THE COBY PROCESS: EFFECTS ON DIGESTIBILITY OF COTTON GIN BYPRODUCTS BY LAMBS

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Abstract

The Cotton Byproduct (COBY) process, developed at the USDA-ARS Cotton Production and Processing Research Unit in Lubbock, Texas, is a procedure used to add value to cotton gin byproducts (CGB) whereby a gelatinized starch solution is applied prior to extrusion. A metabolism study and two in vitro experiments were performed to determine the effects of the COBY process on in vitro dry matter digestibility (IVDMD), apparent dry matter digestibility (ADD), feed intake (FI), nitrogen balance (NB), and nitrogen retention as a percentage of intake (NRi) and absorption (NRa). Concentrate diets containing a 30% roughage portion of cottonseed hulls (CSH), ground gin byproducts (GGB), COBY with 4 (COBY 4) or 13% (COBY 13) added starch were analyzed via two separate in vitro analyses and used in a metabolism study. Twenty-four crossbred wether lambs were utilized to determine the effects of the experimental diets. In vitro results indicated that CGB were more digestible ($P < 0.01$) than cottonseed hulls. Results of the metabolism study exhibited 6 to 10% higher digestibility values than those obtained during the in vitro studies. The GGB and COBY 4 showed more acceptable NB, NRi, and NRa. Of all variables measured, CSH treatment diets were superior only for feed intake. However, when all variables were simultaneously accounted for, the best overall feeding value was the GGB and COBY 4 treatments. Data obtained from all experiments conducted during this study indicate CGB processed via COBY to be a viable roughage alternative for ruminant animals.

Introduction

Cotton gin byproducts (CGB) consist primarily of organic components of the cotton plant removed during the ginning process. The byproducts, traditionally referred to as gin waste, are generally comprised of burs, immature lint (motes), stems, leaves, seed, and other material resulting from the ginning operation (Logan et al., 1958; Alberson and Hurst, 1964). There are approximately 2.5 million plus tons of byproducts being generated from cotton gins each year across the cotton belt of the United States (1997 Census of Agriculture). Due to the quantity being generated, an economical and efficient means of utilizing CGB has been the focus of numerous research projects over the years. These research projects have evaluated the usefulness and feasibility of using the byproducts in various applications such as fire logs (Karpiscak et al., 1982), an energy source (Beck and Clements, 1982; Lacewell et al., 1982; Parnell et al., 1991 ; White et al. 1996)), raw materials in asphalt roofing products (Kolarik and Smith, 1978), compost (Hills, 1982; Shumack et al., 1991; Truhett, 1994, Ayers, 1997) and livestock feed (Holloway et al., 1974; Conner and Richardson, 1987; Poore and Rogers, 1995). The amount of research that has been performed on this subject is far more extensive than indicated in the few examples above. For a more thorough overview of research efforts, refer to Thomasson (1990). Despite extensive research efforts, very few uses for CGB ever reached widespread commercial acceptance.

In an effort to address widespread utilization of CGB, a patent pending process was developed at the United States Department of Agriculture, Agriculture Research Service (USDA-ARS) Cotton Production and Processing Research Unit (CPPRU) in Lubbock, TX to enhance the value of these byproducts. The system is known as the COBY (COtton BYproducts) process and is designed as a value-added operation to produce either a livestock feed, fertilizer, fuel, and/or mulch utilizing the same basic equipment regardless of the final product desired. Due to the concentration of livestock feeding operations within a 300 mile radius of the CPPRU, seven million plus head of cattle fed in 1998 (Southwestern Public Service Company, 1999), data were needed on the quality of forage produced as a result of the COBY process.

Mayfield (1991) stated that the highest value of CGB could be achieved through livestock feeding. Following laboratory nutritional analysis, Lalor et al. (1975) determined raw unprocessed CGB to be of moderate energy and protein content similar to bermuda and prairie grass hay. Additional studies have shown unprocessed CGB to be lower in total digestible nutrients when compared to alfalfa hay, but the energy contents of both were similar (Johnson, 2000). However, poor handling characteristics and low digestibility, compared to other common roughages, has limited the use of unprocessed CGB by feedlots and livestock producers. Extrusion is one processing technique that has shown the ability to alter both chemical and physical structures of feedstuffs. Research has shown that extrusion not only gelatinizes starch and denatures proteins (Lund, 1984; Williams, 1986; Insta Pro, 1997; Riaz, 2000), but increases the availability of nutrients to microbial fermentation and enhances overall digestibility of a number of feedstuffs (Bjorck et al., 1984; Cheftel, 1986; Hauck et al. 1994). Likewise, extrusion of byproducts has been found to be an effective means of processing waste materials into high quality feeds (Kiang, 1999; Said, 2000).

The abrasiveness of CGB has been a major cost factor associated with processes designed to add value or handle them. Costs associated with CGB cleaning and wear and tear of the equipment often accounts for one-half the cost of processing. The application of a gelatinized starch solution, to the CGB, prior to extrusion has resulted in significantly reducing wear of the processing equipment (Holt et al., 2001). Processing of CGB via the COBY process is a new concept, and its effect on the quality and value of roughage for ruminants are unknown. Thus the objective of this research was to determine the effects of the COBY process on digestibility and nitrogen utilization when CGB are used as a roughage source in concentrate diets of growing and finishing lambs.

Equipment and Procedures

Overview of the COBY Process

The COBY operation is a process that converts CGB into a uniform extruded product, or into a pelletized material, Figure 1. Raw CGB consists primarily of burs, sticks, leaves, lint, and immature seed. This raw product is typically conveyed into a live-bottom bulk storage bin. From the bulk storage bin, the CGB is fed at a regulated rate into an auger conveyor equipped with overhead spray nozzles. The spray nozzles apply a gelatinized starch and water slurry to the CGB. The blending action of the auger conveyor distributes the starch solution throughout the byproducts. The resulting mixture is then conveyed under ingredient feeders (not used for this research) for application of various additives that are helpful in processing or that add value to the final product. The blending conveyor, blends and conveys the coated raw materials to a side feeder which feeds an extruder. From the extruder, the product is conveyed under additional ingredient feeders (not used) to a belt drier. After drying, the extrudate is cooled, or pelletized, and then packaged for storage.

Experimental Procedure for In Vitro Study

Two laboratory analyses were conducted to determine the effects of the COBY process , with two levels of added starch, on in vitro dry matter digestibility (IVDMD) of CGB. Treatments for this experiment were arranged in a complete randomized block design and included the four concentrate diets of cottonseed hulls (CSH), ground gin byproducts (GGB), and COBY products with 4% (COBY 4) and 13% (COBY 13) added starch. Composition of the individual forages is shown in Table 1. Prior to analysis, all samples were ground through a Wiley Mill fitted with a 1-mm screen. In vitro dry matter digestibility was determined by the Moore modification of the two-stage Tilley and Terry procedure as described by Harris (1970). Ammonia release determination, the second stage of the procedure, was not performed.

The CGB used for this study were obtained from a gin located in the Texas South Plains and processed at the USDA-ARS Cotton Production and Processing Research Unit in Lubbock, Texas. An Insta-Pro model 2000 Extruder was used in the process. Extrusion temperatures obtained during processing were 190 to 225°F. A water solution of feed-grade gelatinized cornstarch was heated to 180 to 190°F and sprayed onto the CGB at predetermined levels prior to extrusion. The extrudate was dried in the belt drier and bagged prior to delivery to the Animal Science Nutrition Laboratory at Texas Tech University, Lubbock, Texas.

Rumen fluid was collected from a ruminally cannulated steer receiving a 50% concentrate diet and fed at maintenance levels. Digestion tubes were placed in a 102°F water bath and incubated for 6, 12, 24, 48, and 72 hours. Following incubation, samples were filtered using a modified Buchner funnel and ashless filter paper (Whatman #541; Whatman International Ltd. Kent, ME). Sample-containing filter papers were dried in a 212°F forced-air drying oven for 24 hours, dried, and weighed.

Data for the metabolism feeds and individual forages were analyzed separately as complete randomized designs with a factorial arrangement of treatments using the general linear model of SAS (1995). Statistical analysis was conducted to determine if treatment, hour of inoculation, or the interaction would effect IVDMD. Digestibility was further tested by contrasting the metabolism feeds and individual forages. Contrasting treatments for the feeds were: 1) CSH versus all CGB treatments; and 2) GGB versus all COBY treatments. For the individual forages, contrasted treatments were: 1) CSH versus all CGB treatments; 2) GGB versus all extruded CGB; and 3) EGB versus COBY treatments. The LS means procedure was utilized to determine the probability of differences between means.

Experimental Procedure for Metabolism Study

Twenty-four crossbred wether lambs (avg. Wt. 59 lbs) were utilized in a completely randomized block design to determine the effects of the COBY product as the primary roughage source in high concentrate diets for growing and finishing lambs. Variables measured included feed intake (FI), apparent dry matter digestibility (ADD), nitrogen balance (NB), and nitrogen retention as a percentage of intake (NRi) and absorption (NRa).

Experimental diets were formulated to meet NRC (1985) requirements for growing and finishing lambs. Diets were composed of 70% concentrate and a 30% roughage portion containing either CSH, GGB, COBY 4, or COBY 13. Cracked corn, cottonseed meal, and soybean meal were utilized to make the diets as isocaloric and isonitrogenous as possible. Ingredient composition and chemical analysis of the experimental diets are shown in Table 2. Prior to the start of the experiment, diets were mixed and analyzed for nutrient content at the Texas Tech University Feed Mill.

Upon arrival at the research farm, lambs were shorn, vaccinated, dewormed, placed into group pens, and adapted to a high concentrate diet. At the start of the study, lambs were weighed and assigned to one of four treatment diets based on initial weight and location within the metabolism building. An environmentally controlled building and individual false-bottom metabolism stalls were utilized to house the animals for the entire study. Lambs had continuous access to water via automatic waterers. The 32-day study consisted of 15 days adaption, 10 days preliminary, and 7 days collection. During the adaptation period, animals were allowed free access to the assigned experimental diets and accustomed to the environment, feed, and feeding schedule. This allowed time for the previously fed diet to void the animals digestive system. The final two periods were identical except that during the collection period the animals were fed at 95% of their predetermined intake and subsequent feces and urine were composited and preserved for analysis.

Each lamb was fed at the same time every day. Urine, feces, and feed refusals were also collected at the same time starting with the first lamb at 0700 hours. Samples of feed were collected daily and composited at the end of the study for further chemical analysis. A 20% aliquot of daily fecal output and feed refusals, for each lamb, were frozen immediately for further chemical analysis, while the rest was dried in a 122°F forced-air oven until completely dry (approx. 24-27 hours) for dry matter determination. Urine was collected in plastic vessels containing sufficient 50% HCl solution to maintain a pH below 2.0. When collected each day, initial urine weight and volume were recorded. Because specific gravity varies in urine, distilled water was used to bring the weight up to a constant 5.5 lbs. The diluted urine was then mixed and a 2% aliquot was poured into a composite sample bottle. Again, pH was maintained below 2.0 by HCl acid addition. At the end of the experiment, composited urine samples were mixed and a 6.5 oz sample was frozen for further analysis. On the last day of collection, animals were weighed and all samples were transported to the lab for analysis.

Dry matter and nitrogen (N) determinations were made on feed, feces, feed refusals, and urine (N determinations only) according to AOAC (1980) procedures. Acid detergent fiber (ADF) and neutral detergent fiber (NDF) analysis of feed, feces, and feed refusals were analyzed by the methods described in Goering and Van Soest (1970). The calculation of ADD and NB were performed as per Harris (1970). Formulas used to calculate NRi and NRa are as follows:

Consumed N	= lbs of Feed Consumed x N Content
Fecal N	= lbs of Feces Produced x N Content of Feces
Urinary N	= oz of Urine Produced x N Content of Urine
N Retained	= Consumed N - Fecal N - Urinary N
Nri	= (N Retained / Consumed N) x 100
Nra	= (N Retained / (Consumed N - Fecal N)) x 100

Statistical analysis was conducted as a complete randomized block design with animals blocked by initial weight. In addition, large variations among initial weights (46 to 75 lbs) resulted in it being applied as a covariate rather than separated into heavy, medium, and light blocks. Experimental parameters evaluated were FI, ADD, NB, NRi, NRa. Means were separated using the least significant difference procedure. Additional analysis by linear contrast of the treatments was performed by contrasting the following: 1) CSH versus all CGB treatments; 2) CSH versus all extruded treatments; and 3) GGB versus all extruded treatments.

Results and Discussion

In Vitro Study

The effects of the COBY process on IVDMD of the metabolism feeds and the individual forages are shown in Tables 3 and 4, respectively. An interaction between treatment and hour did exist ($P < 0.01$) and reported values account for this interaction.

Overall, metabolism diets containing CGB were more digestible ($P < 0.01$) than those containing CSH. However, the COBY treatments did not differ ($P = 0.2881$) from GGB. Rates of digestibility appeared similar among all treatments and peak digestibility was reached by 24 hours for all diets except COBY 13. COBY 13 treatment reached peak digestibility at 48 hours incubation. As can be seen on Table 3, the highest digestibility for COBY 4 occurred at 72 hours and not 24 hours as previously stated. However, this value could easily be considered an outlier since digestibility typically tapers off by 24 to 48 hours for concentrate feeds. Likewise, there is not significant difference between digestibilities, for any given treatment, at the 48 and 72 hour intervals.

COBY 13 exhibited the highest IVDMD, while COBY 4 was approximately 10% less. EGB was consistently less digestible that GGB, suggesting that extrusion alone had little effect on the digestibility of CGB. The byproduct treatments as a whole proved more digestible ($P < 0.01$) than CSH with all extruded treatments demonstrating faster rates of digestibility.

One point of interest that could affect the IVDMD of the EGB and COBY 13 is the lower temperatures and thus less size reduction obtained during processing. Since extrusion increases surface area of the material for microbial attack (Cheftel, 1986), less grinding by the extruder could alter the digestibility. Variations occurred due to the difficulty in extruding 100% CGB. When extruding 100% CGB, excess water was required to allow for processing. This resulted in lower processing temperatures (approx. 25°F) than was obtained for COBY 4. The COBY 13 treatment experienced decreased operating temperatures due to excess moisture but for a different reason . At the time of processing, additional starch was added using the slurry pump shown in Figure 1. Since that time, the process has been refined to allow for the addition of higher starch levels without adding excess moisture, thus allowing processing temperatures to be maintained at a steady 220 to 225°F. Constant processing temperature aides in producing a more consistently ground product.

Metabolism Study

The effects of the COBY process on FI, ADD, N balance, NRi, and NRa are shown in Table 5. Feed intake was greatest ($P < 0.05$) for those animals consuming the diet with CSH when compared to those receiving the GGB or COBY treatments. Palatability is another issue that affects feed intake. By observing the lambs during this study, COBY 4 was the least acceptable and exhibited the lowest palatability of all treatments diets. However, feed intake for GGB and COBY treatments were not different ($P > 0.05$).

The COBY treatments demonstrated the highest values for ADD. Cottonseed hulls exhibited the lowest ADD, but did not differ from GGB. Unlike the results observed for ADD, COBY treatments did not positively affect NB. GGB and CSH displayed similar higher values ($P < 0.05$) for NB when compared to COBY 4 and 13. GGB demonstrated the highest nitrogen retention ($P < 0.05$) values, but did not differ from COBY 4 in the case of NRa. Cottonseed hulls and COBY 13 did not differ in NRi and NRa, but COBY 13 did exhibit the lowest numerical values in both cases. Percent crude protein of all diets used for this experiment must be considered when comparing the nitrogen utilization data. Due to the inconsistent composition of CGB, formulation of isonitrogenous diets was not accomplished. Because the crude protein (CP) content of CSH and GGB diets was slightly higher (1.4%) than that of the COBY treatments, it could be a factor in some of the nitrogen utilization responses observed.

Even though the exact cause of the nitrogen utilization is unknown, reduced utilization in the COBY 13 treatment could be the result of a Maillard reaction and a more acidified rumen environment from additional starch. Nitrogen retention of COBY 4 was greater ($P < 0.05$) than that of COBY 13, suggesting that additional starch may increase the amount of indigestible protein resulting from the Maillard reaction. A limited amount of starch does appear to be beneficial though since the COBY 4 treatment had 1.4% less CP and yet showed higher numerical values for NRi and NRa than CSH. Even though GGB had the highest values for NR, it could be the result of having the highest level of dietary CP compared to the other concentrate diets.

Summary

The in vivo and in vitro analyses accomplished in this study provide evidence that digestibility of CGB can be enhanced by the COBY process. In the metabolism study, however, positive results were not apparent in the case of FI and NB. Of all the treatments utilized, GGB proved the best in terms of NB but differed little from COBY 4 in terms of NR. Cottonseed hulls and the extruded treatments were not different in terms of NR. By combining all the information gathered during this study, it appears that GGB and COBY 4 are excellent roughage sources for ruminants consuming primarily concentrate rations. These products could possibly replace all or a portion of the commonly utilized CSH. Further research is needed to determine the effects of GGB and COBY products as roughage sources on performance characteristics of ruminants receiving high concentrate rations.

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Disclaimer

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Table 1. Composition of individual forages.

	Treatments*				
	CSH	**GGB**	**EGB**	**COBY 4**	**COBY 13**
Dry Matter, %	91.24	90.67	92.58	93.37	92.75
Crude Protein, %	7.23	8.54	7.10	7.92	7.94
Neutral Detergent Fiber, %	77.63	53.29	73.59	63.78	53.66
Acid Detergent Fiber, %	63.96	44.46	33.87	40.86	32.63
Hemicellulose, % #	13.67	8.83	39.72	22.92	21.03

[*] All values except dry matter are expressed on a dry matter basis. CSH = Cottonseed Hulls; GGB = Ground Gin Byproducts; EGB = Extruded Gin Byproducts; COBY 4 & 13 = COBY processed byproducts with 4% and 13% added starch, respectively.
Calculated by subtracting Acid Detergent Fiber from Neutral Detergent Fiber.

Table 2. Ingredient and chemical composition of metabolism diets.

	Treatments*			
	CSH	**GGB**	**COBY 4**	**COBY 13**
Ingredient Composition (% of DM)				
Corn, cracked	42.93	46.45	48.21	45.19
Cottonseed meal, 41% CP	10.32	8.56	7.50	9.38
Soybean meal, 44% CP	6.00	4.24	3.54	4.68
Cottonseed hulls	30.00			
Ground gin byproducts		30.00		
COBY 4			30.00	
COBY 13				30.00
Molasses, cane	7.00	7.00	7.00	7.00
Fat, vegetable	1.50	1.50	1.50	1.50
Limestone, ground	1.25	1.25	1.25	1.25
Salt	0.25	0.25	0.25	0.25
Ammonium chloride	0.50	0.50	0.50	0.50
Vitamin/Mineral premix #	0.25	0.25	0.25	0.25
Chemical composition				
Dry Matter, %	86.72	85.88	86.87	86.61
Energy (Nem), mcal/kg @	1.67	1.66	1.69	1.70
Crude Protein, %	13.15	13.41	11.74	11.95
Neutral Detergent Fiber, %	33.42	23.59	27.19	20.31
Acid Detergent Fiber, %	22.45	17.04	17.55	16.05
Hemicellulose, % &	10.97	6.55	9.64	4.26

[*] CSH = Cottonseed Hulls; GGB = Ground Gin Byproducts; COBY 4 & 13 = COBY processed byproducts with 4% and 13% added starch, respectively.
[#] Vitamin/Mineral premix provides 1410 IU/kg Vitamin A, 15 IU/kg Vitamin E, 166.5 IU/kg Vitamin D, and 0.3 mg/kg Selenium.
[@] Calculated values based upon NRC 1985.
[&] Calculated by subtracting Acid Detergent Fiber from Neutral Detergent Fiber.

Table 3. In vitro dry matter digestibility of metabolism treatment diets.

	Incubation Hour #				
Treatment:*	**6**	**12**	**24**	**48**	**72**
CSH	32.44aw	47.44ax	64.19ay	65.79ay	65.74ay
GGB	39.97bw	52.47bx	71.71by	68.81bz	67.73abz
COBY 4	41.99bcw	55.16cx	68.65cy	68.08by	68.70by
COBY 13	39.31bdw	53.59bcx	65.27ay	68.16bz	68.03bz

abcd = Different superscripts within the same columns differ (P < 0.05)

wxyz = Different superscripts within the same row differ (P < 0.05)

SE for all means = 0.7381

* CSH = Cottonseed Hulls; GGB = Ground Gin Byproducts; COBY 4 & 13 = COBY processed byproducts with 4% and 13% added starch, respectively.

Table 4. Comparison of two individual in vitro dry matter digestibility forage analyses.

	Incubation Hour					
	12		24		48	
Treatment:*	**Trial 1**	**Trial 2**	**Trial 1**	**Trial 2**	**Trial 1**	**Trial 2**
CSH	12.55b	4.60a	11.31b	9.93a	5.79a	22.90a
GGB	17.65c	19.81c	14.61c	25.63c	16.00b	30.55b
EGB	4.44a	9.80b	10.33a	23.51b	25.15c	35.37c
COBY 4	20.39d	30.43d	33.42e	33.35d	38.46d	44.13d
COBY 13	33.42e	34.05e	31.97d	42.95e	46.74e	52.22e
Mean Std. Err.	1.63	0.70	2.15	0.70	1.11	0.70

Different superscripts within the same columns differ (P < 0.05)

* CSH = Cottonseed Hulls; GGB = Ground Gin Byproducts; EGB = Extruded Gin Byproducts; COBY 4 & 13 = COBY processed byproducts with 4% and 13% added starch, respectively.

Table 5. Treatment effects on feed intake, apparent dry matter digestibility, nitrogen balance, and nitrogen retention as a percent of intake and absorption.

	Treatment*			
Treatment:#	**CSH**	**GGB**	**COBY 4**	**COBY 13**
Feed Intake, g/day	1345a	1162b	1052b	1133b
ADD, %	71.36a	71.99ab	74.79bc	76.66c
NB, g/day	8.40a	8.71a	6.10b	5.64b
NRi, %	29.79a	35.46b	30.70ac	25.81ad
NRa, %	48.00a	58.59b	53.55ab	44.53ac

Different superscripts within the same row differ (P < 0.05)

* CSH = Cottonseed Hulls; GGB = Ground Gin Byproducts; COBY 4 & 13 = COBY processed byproducts with 4% and 13% added starch, respectively.

ADD = Apparent Dry Matter Digestibility; NB = Nitrogen Balance; NRi = Nitrogen Retention as a percent of intake; NRa = Nitrogen Retention as a percent of absorption.

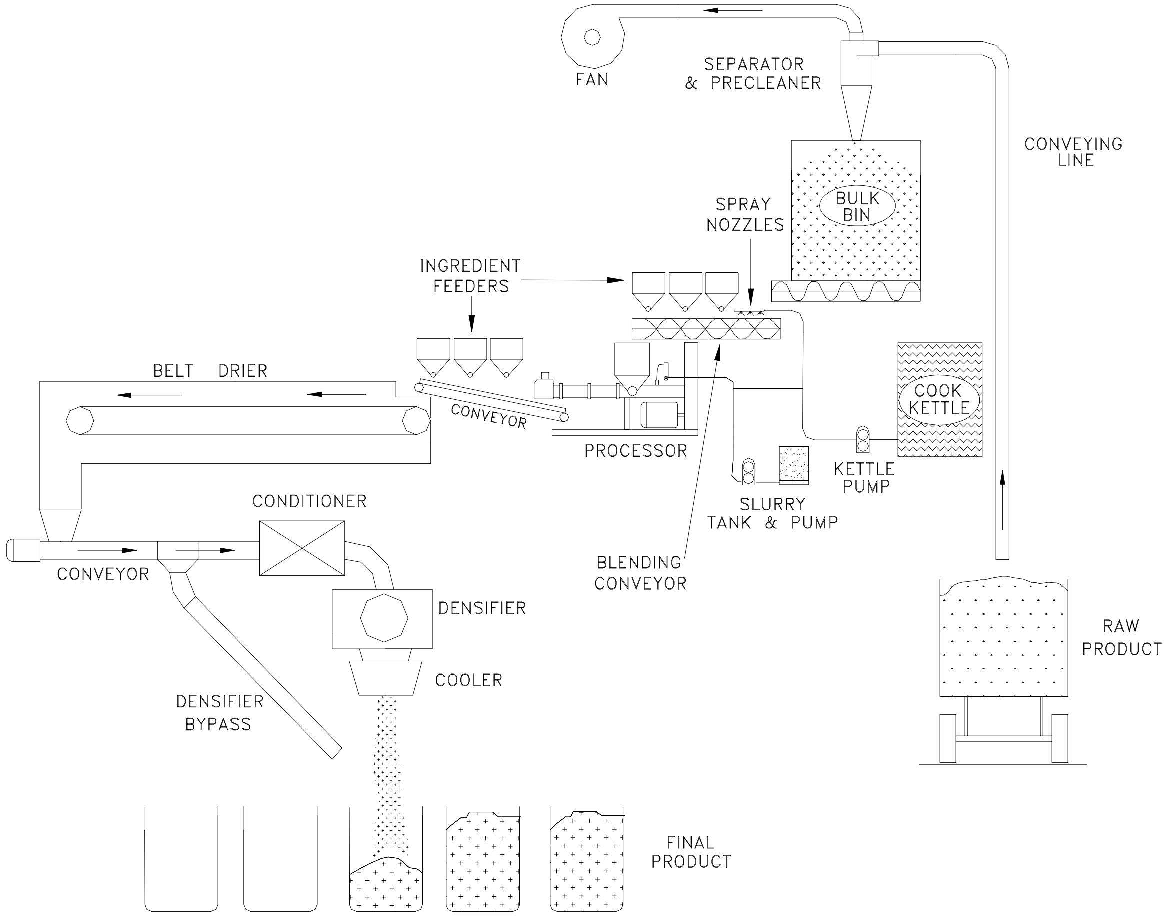

Figure 1. Schematic flow diagram of the COBY process.