UPDATE ON DRY EXTRUDING COTTON GIN BYPRODUCTS TO REDUCE CHEMICAL RESIDUES

Michael D. Buser, Agricultural Engineer
Cotton Ginning Research Unit,
Agricultural Research Service
U.S. Department of Agriculture
Stoneville, MS

Abstract

Whole cottonseed and cotton gin by-products (CGBP) were mixed together and processed in a dry extruder to determine the feasibility of the mixture as a livestock feed. Samples were collected during the study to determine if the temperature, pressure and shear associated with extrusion would reduce the chemical residues in the CGBP and affect the nutritional value of the mixture. The first test focused on mixing ratios of CGBP and cottonseed with a constant temperature and pressure during processing. Results show a significant reduction in Methyl Parathion and DEF, while there were no significant reductions in Karate (Karate levels were below 1 ppm before the CGBP mixture was extruded). The second study focused on the extrusion of a 75% CGBP and 25% cottonseed processed multiple times by dry extrusion. The results of this study show significant reductions in Methyl Parathion and Dropp. A nutritional analysis was completed on the extruded material of the first study, showing significant differences in nutritional values of the various mixtures. Nutritional results from the second study showed significant differences in nutrient values due to the number of times the material was processed.

Introduction

An estimated 2.8 million tons of cotton gin by-products (CGBP) are produced by U. S. cotton gins annually, creating a significant problem in the ginning industry (Thomasson, 1990A). The quantity of CGBP per bale of ginned lint varies by harvesting method. Spindle-picked seed cotton contains from 81 (Pendleton and Moore, 1967) to 325 (Reeves, 1977) pounds per bale, with typical estimates of 75 to 150 pounds per bale (Parnell, et. al., 1994). Stripper harvesting produces from 524 (Pendleton and Moore, 1967) to 1476 (Kolarik, et al., 1978) pounds of CGBP per bale, with representative estimates of 700 to 1000 pounds per bale (Parnell, et. al., 1994). Extractors on stripper harvesters reduce the by-products per bale to 250 to 500 pounds per bale. Currently, the most common methods of disposal include composting, direct land application, and livestock feed. Kolarik, et al. (1978) reported that 37% of the CGBP produced by surveyed gins was utilized either at a profit or at no cost to the gins, while the other 63% paid for disposal. Even two decades after the Kolarik survey, disposal costs to gins and cotton producers constitute a major economic problem. Parnell, et al. (1994) estimated that the cotton ginning industry would spend $15 to $25 million annually for cotton gin by-product disposal.

Typical CGBP consists mainly of fruit and vegetative parts of the cotton plant collected during harvesting. These plant parts include fragments of leaves, stems, petioles, bracts, bolls, and lint. The natural constituents of CGBP are like those of any biomass: organic matter including lignin and cellulose with an approximate ash content of 10%. Due to these constituents, a keen interest in processing a livestock feed composed of CGBP has emerged.

Interest in feeding livestock CGBP dates back to the early 1950's. During the last 50 years, a vast amount of supportive information was generated. Lalor, et al. (1975) reported that the nutritional value per ton of CGBP as a roughage-type feed was higher than prairie hay, bermuda hay, rice hulls, and sorghum stove but lower than alfalfa hay, shown in Table 1. Numerous feeding trials have been conducted, including a report which found no significant differences in rates of weight gain, slaughter weights, or carcass characteristics between steers on a CGBP ration and those on a regular ration (Williams et al., 1982). Stent (1974) suggested a ration of 25% CGBP was acceptable, if economically feasible. Based on nutritional values, monetary estimates for CGBP as a feed product range from $19 (Williams, et al. 1982) to $35 (Lalor, et al., 1975) per ton.

The limited use of CGBP as a livestock feed throughout the Cotton Belt is due to its limited protein availability, relatively poor digestibility in ruminants, and chemical residues. Sagebiel and Cisse (1984) suggested that the analyses showing limited protein availability of CGBP was unrepresentative of the available protein due to lignification, silification, and/or low energy digestibility. Digestibility can be improved through chemical treatment of the CGBP. Gaseous oxidants such as ozone, hydrogen peroxide, and other superoxide species can be dissolved in a caustic solution and blended with CGBP to increase in virto digestibility (Cornett, 1991). Although research has shown the beneficial utilization of CGBP in livestock rations, the widespread practice is discouraged since chemical residue tolerances for most agricultural chemicals have not been established. In addition, certain agricultural chemicals posses labels stating "do not feed any crop material, which has had this chemical applied, to livestock", making it illegal to feed CGBP (in this instance) to any livestock.

The potential for chemical residues in CGBP result from the application of agricultural chemicals (insecticides, herbicides,

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growth regulators, and defoliants), during the growing of cotton. Chemical companies have improved chemicals through shorter half-lives and by phasing out the use of arsenic. Even with the improved chemicals, some of the chemical labels, especially defoliants, prohibit the feeding of CGBP to livestock when the chemical has been used on the crop. Chemical labeling is currently a major concern in the ginning industry, due to the re-registration and registration of several crop protectants under the new Food Quality Protection Act (FQPA). The industry is working with the Environmental Protection Agency (EPA) to determine the acceptable or anticipated chemical residue levels in CGBP (Swanson, 1998).

Mayfield (1994) stated that blending cottonseed and CGBP in an extruder at high temperatures and pressures may reduce the chemical residues found in CGBP, since some chemicals are subject to thermal breakdown and some of the chemicals are designed with relatively short half-lives. Thomasson, et al. (1998) conducted an extrusion study to determine chemical residue reductions associated with cottonseed and CGBP mixtures, using an Anderson 4.5-inch Expander Cooker. The mixtures were shown to have a relatively good feed value and no palatability problems. They concluded that the extrusion process reduced methomyl residues by two-thirds and reduced Dropp residues by about 90%. This preliminary work has shown that a simple, relatively low-cost extrusion process can be used to produce a livestock feed from cottonseed and CGBP with reduced chemical residue levels in the product.

In another study, a twin-screw extruder was used to process CGBP and CGBP treated with a SP2000 solution. The SP2000 solution is an oxidant, which appears to improve digestibility of low quality roughages (Bernard, 1998). The extruder was operated at an approximate pressure of 316.4 g/cm^2 and an exit temperature of 88 °C. Bernard (1998) concluded that the extrusion process improved the texture of the material in terms of handling, increased the bulk density of the CGBP by 61.5%, and did not affect the nutrient digestibility. Treatment with SP2000 was shown to further increase the digestibility of the CGBP and, based on a feeding trial; there were no significant differences in the nutrient intake of the extruded materials when compared to pelleted cottonseed hulls. A summary of the nutrient composition and densities of the extruded CGBP and SP2000 treated CGBP are shown in Table 2.

This study is a continuation of work by Thomasson, et al. (1998) and focuses on a more narrow range of CGBP and cottonseed mixing ratios, higher extrusion temperatures and multiple pass extrusion as a means of testing the effects of increased dwell time on the reduction chemical residues. The purpose of this study is to determine the feasibility of dry-extruding cottonseed and CGBP together to produce an acceptable livestock feed. The extrusion process will be evaluated to determine the effectiveness of the heat, pressure, and shear associated with extrusion on the reduction of crop-production-chemical residues in CGBP. Dry-extrusion is a process, which applies heat, pressure, and shear to the material being extruded; in additional, the material is being internally mixed, in the extruder, to create a more uniform final material. These four characteristics of dry-extrusion are extremely dependent on one another; therefore, these characteristics will be lumped together and defined as the dry extrusion process. The dry extrusion process will be quantified in terms of extruder temperature (this parameter is based on the four characteristics previously discussed).

Materials and Methods

This project was divided into two sections to fulfill the objectives of the study. The sections include: 1) evaluation of chemical residue reductions associated with dry-extruding various mixing ratios of CGBP and cottonseed at relatively high extruder temperatures; 2) the chemical residue reductions associated with multiple pass dry-extrusion of a 75% CGBP and 25% cottonseed mixture.

The chemical residue study for various mixing ratios required 1,000 pounds of CGBP and 1,000 pounds of cottonseed. The CGBP (not including motes from the upper moting system of a gin stand or lint cleaner waste) and cottonseed were collected during the ginning of spindle-picked Midsouth seed cotton. Burdette Gin Company in Burdette, Mississippi supplied the CGBP and the cottonseed was collected at the U. S. Cotton Ginning Laboratory (USCGL), USDA-ARS, in Stoneville, Mississippi. Similar CGBP and cottonseed were provided by the USCGL for the multiple pass extrusion tests.

In order to determine if the dry-extrusion process would reduce chemical residues in CGBP, it was necessary to apply known chemicals in known concentrations to the CGBP. Applying additional chemicals, in known quantities, to the CGBP ensures chemical presence in all the CGBP used in the study and sets a relatively uniform minimum level of chemical concentrations expected in the initial samples before extrusion. In addition, application of these chemicals will allow the chemical residue analyses to focus on specific residues, thereby increasing the efficiency and precision of the residue analyses.

Based on Willifords (1998) recommendation, five commonly used chemicals in the cotton industry were applied to the CGBP. These chemicals included DEF, Dropp, Methyl Parathion, Prep, and Karate. Mayfield (1994) suggested that DEF was most likely the highest concentrated residue found in typical CGBP. Based on this information and information obtained from the USDA-ARS Cotton Ginning Research Unit in Mesilla Park, New Mexico, it was determined that 0.8% of the normal application rate for DEF could represent the high end of the expected chemical residue range for DEF in CGBP. Due to the limited information on current chemical residues in CGBP, the five selected chemicals were applied to the CGBP at 0.8% of the normal application rates. The rates were 0.01, 0.0016, 0.008, 0.004, and 0.001 pounds per acre for DEF, Dropp, Prep, Methyl Parathion, and Karate, respectively.

Application of the chemicals to CGBP was performed at the USCGL in the following manner. First, the CGBP material was spread out in a thin-layer on a plastic sheet. Next, the Application and Production Technology Unit of the USDA/ARS in Stoneville, Mississippi, used a side-boom spray rig mounted on a tractor to individually apply the chemicals to the CGBP in pre-discussed concentrations. After the recommended re-entry period, the CGBP was baled. The CGBP bales and cottonseed collected at the USCGL was then shipped to Des Moines, Iowa, for extrusion.

The commercial-size dry-extruding machinery at the Insta-Pro International Research and Development Facility in Des Moines, Iowa was used in this study. Both sections of this study utilized the Insta-Pro Model 2500 dry-extruder followed by an Insta-Pro air type belt drier to cool the material.

This dry-extruder is a single screw adiabatic extruder that generates heat through friction. It is commonly referred to as a high temperature, short-time extruder, which can achieve temperatures up to 350 °F in less than 20 seconds. The inside diameter of the barrel is 6 ½-inches and the overall length is 42-inches, with a constant diameter screw. The barrel was configured with two compression chambers. Compression is accomplished by changing the pitch of the worm flights and shear is achieved by selecting the size of the steamlocks and screw flight, and adjusting the nose bullet and cone in the last chamber of the barrel. The barrel wall and steamlocks are grooved to allow more mixing and shearing. (Said, 1998)

The material is fed into the extruder through a top electronic controlled volumetric feeder with an agitator, which provides a uniform and free-flowing material. Once the material enters the inlet chamber, it is forced into the first steamlock by the screw. Grooves in the steamlock walls allow for a gradual build-up in pressure as the material passes through the compression chambers. When the material reaches the last chamber containing the nose bullet and cone, a maximum pressure of 40 atmospheres is achieved.

The mixing ratio extrusion process for the CGBP and cottonseed mixture test required a total weight of 100 pounds per sample. Mixing ratios of CGBP and cottonseed were based on Thomassons, et al. (1998) recommendations, which suggested mixing ratios composed of less than 25% cottonseed produced a loose and fluffy product. Mixing ratios used in this study, in terms of percent cottonseed to percent CGBP, were 25:75, 30:70, 40:60, 50:50, and 60:40. Three replicates of each mixing ratio were performed for a total of 15 test lots.

For the CGBP and cottonseed mixture section of this study, several samples were collected for various analyses. Before the chemicals were applied to the CGBP, five random samples were taken for chemical residue analysis. These samples generated the base residue levels, which will be compared to samples collected before mixing to determine the actual amount of additional chemicals that settled on the CGBP during chemical application. While mixing the CGBP and cottonseed, a total of 13 CGBP and 3 cottonseed samples were randomly taken for residue, and nutritional analyses. Ten CGBP samples were used for residue analyses, and three CGBP and three cottonseed samples were used for initial nutritional analysis. Before each CGBP and cottonseed mixture was extruded, six random samples were taken. Five of the samples were blended together for chemical residue analysis and one sample was used to determine the nutritional value of the mixture. After the extrusion process, seven random samples were collected. Residue analysis was performed on a blended sample consisting of five of the collected samples, one sample was used to determine the nutritional value of the mixture, and one was used for texture observation. The chemical residue samples were originally collected as individual samples but were blended together to produce one sample per replication due to the expense and time required to analyze each sample.

The various samples collected during the CGBP and cottonseed mixture section were analyzed at different facilities. Samples were analyzed by Alabama State Pesticide Laboratory at Auburn University for chemical residues. The nutritional samples were analyzed by Dairy One in Ithaca, New York for ration balance and ash analysis. The texture evaluation will be performed by the USCGL in Stoneville, Mississippi.

The multiple pass extrusion process used a mixture of 75% CGBP and 25% cottonseed and required a total of 275 pounds of material for each of the three replications performed. After the material was mixed, it was fed through the extruder followed by a cooler. Samples for chemical residue and nutritional analysis were collected in the same manner as the mixing ratio test. During the first pass, samples were collected and once all the material passed through the system, it was reprocessed through the extruder and cooler. After the material exited the system for the second time, samples were collected for the same analysis and in the same manner as in the first pass. This process was repeated two additional times with samples collected after each pass. The test was completed in triplicate fashion and the nutritional samples were shipped to the same laboratory as the samples collected in the mixing ratio test. The chemical residue samples were analyzed by Mississippi State Chemical Laboratory in Starkville, Mississippi.

Results

Originally, the mixing ratio and multiple pass extrusion studies were to focus on five chemical residues, including DEF, Dropp, Prep, Methyl Parathion, and Karate. After both laboratories began analyzing the samples, Prep analysis was not completed due to potential accuracy problems associated with the chemical properties and analysis procedures. In addition, Dropp analysis was not conducted on the mixing ratio study due to current time and resource constraints at Alabama State Pesticide Laboratory.

During the mixing ratio study, an extruder temperature range of 270- to 275 °F was maintained and approximately 95 to 100 amperes were used to operate the extruder. The water injection rates were 10, 10, 8, 3, and 2 gallons per hour for the 75, 70, 60, 50, and 40 percent CGBP mixtures, respectively. The production rates were 1100, 1250, 1420, 1650, and 1740 pounds per hour for the 75, 70, 60, 50, and 40 percent CGBP mixtures, respectively.

Initial CGBP samples collected before the additional chemicals were applied contained a concentration of 0.48 ppm of DEF and no detectable concentrations of Methyl Parathion or Karate. Chemical residue levels were expected to slightly deviate from the amount applied to the material, due to the natural breakdown of the chemicals between the time the chemicals were applied and when the material was extruded (a period of approximately three weeks) and losses associated with the application process. The results of the mixing ratio study are presented in Table 3 by mixing ratio and processing method, extruded or non-extruded. Based on the chemical residue analysis before chemical application and before extrusion, there were large deviations in the optimum and actual chemical residue levels in the CGBP. For example, the optimum level of DEF (for this test) was 38 ppm and the actual level obtained was approximately 20 ppm. Therefore, the range of differences, presented in Table 3, for non-extruded versus extruded are based on extremely low levels, especially Methyl Parathion and Karate, most likely due to the natural breakdown of the chemicals during the lag period between chemical application and extrusion. There are chemical residue reductions due to the addition of cottonseed, which was not sprayed with additional chemicals, and represent the material dilution reductions. Further, Table 3 shows the differences in extruded and non-extruded material for the given mixing ratios. The CGBP samples, 100 % CGBP, were collected after chemical application and before mixing and show that the chemical application process increased the chemical residue levels to 3.44, 19.9, and 0.66 ppm for Methyl Parathion, DEF, and Karate, respectively. Further, Table 3 shows that the extrusion process significantly, at the 0.05 level, reduced levels of Methyl Parathion in all mixing ratios used in this study. The extrusion process also significantly reduced chemical residue levels for DEF at the 70 and 75 % CGBP ratio but did not affect the other ratios. Karate was not affected by extrusion in the mixing ratio study; however, it should be noted that Karate residue levels were less than 1 ppm prior to extrusion.

The chemical residue analyses from the mixing ratio study were adjusted by the percent of CGBP weight in the mixture to compare the effect of extrusion on Methyl Parathion, DEF, and Karate residues. Table 4 shows the adjusted chemical residue levels. Based on this information, Methyl Parathion and DEF were significantly lowered by extrusion, while Karate remained stable. The estimated reduction rates due to the extrusion process were 36-, 40-, and 3% for Methyl Parathion, DEF, and Karate, respectively.

Nutritional values for the extruded mixtures of CGBP and cottonseed are shown in Table 5. There are significant differences in several of the nutritional components, which were expected due to the varying amount of CGBP.

During the mixing ratio study an extruder temperature range of 264 to 280 °F was maintained and approximately 95 to 100 amperes were used to operate the extruder. The water injection rate was held constant at 5 gallons per hour.

The multiple pass extrusion study used a mixing ratio of 75% CGBP and 25% cottonseed and Methyl Parathion, DEF, Dropp, and Karate chemical residue analysis was performed on the collected samples. Table 6 shows the chemical residue results of this study, based on the number of times the material was processed. Methyl Parathion was not significantly impacted by the first two stages of extrusion, at the 0.05 level; however, the residues were significantly reduced by the third stage of extrusion. The Methyl Parathion sample standard deviation was much lower in the extruded material as compared to the non-extruded material. The DEF results of the extruded material were highly variable as compared to the non-extruded material. Further, the non-extruded material was significantly lower than the material processed through the extruder one time. The Karate results are similar to the results obtained in the mixing ratio study. Karate residues were not significantly impacted by the extrusion process. Dropp residues were significantly reduced by the extrusion process and appear to continually reduce with additional processing. In addition, the Dropp sample variance was lower in the extruded material as compared to the non-extruded material.

Table 7 shows a composite summary of the multiple pass extrusion study. Methyl Parathion residues were significantly lower at the 0.1 level but not at the 0.05 level for the extruded material compared to the non-extruded material. DEF residues were not lowered by extrusion and the residue sample analysis or sample uniformity was not adequate in obtaining meaningful information about the affects of extrusion on DEF residue levels. Dropp residues were significantly lowered by the extrusion process, approximately 95% based on means in Table 7. Reduction rates due to the extrusion process were 37- and 31% for Methyl Parathion and Karate, respectively.

Multiple pass extrusion did not significantly affect most of the mineral concentrations in the 75% CGBP and 25% cottonseed material, as shown in Table 8. The crude protein, TDN, calcium, magnesium, sulfur, and net energies were significantly lowered at the 0.05 level; however, the material still appears to be acceptable for a roughage material in fact, the percent of soluble protein was significantly reduced by the extrusion process. The fiber content of the material was significantly higher for the extruded material as compared to the non-extruded material.

Conclusions

Results from the mixing ratio study indicate that Methyl Parathion and DEF chemical residues can be significantly lowered by the extrusion process and that the resulting material will maintain a nutrient value comparable to other roughage products. Based on the multiple pass extrusion study, Methyl Parathion and Dropp residues can be reduced by extruding the material multiple times or by increasing the material dwell time. Extruding the material multiple times does affect several of the nutrient concentrations; however, the final material is still a relatively good roughage material. Karate residues were not significantly affected by the extrusion process, which could de due to the low residue levels in the CGBP prior to extrusion. Further, it is expected that as the initial chemical residue levels increase the reduction rates will increase due to the extrusion process, for certain agricultural chemicals.

Although this study indicates that Methyl Parathion, DEF, and Dropp residues are reduced by the extrusion process, further work is needed to determine the expected chemical residues and residue levels in CGBP across the Cotton Belt. Lowering residue levels may be a step in the right direction but feeding CGBP, in which chemicals have been applied during the growing of cotton, is not recommended until tolerances have been set by the EPA under the FQPA.

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Disclaimer

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Table 1. Comparative chemical and nutritive value of selected roughages.

Nutrient Value	Alfalfa Hay	Bermuda Hay	Cotton Gin Waste	Prairie Hay	Rice Hulls	Sorghum Stover
ENE[1] Maintenance (MC[2]/Cwt[3])	55	48	46	49	41	41
ENE Production (MC/Cwt)	23	13	15	13	15	13
TDN Ruminant (%)	54.2	43	45	45	32	40
Crude Protein (%)	17.0	7.9	7.0	4.5	3.0	3.6
Digestible Protein (%)	12.6	4.0	3.0	2.5	1.5	1.2
Crude Fat (%)	2.0	2.0	1.5	3.2	1.0	1.2
Crude Fiber (%)	24.3	28.7	35.0	33.0	40.0	32.3
Ash (%)	9.0	0	10.0	8.0	10.0	8.0
Calcium (%)	1.4	0.41	0.15	0.34	0.1	0.6
Phosphorous – Total (%)	0.2	0.21	0.25	0.21	0.1	0.12
Potassium (%)	0.12	1.57	0.9	1.08	0	1.6
Roughage Activity (%)	20	100	100	100	100	100

(Lalor et al., 1975)

[1] ENE = Estimated Net Energy

[2] MC = Millions of Calories

[3] Cwt=Hundred weight

*Not Reported

Table 2. Nutrient composition (% DM) and density (lb/ft^3) of chemically and mechanically treated cotton gin waste.

Nutrient Value[1]	Treatments[2]		
	Cont	Ext	P&E
DM	85.07	86.82	86.12
Ash	8.66	9.23	8.59
OM	91.34	90.77	91.41
CP	11.40	11.37	10.48
NDF	59.52	66.26	65.99
ADF	50.98	54.20	54.38
Density	6.43	10.17	10.80

(Bernard, 1998)

[1] DM – dry matter, OM – organic matter, CP – crude protein, ADF – acid detergent fiber, NDF – neutral detergent fiber

[2] Cont – untreated cotton gin waste, Ext – extruded cotton gin waste, P&E – predigested and extruded cotton gin waste

Table 3. Chemical residues for various mixing ratios of cotton gin by-products and cottonseed.

Cotton Gin By-Product Percentage (%)	Methyl Parathion (ppm)		DEF (ppm)		Karate (ppm)	
	Non-Extruded	Extruded	Non-Extruded	Extruded	Non-Extruded	Extruded
100	3.44	0	19.90	0	0.66	0
75	2.96a	2.28b	19.90a	11.56b	0.47a	0.35a
70	3.16a	2.56b	16.27a	9.95b	0.49a	0.43a
60	2.57a	1.62b	9.01a	5.40a	0.43a	0.34a
50	2.37a	1.80b	11.79a	6.67a	0.68a	0.38a
40	1.74a	1.21b	6.81a	4.58a	0.46a	1.17a

All values based on dry matter

*Not Reported

Table 4. Chemical residues based on mixing ratio information and adjusted by cotton gin by-product weight.

Process	Methyl Parathion (ppm)	DEF (ppm)	Karate (ppm)
Not Extruded	2.56a	12.76a	0.53a
Extruded	1.89b	7.63b	0.51a

All values based on dry matter.

Table 5. Nutritional values for various mixing ratios of cotton gin by-products and cottonseed.

Nutrient Value	100% CS	100% CGBP	25% CS	30% CS	40% CS	50% CS	60% CS
Crude Protein (%)	30.0a	15.5d	16.6cd	17.4cd	17.7cbd	19.1bc	20.1b
Adjustable Crude Protein (%)	30.0a	15.5d	16.6cd	17.4cd	17.7cbd	19.1bc	20.1b
Soluble Protein (%)	21.7a	19.0a	14.8a	16.5a	9.8a	23a	14.8a
Acid Detergent Fiber (%)	30.3a	46.5a	42.3a	47.1a	44.5a	46.7a	43.8a
Neutral Detergent Fiber (%)	41.5c	51.8b	56.0ab	58.1a	54.5ab	55.1ab	53ab
Total Digestible Nutrients (%)	80.0a	37.3f	41.5de	40.3e	42.8cd	44.5bc	45.7b
Net Energy of Maintenance (MCAL/LB)	0.95a	0.37f	0.42de	0.40e	0.43cd	0.45bc	0.46b
Net Energy of Gain (MCAL/LB)	0.70a	0.02e	0.08d	0.06de	0.10cd	0.12bc	0.14b
Calcium (%)	0.19e	2.11a	1.92ab	1.90ab	1.69bc	1.39cd	1.10d
Phosphorus (%)	0.84a	0.26e	0.41d	0.42d	0.49c	0.56b	0.61b
Magnesium (%)	0.40a	0.34b	0.35b	0.36ab	0.38ab	0.38ab	0.37ab
Potassium (%)	1.22c	1.61a	1.64a	1.63a	1.53ab	1.57ab	1.48b
Sodium (%)	0.004e	0.049ab	0.051a	0.047ab	0.042bc	0.035c	0.026d
Iron (ppm)	86e	1043a	554bc	631b	581b	400d	428dc
Zinc (ppm)	41a	30cd	29d	33bc	35b	33bc	35b
Copper (ppm)	5.67a	4.00b	4.33b	4.50b	5.00ab	4.50b	4.83ab
Manganese (ppm)	14e	83a	59bc	63b	59bc	48cd	44d
Molybdenum (ppm)	1.20b	1.73a	1.25b	1.47ab	1.50ab	1.42b	1.35b
Sulfur (%)	0.29c	0.39a	0.37ab	0.37ab	0.35ab	0.32bc	0.32bc
Ash (%)	*	*	12.1ab	12.5a	11.25b	9.1c	8.6c

All values based on dry matter

*Not reported

Table 6. Chemical residues for 75% cotton gin by-products and 25% cottonseed mixture extruded multiple times.

Number of Times Processed	Methyl Parathion (ppm)		DEF (ppm)		Karate (ppm)		Dropp (ppm)	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
0	10.3a	4.3	47.8b	7.3	3.6a	2.00	6.25a	0.843
1	10.8a	1.5	81.0a	10.6	2.5a	0.40	0.40b	0.161
2	8.0ab	2.8	71.0ab	22.5	2.3a	0.20	0.34b	0.063
3	4.2b	1.3	70.7ab	18.9	2.2a	0.37	0.32b	0.138
4	3.1b	0.5	74.7ab	22.2	2.9a	1.66	0.29b	0.078

All values based on dry matter

Table 7. Chemical residues for 75% cotton gin by-product and 25% cottonseed mixture.

Process	Methyl Parathion (ppm)		DEF (ppm)		Karate (ppm)		Dropp (ppm)	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Not Extruded	10.3a	4.3	47.8b	7.3	3.6a	2.0	6.25a	0.84
Extruded	6.5a	3.5	74.3a	16.9	2.5a	0.8	0.34b	0.11

All values based on dry matter

Table 8. Nutritional values for 75% Cotton gin by-products and 25% cottonseed extruded multiple times.

Nutrient Value	Pass 0	Pass 1	Pass 2	Pass 3	Pass 4
Crude Protein (%)	18.7ab	19.7a	18.1bc	17.0c	16.9c
Adjusted Crude Protein (%)	17.1a	19.7a	18.1a	17.0a	16.9a
Soluble Protein (%)	20.0a	14.0b	14.7b	14.7b	14.3b
Acid Detergent Fiber (%)	52.2ab	49.0b	52.1ab	53.9ab	54.7a
Neutral Detergent Fiber (%)	60.1bc	59.2c	63.4abc	66.2a	64.7ab
Total Digestible Nutrients (%)	43.8ab	44.3a	42.7abc	41.7c	42.3bc
Net Energy of Maintenance (MCAL/LB)	0.31ab	0.32a	0.29abc	0.27c	0.28bc
Net Energy of Gain (MCAL/LB)	0.068ab	0.077a	0.047abc	0.030c	0.040bc
Calcium (%)	1.45ab	1.67a	1.48ab	1.41b	1.39b
Phosphorus (%)	0.43b	0.48a	0.44b	0.41b	0.42b
Magnesium (%)	0.33bc	0.37a	0.34b	0.32c	0.33bc
Potassium (%)	1.44a	1.45a	1.44a	1.41a	1.43a
Sodium (%)	0.018a	0.019a	0.018a	0.017a	0.018a
Iron (ppm)	1127a	1290a	1270a	1157a	1377a
Zinc (ppm)	147a	158a	159a	144a	140a
Copper (ppm)	6.83a	7.33a	7.33a	6.67a	6.67a
Manganese (ppm)	57a	63a	59a	56a	57a
Molybdenum (ppm)	0.90a	1.03a	1.17a	0.90a	1.27a
Sulfur (%)	0.30ab	0.32a	0.30ab	0.29ab	0.28b

All values based on dry matter