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ENGINEERING AND GINNING

Engineering Economic Analysis of a Cotton By-Product Fuel Pellet Operation

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ABSTRACT

In the 2001 crop year, the United States produced approximately 19.8 million bales of upland cotton. From the bales produced, there was an estimated 2.9 million t (3.2 million tons) of waste generated in the ginning process. Moving cotton by-product from a liability to a source of income would be a positive strategy for ginners, oil mills, the textile industry, and producers. Processing cotton by-products into fuel pellets would furnish a renewable resource that could be used to reduce the consumption of fossil fuels, while having a minimal impact on the environment. The objective of this study was to explore the cost feasibility of creating a fuel pellet manufacturing operation utilizing cotton gin byproducts. In order to conservatively address key elements, such as marketing, transportation, and manufacturing, an economic model was developed and evaluated assuming a worst-case scenario. The cost system model was developed and analyzed to examine the factors influencing the sensitivity of critical areas such as cost and profits. The cost system model simulated changes for 24 cost variables associated with the proposed fuel pellet operation. Results from the analysis indicate the probability of obtaining a 15% return on investment as 29.95 or 54.4% depending on whether the product was shipped to various distribution hubs via truck or rail, respectively. Based upon the information contained in this study, it appears that a fuel pellet operation can be a viable means of utilizing cotton gin byproducts to enhance revenue.

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It was estimated that in the United States, there are approximately 2.04 million tonnes (2.25 million tons) of cotton gin waste (by-products) generated each year across the Cotton Belt (Holt et al., 2000a). In crop year 2001, the United States produced approximately 19.8 million bales of upland cotton (USDA-NASS, 2002). From the bales produced, there was an estimated 2.9 million t (3.2 million tons) of waste generated in the ginning process. In the same year, Texas produced 4,153,866 bales of upland cotton (USDA-AMS, 2002), which equates to an estimated 680,400 t (750,000 tons) of cotton gin waste. Past research has explored other ways to utilize gin by-products such as livestock feed, gardening compost, and raw materials in asphalt roofing products. Despite these efforts, most of the waste generated by the gins is discarded onto fields where it becomes a soil additive (Holt et al., 2000b). In the past, gin waste or byproducts have not been considered to have monetary value and were actually considered a liability (Holt et al., 2000a).

Converting cotton by-products (COBY) into usable materials was the premise of the USDA's work on the COBY process. This work resulted in a patent being issued for the COBY process (Holt and Laird, 2001a). Moving cotton by-product from a liability to a source of income would be a positive strategy for ginners, oil mills, the textile industry, and producers. Processing cotton by-products into fuel pellets would furnish a renewable resource that could be used to reduce the consumption of fossil fuels, while having a minimal impact on the environment.

During the 2000/2001 winter months (heating season), 662,200 t (730,000 tons) of fuel pellets were consumed (PFI, 2001). Fuel pellets are composed of biomass materials such as commonly grown plants and trees. The most common residential fuel pellets are made from sawdust and ground wood chips, which are byproducts generated from furniture, lumber, and other industries. Fuel pellets can be used in pellet burning fireplaces or stoves for residential use or burned in solid fuel boilers for industrial use. Figure 1 shows an example of a pellet burning commercial furnace that is used to heat office space.

Pellet stoves have become more popular in recent years. Data from the Pellet Fuels Institute (PFI) shows sales of fuel pellets in the 2000/2001 heating season increased 14.7% compared with the previous season (PFI, 2001). The regional distribution and sales in the United States indicate that nationally there has been a steady demand for fuel pellets over the past 6 yr. (Table 1). Some of the primary reasons for the steady sales of fuel pellets are due to a concern for the environment, unseasonably cold winters, and high natural gas and heating oil prices. A cost comparison between several fuel sources indicates that premium wood pellets compare favorably to common residential fuels, such as electricity, propane, and natural gas (Table 2).

Figure 1. Pellet-burning industrial furnace.

Table 1. Tonnes of fuel pellets distributed in the United States by region (PFI, 2001)

Region	2000-2001	1999-2000	1998-1999	1997-1998	1996-1997	1995-1996
Pacific	185,100	213,600	209,600	214,100	206,800	237,700
Mountain	109,800	80,740	108,900	97,980	97,980	111,600
Central	39,010	15,880	28,120	44,450	32,660	17,240
Great Lakes	23,590	17,330	24,490	19,960	40,820	32,660
Northeast	178,700	133,400	122,500	139,700	129,700	97,070
Southeast	57,150	56,250	52,620	44,450	44,450	35,380
Total	593,350	517,200	546,230	560,640	552,410	531,650

Table 2. Fuel cost comparison of wood pellets to other commonly used fuels (PFI, 2001)

Fuel[z]	Price ($)	Cost ($) per kJ (MMBTU) of usable heat
Premium wood pellets – 6% moisture 19.07 MJ/kg (8200 BTUs/lb) 80% efficiency	176.36 per tonne (160 per ton)	11.56 (12.20)
Electricity 3603 kJ/kW-h (3415 BTUs/kW-h) 95% efficiency	0.10 per kW-h	29.19 (30.80)
Propane 359.4 MJ/L (90,000 BTUs/gal) 80% efficiency	0.37 per liter (1.40 per gallon)	29.19 (30.80)
Oil #2 551 MJ/L (138,000 BTUs/gal) 80% efficiency	0.317 per liter (1.20 per gallon)	10.29 (10.86)
Natural gas 3599.4 kJ/kW-h (100,000 BTUs/therm) 80% efficiency	1.00 per MCF	11.85 (12.50)
Coal 27.9 MJ/kg (12,000 BTUs/lb) 75% efficiency	176.36 per tonne (160 per ton)	8.42 (8.88)
Firewood 18.96 kJ (20 MMBTU) 65% efficiency	130 per cord	9.48 (10.00)

[z] Efficiency rating is based on newer modern appliances. Older heating appliances may be far less efficient, therefore increasing cost per kJ.

MATERIALS AND METHODS

The overall objective of this study was to explore the economic feasibility from marketing, transportation, and manufacturing aspects of creating a fuel pellet manufacturing operation utilizing cotton gin by-products. To accomplish the overall objective, various goals were set for each of the financial aspects of marketing, transportation, and manufacturing.

From a marketing perspective, the two goals were 1) to determine the most economically feasible distribution area or target market region appropriate for the manufacturing location selected, and 2) to establish inventory requirements for both raw material and finished product to meet sales requirements. The transportation goals were 1) to determine the most economical mode of transportation for the finished product, and 2) to evaluate the sensitivity of return on investment to freight cost and mode of transportation. The manufacturing goals were 1) to develop a comprehensive cost system that could be used to determine machine and labor requirements, and 2) to examine economic sensitivity issues, such as sensitivity to raw material availability, capital equipment cost, productivity, transportation cost, labor cost, selling price, etc.

In order to address the three major components of the study (marketing, transportation, and manufacturing) several assumptions were made. The assumptions and their corresponding rationale are listed in Table 3.

The economic model addressed 14 key elements as follows: (1) annual operating profit, (2) annual sales, (3) production per season, (4) usable tonnes of waste, (5) total annual operating expense, (6) capital depreciation amount, (7) total utility cost, (8) total packing cost, (9) total shipping cost, (10) total freight cost, (11) total rental (lease) cost, (12) total repair and maintenance cost, (13) total cost savings to gin for waste disposal, and (14) return on investment (ROI).

To determine the projected values for these key elements, several "what if" analyses were performed using the Crystal Ball software package (Crystal Ball 2000, Decisioneering Inc., Denver, CO). The results are displayed as a forecast of what can be expected based on the laws of probability within a representative distribution.

Machinery and facility layout. A gin located in the West Texas region provided actual production data for the study. During the 2001 crop year, the gin production was 55,000 bales of cotton with an average processing rate of 50 bales per hour. According to the gin, half of their producers use field cleaners during harvesting. Past research has shown that non-field-cleaned cotton will yield about 317.5 to 362.9 kg (700 to 800 lbs) of waste per bale and field cleaned cotton about 136.1 to 158.8 kg (300 to 350 lbs) per bale (Baker et al., 1994; Holt et al., 2000b). Based

Table 3. Assumptions with their corresponding rationale used in the economic analysis

Assumptions	Rationale
1. There is a current demand for the product.	From PFI, 2001 (See Table 1).
2. All pellets produced will be bagged [18.14 kg per bag (40 lbs)].	Standard practice for the industry (PFI, 2001).
3. All pellets will be for the consumer market.	No commercial sales of pellets in bulk (worst-case scenario).
4. Distribution will be limited to a five state area (Texas, New Mexico, Colorado, Missouri, and Kansas).	History of fuel pellet consumption and proximity to the manufacturing plant.
5. All production will be sold wholesale to existing distribution companies.	Marketing strategy
6. There will be no long term warehousing of finished product.	Manufacturing strategy
7. A strategic advantage will be gained by operating in the five state region selected.	Based on current regional consumption (PFI, 2001) and proximity to the manufacturing plant.
8. No account for product spillage or loss	Spillage will be re-worked.
9. All costs include shipping the product to one of three distribution hubs.	Marketing strategy
10. No taxes or insurance costs will be considered in the analysis.	Analysis decision since taxes and insurance can vary based on plant location.
11. All transportation will be accomplished by rail or truck.	These are considered the two extremes for transportation.

on these numbers and input from the gin, it was calculated that the gin produced approximately 13,100 t (14,437 tons) of waste during the 2001 ginning season; this averages out to approximately 238.1 kg (525 lbs) of waste per gin bale. Not all waste is recoverable or usable. Other impurities, such as dirt and sand that are not desirable for this type of product, also exist in the raw material. From previous research, it was estimated that only about 80% of the total waste generated by the ginning process would be usable for the pellet operation (Holt et al., 2000a). This equates to 190.5 kg (420 lbs) of usable waste per bale. Currently, the gin pays $2.00 per bale to dispose of the waste, which calculates to a yearly disposal cost of $110,000.

The size and configuration of the production facilities were determined based on the production capacity of the machinery selected. Since the cooperating gin had ample acreage surrounding the gin, the building housing the fuel pellet processing equipment was to be located adjacent to the current gin operation. This would allow the gin's current waste disposal system to be utilized to feed the fuel pellet operation. The actual construction consists of a 306.6 m^2 (3300 ft^2) metal building on a concrete slab. The design of the building will utilize natural ventilation and a sufficient amount of lighting to assure a safe work environment. The building will be equipped with a covered loading dock to allow product to be loaded during inclement weather. There will be a 46.5 m^2 (500 ft^2) allotment of storage area designed into the building that will allow approximately three truckloads of palletized fuel pellet bags to be staged for truck loading. This will limit the on-site storage to approximately 8 hr of production.

The machinery selected for this operation was based on the information supplied by Insta-Pro International (Des Moines, IA) and other suppliers. The production rates and cost factors are considered to be "conservative" in nature. "Conservative" is defined as using the mid to upper level cost estimates obtained from equipment manufacturers that would represent a worst-case scenario. The production facilities daily production rate was set at approximately 70% of the anticipated average waste production of the gin (9527 kg/hr). From a production standpoint, it was considered ineffective to attempt to match the waste output of the gin, since the waste amounts could vary depending on whether the gin was experiencing operational difficulties. In an effort to reduce the impact that upset conditions in the gin would have on the throughput of the fuel pellet operation, the fuel pellet operation was designed to handle 70% of the gins output with the other 30% being stored outside for later processing.

Three Insta-Pro Model 9800 Extruders (Insta-Pro International, Des Moines, IA) were selected to give versatility to the production capacity. Insta-Pro estimates that the throughput of each extruder will be approximately 50% of its rated capacity for this type of waste. The actual capacity could be slightly higher or lower depending on the extruder's ability to handle the waste produced by the gin. The manufacturers' 100% capacity rating for each extruder is 4445 kg (9800 lbs) per hour. The remaining equipment was sized to handle the capacity of the extruders at approximately 75% of their rated capacity. This type of design enables the operation to scale back extruders in times of low gin trash production and scale up when the waste production increases.

It is believed that with the system design, a standard rate of 6668 kg (14,700 lbs) per hour could be maintained. During low gin waste generation times, an external feed hopper would be used to supplement the pellet operation by feeding previously bypassed waste back into the system. Table 4 contains a general description list and average cost of the capital equipment used for the study.

Due to the nature of the cotton by-products, a binding agent must be added to hold the pellet together after it is formed. In prior work, a gelatinized polysaccharide was utilized as the binder that required heated mixing tanks (Holt et al., 2001b). For this project, a different approach of using a cold starch slurry was implemented. The use of a cold starch slurry eliminated the need for boilers and hot mixing tanks. Our system utilized commercially available polypropylene 11,356 L (3000 gal) holding and mixing tanks. The volume of dry starch used in the process per season, approximately 417,300 kg (920,000 lbs), requires the use of a starch silo to hold bulk product. The cost for a used silo with all the equipment needed to deliver the product to the mixing tanks is approximately $100,000.

Short-term finished product storage was addressed by a staging area built into the pellet operation building and a 371.6 m^2 (4000 ft^2) short-term storage warehouse. Since the product is sensitive to external conditions, it was felt that a short-term on site storage facility would be prudent. The on-site warehouse was used to temporarily store approximately 400 pallets or about

Table 4. Capital equipment list with associated cost, in dollars, for the project

Item	Quantity	Description	Unit price ($)	Unit total ($)	Total ($)
1	1	External feed hopper	25,000	25,000	
2	2	Condensers	8500	17,000	
3	1	1.7 m x 1.5 m x 3.6 m live bottom hopper	25,000	25,000	
4	1	30.5 cm x 9.14 m screw conveyor	5141	5141	
5	1	3-way live bottom feeder bin w/ Leveling screw	15,625	15,625	
6	2	50.8 cm belt conveyor	6778	13,556	
				Sub-total	101,322
7	3	Insta-Pro Model 9800 extruders	173,250	519,750	
8	3	Cotton feeders for Model 9800 extruder	10,025	30,075	
9	3	Spare parts kit for Model 9800 extruder (optional)	6250	18,750	
10	1	BOM 430 box dryer	125,000	125,000	
11	1	Landers Model 4000-145 pellet mill	161,188	161,188	
12	1	45.75 cm x 9.14 m cleated belt conveyor	12,233	12,233	
13	1	BOM 207CX pellet cooler	46,351	46,351	
14	1	61 cm x 6.1 m Vibro screening conveyor	10,381	10,381	
15	1	15.25 cm x 15.2 m rerun screw Conveyor	5189	5189	
				Sub-total	928,917
16	1	Bag dump station w/ dust filter	9375	9375	
17	1	15.25 cm x 3.1 m screw feeder	2813	2813	
18	1	C3-175 bucket elevator x 7.3 m with service platform	4918	4918	
19	1	1.8 cubic m surge bin w/ support stand and gate	1744	1744	
20	1	15.25 cm x 3.1 m screw feeder	2813	2813	
21	2	Volumetric feeders for load cells	9375	18,750	
22	1	Tandem 11.6 cubic m Wylie tanks	6000	6000	
23	3	Additive spray systems	1600	4800	
24	1	Pump and piping for starch system	9000	9000	
25	1	371.6 sq. m warehouse	43,000	43,000	
26	1	Starch silo (used)	100,000	100,000	
27	1	Abel 4 bin cluster (90.61 cubic m capacity)	50,000	50,000	
28	1	Inglett 8300GVR-3500 bagging scale	174,663	174,663	
29	1	Fischbein PILS-200 bag sealer	39,938	39,938	
30	1	Chantland bag kicker	6072	6072	
				Sub-total	473,886
				Machine total	1,504,125
			Cost/sq m		
		Building	115.72		35,475
		Machine installation and start-up			250,000
		Machine electrical installation			225,000
		Miscellaneous and startup cost			150,413
Total cost					2,165,013

362,900 kg (800,000 lbs) of finished product. This equates to 20,000 bags of product that can temporarily be stored until time of shipping.

An automated bagging station was recommended by Insta-Pro. The automated bagging station would fill each bag with 18.14 kg (40 lbs) of pellets, heat seal the bags, stack 50 bags on a pallet, and then wrap the pallet with cellophane. This setup represented about 15% of the total capital cost of the project. Several laborers, if deemed necessary, could possibly replace the bagging system. At standard production there will be 368 bags produced per hour, which will be used to create 7.4 pallets.

A building of 306.6 m^2 (3300 ft^2) was determined to be sufficient to house the production equipment. An estimate of \$115.72/m^2 (\$10.75/ft^2) was obtained from a contractor that currently constructs these types of buildings. The machine installation and electrical costs were obtained from estimates of similar facilities, Insta-Pro, and cost engineering text. Insta-Pro provided estimates based on their experience installing similar equipment in oilseed production facilities. Cost engineering data were obtained from Humphreys and Wellman (1996). To cover startup and miscellaneous cost (including new employees training and minor unforeseen expenses), a value of 10% of the total machinery cost was used.

Raw materials. The participating gin averaged approximately 55,000 bales of cotton ginned per harvest season (October to December). For this analysis, an average of 238.1 kg (525 lbs) of waste was used for the average amount of waste produced per ginned bale of cotton. In addition to the waste produced at the gin, there was an option of purchasing waste from other gins located within a 32 km (20 mile) radius of the processing plant. The amount of waste purchased and the price necessary to both purchase and transport the additional waste was considered as variables to be evaluated. The cost to purchase and transport the additional waste was established at \$8.81 per tonne (\$8.00 per ton). The base information for the raw material used in this study were as follows: annual production – 55,000 bales; bales/h – 50; average waste/bale – 238kg; waste purchased – 13,100 t; usable waste – 80%; usable waste/season – 10,480; gin operation – 50d; operation/day – 22h; usable waste/h – 9.53t.

Labor cost. Labor for this operation used a combination of seasonal contract labor and full-time permanent positions. The ginning industry has traditionally used full-time temporary employees to work during the ginning season only. After completion of the ginning season, these employees are released.

Direct labor included laborers, forklift operators, front-end loader operators, and lead men for each shift. As mentioned before, these employees were full-time temporary contract laborers for the duration of the production season. For this reason the employees worked straight time with no benefits. Hourly pay rates were higher than the minimum wage usually paid in the area and reflected the need for employees that were willing to work the time required.

The pellet operation had two full-time employees: a manager and foreman. There was also a one 6-month clerical position. It was important to have these as annual positions so that a level of operational expertise was maintained. The full-time employees were responsible for training the employees each year, as well as working to develop sales and marketing for the company. This type of arrangement worked to maintain the stability of the operation during the off-season. For this study, a 22 h workday was used with 2 h of cleanup and minor maintenance. A total of three 8-h shifts were used with seven employees per shift, not including the manager, foreman, and secretary. Each shift was comprised of three laborers, one leadman, one loader operator, and two floor operators.

Expenses. Operational expenses comprise approximately 63% of the total cost of the product and are directly related to the run time of the production facility. In this case the dryer fuel (natural gas) and electricity are consumed for approximately 3 months out of the year. The remaining 9 months of the year the utility consumption is negligible.

The bags used for this process are unique. They are doubled-walled and perforated. The perforation allows the product to breath and prevents moisture build-up during and after the bagging process. They are also designed to offer the consumer a tear resistant package.

As for the mobile material handling equipment used, lease of a front-end loader and forklift was a more viable option than purchasing, since purchasing would add more capital cost to the project. The other expense related to the mobile material handling equipment is fuel.

Repair and maintenance costs were obtained from an estimate by Insta-Pro International based on their experience of having this type of equipment in the field. This estimate is based on tonnes of production and works out to be $2.76 per tonne processed ($2.50 per ton). An overall reduction in gin operating expense of $110,000 was taken as an annual cost savings. This reduction was the result of cost savings realized due to the gin not having to dispose of waste at a cost of $2.00 per bale ginned.

The product used, in this analysis, for binding the pellet together was feed grade cornstarch. A solution of cornstarch mixed in water was added at a rate of 4% by weight of waste being fed into the extruders. Based on 18.14 kg (40 lbs) per bag of fuel pellets, there was 0.725 kg (1.6 lbs) of cornstarch per bag of fuel pellets produced. With a season's production of 577, 500 bags, there was 419,100 kg (924,000 lbs) of cornstarch consumed. The actual cost per bag was $0.10 for the cornstarch binder.

Since the COBY process is a patented process, the licensee is entitled to royalties. The royalties for making a fuel pellet are set at 4% of the profit per 0.91 t (1 ton) of the product produced. The royalties were considered in the operational cost of the plant.

Transportation. In an effort to establish transportation cost parameters, four shipping points were selected. The four shipping distribution hubs (Albuquerque, NM; Denver, CO; and Kansas City, MO; Lubbock, TX) were used to service the five destination states (NM, CO, MO, KS, and TX). In both trucking and rail estimates the cost of shipping was directly related to the distance traveled. The initial cost system was set up with the general assumption that the fuel pellets would be shipped in equal proportions to the three distribution hubs. Table 5 contains freight cost per bag for equal destination allocation and several different destination combinations. It should be noted that the shipping cost is expressed as a weighted average and summed to obtain the freight cost as an average cost per bag. The second part of the table demonstrates the shipping allocation by destination effect on cost and profit per bag. It should be noted that shipping the finished product to the nearest rail spur [64.4 km (40 mi)] had an associated transportation cost of $0.114 per bag.

Table 5. Freight cost ($) per bag for Albuquerque, NM, Denver, CO, Kansas City, MO, and Lubbock,TX

Freight cost per bag							
Location	Distribution	Truck allocation (%)	Truck ($)	Truck wt. avg. ($)	Rail allocation (%)	Rail ($)	Rail wt. avg. ($)
Albuquerque	1/3	33.3	0.561	0.187	33.3	0.329	0.110
Denver	1/3	33.3	0.750	0.250	33.3	0.391	0.130
Kansas City	1/3	33.3	0.953	0.317	33.3	0.453	0.151
Cumulative cost/bag				0.754			0.391

Location	Allocation	Truck total cost ($)	Truck profit ($)		Rail total cost ($)	Rail profit ($)
1/3,1/3,1/3	A	2.101	0.399	A	1.860	0.640
1/4,1/2,1/4,	B	2.100	0.400	B	1.860	0.640
1/4,1/4,1/2	C	2.150	0.349	C	1.870	0.630
1/2,1/4,1/4	D	2.050	0.447	D	1.840	0.660
3/4,1/8,1/8	E	1.980	0.519	E	1.820	0.680
1/8,3/4,1/8	F	2.099	0.401	F	1.860	0.640
1/8,1/8,3/4	G	2.226	0.274	G	1.900	0.600
100% Albuquerque	H	1.908	0.592	H	1.800	0.700
100% Denver	I	2.097	0.403	I	1.860	0.640
100% Kansas City	J	2.300	0.200	J	1.920	0.580
Cost/bag for Lubbock		0.114				

Model development and analysis. To evaluate the economic feasibility of building and operating a cotton byproduct processing plant, a spreadsheet model was developed and analyzed. The following formulas form the basis of the model used to calculate various aspects of the cost system:

<u>1) Annual Operating Profit (AOP)</u>

AOP = Annual Sales - Total Annual Operating Expenses,

<u>2) Total Annual Operating Expense (TAOE)</u>

TAOE = Capital Depreciation (CD) + (CD * Interest Rate) + Utility Cost + Bag Cost + Pallet Cost + Freight Cost + Rental Charge + Labor + Fuel Cost + Repair and Maintenance + Office Supplies + Starch +Cost of Additional Gin Waste + Royalties + Cost Savings,

<u>3) Return on Investment (ROI)</u>

ROI = Annual Operating Profit / Capital Investment.

Since changes in costs of materials, labor, supplies, transportation, and other variables occur and can have a significant affect on the feasibility of a project, 24 variables were assigned distributions with ranges deemed appropriate based on research and experience. Table 6 presents a list of all the variables and their respective distributions and parameters used in the forecast model for all the different analyses performed.

Due to the fact that cost overruns can occur during construction, one of the primary variables used in the model was capital cost. During the simulations, the capital cost was allowed to increase up to 7.8% above the baseline listed in Table 5. The 7.8% increase was based on equipment cost variations encountered while obtaining prices for the machinery listed in Table 4.

RESULTS AND DISCUSSION

The forecasting model performed 50,000 iterations adjusting each variable within the specified range for the assigned distribution. The model output contained the mean and standard deviation of key elements, such as number of years to payback, ROI, annual profit, cost per bag, etc., based on cost variable changes within the specified distributions. The break-even selling price per bag was established based on market information gathered from the Pellet Fuels Institute and other similar organizations. When manufacturing and transportation cost are taken into consideration, the break-even selling price for fuel pellets being trucked and shipped by rail is 2.17 and $1.95, respectively. The break-even price per bag standard deviation for the truck and rail were 0.17 and $0.15, respectively.

An analysis was performed to examine the break-even waste quantity at a delivered selling price of $2.50 per 18.14 kg (40 lb) bag. In the analysis it can be seen that as waste quantity is reduced the operation's ability to cover cost is inhibited. The actual break-even waste quantity varied depending on the mode of transportation used. The break-even quantities for truck and rail were 7783 t (8579 tons) and 6320 t (6967 tons), respectively. These break-even values would equate to 40,850 and 33,175 bales of cotton, for truck and rail, respectively, with an average waste per bale of 190.5 kg (420 lbs). The break-even bale quantity is significant because the worst crop year this gin has experienced in the last 25 yr was 21,000 bales, which equates to 4001 t (4410 tons) of waste. For years, when the cotton gin processed fewer bales than the break-even quantity, additional waste had to be purchased in order to break-even.

Transportation sensitivity. Since transportation costs are keys to the total cost of the product an analysis was performed to determine if the cost of the product would be sensitive to a change in freight charges. The analysis used incremental values from a 25% decrease to a 50% increase in freight cost. An increase in trucking freight cost is more significant because of the limited capacity of each truckload, 1100 bags; whereas a change in rail freight cost is distributed over the carloads carrying capacity of 5000 bags. This would indicate a need to shift the shipping allocation more heavily toward rail. The results of this comparison are contained in Figure 2.

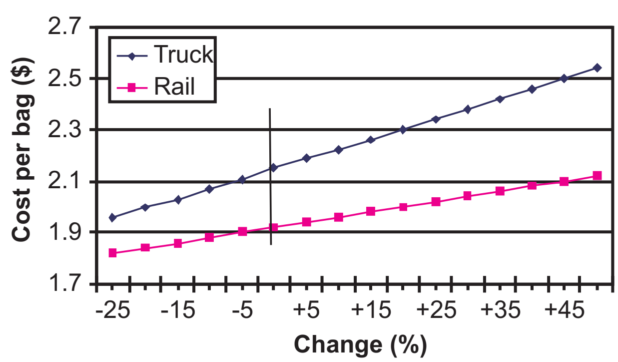

Figure 2. Effect of change in transportation cost on total cost.

Table 6. Distributions and their associated parameter variables used in the forecast modeling

Variable	Distribution	Units[z]	Distribution parameters	Range
Extruder production rate	Normal	kg/hr (lbs/hr)	Mean = 2223 (4900) Std. dev. = 222 (490)	1556 – 2889 (3430 – 6370)
Waste per bale	Normal	kg/hr (lbs/hr)	Mean = 238 (525) Std. dev. = 23.8 (52.5)	166.7 – 309.6 (367.5 – 682.5)
Usable waste	Normal	%	Mean = 78 Std. dev. = 4	66 - 90
Number of bales ginned	Beta	#	Alpha = 9.0; Beta = 2.5; Scale = 66,000	33,000 – 66,000
Starch applied	Normal	%	Mean = 4.0; Std. dev. = 0.4	2.8 – 5.2
Price per kWh	Normal	$	Mean = 0.055; Std. dev. = 0.003	0.051 – 0.065
Cost of starch	Triangular	$/Mg ($/ton)	Min. = 99 (90); Max. = 149 (135); Likeliest = 127 (115)	99 – 149 (90 – 135)
Bag cost	Normal	$	Mean = 0.25; Std. dev. = 0.015	0.205 – 0.295
Pallet cost	Triangular	$	Min. = 6; Max. = 11; Likeliest = 8	6 – 11
Maintenance and repair cost	Normal	$/Mg ($/ton)	Mean = 2.50 Std. dev. = 0.25	1.75 – 3.25
Natural gas cost	Triangular	$/Mcm ($/Mcf)	Min. = 0.119 (3.37); Max. = 0.145 (4.11); Likeliest = 0.132 (3.74)	0.119 – 0.145 (3.37 – 3.74)
Gasoline cost	Normal	$	Mean = 1000; Std. dev. = 50	850 – 1150
Selling price per bag	Normal	$	Mean = 2.50 Std. dev. = 0.15	2.05 – 2.85
Interest rate	Normal	%	Mean = 8.0; Std. dev. = 0.85	5.45 – 10.55
Office operational cost	Triangular	$	Min. = 850; Max. = 1150; Likeliest = 1000	850 – 1150
Disposal cost	Normal	$	Mean = 2.00; Std. dev. = 0.67	0.01 – 4.00
Additional waste purchased	Exponential	Mg (tons)	Rate = 0.0	– 25,382 (0.0 – 23,026)
Laborer wages	Pareto	$/hr	Location = 5.25; Shape = 2	5.25 – 6.50
Leadman wages	Pareto	$/hr	Location = 7.25; Shape = 2	7.25 – 8.75
Loader operator	Pareto	$/hr	Location = 6.00; Shape = 2	6.00 – 7.25
Floor operator	Pareto	$/hr	Location = 5.75; Shape = 2	5.75 – 6.75
Secretary	Pareto	$/hr	Location = 6.50; Shape = 2	6.50 – 7.50
Cost of additional waste	Normal	$/Mg ($/ton)	Mean = 3.31 (3.00) Std. dev. = 0.44 (.40)	1.98 – 4.63 (1.80 – 4.20)
Capital cost	Uniform	$	Min. = 2,165,013 Max. = 2,350,000	2,165,013 – 2,350,000

[z]Mg = Megagram = 1 tonne

Table 7 shows the top six variables that have the largest impact on the sensitivity of ROI for both truck and rail. The top three variables are the same for both modes of transportation with additional waste purchased being the primary contributor to the variance of ROI. The primary difference between truck and rail is the inclusion of freight cost. Truck freight cost added to the variation of ROI by 9.3%; whereas rail freight only affected the variation by 0.7%.

Cost system. By approaching this project as an enhancement to a current operation, a minimum attractive rate of return was not predetermined. Based upon the target value given to us by the participating gin, the minimum ROI desired was established at 15%. The cost system model was developed in Microsoft Excel spreadsheets and was used to examine factors that influenced the sensitivity of critical areas, such as cost and profits. One such area was the relationship between finished product transportation and the amount of waste available for the pellet operation. Rates of return were calculated using the future value of the capital cost if the money was simply invested for 10 yr. These values were used as benchmarks. The waste generated, in the form of thousands of bales ginned, was manipulated until the profits matched the benchmark values. This allowed a comparison to be made that showed how many bales would have to be processed in order to meet the various return rates.

With 15% return on investment, as a minimum standard, transporting finished product by truck did not appear to be a viable option. For trucking to be viable, the long-term interest rate on capital cost had to be 4% or below. Using rail as the primary transportation is less sensitive to a change in interest rate and was found to meet the required ROI even at 16% interest rate levels. Figure 3 shows the ROI changes to variations in the interest rates.

What-if analysis. Several "what if" analyses were produced using the Crystal Ball software package. The first analysis examined a ROI of 15% as it relates to the current cost system. A total of 50,000 trial runs were performed. The results were displayed as a forecast of what ROI can be expected based on the laws of probability within a normal distribution. The results of this analysis for both modes of transportation are contained in Table 8. The mean ROI for truck and rail were 10.1 and 16.06%, respectively. The certainties of obtaining a 15% ROI, based on the assumptions of the model, for truck and rail were 29.95 and 54.40%, respectively.

The same process was used to forecast the effect that total usable waste has on the process. Using the same basic arrangement, the total tons of usable waste per season was examined using 50,000 trial runs. The forecast of the amount of usable waste available was as follows: 0.0% - 4747 t; 5.0% - 8401 t; 10.0% - 9100 t; 50.0% - 12,466 t; 90.0% - 18,283 t; 95.0% - 20,821 t; 100.0% - 54,879 t.

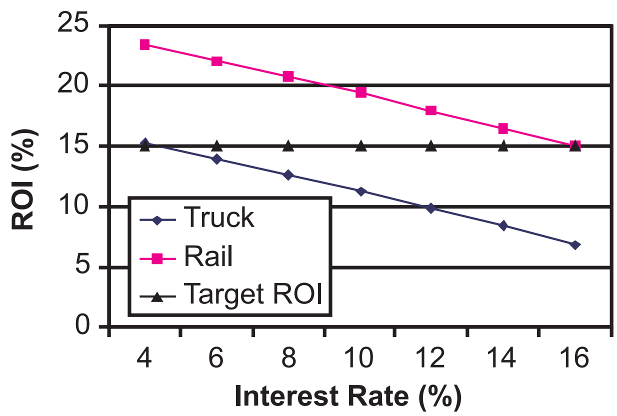

Figure 3. Effect of interest rate change on return of investment (ROI).

Table 7. Top six variables that contribute to the variation of return-on-investment (ROI) for transportation by truck and rail

Variable	Contribution to variance (%)	
	Transportation – truck	Transportation – rail
Additional waste purchased	34.7	45.8
Selling price per bag	26.6	20.8
Number of bales ginned	15.1	17.7
Freight cost	9.3	-
Amount of waste per bale	5.0	6.5
Current waste disposal cost	3.4	2.7
Percentage usable waste	-	2.7

Table 8. Distribution of return-on-investment (ROI) for both truck and rail transportation

Transportation – truck		Transportation – rail	
Percentile (%)	ROI (%)	Percentile (%)	ROI (%)
0.0	-13.40	0.0	-11.43
10.0	0.89	10.0	5.95
20.0	3.76	20.0	9.09
30.0	6.00	30.0	11.53
40.0	8.04	40.0	13.81
50.0	10.10	50.0	16.06
60.0	12.29	60.0	18.55
70.0	14.95	70.0	21.51
80.0	18.22	80.0	25.33
90.0	23.54	90.0	31.48
100.0	99.86	100.0	120.09

This forecast supports the premise that the operation will be viable even in years with low waste quantities from a cost per bag perspective. At the 10% value of 9100 t (10,031 tons), the operating cost would be $2.36 per bag for truck transportation and $2.14 for rail. Based on this cost and a delivered selling price of $2.50 per bag, the ROI for this combination would be 3.11 and 8.27%, respectively. The forecast results suggest that 90% of the time the ginned bales should exceed 9100 t (10,031 tons), which would allow a modest ROI in seasons of poor supply. To obtain the ROI of 15%, the minimum quantity necessary would be 11,780 t (12,985 tons).

Based on the model, the average number of years to pay-back the capital cost would be 7.37 for truck and 5.74 for rail. These averages are based on the capital cost being allowed to vary uniformly from 2.16 to 2.35 million dollars. The interest rate on the capital cost investment varied according to a normal distribution with a mean of 8% and a standard deviation of 0.85%.

CONCLUSIONS

Using the information contained in this study it does appear that a fuel pellet operation can be a profitable development. Treasury bills return about 3.86% on a 10-yr investment (as of 20 February 2003; Bloomberg.com, 2003). The stock market historically returns approximately 12% (Coe, 2002; Stuhlreyer, 2002; and Wibel, 2002). Based upon the assumptions and values used in the forecast model, the ROI of 15% would have a 29.95 and 54.4% chance of certainty if transporting the product to market by truck or rail, respectively. To be able to achieve the optimal transportation cost, a combination of truck and rail will most likely be used.

The ROI can be further improved by examining the projects capital cost. For example, if the three extruders were replaced with blending augers, there would be a drastic reduction in power consumption and capital cost. Replacing extruders with blending augers would also increase the throughput of the operation. Replacing the three extruders would eliminate approximately 745.7 kW (1000 Hp) and would reduce the capital cost by approximately $500,000. Even though replacing the extruders with blending augers would improve the overall economic analysis, it was not considered in this study since it did not represent a worst-case scenario. Forecast modeling using a worst-case scenario, based on higher capital cost, was performed in order to provide an overall conservative economic analysis.

The COBY process does not require the use of an extruder, but an extruder is often incorporated in the process. The use of an extruder in the process expands the possible consumer products that can be manufactured, but is not a COBY process requirement. Narrowing the estimates to quotable amounts could result in overall ROI improvements. The information for this project was gathered in good faith. Pricing figures contained in this study are for budgetary estimation only and are not intended as quotable amounts.

DISCLAIMER

The use of product or trade names does not constitute an endorsement by the USDA-ARS or Texas Tech University over other comparable products. Products or trade names are listed for reference only.

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