Evaluation of the Food Use Potential of Sixteen Varieties of Cottonseed

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ABSTRACT AND SUMMARY

Sixteen new or experimental varieties of cottonseed, eight glandless and eight glanded, were extensively analyzed in this study. Ginned seed from each were studied and then kernel samples and finally oil and flour samples prepared from the kernels. Mean values determined for each attribute measured are presented for each type seed. These data are useful for (a) showing the magnitude of particular desirable properties presently being achieved in varieties of each type seed, (b) showing something of the variation of these properties among varieties within seed types, and (c) comparing glandless and glanded seed types for compositional differences.

INTRODUCTION

With the development of edible glandless cottonseed and processing technology which permits the utilization of protein from conventional glanded cottonseed for human food, it becomes imperative that cotton breeders and cottonseed processors assess the potential of each new variety for food use. Possession of characteristics which make seed desirable for food use will increase their value.

The increasing significance of cottonseed in relation to the total monetary value of the cotton crop is illustrated by the fact that cottonseed provided 14% of the total revenue during the 10-yr period 1963-1973 and accounted for 20% of the total revenue from cotton production during the 1974-75 season (1,2). Food technologists foresee cottonseed becoming more and more prominent as a source of food protein in the years ahead. Investigators at the Food Protein Research & Development Center at Texas A&M University have already tested the utility of cottonseed products in several food applications (3-7).

In previous cottonseed studies by other researchers involving glanded seed, the effects of variety, growing location, and their interaction on the composition of cottonseed were examined (8-11). In the study reported here, the primary object was to thoroughly examine new and relatively new varieties of cottonseed (both glandless and glanded) and their products, emphasizing those seed attributes generally regarded as desirable for food use, so as to establish optimal levels of each attribute currently being achieved by seed breeders. Variation in these seed properties among varieties of the same type seed (glandless or glanded) and between seed types would also be revealed.

EXPERIMENTAL PROCEDURES

Seed from sixteen new and experimental cottonseed varieties, eight glandless and eight glanded, were thoroughly analyzed as fuzzy seed before delintering. A sample of each variety was then processed into kernels, flour, and oil and each of these products in turn subjected to complete analysis.

Seed Samples

Ginned cottonseed samples of each variety weighing at least 10 lb were obtained from leading seed breeders. Each breeder was requested to furnish seed from his most promising variety or varieties for inclusion in the study. Due to the stage of varietal development, in some instances, no more than 10 lb of seed were available. Thus, limitations on the amount and treatment of data obtained were imposed. It was assumed that each variety was grown in a geographical location favorable to it.

Ginned or "fuzzy" seed samples were thoroughly analyzed as received. A portion of each sample was then decorticated and hull-free kernels subjected to proximate analysis and other measurements of choice. Flours and oils were next prepared from hull-free kernels using a low-heat, direct, hexane extraction technique and each of these products analyzed in turn as described.

Analytical Measurements

Moisture, oil, crude fiber, free fatty acids, total gossypol, ash, iodine number, and refined and bleached oil colors were determined according to standard AOCS methods (12). Nitrogen was determined by the micro-Kjeldahl method. Protein was calculated as nitrogen multiplied by 6.25.

Amino acid analyses of flours (with the exception of tryptophan and cystine) were quantitatively measured by the procedure of Spackman et al. (13). Tryptophan was determined by the method of Kohler and Palter (14). Cystine was measured using a modification of the procedure of Schram et al. (15).

Samples were hydrolyzed for determination of all amino acids except cystine and tryptophan in constant-boiling HCl for 24 hr under a nitrogen flush. Procedures for preparing protein hydrolysate for cystine and tryptophan are specified in the methods cited. Available lysine analyses were made following a method by Rhee et al. (16).

Nitrogen solubility was measured on each flour sample at pH 3, 4, 5, 7, and 9 following a modification of a method by Lyman et al. as previously described by Lawhon et al. (5). Total sugars in terms of glucose were measured colorimetrically by the phenol-sulfuric acid method of Dubois et al. (17). Total phosphorus was determined by the method of Sumner (18).

Flour color measurements were made using a Hunter Digital Color and Color Difference Meter, Model 25D. Measurements were first made with flours in a dry form and then as a wet paste prepared by adding water (5:1 water/flour w/w).

Fatty acid profiles of cottonseed oils were obtained according to the AOCS procedure (Ce 1-62, Ce 2-66) (12). A commercial standard (Supelco Inc., Bellefonte, PA) of mixed fatty acid methyl esters (RM-1) was used for reference. Quantitation of the various peaks from the sample consisted of calculating the percentage of the area of each peak as a percentage of the total area under fatty acid peaks.

The method used for determination of cyclopropenoid fatty acid (CPFA) in oils was from "Official Methods of Analysis of the AOAC" (19). Some modifications of the method were necessary such as (a) changing the stipulated 200 mg oil sample size to 50 mg, and (b) constructing a standard curve by diluting various levels of CPFA in 50 mg of corn oil (i.e., size of sample used to construct standard curve had to match size of test sample). Improved results for dark-colored oils could be obtained by using a similar colored CPFA-free oil in the reagent blank.

Unit weight of ginned seed represents the weight in grams of 100 seed which have been fumed for 1 hr at 115 C and dried for 30 min at 130 C to remove variation in lint from sample to sample and to minimize moisture variation among samples. For undefatted kernels, "Unit Weight" values represent the weight of 100 moisture-free kernels. Volume index reflects either the number of fumed seed required to fill a volume of 50 ml or the number of kernels required to fill a volume of 25 ml. Values for "% Kernels" represent the percentage of lint-free seed weight constituted by kernels.

RESULTS

Ginned Seed Analyses

Data on ginned seed samples from sixteen test varieties, eight glandless and eight glanded, are presented in Table I. Mean values of each attribute measured are shown for each type seed. Each determination was performed in duplicate. Inspection of the tabulated data from glandless varieties reveals that oil contents (dry weight basis) ranged from 16.5% to 25.6%, with the mean value being 21.1%. Glanded seed oil contents ranged from 17.4% to 23.2% with a mean value of 21.1%. Thus, no difference was apparent in the mean values for oil in seed from the two types of cotton. However, the oil content of individual varieties was found to vary widely as reflected in Table I. This applies to varieties from each type seed.

A large variation in unit weight and volume index was observed for the seed. Glandless seed were more variable among varieties, varying from 7.0 g to 13.0 g per 100 fumed seed. Glanded seed weighed from 9.1 g to 11.3 g per 100 fumed seed. Mean values were 10.6 g and 10.0 g, respectively. Generally, the volume index is inversely related to the unit weight. Seed with a high unit weight are expected to be large and therefore a smaller number of the seed are required to fill a given volume. Mean volume index values for glandless and glanded seed were 225 and 271, respectively.

Glanded seed contained a slightly larger percentage of kernels (2.15%) than did glandless seed on the average. However, the variety containing the largest percentage of kernels was a glandless variety. A spread in % kernels values of 13.9 and 7.9 was found for glandless and glanded seed, in that order.

Iodine numbers were found to vary from 117.5 to 103.7 (a difference of 13.9) for glanded oils. The mean value for glandless oils was 1.0 higher than for glanded oils.

Protein contents of glandless seed varied from 19.6% to 24.0% and from 21.2% to 26.0% for glanded seed. Mean values for the two types of seed were 22.5% and 23.1%, respectively.

The excessively high free fatty acid indicated for glanded seed resulted from poor field and storage conditions which affected that property in two glanded seed samples.

These data indicate that a cottonseed processor should choose carefully among available varieties to select one which excels in the attribute(s) (i.e., oil, protein, kernel size, etc.) of greatest interest to him.

Undefatted Kernels Analyses

Data from analyses of undefatted kernels are contained in Table II. Again, mean values for varieties of each type seed are shown.

Oil content: Glandless seed kernels averaged almost 2% higher in oil than glanded kernels. The spread in glandless oil values was 7.4% as compared to 4.9% for glanded values. Glandless oil contents ranged from 43.9% to 36.6% while glanded oil values ranged from 40.5% to 35.6%.

Protein content: Mean protein values for kernels did not differ significantly between glandless and glanded varieties. Within glandless varieties the spread was greater, however, from a high of 41.4% to a low of 31.6% (9.8%). Glanded varieties ranged from 41.6% to 35.8% (a spread of 5.8%).

Unit weight and volume index: Unit weight values ranged from 5.5 g to 9.0 g with a mean of 7.0 g for glandless kernels. Glanded kernels ranged from 5.6 g to 7.3 g with a mean of 6.5 g.

The largest kernels were from a glandless variety which had a volume index of 163. The smallest glandless kernels had a volume index of 261. Overall the glandless kernels were larger than glanded kernels having a mean volume index of 211 compared to a mean volume of 228 for glanded kernels. The largest glanded kernels had a volume index of 205. The smallest glanded kernels had a volume index of 274.

Phosphorus content: Total phosphorus content in glandless kernels ranged from 1.1% to 0.6% with a mean of 0.9%. For glanded kernels the range was from 1.1% to 0.4% with a mean of 0.8%. The spread among the phosphorus values for individual varieties was surprising. As indicated, kernels from some varieties were found to contain twice as much total phosphorus as others.

Sugar content: Total sugars in glandless kernels varied from 7.6% to 4.8% with the mean value being 6.8%. In glanded kernels, total sugars ranged from 9.2% to 5.9% with the mean being 7.4%.

Gossypol content: All of the glandless variety seed were desirably low in total gossypol. None of the glanded varieties were especially high in gossypol for that type seed.

Defatted Flour Analyses

Table III contains composite proximate analyses on glandless and glanded cottonseed flours. Table IV presents amino acid data on each type flour. Table V shows nitrogen solubility profiles prepared on flour from each test variety.

Protein content: Looking particularly at the protein contents shown in Table III, it is apparent that glandless flour values ranged from 65.9% to 55.2% (a spread of 10.7%) with a mean value of 62.6%. Glanded flour values ranged from 66.5% to 60.4% (a spread of 6.1%) with a mean of 63.2%. Three glandless varieties were higher than 65.0% in protein.

Flour color: A dimensionless color reading was made in triplicate on each flour, first in a dry form and then as a paste. Higher readings indicate greater lightness of color. Dry color values varied from 90.8 to 88.6 for glandless flours and from 86.3 to 79.2 for glanded flours. Mean values were 89.8 and 84.3, respectively. In a wet paste form, glandless color values spread from 75.6 to 66.5 with a mean of 71.3. Color readings on glanded flours as pastes varied from 60.1 to 36.3 with a mean of 48.1. It is important to notice that the difference between glandless and glanded mean color values in the dry state is 5.5, whereas, in the wet form the two means differ by 23.2. This is characteristic of flours from the two types of seed. Gossypol can add undesirable color to a food system.

Actually, flours would not be prepared from glanded cottonseed for food use by a process such as was used in this evaluation. As is apparent from the total gossypol values of Table III, the method used did not remove the pigment glands.

Phosphorus and sugar content: No substantial differences in magnitude were noted between mean values of glandless and glanded flours for phosphorus and sugars. However, wit-in the glandless varieties total phosphorus varied from 1.6% to 1.3% and within the glanded group it varied from 1.7% to 1.0%. Total sugars varied from 16.9% to 11.4% among glandless varieties and from 14.6% to 12.2% for glanded varieties.

TABLE I

Analytical Data on Cottonseed from Sixteen Varieties[a]

Analyses made	Glandless seed varieties									Glanded seed varieties								
	A	B	C	D	E	F	G	H	Mean	A	B	C	D	E	F	G	H	Mean
Oil, %	21.0	20.0	17.6	20.7	23.9	23.4	25.6	16.5	21.1	23.2	20.0	21.2	17.4	21.7	21.8	21.4	21.6	21.0
Free fatty acids, %	0.1	1.0	1.0	0.1	0.1	0.4	0.7	0.3	0.5	0.1	0.2	0.7	1.2	0.8	1.0	20.7	12.2	4.6
Unit wt., g	11.6	10.9	7.6	12.6	13.0	11.9	10.4	7.0	10.6	10.8	11.3	8.7	9.1	10.7	10.1	10.3	9.1	10.0
Vol. index	247	242	290	208	222	233	268	330	255	284	248	303	255	257	286	250	287	271
% Kernels	62.2	58.8	51.2	61.5	65.0	62.9	62.3	52.6	59.6	64.0	61.8	62.8	56.1	62.9	63.2	62.3	60.7	61.7
Iodine no.	107.5	114.5	117.5	105.4	109.3	109.8	103.7	111.4	109.9	108.9	105.0	107.4	116.8	111.7	106.9	105.3	108.9	108.9
Protein, % (N x 6.25)	23.2	24.0	23.0	24.0	23.3	23.1	20.0	19.6	22.5	21.2	23.6	23.2	22.2	23.2	25.9	24.0	21.6	23.1

[a]Dry weight basis.

TABLE II

Analytical Data on Cottonseed Kernels from Sixteen Varieties[a]

Analyses made	Glandless seed varieties									Glanded seed varieties								
	A	B	C	D	E	F	G	H	Mean	A	B	C	D	E	F	G	H	Mean
Oil, %	39.5	38.3	38.3	36.6	40.6	39.7	43.9	40.3	39.7	40.5	36.7	38.1	36.4	37.7	37.8	35.6	39.4	37.8
Protein (N x 6.25), %	41.0	41.4	40.0	40.9	39.9	39.2	31.6	37.3	38.9	35.8	41.6	39.1	41.1	39.2	40.0	40.9	36.8	39.3
Unit weight, g	6.6	6.7	6.5	9.0	8.3	7.5	5.5	6.0	7.0	6.0	6.8	5.6	6.9	7.3	6.9	6.4	6.2	6.5
Volume index	217	209	225	170	163	195	250	261	211	237	222	274	213	205	210	223	238	228
Crude fiber, %	1.7	1.6	2.0	1.7	1.6	1.6	1.8	1.7	1.7	1.5	1.4	1.5	1.6	1.6	1.5	1.8	1.9	1.6
Total phosphorus, %	1.1	0.9	0.9	0.7	0.6	0.9	0.9	1.1	0.9	0.4	1.1	0.6	0.9	0.8	0.9	0.7	1.1	0.8
Total sugars, %	7.3	7.3	7.3	5.0	4.8	7.5	7.6	7.6	6.8	6.5	6.8	7.1	9.2	8.8	7.4	5.9	7.5	7.4
Total gossypol, %	0.02	0.01	0.01	0.02	0.01	0.03	0.01	0.03	0.02	1.3	1.3	1.3	1.1	1.3	1.2	1.3	1.2	1.2

[a]Dry weight basis.

TABLE III

Analytical Data on Cottonseed Flours from Sixteen Varieties[a]

Analyses made	Glandless seed varieties									Glanded seed varieties								
	A	B	C	D	E	F	G	H	Mean	A	B	C	D	E	F	G	H	Mean
Oil, %	0.5	0.7	1.1	1.0	0.9	0.8	0.2	1.1	0.8	0.4	0.4	1.0	1.0	0.6	0.7	0.9	1.1	0.8
Protein (N x 6.25), %	65.7	65.9	65.3	62.2	61.2	64.1	55.2	61.0	62.6	60.4	65.0	63.2	62.1	62.5	66.5	65.0	60.1	63.2
Crude fiber, %	2.5	2.9	2.7	2.8	2.7	2.9	2.9	3.1	2.8	2.5	2.2	2.5	3.6	2.4	2.3	3.0	2.8	2.7
Total phosphorus, %	1.6	1.5	1.4	1.3	1.3	1.3	1.5	1.3	1.4	1.7	1.3	1.3	1.3	1.0	1.2	1.2	1.7	1.3
Total sugars, %	13.1	13.2	11.4	13.5	14.4	12.9	16.9	13.8	13.7	14.6	13.8	13.3	12.6	14.0	12.2	12.4	14.0	13.4
Total gossypol, %	0.03	0.02	0.01	0.01	0.01	0.04	0.01	0.02	0.02	1.5	1.3	1.7	1.2	1.7	1.3	2.0	1.7	1.6
Ash, %	8.5	7.4	8.0	7.0	7.1	7.6	9.2	8.0	7.8	9.0	8.2	7.0	7.5	7.6	7.5	8.4	9.0	8.0
Color, dry	89.8	88.9	88.6	90.1	90.6	89.7	90.8	90.1	89.8	86.1	85.6	85.1	83.5	86.3	85.7	79.2	82.7	84.3
Color, wet	70.9	66.5	66.8	75.6	75.2	70.3	72.8	72.0	71.3	60.1	52.7	50.4	41.1	49.0	55.3	36.3	40.2	48.1

[a]Dry weight basis.

TABLE IV

Amino Acid Composition of Cottonseed Protein from Sixteen Varieties

	Glandless seed			Glanded seed		
Amino acids	High	Low	Mean	High	Low	Mean
			(g/16 gN)			
Lysine	4.6	4.3	4.5	4.6	4.2	4.4
Histidine	2.9	2.6	2.7	2.8	2.6	2.7
Ammonia	2.2	1.9	2.0	2.3	1.9	2.1
Arginine	13.2	11.2	12.1	12.3	10.9	11.6
Tryptophan	1.3	1.0	1.2	1.4	1.0	1.2
Cystine	2.6	2.2	2.4	3.4	2.3	2.6
Aspartic acid	9.3	8.6	9.1	9.5	8.8	9.2
Threonine	3.2	2.8	3.0	3.2	2.8	3.0
Serine	4.4	3.9	4.2	4.4	3.9	4.2
Glutamic acid	22.4	19.9	21.6	22.4	20.5	21.7
Proline	3.7	3.1	3.4	4.0	3.1	3.6
Glycine	4.6	3.7	4.1	4.5	3.8	4.1
Alanine	4.2	3.6	3.9	4.2	3.6	3.9
Valine	4.8	4.1	4.4	4.7	4.3	4.5
Methionine	1.7	1.2	1.4	1.8	1.3	1.5
Isoleucine	3.2	2.8	3.0	3.4	3.0	3.1
Leucine	6.1	5.3	5.7	6.1	5.5	5.8
Tyrosine	3.6	1.6	2.9	3.3	2.8	3.1
Phenylalanine	6.2	5.0	5.4	5.6	5.0	5.4
Available lysine	4.2	3.9	4.1	4.1	3.9	4.0

Amino acid analyses: Protein from glandless and glanded varieties was found not to differ substantially in amino acid composition. Variations among varieties within each type seed were found to be of the same general magnitude.

Nitrogen solubility measurement: Nitrogen solubility measurements at several pH values are shown in Table V for each type flour. Also, nitrogen solubility in 0.02 NaOH (the traditional method of determining nitrogen solubility) is shown for each type flour.

At pH 3, 4, 6, and 7, mean values of glandless flours were slightly higher than those for glanded flours. At pH 9, the mean for glanded flours was higher. No essential difference was apparent between the two types when measured in 0.02 N NaOH. At a particular pH value considerable variation between flours from the same type seed was found. This was especially true at pH 9 where the solubility changes rapidly with a slight shift in pH.

Glandless flour values varied at pH 9 from 88.5% to 56.2% (a difference of 32.3%). Glanded flour values varied from 87.5% to 71.2% at pH 9 (a difference of 16.5%).

Oil Analyses

The analyses of primary interest made on cottonseed oils were for cyclopropenoid fatty acids and fatty acid composition. These data are given in Tables VI and VII.

Samples of oil from each variety were refined and bleached by AOCS methods. However, less oil was available for refining than the method specified. Therefore, these results are included in Table VI only for whatever indications they provide and should be interpreted with the above mentioned limitation in mind. As expected, glandless oils yielded lower refined and bleached colors.

Cyclopropenoid fatty acid content: Cyclopropenoid fatty acid analyses revealed the mean value for glandless oils to be the same as the mean for glanded oils (0.23%). Cyclopropenoid fatty acids could not be statistically correlated with total gossypol, free fatty acid content, or iodine numbers.

Fatty acid spectra: The composition of fatty acids in oil from each variety was determined by gas chromatography. Values for each fatty acid are given in Table VII according to seed type.

Considerable variation was found in the amount of palmitic acid among varieties within each seed type. Palmitic acid varied from 26.0% to 17.6% and from 24.8% to 17.6% for glandless oils and glanded oils, respectively. Also, linoleic acid was found to vary substantially among varieties within each seed type. The quantity of linoleic spread from 60.5% to 52.2% for glandless oils and from 60.6% to 53.0% for glanded oils. Mean values for individual fatty acids did not vary appreciably between glandless and glanded oils.

DISCUSSION

A list of attributes generally regarded as desirable in cottonseed destined for food use might include the following:

1. High protein content.
2. Low sugar content.
3. Low phosphorus content.
4. Completely gland-free (glandless varieties).
5. Low total gossypol (glanded varieties).
6. High percentage of kernels.
7. High nitrogen solubility.
8. Low cyclopropenoid fatty acid content.
9. Large-sized kernels.
10. Flour color, light.
11. Flour taste, bland.
12. High iodine number.
13. Protein high in essential amino acids.
14. Low refined and bleached oil color.
15. Low oil content (for nut use).
16. High oil content (for flour use).

Thus far, no overall formula has been advanced into which values for these characteristics could be inserted and a number derived to rank one variety relative to another. Actually, the properties suggested as desirable would vary in their importance depending on the end use of the kernels or products from the kernels. For example, if kernels are to be prepared as edible nuts, the size of the kernels is more important than if they are to be made into flour and oil.

As expected, no particular variety among the sixteen studied was found to possess optimal values for all of the attributes deemed desirable.

ACKNOWLDGMENTS

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TABLE V

Nitrogen Solubility Percentages on Cottonseed Flours from Sixteen Varieties

	Glandless seed varieties									Glanded seed varieties								
pH of measurement	A	B	C	D	E	F	G	H	Mean	A	B	C	D	E	F	G	H	Mean
3	13.1	27.3	20.9	22.9	22.7	18.5	12.6	23.2	20.2	15.2	11.4	19.3	16.0	13.0	16.5	12.3	12.0	14.5
4	10.5	19.8	19.5	19.7	16.7	12.1	12.9	21.1	16.5	13.3	12.4	13.0	16.9	13.8	12.6	12.1	14.0	13.5
6	19.7	27.0	31.5	28.7	28.8	21.8	23.4	31.3	26.5	22.2	18.9	20.2	20.2	18.1	20.5	22.3	22.7	20.6
7	25.1	31.9	34.6	31.8	30.6	24.1	29.7	36.8	30.6	23.0	22.7	25.6	23.2	20.9	24.4	25.0	26.3	23.9
9	57.9	88.5	85.3	71.0	64.1	56.2	82.4	68.4	71.7	87.7	75.8	86.9	73.3	71.2	82.1	77.1	76.5	78.8
Solubility in 0.02 N NaOH	99.7	99.8	100.0	99.6	100.0	99.8	99.5	99.7	99.8	97.4	100.0	97.5	97.6	99.1	100.0	95.8	96.9	98.0

TABLE VI

Analytical Data on Cottonseed Oils from Sixteen Varieties

	Glandless seed varieties									Glanded seed varieties								
Analyses made	A	B	C	D	E	F	G	H	Mean	A	B	C	D	E	F	G	H	Mean
Cyclopropenoid fatty acids, %	0.28	0.28	0.10	0.31	0.31	0.06	0.23	0.29	0.23	0.28	0.32	0.24	0.11	0.07	0.27	0.23	0.28	0.23
Refined oil color, red	3.9	3.5	5.0	3.0	3.2	3.5	3.8	4.0	3.7	7.0	5.0	10.0	3.5	3.5	3.6	14.8	8.0	6.9
Bleached oil color, red	3.4	1.0	5.0	0.6	0.6	1.3	3.8	1.6	2.2	3.0	2.5	7.4	1.3	1.3	0.6	4.6	2.5	2.9

TABLE VII

Composition of Fatty Acids in Cottonseed Oils from Sixteen Varieties

	Glandless seed varieties									Glanded seed varieties								
Fatty acids	A	B	C	D	E	F	G	H	Mean	A	B	C	D	E	F	G	H	Mean
Myristic, %	0.8	0.7	0.7	0.9	0.8	0.7	0.6	0.6	0.7	0.8	1.5	0.7	1.0	1.0	0.6	0.8	0.6	0.9
Palmitic, %	24.0	20.3	17.6	26.0	24.1	22.1	26.0	20.8	22.6	23.9	24.6	24.0	17.6	22.1	22.1	24.5	24.8	23.0
Stearic, %	2.1	2.0	2.1	2.4	2.0	1.9	2.4	2.1	2.1	2.1	2.2	2.1	2.2	2.0	2.2	2.4	2.5	2.2
Oleic, %	16.0	17.1	19.2	17.9	17.3	18.6	16.3	19.2	17.7	18.3	18.1	16.3	18.2	16.4	20.7	18.7	15.0	17.7
Linoleic, %	56.5	59.4	60.4	52.1	55.8	56.1	54.7	57.0	56.5	54.9	52.7	56.4	60.5	58.0	53.9	53.0	57.1	55.8
Unknown, %	0.7	0.5	0.0	0.7	0.0	0.6	0.0	0.3	0.4	0.0	0.8	0.5	0.5	0.5	0.5	0.6	0.0	0.4

plied seed from their varieties for this study: (a) ACCO Seed, Plainview, Texas, (b) Dr. Luther Bird, Texas A&M University, (c) Coker's Pedigreed Seed Company, Lubbock, Texas, (d) Dunn Seed Farms, Inc., Lamesa, Texas, (e) Gregg Seed Farms, Plainview, Texas, (f) Lambright Seed Farms, Slaton, Texas, (g) Lockett Seed Company, Vernon, Texas, (h) Dr. N.R. Malm, New Mexico State University, (i) U.S. Cotton Research Station, Shafter, California. Appreciation is expressed to Ms. Carolyn Hines for technical assistance rendered. This research was funded in part by the Natural Fibers and Food Protein Commission of Texas.

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