Variation in the Nutrient and Gossypol Content of Whole and Processed Cottonseed

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Introduction

Two types of cotton are grown commercially in the United States; Upland (*Gossypium hirsutum*) and Pima (*G. barbadense*). Upland cottons are produced in all cotton growing regions of the country. In contrast, Pima cottons are produced in southwest Texas, New Mexico, Arizona, and California. Generally, Pima cottons represent less than 2% of cotton acreage; however, most is grown in the San Joaquin Valley of California, in close proximity to the California dairy industry. Both types are used extensively in diets of lactating dairy cattle. New varieties are continually being developed by cotton breeders. The primary focus of their breeding programs is on the quality and quantity of lint produced. Generally, little attention is given to seed. Regardless, improved varieties often are quickly adopted by cotton growers. Examples are, the rapid increase in percentages of acres planted in the United States to genetically modified (transgenic) cottons from 12% in 1996 (USDA AMS, 1996) to 78% in 2001 (USDA AMS, 2001), and the introduction of Bayer Crop Science FiberMax varieties from Australia, particularly in the Southwestern United States, since 1998 (USDA AMS, 2001). Because the cotton varieties being grown are continually changing, it is important to continually check seed composition.

During the last 15 years there have been significant changes in the processing and utilization of cottonseed. The number of conventional oil mills extracting oil from cottonseed has decreased from about 50 in 1990 to less than 14 today (NCPA, 2004). During this same period the percentage of cottonseed crushed for oil decreased from 63 to less than 45. Accompanying the decrease in the number of conventional oil mills has been the appearance of mini-mills. During the fall and winter of 2001-2002 there were six in operation in central and west Texas. Mini-mills are much smaller than conventional oil mills and the process is different. In conventional oil mills, seed is delinted and dehulled; whereas, these steps are omitted at the mini-mills. Instead, cottonseed is processed by passing it through an extruder to condition the seed, and then through an expeller to extract a portion of the oil.

Many factors contribute to variation in the nutrient and gossypol content of cottonseed. Type of cotton, variety, and growing conditions are important sources of variation, but harvesting and storage conditions and processing can also have an impact. Equally important, but possibly not fully appreciated, is variation due to the analytical laboratories and procedures used to determine cottonseed composition. This report represents an effort to summarize current information on the nutritional and gossypol content of whole and processed cottonseed, and factors that contribute to variation in composition; including the role of laboratories and procedures used to determine major components of whole and processed cottonseed.

Nutrient Composition of Pima Cottonseed

Seed of Upland cottons, commonly referred to in the feed trade as white or fuzzy cottonseed, have short cotton fibers still attached to the seed coat; whereas, seed of Pima cottons are basically bare, black seed without attached short fibers. Pima seed is sometimes called black seed; however, some delinted Upland seed is available for feeding and the bare seed coat is also black. Upland seed is fed primarily as whole seed, just as it comes from the gin. In contrast, Pima seed generally is cracked or ground prior to feeding. Although considerable information is available for Upland seed (Calhoun et al., 1995;

NRC, 2001; Dairy One, 2004), with the exception of the values for oil, nitrogen, and gossypol reported yearly since 1977 in the National Cotton Variety Tests publications, little information is available for Pima seed. Because of this, two recent studies (DePeters et al., 2000; Robinson et al., 2001) were conducted specifically to provide this information. However, the percentages of crude protein and fat reported by DePeters et al. (2000), for 10 samples of Pima seed collected in 1998 from one location in California, and by Robinson et al. (2001), for 29 samples of Pima seed collected during the fall of 1999 at 10 cotton gins located in the southwestern United States were much higher than for values reported for Pima seed in the 1998 and 1999 National Cotton Variety Test publications (NCVT, 1998, 1999). In contrast, the free gossypol levels reported by both DePeters et al. (2000) and Robinson et al. (2001) were much higher than those reported in the NCVT publication s. Since seed from both studies

were submitted to the Texas Agricultural Experiment Station's (**TAES**) Nutrition and Toxicology Laboratory in San Angelo, TX for gossypol analysis, and sufficient seed was available to conduct additional analyses, we were able to evaluate the data reported by DePeters et al. (2000) and Robinson et al. (2001).

A subset of ten samples of Pima seed was selected from those submitted to my laboratory by Dr. Peter Robinson. Each was split into three samples, and a sample of each was submitted to Mid-Continent Laboratories, Inc (Jackson, MS); Hahn Laboratories, Inc. (Columbus, SC); and Dairy One (Ithaca , NY) for protein and fat analysis. Results are presented in Figure 1 for fat and in Figure 2 for crude protein. There was excellent agreement for both

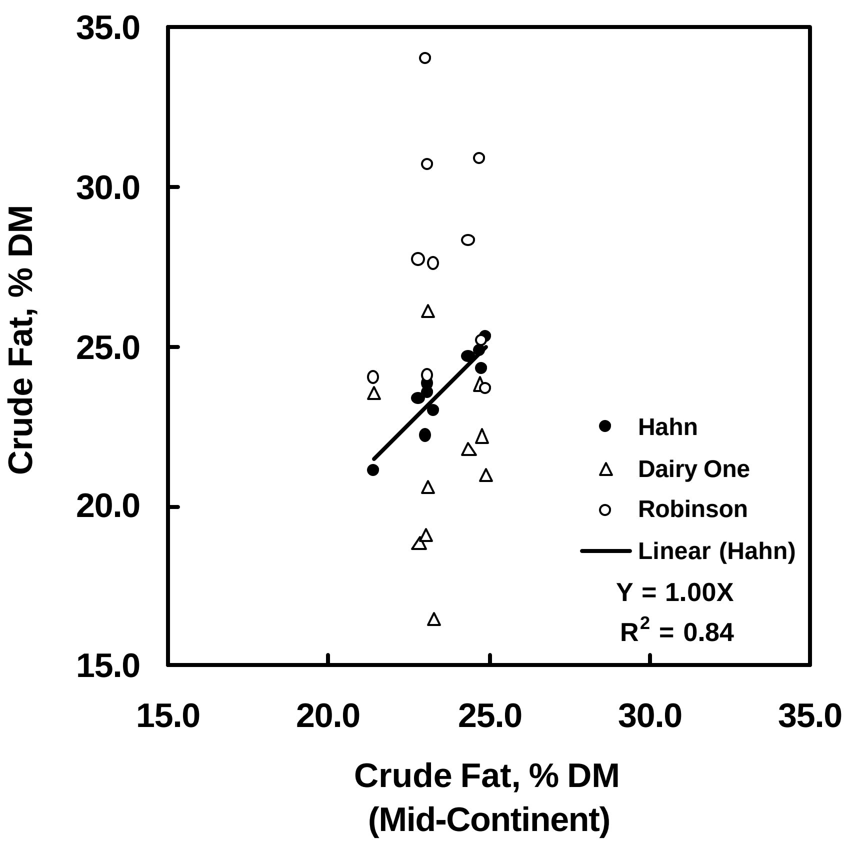

Figure 1. Crude fat in ten samples of whole Pima seed determined by a reference laboratory (Mid-Continent Laboratories, Inc., Jackson, MS) using the official method of the American Oil Chemists Society and by three other laboratories.

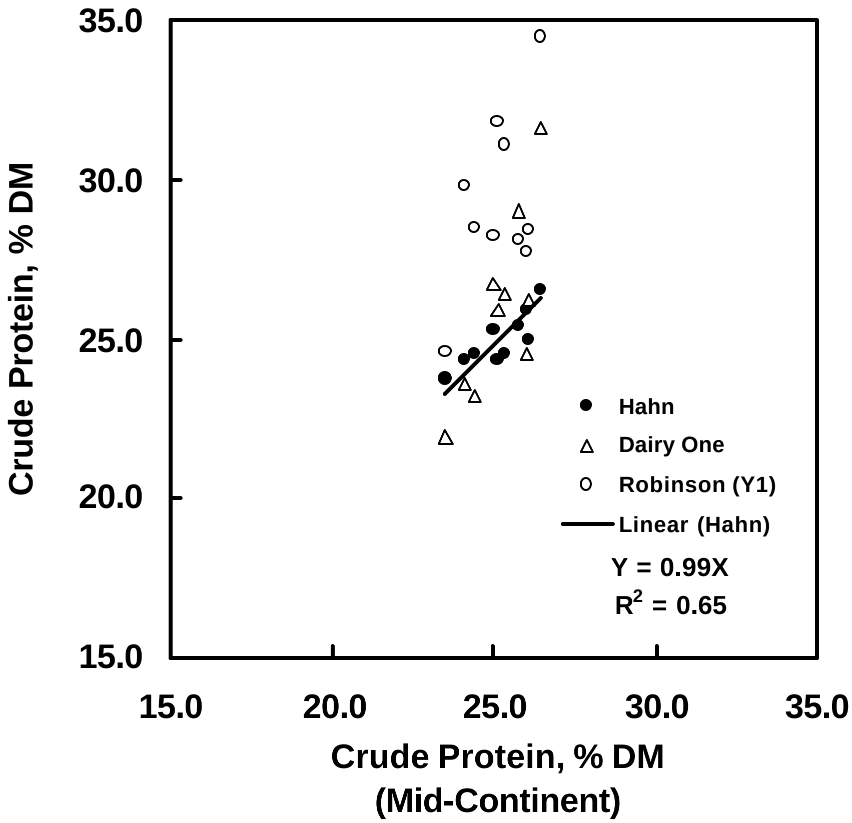

Figure 2. Crude protein in ten samples of whole Pima seed determined by a reference laboratory (Mid-Continent Laboratories, Inc., Jackson, MS) using the official method of the American Oil Chemists Society and by three other laboratories.

fat and protein between Mid-Continent and Hahn. This was anticipated because both used the official methods of the American Oil Chemists Society (**AOCS**) for protein and fat, and were chosen based on their performance in the Laboratory Proficiency Program administered yearly by AOCS. In 1999-2000, Frank Hahn, with Hahn Laboratories, Inc. and Charles Norris, with Mid-Continent Laboratories, Inc., ranked first and second, respectively, for cottonseed analysis, and in 2000-2001 Charles Norris was first and Frank Hahn was second. Results from Dairy One were lower for fat ($P < 0.01$) than Mid-Continent and Hahn, and more variable. Although the average values for crude protein were similar for the three laboratories, results were more variable for Dairy One. Dairy One was chosen as a participating laboratory because of the range of analyses and services they have available that are important to the dairy industry and because they are widely used by dairy professionals across the United States. Values reported by Robinson were higher for fat and protein, the range of values was much greater and they were not correlated with those reported by Hahn and Mid-Continent.

Table 1 contains information on the nutrient composition of 50 samples of Pima seed that were originally submitted to my laboratory for gossypol analysis by consulting nutritionists and veterinarians working with commercial dairies in California, New Mexico, and Texas; animal scientists at universities; and cotton breeders. Crude protein and crude fat

Table 1. Nutrient composition of Pima seed submitted to the Texas Agricultural Experiment Station's Nutrition and Toxicology Laboratory at San Angelo, TX, compared with values reported by Robinson et al. (2001) for Pima seed.[1]

	TAES[2]				Robinson et al., 2001			
Item	N	Mean	SD	Range	N	Mean	SD	Range
Dry matter, %	50	92.7	0.39	91.8 – 93.5	29	93.3	0.65	92.1- 94.3
Crude protein, %	50	24.6	1.41	20.5 - 26.7	29	29.1	3.38	19.8 - 34.5
Soluble protein, % of CP	40	22.9	4.58	11.0 - 32.0	29	26.2	3.83	14.0 - 32.0
Crude fat, %	50	24.1	1.42	20.6 - 27.6	29	27.1	3.96	20.0 - 34.0
ADICP, % of CP	21	2.1	0.33	1.8 - 2.9				
NDICP, % of CP	21	2.1	0.25	1.8 - 2.9				
ADF, %	21	31.8	1.63	28.9 - 34.4	29	31.3	6.38	20.0 - 44.5
NDF, %	21	41.1	1.56	37.8 - 43.6	29	44.4	7.55	36.6 - 58.1
Lignin, %	50	17.2	2.24	12.4 - 25.0				
Ash, %	40	4.4	0.23	3.9 - 4.9				
Calcium, %	50	0.24	0.03	0.19 - 0.30	29	0.19	0.02	0.16 - 0.23
Phosphorus, %	50	0.72	0.08	0.53 - 0.91	29	1.03	0.13	0.88 -1.26
Magnesium, %	50	0.37	0.02	0.32 - 0.42	29	0.44	0.04	0.40 - 0.50
Potassium, %	50	1.35	0.08	1.11 - 1.50	29	1.29	0.08	1.19 - 1.38
Sodium, %	50	0.02	0.01	0.00 - 0.04	29	0.01	0.01	0.01 - 0.01
Chloride, %	50	0.09	0.04	0.02 - 0.17	29	0.09	0.03	0.02 - 0.19
Sulfur, %	50	0.25	0.04	0.17 - 0.39	29	0.31	0.04	0.21 - 0.46
Copper, ppm	50	9	1.5	7 - 15	29	9	1.37	7 - 12
Iron, ppm	50	45	9.0	29 - 68	29	55	19.36	35 - 130
Manganese, ppm	50	12	1.2	10 - 15	29	14	1.34	12 - 17
Zinc, ppm	50	34	5.4	25 - 56	29	41	6.23	31 - 52
Molybdenum, ppm	13	1.1	0.15	1.00 -1.40	29	1.2	0.55	1.0 - 2.3

[1] Nutrient values are on a 100% dry matter basis.
[2] Crude protein and crude fat in TAES samples were determined by Mid-Continent Laboratories, Inc., Jackson, MS. All other nutrients in TAES samples were determined by Dairy One, Ithaca, NY. Acid detergent insoluble crude protein (ADICP), neutral detergent insoluble crude protein (NDICP), acid detergent fiber (ADF) and neutral detergent fiber (NDF) were determined after cold acetone extraction of ground Pima seed.. All minerals were determined in duplicate.

were determined for these samples by Mid-Continent Laboratories. All other nutrients were determined by Dairy One. Acid detergent insoluble crude protein (**ADICP**), neutral detergent insoluble crude protein (**NDICP**), acid detergent fiber **(ADF**), and neutral detergent fiber (**NDF**) were determined after cold acetone extraction of ground Pima seed, as described by Van Soest and Robertson (1980). This was done because of the effect of the high fat content of the seed on the results of the detergent fiber analyses. All minerals were determined in duplicate. Nutrient information from the study of Robinson et al. (2001) are included in Table 1 for comparison purposes.

Crude protein and crude fat were higher and more variable in the Pima seed analyzed by Robinson et al. (2001). This was anticipated based on laboratory comparisons in Figures 1 and 2 for crude protein and crude fat. Acid detergent fiber and NDF values, after cold acetone extraction (TAES), were similar for both sets of samples; however, the ranges were much greater for ADF and NDF in Robinson's samples. Acid detergent fiber and NDF in the TAES samples were decreased 13.1% and 19.6%, respectively by cold acetone extraction. It is not know if Robinson's samples were extracted with acetone prior to fiber analysis. Values for the various minerals in both sets agree fairly well. Probably, the only important difference is for phosphorus. The average value reported by Robinson et al. (2001) is 43.0% higher than the TAES value (1.03 vs 0.72%).

Each year, in September, the USDA Agricultural Marketing Service-Cotton Program publishes a list of cotton varieties planted, along with an estimate of the percentage of each variety planted in each state. In addition, seed data (oil, nitrogen, gossypol) have been included in National Cotton Variety Test (**NCVT**) publications since 1977. Consequently, there are considerable data for these seed constituents for many cotton varieties. Unfortunately, many of the commercially important cotton varieties are not included in these tests. For those that are, about one year is required to analyze and report the data, which means the seed most likely was used before the information was available. The result is that cottonseed with markedly different physical characteristics and/or chemical composition could be used without livestock feeders or processors being aware of these changes.

Table 2 gives the percentages of acres planted to six commercially important Pima cotton varieties in 2001, that were included in the 2001 NCVT, at three locations (El Paso, TX; Las Cruces, NM; and Maricopa, AZ). The oil and crude protein content of seed summarized by variety and location are also presented. Values reported in the NCVT are percentages of oil and nitrogen in whole seed, on an as received moisture basis. These were converted to a 100% DM basis by dividing by 0.93 and nitrogen was converted to crude protein by multiplying by 6.25. Oil and nitrogen were determined for the NCVT program by Woodson-Tenent Laboratories, Inc. (Little Rock, AR) using the official methods of AOCS. The six varieties tested accounted for 89.9% of Pima acreage in 2001.Variation among varieties was fairly modest for both oil and protein. This was not unexpected because many of the varieties currently being grown are selections from Pima S-6 and S-7. Oil content of the seed was similar across growing locations, but there was a significant location effect for crude protein. Seed from cotton grown in Maricopa contained 35.8% more protein than seed from the same varieties grown in El Paso, and 11.0% more than seed from cottons grown in Las Cruces.

The oil and protein analysis done by Woodson-Tenent Laboratories, Inc for the NCVT was evaluated by submitting seed of three varieties grown at three locations to Mid-Continent Laboratories. Using a paired t-test the percentage of oil reported by NCVT was higher ($P < 0.01$) than Mid-Continent Laboratories (24.3 vs 23.5%), but the absolute difference was fairly small (0.8%). Protein values were not significantly different. Considering that separate sub-samples were analyzed by the two laboratories, this is acceptable agreement.

Gossypol Content of Pima Cottonseed

Total and free gossypol determined by the Official Methods of AOCS (AOCS, 1985a,b) are essentially the same in recently harvested and properly stored whole cottonseed (Robinson et al., 2001). Seed analysis by HPLC gives values that are slightly lower than the Official Methods. However, poor agreement between laboratories is a serious problem, even when laboratories use the official methods of AOCS for determination of gossypol. The problem can be much worse when a laboratory uses an HPLC procedure that does not include a complexing reagent, such as an amino propanol, in the solvent used for extracting gossypol. For example, the procedure used by Woodson-Tenent

Table 2. Percentages of acres planted to commercially important Pima cotton varieties in 2001, that were included in the 2001 National Cotton Variety Tests (NCVT), and variation in oil and crude protein content of seed grown at three locations[1, 2]

	Acreage[3]	Oil, % DM			Crude protein, % DM		
Item	%	Mean	SD[4]	Range	Mean	SD	Range
Variety							
Deltapine 744	4.49	25.6	0.47	25.3 - 26.3	23.9	3.33	20.6 - 27.2
Phytogen 57	24.12	25.9	0.45	25.4 - 26.2	24.5	4.58	19.4 - 28.3
Phytogen 76	23.62	23.8	1.04	22.6 - 24.6	23.7	3.33	20.1 - 26.7
OA 325 (DP-HTO)	12.56	25.7	0.28	25.5 - 26.0	24.7	2.36	22.2 - 26.9
OA 340	8.15	25.7	0.65	25.1 - 26.4	24.1	3.83	20.2 - 27.8
Pima S-7	16.98	25.2	0.57	24.6 - 25.6	23.7	3.28	20.2 - 26.6
Location							
El Paso		25.5	0.91	24.2 - 26.4	20.4[a]	0.93	19.4 - 22.2
Las Cruces		25.4	0.46	25.3 - 26.0	24.6[b]	0.68	24.0 - 25.8
Maricopa		25.1	0.90	22.6 - 26.2	27.3[c]	0.68	26.6 - 28.3

[1] 2001 National Cotton Variety Test. USDA ARS, Stoneville, MS.
[2] Values in the NCVT were oil and nitrogen in whole seed, as received DM basis. These were converted to a 100% DM basis by dividing by 0.93. Nitrogen was converted to crude protein by multiplying by 6.25.
[3] Cotton Varieties Planted 2001 Crop, USDA AMS, Cotton Program, Memphis, TN, August 2001.
[4] Standard deviation.
[a, b, c] Means without a common superscript are different (P<0.05).

Laboratories since 1988 to analyze cottonseed samples for the NCVT involves direct injection into the HPLC of an aqueous acetone (30% water and 70% acetone) extract of cottonseed. In 2001, Woodson-Tenent Laboratories switched to the HPLC procedure of Hron et al. (1999), which uses 2-amino propanol in the complexing reagent for determination of gossypol, and gossypol levels in seed essentially doubled compared with values reported by NCVT in recent years. An additional advantage is that complexing gossypol with 2-amino propanol separation of (+)- and (–)-gossypol by HPLC. Thus, starting with 2001, levels of both (+)- and (–)-gossypol are reported for seed of cotton varieties in the NCVT (NCVT, 2001).

Total gossypol content and (–)-gossypol, expressed as a percentage of total gossypol, in meats of seed of commercially important Pima cotton varieties grown at three locations in 2001, and included in the 2001 NCVT, are summarized in Table 3. Since the procedure involves drying the cottonseed meats at 180E F for four hours prior to determining gossypol, the gossypol values reported by Woodson-Tenent Laboratories are assumed to be on a 100% DM basis. The range of values for total gossypol for the six varieties was 0.95 to 1.58% of meats DM, and (–)-gossypol, as a percentage of total gossypol, ranged from 47.9 to 55.6%. Varietal differences were fairly modest, and most of the variation appeared to be associated with the location where the cotton was grown. Total gossypol was lower ($P < 0.05$) at Maricopa (1.02%) compared with El Paso (1.39%) and Las Cruces (1.35%). In order to express gossypol values on a whole seed basis, it is necessary to know the percentage of meats in the seed. This was not determined by Woodson-Tenent Laboratories; however, the percentage of meats was

Table 3. Variation in total gossypol content and minus gossypol, expressed as a percentage of total gossypol, in meats of seed of commercially important Pima cotton varieties grown at three locations in 2001, and included in the 2001 National Cotton Variety Tests (NCVT).[1]

Item	Total gossypol, % of meats DM[2] Mean	SD[3]	Range	Minus gossypol, % of total Mean	SD	Range
Variety						
Deltapine 744	1.35	0.27	1.06 - 1.58	51.7	0.62	50.9 - 52.1
Phytogen 57	1.20	0.22	0.95 - 1.35	52.8	0.52	52.3 - 53.3
Phytogen 76	1.28	0.23	1.02 - 1.42	49.9	1.95	47.9 - 51.8
OA 325 (DP-HTO)	1.18	0.14	1.02 - 1.28	52.1	1.83	50.0 - 53.2
OA 340	1.22	0.15	1.06 - 1.35	54.8	1.38	53.2 - 55.6
Pima S-7	1.28	0.23	1.02 - 1.47	52.4	1.35	51.5 - 53.9
Location						
El Paso	1.39[b]	0.10	1.28 - 1.58	52.2	2.55	47.9 - 55.6
Las Cruces	1.35[b]	0.10	1.24 - 1.47	52.4	0.68	51.7 - 53.2
Maracopa	1.02[a]	0.04	0.95 - 1.06	52.2	2.30	50.0 - 55.7

[1] 2001 National Cotton Variety Test. USDA ARS, Stoneville, MS.
[2] Values in the NCVT were for decorticated cottonseed (meats), on a DM basis. The percentage of meats in whole seed was not determined by NCVT.
[3] Standard deviation.
[a,b] Means without a common superscript are different ($P < 0.05$).

determined by TAES for the 50 seed samples reported in Table 1 and averaged 63.3 ± 0.22%. Using this figure, total gossypol levels in whole seed can be estimated by multiplying the values for total gossypol in Table 3 by 0.633. Based on this calculation, total gossypol on a whole seed basis ranged from 0.60 to 1.00% for the six varieties in Table 3. For comparison purposes the 50 samples of Pima seed in Table 1 averaged 0.93 ± 0.016% total gossypol and ranged from 0.70 to 1.24%. The (–) isomer of gossypol was 52.2 ± 0.19% and ranged from 49.2 to 55.3%.

Nutrient Composition of Upland Cottonseed

Several sources provide extensive information on nutritional values for whole Upland cottonseed (Calhoun et al., 1995; NRC, 2001; Dairy One, 2004). This information is presented in Table 4, and includes the number of samples analyzed and the standard deviation for each mean. In the study reported by Calhoun et al. (1995), eighty three samples of whole cottonseed were collected from 31 cotton oil mills and analyzed for nutrient and gossypol content. Samples were collected at the beginning, middle, and end of the 1993-94 crushing season. Samples were composited over five working days and sampled regularly across shifts for each date. All samples were sent to the TAES Nutrition and Toxicology Laboratory at San Angelo, TX. The first 28 samples received were sub-sampled and submitted to Dairy One for nutritional analyses. The results were highly variable. The variability was believed to be related to the lint and high oil content of the seed, which made it difficult to obtain a representative sub-sample for analysis. To address this problem, seed were separated into lint, hulls, and meats fractions using a kitchen blender and a series of screens. The fractions were ground through a 1 mm screen and then recombined in the correct proportions for each nutrient to be measured (i.e., dry matter, crude protein, fat, etc.) and sent to Dairy One for analysis. A sub-sample of the original seed was also sent to Mid-Continent Laboratories for crude protein and fat analysis. The results for crude protein are shown in Figure 3 and for fat in Figure 4.

Extreme variability in crude protein values for the initial analyses done by Dairy One is very apparent; however, after processing to obtain a representative sub-sample, the results from Dairy One were in excellent agreement with those obtained by Mid-Continent Laboratories (Figure 3). Initially, the 28 samples averaged 27.6 ± 0.75% crude protein and ranged from 20.8 to 34.1%. After preparation, to obtain a representative sub-sample, the same samples averaged 22.4 ± 0.20% crude protein, and ranged from 20.7 to 25.8%. A decrease in variability was also evident for fat when the samples were prepared for analysis prior to sending them to Dairy One; however, in this case the agreement with the analyses done by Mid-Continent was not as good as for crude protein (Figure 4). Dairy One values for fat were consistently lower ($P < 0.05$) than Mid-Continent values (17.9 ± 0.24 vs 20.1 ± 0.18%). The crude protein and crude fat values reported in Table 4 for Calhoun et al. (1995) were determined by Mid-Continent Laboratories, and differ from the original report. In the original report the analyses were done by Dairy One; crude protein was 22.4% with a SD of 1.06, and fat was 17.9% with a SD of 1.24. All other nutrients were determined by Dairy One. Acid detergent fiber, NDF and crude fiber were determined after cold acetone extraction of seed, as described by Van Soest and Robertson (1980). Cold acetone extraction decreased ADF from 44.3 to 38.9%, NDF from 54.0 to 47.3%, and crude fiber from 31.4 to 29.5%.

According to Dairy One the data for whole cottonseed are for samples analyzed during the period 5/01/2000 thru 4/30/2003. The standard deviations for all nutrients are much larger than those reported by Calhoun et al. (1995) for the same constituents, which is consistent with the greater variability for cottonseed samples analyzed by Dairy One previously mentioned in this report. With the exception of a few nutrients there is not a lot of difference between values reported by the three sources. Crude protein and fat are higher for Dairy One than for Calhoun and NRC. Neutral detergent fiber is lower for Calhoun than for Dairy One and NRC, probably reflecting the use of cold acetone extraction by Calhoun.

Percentages of acres planted to commercially important Upland cotton varieties in 2001, that were included in the 2001 National Cotton Variety Tests (NCVT, 2001), number of test locations for each variety, and variation in oil and crude protein content of seed are presented in Table 5. The total number of varieties listed in Cotton Varieties Planted (**CVP**) in the United States in 2001 was 166 (USDA AMS, 2001). Fifty-one varieties were listed in the NCVT publication for 2001, and of these 30 were raised commercially. Only varieties with greater than 0.05 percent of total acres planted are included in Table 5 (24 varieties). These represent 54.1% of cotton acreage in 2001, and provides a cross section of the major brands planted (Paymaster, 37.1%; Deltapine, 30.7%; Stoneville, 12.1%; Sure-Grow, 7.8%; and FiberMax, 4.5% of U.S. cotton acreage). Transgenic varieties, genetically engineered varieties resistant to worms, herbicides, or both; accounted for about 78% of the Upland cotton planted in the United States in 2001. Eleven transgenic varieties are included in Table 5. These are designated by the suffixes BG, for Boll Guard, and RR, for Roundup Ready.

Samples of Upland seed were submitted from every cotton-growing region in the United States except Arizona and California. Four varieties, designated as National Standards, were grown at all locations where Upland varieties were tested. In 2001, seed data were available from 22 locations for the National Standards (Acala Maxxa, All Tex Atlas, Deltapine NU 33B, and Sure-Grow 747). In the High Quality Region, which includes eight locations and covers eight states across the cottonbelt from the east coast to Texas, the same eighteen varieties were grown at all locations. However, only the four National Standards were planted commercially.

It is obvious from examination of Table 5 that there is as much variation within a variety as there is between varieties for oil and crude protein. Much of this appears to be associated with the location where the cotton is grown. Regardless, there are significant differences between varieties and between locations. Averaged across all locations the percentages of oil in the National Standards were: 19.9^{c}, 21.0^{b}, 21.1^{b}, and 22.9^{a} for Sure-Grow 747, Deltapine Nu 33B, Acala Maxxa, and All Tex Atlas; respectively

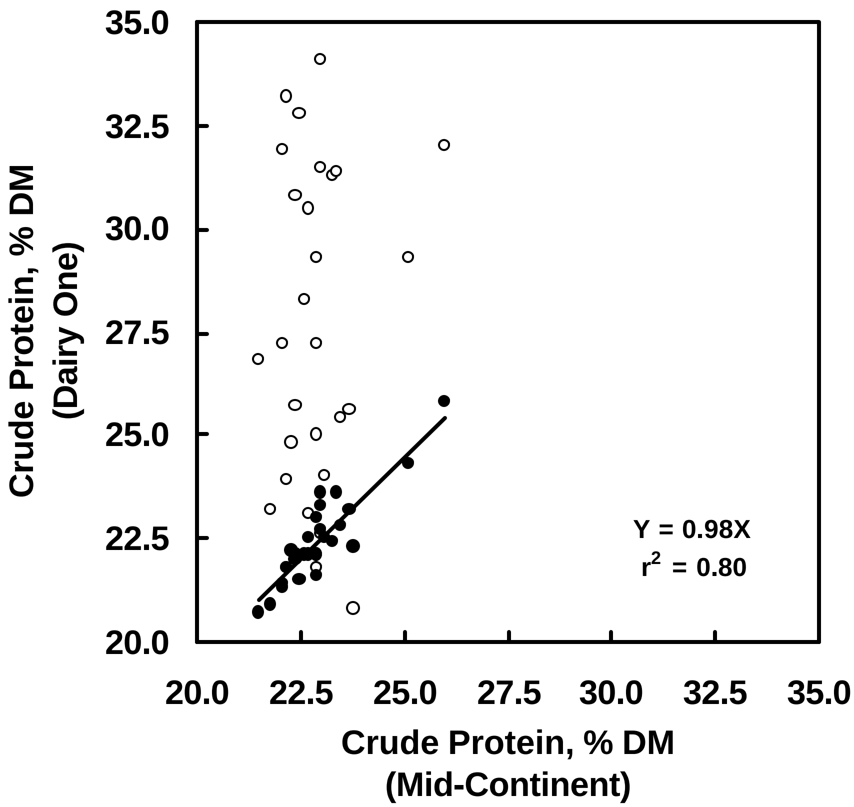

Figure 3. Crude protein content of Upland cottonseed determined by a reference laboratory (Mid-Continent Laboratories, Inc., Jackson, MS) using the official method of the American Oil Chemists Society and by Dairy One. The open circles represent seed submitted to Dairy One as received from the cottonseed oil mills; the solid circles seed that was prepared for analysis, as described in the text, and then submitted to Dairy One.

(averages without a common superscript are significantly different at $P < 0.05$). Crude protein percentages for the National Standards were: 21.6[c], 22.4[b], 23.0[b], and 25.8[a] for Deltapine Nu 33B, Sure-Grow 747, All Tex Atlas, and Acala Maxxa; respectively. Averaged across the four National Standard varieties there were significant location differences for oil and crude protein, but there was not a clear geographical pattern to these differences. However, oil content was lowest at Bossier City, LA (18.8%) and highest for Artesia, NM (23.7%); and crude protein content was lowest at Tunica, MS (19.8%) and highest at Lubbock, TX (26.9%). There were significant differences between varieties and between locations for the High Quality Region, but the only differences of commercial importance were the ones already discussed for the four National Standards. Oil and crude protein values for seed from the transgenic cottons were similar to values for non-transgenic cottons. There are no obvious differences; however, the varieties necessary to make direct comparisons, i.e., Deltapine 451 vs Deltapine 451 BGRR planted at the same location(s), were not included in the tests. There were several locations in the southwestern states where cotton was irrigated and comparison with the same varieties grown without irrigation was possible. Irrigation increased the average oil content of the four National Standards from 20.2 to 22.6%, but crude protein content was unchanged.

Gossypol Content of Upland Cottonseed

Variation in total gossypol content, and minus gossypol, expressed as a percentage of total gossypol, in meats of seed of commercially important

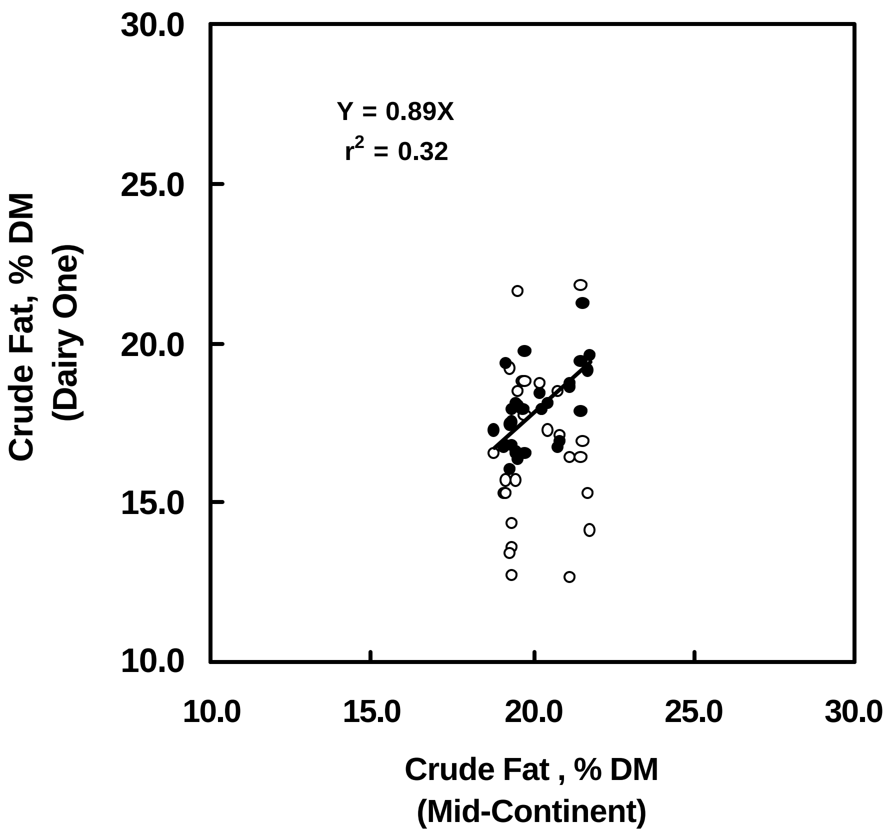

Figure 4. Crude fat content of Upland cottonseed determined by a reference laboratory (Mid-Continent Laboratories, Inc., Jackson, MS) using the official method of the American Oil Chemists Society and by Dairy One. The open circles represent seed submitted to Dairy One as received from the cottonseed oil mills; the solid circles

seed that was prepared for analysis, as described in the text, and then submitted to Dairy One.

Upland cotton varieties, that were included in the 2001 National Cotton Variety Tests (NCVT, 2001), are presented in Table 6. There is much more variation among and within varieties for total gossypol then there was for either oil or protein in seed. As a group the FiberMax varieties are consistently low and the Stoneville varieties consistently high compared to the other major brands of cotton. Deltapine brand varieties and Paymaster brand varieties tend to be intermediate between FiberMax and Stoneville, but individual varieties within these brands were quite variable. The four Sure-Grow varieties cover the spectrum from low to high. There is much less variation in the proportion of the minus isomer of gossypol. An excess of the minus isomer is a characteristic of Pima cottons that are grown commercially in the United States (Percy et al., 1996) and suggests *Gossypium barbadense* genetics may have been used in the development of FiberMax 958.

There were significant differences among varieties and among locations for total gossypol and the proportion of the minus isomer of gossypol. Averaged across all locations, the percentages of total gossypol in meats, for the National Standards were: 1.05[d], 1.25[c], 1.32[b], and 1.69[a] for Acala Maxxa, Sure-Grow 747, All Tex Atlas, and Deltapine Nu 33B; respectively. Values for minus gossypol, expressed as a percentage of total gossypol, were: 37.0[d], 41.2[c], 42.7[b], and 44.5[a] for Acala Maxxa, Deltapine Nu 33B, All Tex Atlas, and Sure-Grow 747; respectively. Averaged across the four National Standard varieties there were significant location differences for total gossypol. Tipton, OK had the lowest average total gossypol (0.98%) and University City, NM had the highest (1.62%). Test locations in the southeast, central, and high plains areas of Texas had consistently low total gossypol values. Far West Texas and New Mexico locations had consistently high total gossypol values. The National Standards grown in the Mississippi Delta and along the east coast tended to have high seed gossypol. The proportion of the minus isomer was not correlated with total gossypol, and there were no obvious geographical patterns.

In order to express gossypol values on a whole seed basis it is necessary to know the percentage of meats in the seed. This was not determined by Woodson-Tenent Laboratories; however, we routinely determine the percentage of meats in samples of whole Upland seed received in the TAES Nutrition and Toxicology Laboratory in San Angelo. Over a period of about 10 years, these have averaged 51.7 ± 0.48% and ranged from 48.1 to 57.3%. Using the average, total gossypol levels in whole seed can be estimated by multiplying the values for total gossypol in meats in Table 6 by 0.517. With this calculation, total gossypol in whole seed ranged from 0.52 to 1.01% for the 24 varieties in Table 6. For comparison purposes the 83 samples of whole Upland seed in Table 4 averaged 0.66 ± 0.01% total gossypol, the (–) isomer of gossypol was 38.8 ± 0.26% of total gossypol.

Composition of Processed Cottonseed

Samples were collected on two occasions from five mini-mills in Texas to study the compositional properties and consistency of products produced at the different processing steps. In conventional cottonseed oil mills most of the lint is removed from the seed and the seed are dehulled; whereas, these steps are omitted at the mini-mills, instead whole cottonseed is passed through an extruder to condition the seed, and then through an expeller to extract a portion of the oil. Processed cottonseed samples were submitted to Mid-Continent Laboratories and to Dairy One for analyses. Free, total, and (+)- and (–)-gossypol were determined in the TAES Nutrition and Toxicology Laboratory. Table 7 contains information on the nutrient composition of extruded and extruded-expelled cottonseed.

The average nutrient composition of 10 samples of whole cottonseed collected at the five oil mills was: dry matter, 91.6%; crude protein, 23.0%; crude fat, 20.8%; ADF, 37.9%; and NDF, 48.0%. Gossypol values for the whole cottonseed were 0.61% free gossypol and 0.58% total gossypol. Minus gossypol was 41.2% of the gossypol present in the seed. Extruded seed was higher in dry matter, ADF, and NDF than the original seed. Crude protein was essentially the same and crude fat was lower. Extruding cottonseed and then passing it through an expeller increased ($P < 0.05$) crude protein and decreased ($P < 0.05$) crude fat. The slight increase in mineral content is consistent with the removal of oil when extruded cottonseed is passed through the expeller. The fact that ADF and NDF were not also increased by the expeller process is believed to be due to the removal of oil, and the effect the high oil content of extruded cottonseed had on ADF and NDF values. The free gossypol content of cottonseed was reduced by both processing steps. Extruded cottonseed contained 0.26 ± 0.03% and extruded-expelled cottonseed 0.10 ± 0.01% free gossypol. The total gossypol content of extruded and extruded-expelled cottonseed was not significantly different than the original seed, and the proportion of gossypol isomers was not affected by processing.

Discussion

Prior to 1980 almost all cottonseed was processed by the oil mills, and little was fed directly to livestock. Since then, the amount fed as whole seed, primarily to cattle, has increased from 15% in 1980 to about 55% in 2003. This has been accompanied by a corresponding decrease in the amount of cottonseed crushed by the oil mills from about 80% in 1980 to about 40% in 2003, and a decrease in the number of oil mills from 74 in 1980 to 14 in 2002 (NCPA, 2004). The cottonseed processing industry established trading rules that enabled pricing cottonseed based on defined quality and quantity factors (NCPA, 2000). Official chemists licensed by the U.S. Department of Agriculture issued grade certificates based on the analyses of these quality (% foreign matter and % moisture, on an as received whole seed basis, and free fatty acids, expressed as a percentage of the oil) and quantity (% oil and % ammonia) factors, that were used by the oil mills in trading cottonseed. Cottonseed grade certificates were sent to the USDA Agricultural Marketing Service - Cotton Division in Memphis, TN and an annual report was issued summarizing the quality of cottonseed by quality factors for each state and the United States (USDA AMS, 1998). The 1980 report contained information for 38,224 seed samples. The number of grade certificates issued each year decreased as the number of oil mills decreased, reaching 4,996 in 1998. At that time, the reports ceased because of lack of interest. The explanation appears to be competition for seed from the dairy industry, which does not appear overly concerned about cottonseed quality.

There was very little change in the yearly averages for oil and ammonia (protein) in cottonseed from 1980 to 1998. Although this is the case, it is important to keep in mind that considerable variation exists among varieties in cottonseed composition, that commercial varieties are continually changing, and that location where the cotton is grown also affects composition (Cherry et al., 1986). Because of the difficulty in preparing a representative sample for analysis and the need for reliable oil (energy) and protein values for cottonseed, it is recommended that cottonseed be submitted to an AOCS certified laboratory for *Feed Grade Cottonseed Analysis*. The cost is around $20.00/sample and includes determination of % foreign matter, % moisture, % oil, and % crude protein, on an as received whole seed basis, and free fatty acids, expressed as a percentage of the oil.

Gossypol, a toxic polyphenolic binaphthyl dialdehyde, occurs throughout the cotton plant, but is concentrated in pigment glands present in cottonseed (Berardi and Goldblatt, 1980). Because of restricted rotation about the bond that joins the two naphthalene groups of the molecule, gossypol exists naturally as a mixture of two sterioisomers, (+)- and (–)-gossypol. The minus isomer appears to have the greatest biological activity and is the isomer responsible for infertility in males (Matlin et al., 1985). High levels of terpenoid aldehydes, like gossypol, as well as a number of other secondary plant metabolites in the vegetative parts of the cotton plant are desirable because of the protection provided against a number of plant pests; whereas, gossypol in seed is undesirable, because of its toxicity to animals (Bell, 1986). Considerable progress has been made toward eliminating gossypol from seed, while at the same time maintaining or increasing gossypol levels in the rest of the plant (Benedict, 2002); however, we are several years away from commercial varieties without gossypol in seed. In the meantime we are confronted with a number of varieties that have very high levels of gossypol in the seed, that are being grown commercially. It is important to know where these are being grown, and to check gossypol levels in seed. The recommended analysis is total gossypol by the AOCS official method. The major problem with deciding on a laboratory to determine gossypol is that gossypol is not included in the laboratory proficiency program for cottonseed analysis.

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Table 1. Nutrient composition of Pima seed submitted to the Texas Agricultural Experiment Station's Nutrition and Toxicology Laboratory at San Angelo, TX, compared with values reported by Robinson et al. (2001) for Pima seed.[1]

	TAES[2]				Robinson et al., 2001			
Item	N	Mean	SD	Range	N	Mean	SD	Range
Dry matter, %	50	92.7	0.39	91.8 – 93.5	29	93.3	0.65	92.1- 94.3
Crude protein, %	50	24.6	1.41	20.5 - 26.7	29	29.1	3.38	19.8 - 34.5
Soluble protein, % of CP	40	22.9	4.58	11.0 - 32.0	29	26.2	3.83	14.0 - 32.0
Crude fat, %	50	24.1	1.42	20.6 - 27.6	29	27.1	3.96	20.0 - 34.0
ADICP, % of CP	21	2.1	0.33	1.8 - 2.9				
NDICP, % of CP	21	2.1	0.25	1.8 - 2.9				
ADF, %	21	31.8	1.63	28.9 - 34.4	29	31.3	6.38	20.0 - 44.5
NDF, %	21	41.1	1.56	37.8 - 43.6	29	44.4	7.55	36.6 - 58.1
Lignin, %	50	17.2	2.24	12.4 - 25.0				
Ash, %	40	4.4	0.23	3.9 - 4.9				
Calcium, %	50	0.24	0.03	0.19 - 0.30	29	0.19	0.02	0.16 - 0.23
Phosphorus, %	50	0.72	0.08	0.53 - 0.91	29	1.03	0.13	0.88 -1.26
Magnesium, %	50	0.37	0.02	0.32 - 0.42	29	0.44	0.04	0.40 - 0.50
Potassium, %	50	1.35	0.08	1.11 - 1.50	29	1.29	0.08	1.19 - 1.38
Sodium, %	50	0.02	0.01	0.00 - 0.04	29	0.01	0.01	0.01 - 0.01
Chloride, %	50	0.09	0.04	0.02 - 0.17	29	0.09	0.03	0.02 - 0.19
Sulfur, %	50	0.25	0.04	0.17 - 0.39	29	0.31	0.04	0.21 - 0.46
Copper, ppm	50	9	1.5	7 - 15	29	9	1.37	7 - 12
Iron, ppm	50	45	9.0	29 - 68	29	55	19.36	35 - 130
Manganese, ppm	50	12	1.2	10 - 15	29	14	1.34	12 - 17
Zinc, ppm	50	34	5.4	25 - 56	29	41	6.23	31 - 52
Molybdenum, ppm	13	1.1	0.15	1.00 -1.40	29	1.2	0.55	1.0 - 2.3

[1] Nutrient values are on a 100% dry matter basis.
[2] Crude protein and crude fat in TAES samples were determined by Mid-Continent Laboratories, Inc., Jackson, MS. All other nutrients in TAES samples were determined by Dairy One, Ithaca, NY. Acid detergent insoluble crude protein (ADICP), neutral detergent insoluble crude protein (NDICP), acid detergent fiber (ADF) and neutral detergent fiber (NDF) were determined after cold acetone extraction of ground Pima seed.. All minerals were determined in duplicate.

Table 2. Percentages of acres planted to commercially important Pima cotton varieties in 2001, that were included in the 2001 National Cotton Variety Tests (NCVT), and variation in oil and crude protein content of seed grown at three locations[1, 2]

	Acreage[3]	Oil, % DM			Crude protein, % DM		
Item	%	Mean	SD[4]	Range	Mean	SD	Range
Variety							
Deltapine 744	4.49	25.6	0.47	25.3 - 26.3	23.9	3.33	20.6 - 27.2
Phytogen 57	24.12	25.9	0.45	25.4 - 26.2	24.5	4.58	19.4 - 28.3
Phytogen 76	23.62	23.8	1.04	22.6 - 24.6	23.7	3.33	20.1 - 26.7
OA 325 (DP-HTO)	12.56	25.7	0.28	25.5 - 26.0	24.7	2.36	22.2 - 26.9
OA 340	8.15	25.7	0.65	25.1 - 26.4	24.1	3.83	20.2 - 27.8
Pima S-7	16.98	25.2	0.57	24.6 - 25.6	23.7	3.28	20.2 - 26.6
Location							
El Paso		25.5	0.91	24.2 - 26.4	20.4[a]	0.93	19.4 - 22.2
Las Cruces		25.4	0.46	25.3 - 26.0	24.6[b]	0.68	24.0 - 25.8
Maricopa		25.1	0.90	22.6 - 26.2	27.3[c]	0.68	26.6 - 28.3

[1] 2001 National Cotton Variety Test. USDA ARS, Stoneville, MS.
[2] Values in the NCVT were oil and nitrogen in whole seed, as received DM basis. These were converted to a 100% DM basis by dividing by 0.93. Nitrogen was converted to crude protein by multiplying by 6.25.
[3] Cotton Varieties Planted 2001 Crop, USDA AMS, Cotton Program, Memphis, TN, August 2001.
[4] Standard deviation.
[a, b, c] Means without a common superscript are different ($P<0.05$).

Table 3. Variation in total gossypol content, and minus gossypol, expressed as a percentage of total gossypol, in meats of seed of commercially important Pima cotton varieties grown at three locations in 2001, and included in the 2001 National Cotton Variety Tests (NCVT).[1]

	Total gossypol, % of meats DM[2]			Minus gossypol, % of total		
Item	Mean	SD[3]	Range	Mean	SD	Range
Variety						
Deltapine 744	1.35	0.27	1.06 - 1.58	51.7	0.62	50.9 - 52.1
Phytogen 57	1.20	0.22	0.95 - 1.35	52.8	0.52	52.3 - 53.3
Phytogen 76	1.28	0.23	1.02 - 1.42	49.9	1.95	47.9 - 51.8
OA 325 (DP-HTO)	1.18	0.14	1.02 - 1.28	52.1	1.83	50.0 - 53.2
OA 340	1.22	0.15	1.06 - 1.35	54.8	1.38	53.2 - 55.6
Pima S-7	1.28	0.23	1.02 - 1.47	52.4	1.35	51.5 - 53.9
Location						
El Paso	1.39[b]	0.10	1.28 - 1.58	52.2	2.55	47.9 - 55.6
Las Cruces	1.35[b]	0.10	1.24 - 1.47	52.4	0.68	51.7 - 53.2
Maracopa	1.02[a]	0.04	0.95 - 1.06	52.2	2.30	50.0 - 55.7

[1] 2001 National Cotton Variety Test. USDA ARS, Stoneville, MS.
[2] Values in the NCVT were for decorticated cottonseed (meats), on a DM basis. The percentage of meats in whole seed was not determined by NCVT.
[3] Standard deviation.
[a,b] Means without a common superscript are different ($P < 0.05$).

Table 4. Nutrient values for whole, linted seed of Upland cottons (*Gossypium hirsutum*).[1]

	Calhoun et al. (1995)			Dairy One[2]			2001 Dairy NRC[3]		
Item	N	Mean	SD[4]	N	Mean	SD	N	Mean	SD
Dry matter, %	83	91.6	0.89	1034	91.4	3.0	1059	90.1	4.6
Crude protein, %	83	23.0	0.98	859	25.0	6.1	1124	23.5	2.6
Sol. protein, % of CP				413	27.5	12.8			
Degrad. protein, % of CP				57	47.3	6.2			
ADICP, % of CP				136	1.96	0.58	4	1.9	0.1
NDICP, % of CP				137	2.55	0.69	71	2.4	1.2
ADF, %	83	38.9	3.59	782	38.1	9.93	1024	40.1	4.4
NDF, %	83	47.3	3.54	790	49.6	10.94	953	50.3	5.8
Crude fiber, %	83	29.5	2.07	89	23.7	7.08			
Crude fat, %	83	20.1	0.95	456	22.5	4.65	27	19.3	1.4
Ash, %	83	3.8	0.23	227	4.4	0.56	193	4.2	2.1
Calcium, %	83	0.14	0.016	603	0.20	0.057	928	0.17	0.08
Phosphorus, %	83	0.56	0.055	603	0.76	0.187	928	0.60	0.08
Magnesium, %	83	0.35	0.020	602	0.40	0.073	928	0.37	0.04
Potassium, %	83	1.14	0.067	602	1.21	0.103	928	1.13	0.07
Sodium, %	83	0.008	0.007	602	0.024	0.009	928	0.02	0.02
Chloride, %				136	0.09	0.018	148	0.06	0.03
Sulfur, %	83	0.20	0.023	417	0.25	0.069	424	0.23	0.04
Copper, ppm	83	7	1.3	600	7	2.4	928	7	3
Iron, ppm	83	50	11.5	600	85	73.3	928	94	185
Manganese, ppm	83	15	2.2	600	17	9.0	928	18	13
Zinc, ppm	83	33	3.5	600	37	12.7	928	37	18
Molybdenum, ppm	83	1.6	0.52	600	0.58	0.47	919	1.3	0.6

[1] Values are on a 100% dry matter basis.
[2] Information accessed at http://www.dairyone.com on February 20, 2004.
[3] National Research Council, Nutrient Requirements of Dairy Cattle 7th Revised Edition, 2001.
[4] Standard deviation.

Table 5. Percentages of acres planted to commercially important Upland cotton varieties in 2001, that were included in the 2001 National Cotton Variety Tests (NCVT, 2001), number of test locations for each variety, and variation in oil and crude protein content of seed.[1]

	Acreage[2]		Oil, % DM			Crude protein, % DM		
Variety	%	N	Mean	SD[3]	Range	Mean	SD	Range
Acala Maxxa	0.75	22	21.1	0.84	16.8 - 22.5	25.8	2.20	21.8 - 28.8
All Tex Atlas	0.98	22	22.3	1.72	18.9 - 25.7	23.0	1.76	20.5 - 27.4
Deltapine 50	0.37	6	21.6	0.51	20.8 - 22.0	22.6	1.59	20.0 - 23.6
Deltapine 451 BGRR	6.39	8	21.6	0.82	20.4 - 22.7	19.7	1.31	17.7 - 21.2
Deltapine 2156	0.21	8	22.8	2.20	21.3 - 26.1	24.4	0.21	24.2 - 24.6
Deltapine 5415 RR	2.47	3	18.3	3.65	15.0 - 22.2	19.4	1.37	18.2 - 20.9
Deltapine Nu 33 BG	1.66	24	21.0	1.42	19.0 - 24.3	21.6	2.11	19.0 - 22.8
FiberMax 832	2.73	4	21.7	0.38	21.2 - 22.0	23.7	1.43	22.0 - 25.1
FiberMax 958	0.45	4	22.2	1.78	20.6 - 23.8	21.1	1.17	20.8 - 22.7
FiberMax 966	0.24	8	23.3	1.07	21.7 - 24.8	21.7	1.05	20.6 - 23.3
FiberMax 989	0.88	3	23.2	1.24	22.3 - 24.6	20.9	2.82	18.1 - 23.7
Paymaster 1218 BGRR	10.72	4	22.2	0.97	21.0 - 23.2	21.8	0.78	20.7 - 22.6
Paymaster 1560 BG	0.16	8	20.3	1.06	19.0 - 21.7	22.6	2.39	19.7 - 25.6
Paymaster 2145 RR	0.81	4	22.6	0.96	21.6 - 23.9	25.8	1.53	23.9 - 27.6
Paymaster 2326 RR	11.44	4	21.2	2.49	18.9 - 24.4	24.5	1.34	23.4 - 26.0
Phytogen PSC 355	0.77	8	22.8	0.95	21.4 - 23.9	22.2	1.21	19.7 - 23.8
Sure-Grow 105	0.18	4	21.3	0.34	20.9 - 21.7	20.3	0.99	19.1 - 21.5
Sure-Grow 125	0.43	4	18.9	1.61	17.8 - 21.3	22.8	1.40	21.6 - 24.9
Sure-Grow 501 BGRR	0.06	4	20.4	0.94	19.3 - 21.6	21.9	1.32	19.9 - 22.9
Sure-Grow 747	0.60	21	19.9	1.62	16.8 - 23.6	22.4	2.05	19.2 - 27.8
Stoneville BXN 47	3.27	4	21.3	0.34	20.9 - 21.7	20.3	0.99	19.1 - 21.5
Stoneville 474	0.78	8	20.4	0.58	19.5 - 21.5	23.9	2.16	20.9 - 27.2
Stoneville 4793 RR	1.20	4	20.5	0.87	19.2 - 21.1	22.0	1.38	21.2 - 24.1
Stoneville 4892 BGRR	5.75	8	21.1	0.86	20.0 - 22.6	21.2	1.57	19.2 - 24.5

[1] Values in the NCVT were oil and nitrogen in whole seed, as received DM basis. These were converted to a 100% DM basis by dividing by 0.91. Nitrogen was converted to crude protein by multiplying by 6.2.
[2] Cotton Varieties Planted 2001 Crop, USDA AMS, Cotton Program, Memphis, TN, August 2001.
[3] Standard deviation.

Table 6. Variation in total gossypol content and minus gossypol (as a percentage of total gossypol) in meats of seed of commercial Upland cotton varieties in the 2001 National Cotton Variety Tests (NCVT, 2001).[1]

	Total gossypol, % of meats DM			Minus gossypol, % of total gossypol		
Variety	Mean	SD	Range	Mean	SD	Range
Acala Maxxa	1.05	0.15	0.78 - 1.27	37.0	1.84	33.9 - 40.7
All Tex Atlas	1.32	0.20	0.95 - 1.70	42.7	1.75	39.6 - 45.8
Deltapine 50	1.27	0.18	1.05 - 1.55	35.2	2.43	33.3 - 40.0
Deltapine 451 BGRR	1.57	0.13	1.33 - 1.69	39.0	1.19	38.0 - 41.6
Deltapine 2156	1.04	0.15	0.91 - 1.25	42.6	1.72	40.6 - 44.1
Deltapine 5415 RR	1.30	0.15	1.14 - 1.42	45.5	2.24	43.0 - 47.4
Deltapine Nu 33 BG	1.39	0.21	1.13 - 1.96	41.2	2.02	37.1 - 45.0
FiberMax 832	1.01	0.14	0.81 - 1.15	42.1	3.31	37.4 - 45.1
FiberMax 958	1.13	0.11	1.00 - 1.26	51.0	1.93	49.1 - 53.5
FiberMax 966	1.13	0.11	0.90 - 1.22	47.4	1.23	46.7 - 48.6
FiberMax 989	1.16	0.12	1.03 - 1.25	44.2	2.15	42.7 - 46.7
Paymaster 1218 BGRR	1.27	0.08	1.16 - 1.33	39.3	1.14	38.3 - 40.8
Paymaster 1560 BG	1.28	0.29	0.90 - 1.68	42.4	1.65	39.8 - 44.8
Paymaster 2145 RR	1.09	0.21	0.86 - 1.37	41.0	2.35	38.4 - 43.1
Paymaster 2326 RR	1.11	0.27	0.88 - 1.49	42.6	2.93	38.6 - 45.0
Phytogen PSC 355	1.59	0.16	1.31 - 1.84	39.3	1.29	37.4 - 41.7
Sure-Grow 105	1.90	0.17	1.74 - 2.12	41.9	1.70	39.4 - 43.1
Sure-Grow 125	1.09	0.14	0.92 - 1.25	42.3	1.36	41.3 - 44.2
Sure-Grow 501 BGRR	1.53	0.07	1.45 - 1.59	42.3	2.04	40.3 - 45.0
Sure-Grow 747	1.25	0.22	0.82 - 1.70	44.5	1.61	41.8 - 46.9
Stoneville BXN 47	1.95	0.26	1.62 - 2.25	39.9	1.02	38.4 - 40.7
Stoneville 474	1.55	0.19	1.30 - 1.88	39.7	2.32	37.2 - 42.3
Stoneville 4793 RR	1.71	0.25	1.33 - 1.86	41.2	1.27	39.8 - 42.9
Stoneville 4892 BGRR	1.76	0.16	1.59 - 2.12	41.2	1.21	41.0 - 42.8

[1] Values in the NCVT were for decorticated cottonseed (meats), on a DM basis. The percentage of meats in whole seed was not determined by NCVT.

Table 7. Nutrient values for extruded and extruded-expelled cottonseed.[1]

	Extruded cottonseed			Extruded-expelled cottonseed		
Item	Mean	SD[4]	Range	Mean	SD	Range
Mid-Continent analysis[2]						
Dry matter, %	93.2	0.61	92.0 - 93.8	92.4	1.25	91.0 - 94.6
Crude protein, %	22.8	1.15	21.2 - 24.7	26.4	1.35	24.4 - 28.2
Crude fat, %	18.6	2.75	11.9 - 21.0	8.0	1.14	6.3 - 10.3
Crude fiber, %	26.0	2.41	22.1 - 24.7	30.4	1.38	28.0 - 32.2
Ash, %	3.8	0.25	3.4 - 4.2	4.4	0.27	3.9 - 4.9
Dairy One analysis[3]						
Dry matter, %	93.3	0.60	92.5 - 94.1	93.2	1.31	91.6 - 95.4
Crude protein, %	23.0	1.39	21.1 - 25.6	27.4	0.88	25.7 - 28.9
Crude fat, %	19.6	1.65	16.7 - 21.4	7.7	0.98	6.4 - 9.9
ADF, %	45.9	2.94	41.6 - 49.0	43.7	1.79	40.8 - 45.7
NDF, %	52.5	2.75	47.9 - 56.9	51.5	1.79	48.6 - 53.5
Calcium, %	0.21	0.02	0.18 - 0.24	0.24	0.03	0.19 - 0.28
Phosphorus, %	0.56	0.06	0.48 - 0.65	0.66	0.14	0.50 - 1.03
Magnesium, %	0.32	0.02	0.29 - 0.36	0.38	0.06	0.32 - 0.54
Potassium, %	1.22	0.11	1.02 - 1.38	1.43	0.21	1.14 - 1.95
Sodium, %	0.01	0.01	0.00 - 0.01	0.01	0.01	0.00 - 0.02
Sulfur, %	0.23	0.02	0.21 - 0.27	0.27	0.02	0.23 - 0.29
Copper, ppm	7	0.70	5 - 8	7	1.26	5 - 10
Iron, ppm	44	9.41	31 - 59	57	13.24	44 - 87
Manganese, ppm	12	0.56	11 - 13	14	1.76	13 - 18
Zinc, ppm	26	2.80	20 - 30	30	5.74	23 - 40
Molybdenum, ppm	0.52	0.63	0.00 - 1.40	0.90	0.76	0.00 - 1.70

[1] Values are on a 100% dry matter basis.
[2] Determined by Mid-Continent Laboratories, Inc., Jackson, MS.
[3] Determined by Dairy One, Ithaca, NY.
[4] Standard deviation.