UPDATE ON THE EXTRUSION OF COTTONSEED AND COTTON GIN WASTE MIXTURES

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Abstract

Whole cottonseed and cotton gin waste (CGW) 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 and pressure associated with extrusion would reduce the chemical residues in the CGW, reduce gossypol and aflatoxins in cottonseed, and affect the nutritional value of the mixture. This report describes the study through the extrusion process. Laboratory analyses of the samples are not available at this time and will be reported later.

Introduction

An estimated 2.8 million tons of cotton gin waste are produced by U. S. cotton gins annually, creating a significant problem in the ginning industry (Thomasson, 1990A). The quantity of cotton gin waste (CGW) 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 CGW per bale, with representative estimates of 700 to 1000 pounds per bale (Parnell, et. al., 1994). Currently, the most common methods of disposal include composting, direct land application, and livestock feed.

Kolarik, et al. (1978) reported that 37% of the CGW 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 gin waste disposal.

Typical CGW consists mainly of 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 CGW 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 CGW has emerged.

Interest in feeding livestock CGW dates back to the early 1950's. During the last 48 years, a vast amount of supportive information was generated. Lalor, et al. (1975) reported that the nutritional value per ton of CGW 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 CGW ration and those on a regular ration (Williams et al., 1982). Stent (1974) suggested a ration of 25% CGW was acceptable, if economically feasible. Based on nutritional values, monetary estimates for CGW as a feed product range from $19 (Williams, et al. 1982) to $35 (Lalor, et al., 1975) per ton.

The limited use of CGW 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 CGW was unrepresentative of the available protein due to lignification, silification, and/or low energy digestibility. Digestibility can be improved through chemical treatment of the CGW. Gaseous oxidants such as ozone, hydrogen peroxide, and other superoxide species can be dissolved in a caustic solution and blended with CGW to increase in virto digestibility (Cornett, 1991). Although research has shown the beneficial utilization of CGW in livestock rations, the widespread practice is generally discouraged due to the lack of knowledge concerning chemical residues in CGW.

The potential for chemical residues in CGW result from the application of insecticides, herbicides, growth regulators, and defoliants. 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 CGW 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 CGW (Swanson, 1998).

Approximately 8.5 million tons of cottonseed are produced annually in the U. S. For over a century, the cattle industry has utilized cottonseed feed products as nutritional supplements. Recent concerns have focused on the levels of gossypol and aflatoxin that may be present in cottonseed and their effects on livestock.

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Gossypol is a natural substance in cottonseed, which can be toxic in its free form. Monogastric animals tend to be affected more than ruminants; however, the feeding of gossypol-contaminated products is discouraged until research establishes safe feeding levels. Lusby, et al. (1991) reported gossypol levels in whole cottonseed from 4,700 to 6,300 parts per million (ppm). Gossypol levels can be reduced through direct solvent, expander solvent, or mechanical extraction to levels of 3,000-, 1,000-, or 400-ppm, respectively (Lusby, et al. 1991).

Cottonseed grown under certain climatic conditions may be infected with the mold Aspergillus flavus, which produces aflatoxin. Aflatoxins have the characteristics of being the most carcinogenic of all natural compounds and are toxic to humans and animals (Groopman, et al., 1981). The maximum level of aflatoxin permitted by the U. S. Food and Drug Administration (FDA) in food, feed, or feed ingredients is 20 parts per billion (ppb). Ammoniation and other treatments have been developed to reduce aflatoxin toxicity in feed meals (Gardner, et al., 1971). There are several conflicting reports on the reduction of aflatoxins due to heat and pressure. Fischback and Campbell (1965) reported that it was necessary to raise the temperature to 300 ^{o}C or higher to decompose aflatoxins. Another report by Goldblatt (1966) stated that a temperature 100 ^{o}C decreased aflatoxin content and that the moisture content of the contaminated material was a significant factor.

Mayfield (1994) stated that blending cottonseed and CGW in an extruder at high temperatures and pressures may reduce the chemical residues found in CGW. Thomasson, et al. (1998) conducted an extrusion study to determine chemical residue reductions associated with cottonseed and CGW 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 CGW with reduced chemical residue levels in the product. Thomasson, et al. (1998) also reported that the heat and pressure associated with the extrusion process greatly reduced gossypol levels in cottonseed.

In another study, a twin screw extruder was used to process CGW and CGW 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 ^{o}C. Bernard (1998) concluded that the extrusion process improved the texture of the material in terms of handling, increased the bulk density of the CGW by 61.5%, and did not affect the nutrient digestibility. Treatment with SP2000 was shown to further increase the digestibility of the CGW 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 CGW and SP2000 treated CGW are shown in Table 2.

This study is a continuation of work by Thomasson, et al. (1998) and will focus on a more narrow range of CGW and cottonseed mixing ratios, higher extrusion temperatures, and aflatoxin contaminated cottonseed. The purpose of this study is to determine the feasibility of dry-extruding cottonseed and CGW 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 cotton-gin-waste. The extrusion process will also be evaluated to determine its effects on gossypol and aflatoxin levels in cottonseed. Further, mixing ratios of cottonseed to cotton-gin-waste will be evaluated to determine the optimum ratio in terms of texture, nutritional value, and economics.

Materials and Methods

This project was divided into two sections to fulfill the objectives of the study. The primary section evaluates the chemical residue and gossypol reductions associated with dry-extruding mixtures of cottonseed and CGW at high temperatures and pressures. The secondary section determines the effect of heat and pressure associated with the dry-extrusion process on aflatoxin reductions in cottonseed.

The chemical residue and gossypol study required 1,000 pounds of CGW and 1,000 pounds of cottonseed. The CGW (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 at full-scale gins. Burdette Gin Company in Burdette, Mississippi supplied the CGW and the cottonseed was collected at the U. S. Cotton Ginning Laboratory (USCGL), USDA/ARS, in Stoneville, Mississippi. The Anderson Clayton Corporation in Phoenix, Arizona supplied 2,000 pounds of aflatoxin-contaminated cottonseed for the secondary section of this study and shipped it to Des Moines, Iowa, for extrusion.

In order to determine if the dry-extrusion process would reduce chemical residues in CGW, it was necessary to apply known chemicals in known concentrations to the CGW. Applying additional chemicals, in known quantities, to the CGW ensures chemical presence in all the CGW 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 CGW. These chemicals included Prep, DEF, Dropp, Methyl Parathion, and Methomyl (Lannate). Mayfield (1994) suggested that DEF was most likely the highest concentrated residue found in typical CGW. Based on this information, it was determined that 1% of the normal application rate for DEF could represent the high end of the expected chemical residue range for DEF in CGW. Due to the limited information on current chemical residues in CGW, the 5 selected chemicals were applied to the CGW at 1% of the normal application rates.

Application of the chemicals to CGW was performed at the USCGL in the following manner. First, the CGW 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 CGW in pre-discussed concentrations. After the recommended re-entry period, the CGW was baled. The CGW 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. An Insta-Pro 1500 continuous horizontal press was used after the dry-extruder in the aflatoxin contaminated cottonseed section.

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 180 °C 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 cambers. 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 extrusion process required a total weight of 100 pounds per sample. Mixing ratios of CGW 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 % seed to % CGW, 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 CGW and cottonseed mixture section of this study, several samples were collected for various analyses. Before the chemicals were applied to the CGW, 5 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 applied chemical reduction due to time. While mixing the CGW and cottonseed, a total of 16 CGW and 6 cottonseed samples were randomly taken for residue, gossypol, and nutritional analyses. Ten CGW samples were used for residue analyses, 3 CGW and 3 cottonseed samples were used to determine the initial total-gossypol and free-gossypol levels, and 3 CGW and 3 cottonseed samples were used for initial nutritional analysis. Before each CGW and cottonseed mixture was extruded, 7 random samples were taken. Residue analysis was preformed on 5 samples, 1 sample was used to determine the total-gossypol and free-gossypol levels in the mixture, and 1 sample was used to determine the nutritional value of the mixture. After the extrusion process, 8 random samples were collected. Residue analysis was preformed on 5 samples, 1 sample was used to determine the total-gossypol and free-gossypol levels in the mixture, 1 sample was used to determine the nutritional value of the mixture, and 1 was used for texture observation.

The various samples collected during the CGW and cottonseed mixture section were analyzed at different facilities. Chemical residue samples were shipped to the Alabama State Pesticide Laboratory at Auburn University for analyses. Gossypol analyses will be preformed at the Agricultural Research and Extension Center in San Angelo, Texas. The nutritional and texture samples were transported to Stoneville, Mississippi, where a local laboratory will perform the nutritional analyses and the USCGL will perform the texture evaluation. The results are not reported herein but will be reported later.

The secondary section of this study, aflatoxin contaminated cottonseed, focused on the dry-extrusion process at 6 temperatures. The temperatures were 104-, 116-, 127-, 138-, 149-, and 160-°C. Three replicates were preformed for a total of 18 test lots. Each lot required 100 pounds of sample material. Test lot numbers were assigned in a randomized arrangement to limit the effects of processing order.

During the secondary section of this study, 4 samples were taken from each test lot. Two of the samples were randomly collected before extrusion and the other two samples were randomly collected after extrusion. All these samples were transported to Stoneville, Mississippi for aflatoxin and nutritional analyses by a local laboratories. The results are not reported herein but will be reported later.

Future Work

Upon completion of the chemical residue, gossypol, nutritional, and aflatoxin analyses, the results will be statistically analyzed to determine the feasibility of extruding CGW and cottonseed together for a livestock feed.

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Table 1. Comparative Chemical and Nutritive Value of Selected Roughages (Lalor et al., 1975)

	Alfalfa Hay	Bermuda Hay	Cotton Gin Waste	Prairie Hay	Rice Hulls	Sorghum Stover
ENE[1]						
Maintenance (MC[2]/Cwt)	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
Dig 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	*	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	*	1.6
Roughage Activity (%)	20	100	100	100	100	100

[1] ENE = Estimated Net Energy
[2] MC = Millions of Calories

Table 2. Nutrient Composition (%DM) and Density (lb/ft^3) of Chemically and Mechanically Treated Cotton Gin Waste (Bernard, 1998).

	Treatments		
	Cont	Ext	P&E
DM2	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

Cont – untreated cotton gin waste, Ext – extruded cotton gin waste, P&E – predigested and extruded cotton gin waste
DM – dry matter, OM – organic matter, CP – crude protein, ADF – acid detergent fiber, NDF – neutral detergent fiber