower in oil are higher in protein and vice versa (8). The variation in oil content among varieties was greater than that of protein. Cartter and Hopper (3) reported that oil content could be influenced by variety, environment and fertility level. However, all varieties but Caribe, which is known to have a lower oil content, contained acceptable oil levels in spite of severe climatic conditions during the period of seed maturation.

TABLE 4

Oil, Protein and Ash in Soybeans

Varieties	Oil (%)[a]	Protein (%)[a, b]	Ash (%)[a]
Cabrillo	20.89	42.94	6.01
Rillito	20.71	41.15	6.06
Jupiter	18.44	40.57	5.81
Caribe	15.84	47.60	5.93
Improved Pelican	19.63	43.74	6.08
Braxton	19.84	43.46	5.97
Davis	20.74	42.45	5.92
DB-1601	21.13	41.87	6.05
Duocrop	20.84	42.29	5.94
EGSY #19-7	20.30	43.12	5.90
IPB 185-77	20.23	42.75	5.94
Jupiter-R	21.20	42.76	6.42
PK-308	21.35	41.93	6.27
SH-1274	20.38	41.89	6.54

[a] Dry basis.
[b] Nitrogen × 6.25.

Physicochemical characteristics of crude oils. The physicochemical characteristics of crude soybean oils are presented in Table 5. The comparison with AOCS standards (9) showed that PK-308, Duocrop and Davis were lower in iodine value, while Jupiter, Rillito and DB-1601 were lower in saponification value. Iodine value indicates the degree of unsaturation, while saponification number is a measure of the average molecular weight. All values for unsaponifiable matter were lower than those reported for soybean oils by Gutfinger and Letan (32). The trading specifications on crude soybean oil limit the unsaponifiable matter to 1.5% or less (33). Hoffman et al. (34) discussed the advantage of lower unsaponifiables on the flavor stability of the oil. All varieties but Davis were low in free fatty acids (FFA) (Table 5). Evans et al. (29) found that soybean oils extracted from certified sound beans contained around 0.1 to 0.14% FFA, while those from sound and damaged beans had around 0.3 to 0.31% and 1.7 to 7.2% FFA, respectively. Lower FFA content in crude soybean oil is desirable not only for trade specifications but also for ease of processing. The peroxide values (Table 5) were generally low. The correlation between peroxide values and flavor is very well known, and oxidation of crude oil should be avoided because severe oxidation may impact on finished oil stability. However, in this study they seem to be of the least importance because the oils were currently extracted.

Metal contents. Table 6 gives the concentrations of phosphorus, calcium, magnesium and iron in crude soybean oils. Phosphorus content ranged from a high of 602.2 ppm in PK-308 to a low of 149.8 ppm in Braxton. Evans et al. (29) reported 312 to 910 ppm, while List et al. (35) reported 500 to 900 ppm phosphorus in crude soybean oils. The content of phosphorus in crude oil is indicative of phospholipid concentration and how well the oil is processed. Crude soybean oils varied in their calcium and magnesium contents from < 1-18 ppm and from 2-24 ppm, respectively (Table 6). Letan and Yaron (36) found 15 ppm calcium in crude Soxhlet-extracted soybean oils and 100 ppm in industrially-extracted, degummed oils. The two elements are known to compete with water, thereby depressing the hydration of phospholipids during degumming (36,37). Their presence in nonhydratable phospholipids has been reported by many workers (38-41). Iron contents in Table 6 ranged from <1 to 4 ppm. Concentration of iron varied from 0.9 to 6.1 ppm (29). The authors found that crude oils from damaged beans had higher iron contents than crude oils from sound beans. Heavy metals, mainly iron and copper, exhibit a prooxidant effect in fats and oils, resulting in odor, flavor and color deterioration (37, 42). The importance of iron and phosphorus removal during degumming of soybean oil was investigated by many authors (35, 43-45). Variations in metal contents in this study might be due to differences in variety and quality of the beans as well as to levels of these elements in the soil and their availability.

Fatty acid composition. The average fatty acid composition of crude oils extracted from the soybean varieties is presented in Table 7. The fatty acid profile was similar and the unsaturated fatty acids (C18:1, 18:2, 18:3) represented

TABLE 5

Physicochemical Characteristics of Crude Soybean Oils

Varieties	Specific gravity (25°C)	Refractive index (25°C)	FFA[a] (%)	Peroxide value (meq/kg)	Iodine value	Saponification number	Unsaponifiable matter (%)
Cabrillo	0.9210	1.4731	0.12	1.90	125.81	188.20	0.89
Rillito	0.9209	1.4732	0.18	2.30	126.75	187.90	0.55
Jupiter	0.9221	1.4742	0.19	2.10	132.51	187.13	0.69
Caribe	0.9209	1.4732	0.18	2.95	127.26	188.96	0.89
Improved Pelican	0.9231	1.4726	0.11	4.88	124.18	191.86	0.95
Braxton	0.9211	1.4726	0.16	4.49	122.15	188.48	0.88
Davis	0.9071	1.4729	0.32	4.62	126.77	190.44	0.86
DB-1601	0.9169	1.4726	0.09	2.70	121.83	187.41	0.93
Duocrop	0.9069	1.4728	0.07	3.42	121.95	188.39	0.77
EGSY 91-7	0.9084	1.4728	0.08	5.40	121.78	190.01	0.89
IPB 185-77	0.9225	1.4726	0.11	5.28	124.97	194.97	0.81
Jupiter-R	0.9179	1.4728	0.10	2.22	124.90	194.05	0.84
PK-308	0.9127	1.4731	0.08	2.49	123.95	190.58	0.82
SH-1274	0.9192	1.4731	0.09	4.00	127.50	193.71	0.73

[a] Calculated as oleic acid. FFA, free fatty acids.

TABLE 6

Phosphorus and Metal Contents of Crude Soybean Oils (ppm)[a]

Varieties	P	Ca	Mg	Fe
Cabrillo	270	8	12	<1
Rillito	150	18	11.6	<1
Jupiter	176.5	4	8	1
Caribe	229.5	2	8	3
Improved Pelican	320.3	4	12	2
Braxton	149.8	8	8	4
Davis	282.7	16	8	3
DB-1601	242.8	<1	2	<1
Duocrop	149.9	<1	6	1
EGSY 19-7	269.4	<1	12	2
IBP 185-77	282.9	2	12	<1
Jupiter-R	216.2	<1	2	1
PK-308	602.2	6	24	4
SH-1274	344.2	2	4	3

[a]Means of duplicate analysis.

more than 80% of the total fatty acids in all crude soybean oils. This is in agreement with the analysis reported by Collins and Howell (6) and Brignoli et al. (10). However, very little difference in either saturated or unsaturated fatty acid level was obtained from the 14 soybean varieties. The difference is most likely due to the different varieties because all varieties were grown in the same location and under the same conditions. Collins and Howell (6) studied the variability of C18:3 and 18:2 in soybean oils from different varieties and found variation from 5.4 to 8.0% in C18:3 and from 43.9 to 51.6% in C18:2.

TABLE 7

Fatty Acid Average Composition (area %) of Crude Soybean Oils

Varieties	C_{16}	C_{18}	$C_{18:1}$	$C_{18:2}$	$C_{18:3}$	Others[a]
Cabrillo	11.57	5.03	27.03	49.39	6.13	0.83
Rillito	9.18	4.66	27.52	51.69	6.1	0.83
Jupiter	12.44	4.33	18.16	57.14	6.26	1.22
Caribe	12.47	4.78	19.04	58.04	4.70	0.96
Improved Pelican	11.23	5.10	26.99	50.56	5.41	0.71
Braxton	12.54	4.25	26.58	49.89	6.05	0.69
Davis	11.91	4.71	26.96	49.39	6.25	0.78
DB-1601	12.32	4.61	27.72	48.60	6.07	0.68
Duocrop	11.95	4.73	29.27	47.81	5.53	0.70
EGSY 19-7	11.57	5.18	27.27	50.10	5.13	0.74
IBP 185-77	11.76	5.23	25.45	51.08	5.85	0.63
Jupiter-R	11.25	4.7	25.98	51.24	6.10	0.71
PK-308	11.98	5.02	26.06	50.18	6.11	0.66
SH-1274	11.61	4.46	25.58	51.62	6.1	0.63

[a]Including C_{14}, C_{20} and C_{22}.

The level of each fatty acid (Table 7) falls in the ranges of fatty acid distributions tentatively adopted by FAO/WHO Codex Alimentarius Committee of Fats and Oils for soybean oil (46). The level of C18:3 was relatively low in some of the crude oils. This is rather desirable because C18:3 is associated with flavor deterioration and autoxidation. Howell and Collins (47) showed that the higher the temperature, the lower the content of both linoleic and linolenic acid components. However, in this study the high temperature during seed development seemed to have little effect on these fatty acids.

The physicochemical characteristics of crude soybeans, and their mineral contents and fatty acid composition, were acceptable in spite of the high percentages of damaged kernels. However, these oils were tested as soon as they were extracted and no storage stability tests were conducted.

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