ECONOMICS OF COTTON GIN WASTE AS A ROUGHAGE INGREDIENT IN CATTLE FEEDLOT RATIONS ON THE TEXAS HIGH PLAINS

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Abstract

A linear programming (LP) model was used to develop the demand relation for CGW as a roughage ingredient in a cattle feedlot ration. The LP was designed to minimize the cost of a feedlot ration subject to a set of nutritional constraints. A total of 13 feed ingredients were included as activities in the LP, including 4 roughage ingredients (CGW, alfalfa, cottonseed hulls, and corn silage). The LP model was solved for the quantity of CGW used in the ration at varying prices of CGW and other roughage ingredients. The output from the LP model was used as data for a regression analysis to estimate the coefficients of the demand for CGW. The estimated demand relation was found to have an inelastic (vertical) segment when $P_{CGW} \leq$ \$70/ton, and an elastic segment (e=-3.8) when $P_{CGW} >$ \$70/ton. The LP model was solved with and without CGW to determine the impact that CGW has on ration cost. Assuming the price of CGW equals \$20/ton, we found a 5% reduction in ration cost from including CGW in the ingredient list for the LP model.

Introduction

The process of ginning cotton separates cotton lint from cottonseed and produces a substantial amount of a byproduct called gin waste (or gin trash). Cotton gin waste (CGW) is the organic remains of the cotton plant discarded during the ginning process. It is mainly comprised of cotton burs (carpels), leaves, stems, twigs, and soil particles that are removed during the initial stages of the ginning process. In the latter stages of the ginning process, lint cleaners remove smaller, more finely textured waste particles—called fines—from the lint (e.g., dust, chips of bur, immature seeds, and small leaves). The fines are added to the consolidated waste pile, and the CGW is ready for disposal.

The primary cotton harvesting method used on the Texas High Plains is the stripper method (as compared to the picker method used in most other regions). Stripper harvesting mechanically removes all the plant matter from the main stalk of the cotton plant. The crop is typically desiccated (by chemical application or by the first freeze of the season) prior to harvesting to remove leaves from the plant, which reduces trash content of the seed cotton and improves the grade of lint cotton. On the Texas High Plains, stripper harvested cotton produces about 700 lbs. of CGW per bale of cotton lint (Thomasson, 1990). The average size gin (ginning 15,100 bales) produces 5,285 tons of CGW per season.

CGW consumes space at the gin and is a potential fire hazard. Thus, cotton ginners are concerned that CGW is quickly removed from their gin yards. It is costly, however, to dispose of CGW. One particular ginner we visited indicated that he was paid \$1.75/ton for CGW delivered to a collection site about three miles from the gin. The ginner noted that after paying the cost of loading and transporting the CGW to the site, he actually came out in the red on his CGW disposal. This is a common scenario for ginners in that the price they typically receive for CGW is so low that the net return is negative (after paying costs of handling and delivery). A 1997 survey of Texas High Plains ginners found that the average disposal cost was \$1.44/ton (Castleberry and Elam, 1998).

Cotton ginners use several disposal methods to rid their gin lots of CGW. A 1997 survey of Texas High Plains cotton ginners found that the primary disposal methods included livestock feed (48%), soil amendment (33%), compost (16%), and other (3%) (Castleberry and Elam, 1998). A similar survey done in 1977 showed lower use of CGW for cattle feed (37%) and compost (0.2%), and higher use for soil amendment (62%) (Kolarik, et al., 1977).

Mayfield (1991) indicated that the highest value use of CGW is for cattle feed. CGW has good nutritional characteristics compared to other roughage ingredients. An early nutritional analysis of CGW (from various regions of the Cotton Belt) indicated that CGW could be used as a ruminant roughage of moderate protein and energy value that is comparable to Bermuda and prairie hay (Laylor, et al., 1975). Although feedlot operators do use CGW as a roughage source, there are problems associated with feeding CGW. One problem is reduced palatability of the ration. Young and Griffith (1976) noted that palatability can be improved by adding molasses, but this increases ration cost. Another problem associated with CGW is that handling and transporting the product is difficult due to the bulky nature of CGW. CGW can be cubed, pelleted, or ground to reduce transportation cost and to make the nutritive components more readily available to ruminant animals. Economics weighs against cubing or pelleting CGW (Arnold, 1998); grinding is the most common preparation done to CGW.

Firms—known as bur brokers—purchase CGW from the gin operator and re-sell it to feedlot operators. The bur broker first grinds the CGW and then transports it to the feedlot. The bur broker obtains the CGW from the gin operator for little or no cost (1997 survey results show that gins actually pay on average to dispose of CGW), and re-sells the ground CGW to a feedlot operator for enough to cover handling and transport cost plus allow for a small

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profit. The selling price depends on transport cost from the gin to the feedlot, but an average price appears to be about $20/ton for CGW delivered to the feedlot (published data are not available) (Richardson, 1998).

From a cattle feeder's perspective, CGW has good nutritional characteristics compared to other roughages; and coupled with its low price, it should be a preferred ingredient in a cattle ration. For 1991-97, the alfalfa price averaged $117/ton and cottonseed hulls averaged $70/ton on the Texas High Plains. The value of CGW (to a cattle feeder) should fall between that of alfalfa and cottonseed hulls, given the nutritional characteristics of the three roughages. CGW has higher levels of protein, energy, calcium, phosphorus, and potassium than cottonseed hulls, and lower levels of these nutritional characteristics than alfalfa. At $20/ton, CGW is the least expensive roughage between alfalfa and cottonseed hulls. Nevertheless, feedlot operators often ignore CGW and include other roughage ingredients in their rations.

A large potential demand exists for CGW by cattle feedlots in the Texas High Plains. Fed cattle marketings averaged 4.8 million head per year in the Texas High Plains for the five-year period 1993-97 (Texas Agr. Statistics Service). Because of the bulky nature of CGW and the high cost to transport it, CGW is typically sold to feedlots located close to cotton gins that gin stripper harvested cotton. Stripper harvesting (which produces the greatest amount of CGW) is done in limited areas of the U.S. (the largest area is the Texas High Plains).

One objective of this research was to quantify the demand for CGW as a roughage ingredient in a cattle feedlot ration (i.e., for cattle fed from 700-1,200 lbs.). This has not been done in previous studies. The demand analysis will allow us to determine the amount of CGW used in a ration at varying prices of CGW. The demand relation for CGW was developed using a least-cost linear programming model. This procedure was called for because standard econometric demand estimation was not possible given the lack of data on CGW prices (published data are not available).

A second objective of this research was to determine the impact that CGW has on ration cost. As noted above, the price of CGW is below the prices of alfalfa and cottonseed hulls, which implies that ration cost will be lower with CGW. The reduction in ration cost (with CGW) will equal the increase in feeding return (to the cattle feeder).

The outline of the paper is as follows. The following section presents the LP model used to develop the demand relation for CGW. The third section presents the results, including the estimated demand relation and the expected reduction in ration cost from using CGW. Demand elasticities and cross price elasticities were derived from the estimated demand relation. The final section provides a summary and the conclusions.

<u>Methods and Procedures</u>

A linear programming (LP) framework was used to develop the demand relation for CGW as a roughage ingredient in a feedlot ration. The demand relation from a least-cost LP is referred to (in economic terms) as a conditional demand relation because it is derived by minimizing cost while assuming a given level of output for the firm (Beattie and Taylor, 1985, pp. 124-25). In total, 13 feedstuffs were included as activities in the LP model (Table 1, column 1). The least-cost ration was formulated to meet the nutritional requirements of a feedlot steer weighing 900 lbs. (on average) and gaining 3 lbs./day. These weight and gain numbers were chosen to represent the average Texas High Plains feedlot steer.

The objective of the LP was to minimize the cost of a specified (100-lb.) unit of ration subject to a set of nutritional constraints. The objective function is shown at the top of Table 2. The prices of the feedstuffs in the objective function (e.g., $.072/lb for corn, dry basis) were obtained from an industry source and represent delivered prices to the Texas High Plains. The least-cost ration was formulated to provide the required levels of energy, protein, roughage, and minerals for a 900 lb. (average weight) feedlot steer gaining slightly more than 3 lbs./day. These levels are represented by constraints in the LP model: dry matter intake (DMI) equal to 100 lbs., dry weight; net energy of maintenance (NEm) and net energy of gain (NEg) in mcals (a unit of heat measurement) per 100 lbs. of ration on a dry basis; and crude protein (CP), calcium (Ca), phosphorus (P), potassium (K), and neutral detergent fiber (NDF) as specified percents of ration weight on a dry basis.

The constraints in the LP model were developed to address each column of Table 1. The first constraint is for DMI. This constraint sums the ingredients in the ration to equal 100 lbs. Another example is the NEm constraint. Each feedstuff includes a certain amount of NEm, e.g., corn has 1.06 mcal./lb. The NEm constraint is constructed by multiplying the quantity of each feedstuff by its NEm level (Table 2). The products are then summed and must be greater than 95 mcals per 100 lbs. (the level required for a 900 lb. (average weight) steer gaining slightly more than 3 lbs./day (NRC (1984) and industry standards)). The remaining nutrient constraints (shown in Table 2) are constructed in a similar manner.

Feedlot cattle are fed rations with high amounts of energy to produce desired gains. These high energy, high density rations are referred to as “hot rations.” A problem with feeding hot rations is the negative effect on an animal’s gastrointestinal performance. An animal that is fed a hot ration over an extended period will eventually decrease in average-daily-gain performance and suffer other problems such as acidosis, liver abscesses, bloat, and rumen parakeratosis (Church and Pond, 1988). Adding roughage to the diet, which reduces the overall density of the ration, minimizes these problems.

A neutral detergent fiber (NDF) constraint was used in the LP model to bring roughage into the ration. NDF measures the cell wall constituents in a feed ingredient (Church, 1991). Cell wall constituents have low biological availability and are used mainly to reduce the density of a feedlot ration (as explained above). Roughage feedstuffs such as alfalfa, cottonseed hulls, corn silage, and CGW are included in a ration because they contain high levels of NDF. The ration was formulated to include 5 to 15% NDF. In addition, each individual roughage was allowed to be included up to 10% of the ration on a DM basis, and the combination of all roughages could not exceed 13% of the ration.

Several feedstuffs were included in the LP model as constant percentages of the ration while other feedstuffs were constrained by an upper and lower bound. These feedstuffs and their respective quantities (or ranges) are: 0.7 to 1.0% urea; 1.04% limestone; 0.12% salt; 2.0 to 2.5% fat; and 3.5 to 4.0% molasses.

The LP model in Table 2 includes 13 variables and 20 constraints. The LP was constructed and solved using Microsoft Excel. The LP model was used to derive a demand relation for CGW. This was accomplished by fixing the prices of the other feedstuffs at their average values (for 1991-97) and varying the CGW price. The LP model was first solved with the CGW price at $0/ton to obtain the quantity of CGW included in the ration. The LP model was solved a second time with the CGW price at $20/ton and the quantity of CGW was determined; and, so on. In total, seven LP models were solved, allowing the price of CGW (as-fed basis) to range from $0 to $120 per ton in $20 increments. A demand relation for CGW was developed, by plotting the price of CGW vs. the quantity used (assuming average prices of the other feedstuff ingredients).

<u>Simulation Procedure Used to Develop the Demand for CGW</u>

Continuing the discussion on derivation of demand for CGW, a simulation procedure was used to generate a data set of the quantities of CGW used in a cattle feedlot ration with varying prices of CGW and other roughage ingredients. (In the previous demand relation, the prices of the other roughage ingredients were held fixed at their mean values.) The data set generated was used to estimate the demand for CGW, allowing for changes in the price of the other roughage ingredients. A data set of historical monthly prices (delivered Texas High Plains) of alfalfa, cottonseed hulls, and corn silage for 1991-97 was obtained from an industry source. The LP was solved each month using actual price data for alfalfa, cottonseed hulls, and corn silage, and with the CGW price assuming values from $0 to $120/ton at increments of $20/ton. Altogether, 539 LP models were solved for the period 1991-97. This produced a data set of n=539 quantities of CGW used in a cattle feedlot ration along with the different price combinations. The data set was used to estimate the demand for CGW as a function of the price of CGW and the prices of alfalfa, cottonseed hulls, and corn silage.

As stated previously, the price of CGW was allowed to vary from $0 to $120/ton in increments of $20/ton. This price range encompasses both competitive and non-competitive price ranges with respect to the other roughage ingredients (average prices with standard deviations are reported in Table 3). When the price of CGW is low compare to the prices of the other roughage ingredients, CGW is the least-cost roughage ingredient for a feedlot ration, and changes in its price have little effect on quantity demanded. By comparison, when the price of CGW is in the range of the prices of other roughage substitutes, then CGW competes with these ingredients on a price basis. The point is that the structure of the demand relation for CGW is different in the price range where CGW is competitive with the other roughages versus where it is non-competitive. The specifics of the differences are addressed in the Results section.

Special econometric procedures are available to estimate a demand relation that follows a particular linear relation in one range of the data, but follows a different linear relation in another range. The procedure used here to estimate the demand for CGW is generally called piecewise regression analysis. This procedure is explained in Neter et al. (1996, pp. 474-78); other references include Greene (1993, pp. 235-38) and Draper and Smith (1981, pp. 250-57). The piecewise regression equation for the demand for CGW is shown below:

$$(1)\quad Q_{CGW} = \beta_0 + \beta_1 P_{CGW} + \beta_2 (P_{CGW} \times \delta) \times D + \beta_3 P_S + \beta_4 (P_S \times D) + \beta_5 P_A + \beta_6 (P_A \times D) + \beta_7 P_H + \beta_8 (P_H \times D) + \beta_9 D + \varepsilon,$$

where P_{CGW}, P_S, P_A, and P_H represent the prices of CGW, silage, alfalfa, and cottonseed hulls, respectively, and ε is a random error term which reflects the impact of factors, other than the above noted prices, on demand for CGW. The symbol delta (δ) represents the point where the slope of the regression line changes. The dummy variable D assumes the value 0 if $P_{CGW} \leq \delta$ and a value of 1 if $P_{CGW} > \delta$. Eq. (1) allows for different demand functions depending on P_{CGW} and allows for a discontinuity (jump) in the demand function at the point δ.

The demand relation for CGW when $P_{CGW} \leq \delta$ and D=0 is given by the equation:

$$(2)\ Q_{CGW} = \beta_0+\beta_1 P_{CGW}+\beta_3 P_S+\beta_5 P_A+\beta_7 P_H+\varepsilon.$$

The theoretical (*a priori*) sign of β_1 is negative, indicating that an increase in the price of CGW will result in a decrease in the quantity of CGW used in the ration. The signs of β_3, β_5, and β_7 (representing the cross price effects) are positive indicating that the other rouhgage ingredients are substitutes with their prices representing positive demand shifters.

The demand relation for CGW when the $P_{CGW} > \delta$ and D=1 is given by the equation:

$$(3)\ Q_{CGW} = \beta_0 - \beta_2\delta_* D + \beta_9 D + (\beta_1+\beta_2)P_{CGW} + (\beta_3+\beta_4)P_S + (\beta_5+\beta_6)P_A + (\beta_7+\beta_8)P_H+\varepsilon.$$

Note that the coefficients in this eq. are different from those in eq. (2). This is called for because the structure of demand is different in the price range (P_{CGW} > \$70/ton) where CGW competes with the other roughage ingredients compared to the price range ($P_{CGW} \leq$ \$70/ton in the previous case) where CGW does not compete with the other, higher priced roughage substitutes. The *a priori* signs of the combined coefficients in eq. (3) should be the same as those in eq. (2).

The coefficients in eqs. (2) and (3) were estimated using ordinary least-squares regression analysis. The variance (and standard error) of the estimated (combined) coefficients in eq. (3) was obtained by calculating the sum of the variances of the individual coefficients plus two times the covariance of the coefficients (e.g., $var(b_1+b_2)=var(b_1)+var(b_2)+2cov(b_1,b_2)$, where b_i represents the least squares estimate of the parameter β_i in the demand relation). Significance of the estimated coefficients was tested using a t-statistic.

The estimated coefficients in the demand relation were used to calculate the own price elasticity of demand for CGW. Cross price elasticities of demand for CGW were calculated to measure the responsiveness of the quantity of CGW used in the ration to a small change in the price of the other roughage ingredients.

Reduction in Ration Cost from Including CGW

The LP model presented in Table 2 was solved with and without CGW to determine the reduction in ration cost from including CGW as a roughage ingredient. The LP model was solved with the other roughage ingredient prices at their mean values, and one standard deviation above the means and one standard deviation below the means (Table 3). The price of CGW was allowed to vary from \$0 to \$120/ton in \$10/ton increments. The prices of all the other feedstuff ingredients (e.g., corn and milo) were held constant at their mean levels. The reduction of the ration cost when including CGW in the LP model at various price levels of CGW was translated into a percentage reduction for ease of interpretation.

Results

The LP model in Table 2 was solved with prices of CGW varying from \$0 to \$120/ton and with the prices of the other feedstuffs at their mean values for 1991-97. The solution process was used to determine the quantity of CGW used in the ration as the price of CGW varied. The step demand relation is shown in Figure 1, with the ration composition (%) shown in Table 4. With the price of CGW at \$0/ton, 9.3% of the ration on an as-fed basis (or 10% dry weight) was CGW (which is the maximum constrained level in the LP). With the CGW price as high as \$87.60/ton, CGW continued to comprise 9.3% of the ration. With the CGW price in the range \$87.60/ton to \$101.40/ton, 3.3% of the ration was CGW. With CGW price above \$101.40/ton, CGW comprised 0% of the ration. These results show that as the price of CGW was increased, the amount of CGW in the ration decreased while the amounts of alfalfa and cottonseed hulls increased (Table 4).

The data set generated by the simulation analysis was used to develop the demand for CGW. The scatter diagram in Figure 2 shows the price of CGW plotted against the quantity used in the ration. These data represent the results from 539 solutions of the LP model with historical prices for other roughages and CGW prices varying from \$0 to \$120/ton (Figure 2 has fewer than 539 points because multiple observations occur at a given price and quantity). The scatter of the points in Figure 2 reflects both changes in the quantity demanded due to changes in the CGW price, along with shifts in the demand for CGW based on changing prices of the other roughage ingredients.

The price and quantity data in Figure 2 along with the data set of historical prices for the other roughage ingredients was used to estimate the piecewise demand relation specified in eq. (1). The estimated coefficients are shown in the second column of Table 5. The demand relations derived from the piecewise regression (i.e., eqs. (2) and (3)) are shown in columns three and four of Table 5. The overall fit of the piecewise regression eq. is quite good with R^2=0.85. Four of the nine t-statistics for the explanatory variables are significant ($p<.01$). Explanations are offered below for the lack of significance in the case of the other five variables.

The estimated demand relation for the price range where $P_{CGW} \leq$ \$70/ton is shown in column three of Table 5. The estimated coefficient for quantity of CGW is approximately zero, which implies that demand is practically vertical. The vertical demand indicates that the price of CGW does not affect the quantity demanded. The small amount of horizontal scatter of the points (for PCGW$\leq$ \$70/ton) indicates that CGW is the preferred roughage regardless of the price levels of the other roughage ingredients. Note that the estimated coefficients for the other roughage prices are not statistically significant (Table 5). This is due to the fact that in this price range the prices of the other roughages are generally higher than the price of CGW and thus do not compete with CGW for inclusion in the ration (CGW is at the maximum level constrained in the LP model).

The estimated demand relation for the price range where P_{CGW} > \$70/ton is shown in column four of Table 5. In this price range CGW competes with the other roughages and the quantity of CGW used in the ration depends on the P_{CGW} and on the prices of the other roughages. The estimated coefficients are significant ($p<.01$) for prices of CGW, alfalfa, and cottonseed hulls, but not for silage. The non-significant coefficient for silage price could be because corn silage behaves more like an energy ingredient due to the high corn grain content (45%, dry weight).

Elasticity of demand for CGW and cross price elasticities of demand were calculated for the price range where P_{CGW} > \$70/ton (Table 6). The own price elasticity of demand is -3.8, indicating that a 1% change in P_{CGW} is associated with a 3.8% change in quantity demanded in the opposite direction. The large (absolute) value for the demand elasticity indicates that quantity demanded is quite responsive to changes in P_{CGW}, and this is due to the substitute roughages that compete for inclusion in the ration—i.e., a small increase in P_{CGW} will bring a substitute roughage into the least-cost ration. The cross price elasticities of demand are positive for the three competing roughages (Table 6). The largest cross price elasticity is +2.2 for alfalfa, indicating that a 1% change in the price of alfalfa is associated with a +2.2% change in the same direction in the demand for CGW.

The final result reported here is the impact on ration cost of including CGW in a cattle feedlot ration compared to including other roughage ingredients (alfalfa, cottonseed hulls, and corn silage). Column three in Table 7 shows the percentage reduction in ration cost from including CGW at various prices of CGW and assuming the other roughage prices are at their 1991-97 mean levels. For example, if P_{CGW} = \$20/ton, ration cost is reduced by slightly more than 5% by including CGW in the list of ingredients included in the LP model. As the P_{CGW} increases (moving down column three), the LP model trades CGW out in favor of another roughage ingredient, and the advantage in terms of reduction in ration cost decreases—e.g., if P_{CGW} = \$50/ton compared to \$20/ton, including CGW in the list of roughage ingredients reduces ration cost by only 3.4% compared to 5%.

The results in columns two and four of Table 7 report the reductions in ration cost from including CGW with the prices of the other roughage ingredients at one standard deviation below and above their mean values. Note that the reductions are smaller (larger) when the prices of the other roughage ingredients are one standard deviation below (above) their mean values (compared to at their means). This is explained by the fact that when the prices of other roughage ingredients are low and the LP favors them in the least-cost solution, less CGW is used in the ration.

It is important, from a cattle feeder's perspective, to interpret the reductions in ration cost shown in Table 7. The results show that ration cost is reduced by 5% from including CGW as a roughage choice in the LP model (for the case where the prices of the other roughage ingredients are at their mean values). For cattle rations at \$100/ton, this represents a \$5/ton reduction in cost. Moreover, assuming that a feedlot animal consumes about 1-1/2 tons of ration while in the feedlot, the \$5/ton reduction in ration cost translates into a \$7.50/head increase in net return to the cattle feeder. To put this in perspective, the estimated average return from custom cattle feeding is only \$7.88/head (assuming a 30% equity level in the feeder animal (Dodson and Elam, 1992)). The \$7.50/head reduction in feed cost from including CGW would cause average cattle feeding returns to almost double (up 95%). For a highly competitive industry such as cattle feeding, this represents a marked increase in return.

Summary and Conclusions

A LP model was used to develop a least-cost cattle feedlot ration. Thirteen feed ingredients were included in the model; these included four rouhgages, corn silage, alfalfa, cottonseed hulls, and CGW. The LP model was used to derive a demand relation for CGW (conditional on a given output of fed cattle). The coefficients in the demand relation were estimated using piecewise regression analysis. The estimated piecewise regression equation incorporated two demand relations—one demand relation for $P_{CGW} \leq$ \$70/ton, and a second demand relation for P_{CGW} > \$70/ton. The demand relation for $P_{CGW} \leq$ \$70/ton was practically a vertical line indicating almost perfectly inelastic demand. In this price range, CGW is the cheapest source of roughage, and thus the LP ignored other roughage ingredients and included the maximum amount of CGW (10% on a dry basis). When P_{CGW} > \$70/ton, the demand relation for CGW was quite elastic ($e = -3.8$). In this price range, CGW competes with alfalfa, cottonseed hulls, and corn silage for inclusion in the ration, with the amount of CGW included depending on the P_{CGW} compared to the prices of the other roughage ingredients.

The LP model was solved with and without CGW to determine the impact that CGW has on ration cost. Assuming P_{CGW}=\$20/ton, we found a 5% reduction in ration cost from including CGW in the ingredients list of the LP model. This reduction in ration cost results in a \$7.50/hd. increase in the cattle feeding return, which is almost equal to the average return earned from custom cattle feeding (\$7.88/head).

The results of this research have implications for the individual firm (feedlot) and for the overall market for CGW. First, in regard to the firm, the LP results presented here strongly suggest that CGW should be a preferred roughage ingredient in a cattle feedlot ration. The reader is reminded that the purpose of roughage is to decrease the density of the ration and stabilize the rumen pH of the feedlot animal. High concentrate diets (including energy feedstuffs such as corn and milo) are fed to achieve favorable rates of gain for feedlot cattle. Fermentation of the carbohydrates in corn and milo creates organic acids that lower rumen pH and cause digestive disorders such as acidosis, liver abscesses, and rumen parakeratosis (Klopfenstein, Stock, and Ward, 1991). Roughage ingredients serve to reduce the formation of organic acids and to minimize associated digestive problems. The point to emphasize is that the stabilization of the rumen pH is accomplished by including any roughage ingredient (they are approximately equivalent in this sense). If the P_{CGW}=$20/ton compared to alfalfa at $117/ton and cottonseed hulls at $70/ton, the economical choice is CGW. In practice, including CGW should lower ration cost and increase feeding returns as our results demonstrate.

The study results suggest that if feedlots are not using CGW in their rations, cattle feeding returns are not being maximized. There are problems associated with feeding CGW (these were discussed in the Introduction). Reduced palatability should not be a major problem due to the small amount of CGW included in a feedlot ration (the LP was constrained to allow a maximum of 10%, dry basis). In addition, other ingredients in the ration such as molasses help ameliorate the palatability problem. Another problem with feeding CGW is that it tends to be a seasonal product, available for a short time after the fall cotton harvest. Yet another problem that looms on the horizon is the potential for contamination of CGW from the pesticides and herbicides used in cotton farming. This problem is presently under close study (Fava, 1999). Suggested future research would be to further examine the economic advantages of feeding CGW to cattle. Feeding studies could generate real-world estimates of the cost advantage of CGW, and in addition uncover nutritional and operational problems that result from feeding CGW.

The research results reported here have implications for the overall market for CGW. CGW is a low value product with an average price of about $20/ton compared to a price of $117/ton for alfalfa and $70/ton for cottonseed hulls. The economics of supply and demand provides an answer as to why the price of CGW is lower than its competing roughages—if the price of a product is low, then demand must be weak and/or supply large. The results of this study address the demand side of the equation. One explanation for the low price of CGW is the fact that a number of feedlots do not use CGW in their rations. It is estimated that 1/3 of feedlots use CGW and only about 1/2 of the roughage requirement is met with CGW (Richardson, 1998).

From a nutritional and cattle feeding perspective, there should be more interest from feedlots in feeding CGW (it is an inexpensive roughage with nutritional content comparable to (or higher than) that of higher-prices roughages such as cottonseed hulls). Demand for CGW can be encouraged by providing information to nutritionists and feedlot operators (and their customers) concerning the cost advantage of including CGW in the ration. If more feedlots would use CGW, the demand would increase and *ceteris paribus* the price would increase. An important result of this research may be to emphasize the point that gin waste or gin trash may need a new name such as cotton gin byproduct or cotton ginfeed (note that the byproducts of rice milling are called rice mill byproduct or rice millfeed). A positive name coupled with economic information might encourage additional feedlot demand, which could lead to enhanced value for CGW.

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Table 1. Nutritional characteristics of feedstuffs

Feedstuff	Dry Matter (%)	NDF	Nem Mcal/lb	Neg Mcal/lb	CP (%)	Ca (%)	P (%)	K (%)
Corn, Flaked	86.	9.0	1.06	0.70	9.8	0.03	0.31	0.33
Milo, Flaked	70.	23.0	0.99	0.68	12.0	0.05	0.34	0.35
Corn Silage	35.	43.0	0.77	0.49	8.6	0.25	0.22	1.14
Alfalfa	91.	39.3	0.59	0.34	25.0	1.41	0.22	2.51
Cotsd Hulls	91.	88.3	0.31	0.07	4.1	0.15	0.09	0.87
CGW	90.	59.9	0.35	0.11	9.3	1.19	0.15	2.35
Cotsd Meal	92.	28.9	0.81	0.53	46.1	0.20	1.16	1.65
Soy Meal	90.	7.8	0.97	0.67	49.9	0.29	0.71	2.36
Lqd. Molasses	74.	0.0	0.77	0.49	5.8	1.00	0.10	0.00
Fat-Yellow Gr.	99.	0.0	2.15	1.59	0.0	0.00	0.00	0.23
Urea	99.	0.0	0.00	0.00	291.0	0.00	0.00	0.00
Grnd. Limestn.	100.	0.0	0.00	0.00	0.0	34.00	0.02	0.12
Salt-Plain	100.	0.0	0.00	0.00	0.0	0.00	0.00	0.00
Requirements*		5-15	0.95	0.63	13.0	0.49	0.24	0.70

National Research Council, 1984 and 1996.

Note: Neutral detergent fiber (NDF), crude protein (CP), Ca, P, and K are dry basis (100% dry matter). Corn silage=45% corn grain; cottonseed meal=41% protein; soy meal=49% protein.

*For 900 lb (average weight) steer gaining 3.0 lb/day.

Table 2. Least-cost linear programming model.

	Selected Ingredients									
	Corn	Corn Silage	Alfalfa	Cottonseed Hulls	CGW	Molasses	Fat	Urea		
min C =	.072 q1	+ .051 q2	+ .064 q3	+ .039 q4	+ .000 q5	+ .068 q6	+ .188 q7	+ .102 q8		Ration Cost ($/100 lbs)
subject to	1.00 q1	+ 1.00 q2	+ 1.00 q3	+ 1.00 q4	+ 1.00 q5	+ 1.00 q6	+ 1.00 q7	+ 1.00 q8	=100.	DryWeight (lbs)
	1.06 q1	+ .77 q2	+ .59 q3	+ .31 q4	+ .35 q5	+ .77 q6	+ 2.15 q7		≥95.	NEm (mcal/100lbs)
	.73 q1	+ .49 q2	+ .34 q3	+ .07 q4	+ .11 q5	+ .49 q6	+ 1.59 q7		≥62.5	NEg (mcal/100lbs)
	9.80 q1	+ 8.65 q2	+ 25.00 q3	+ 4.10 q4	+ 9.30 q5	+ 5.80 q6		+ 291. q8	≥13.	CP (%)
	.03 q1	+ .25 q2	+ 1.41 q3	+ .15 q4	+ 1.19 q5	+ 1.00 q6			≥.49	Ca (%)
	.31 q1	+ .22 q2	+ .22 q3	+ .09 q4	+ .15 q5	+ .10 q6			≥.24	P (%)
	.33 q1	+ 1.14 q2	+ 2.51 q3	+ .87 q4	+ 2.35 q5	+ 4.01 q6	+ .23 q7		≥.70	K (%)
								+ 1.00 q8	≥5.	NDF (%)
								+ 1.00 q8	≤15.	NDF (%)
								+ 1.00 q8	>.70	Urea (%)
								+ 1.00 q8	≤1.00	Urea (%)
							+ 1.00 q7		≥2.50	Fat (%)
							+ 1.00 q7		≤3.50	Fat (%)
						+ 1.00 q6			≥3.50	Molasses (%)
						+ 1.00 q6			≤4.50	Molasses (%)
		+ 1.00 q2							≤10.00	Silage (%)
			+ 1.00 q3						≤10.00	Alfalfa (%)
				+ 1.00 q4					≤10.00	CottonseedHulls (%)
					+ 1.00 q5				≤10.00	CGW (%)
		+ 1.00 q2	+ 1.00 q3	+ 1.00 q4	+ 1.00 q5				≤13.00	Total Roughage (%)

Ingredients on dry basis (100% dry matter).

Table 3. Means and standard deviations of roughage ingredient prices, Texas High Plains, 1991-97.

Ingredient	Mean ($/ton)	Standard Deviation ($/ton)
Alfalfa	116.84	13.56
Corn Silage	35.45	5.74
Cottonseed Hulls	70.25	17.39

Private feed company, Texas High Plains.

Table 4. Composition of least cost ration (% as fed) for varying prices of CGW (with other roughage prices at their means), and cost of rations (dry basis).

	Price of CGW ($/ton, as fed)		
Feedstuffs	0 to ≤87.60	>87.60 to ≤101.40	>101.40
	(% as fed)		
Corn, Flaked	73.73	70.58	72.34
Milo, Flaked	0.00	0.00	0.00
Corn Silage	5.38	12.05	8.73
Alfalfa	0.39	1.18	4.32
Cotsd Hulls	0.36	2.48	4.03
CGW	9.30	3.33	0.00
Cotsd Meal	2.27	2.18	2.22
Soy Meal	0.00	0.00	0.00
Lqd. Molasses	5.06	4.85	4.96
Fat-Yellow Gr.	1.69	1.62	1.65
Urea	0.84	0.81	0.68
Grnd. Limestn.	0.87	0.83	0.85
Salt-Plain	0.10	0.10	0.10
Ration Cost ($/ton, dry basis	133.87 to 143.62	143.62 to 144.20	144.20 or more

Table 5. Estimated coefficients in piecewise demand equation for CGW (eq. 1), and demand relations for CGW with $P_{CGW} \leq \$70$/ton (eq. 2) and $P_{CGW} > \$70$/ton (eq. 3).

	Derived Demand for CGW		
Variable	Piecewise Regr., Eq.(1)	$P_{CGW} \leq \$70$/ton	$P_{CGW} > \$70$/ton
Intercept	179.56*	179.56*	124.17*
P_{CGW}	- 0.00	- 0.00	- 3.56*
$(P_{CGW}-70)*D$	- 3.56*		
P_S	0.48	0.48	0.30
P_S*D	- 0.18		
P_A	- 0.07	- 0.07	- 1.66*
P_A*D	1.72*		
P_H	- 0.04	- 0.04	1.44*
P_H*D	1.48*		
D	- 304.62*		

*Significant at .01 level based on two-tailed t-test.

Table 6. Price elasticity of demand for CGW and cross price elasticities of demand for price range where $P_{CGW} > \$70$/ton (calculated at mean prices, 1991-97).

Own Price Elasticity	-3.8
Cross Price Elasticity —Alfalfa	+2.2
--Cottonseed Hulls	+1.2
--Corn Silage	+0.1

Table 7. Reduction in ration cost (%) from including CGW in LP model, with other roughage ingredient prices at their mean levels, one standard deviation (SD) below the mean, and one standard deviation above the mean.

Price of CGW	Prices of Other Roughage Ingredients		
($/ton, as fed)	Mean -1 SD	Mean	Mean +1 SD
0	5.5	6.2	6.9
10	4.9	5.6	6.3
20	4.4	5.1	5.8
30	3.8	4.5	5.2
40	3.2	4.0	4.7
50	2.7	3.4	4.1
60	2.1	2.8	3.6
70	1.5	2.3	3.0
80	1.0	1.7	2.5
90	0.4	1.2	1.9
100	0.0	0.6	1.4
110	0.0	0.0	0.8
120	0.0	0.0	0.3

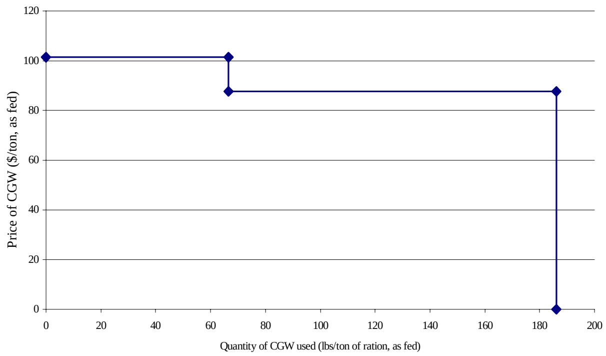

Figure 1. Quantity of CGW used in a cattle feedlot ration as the price of CGW varies (with other ingredient prices held fixed at their mean values).

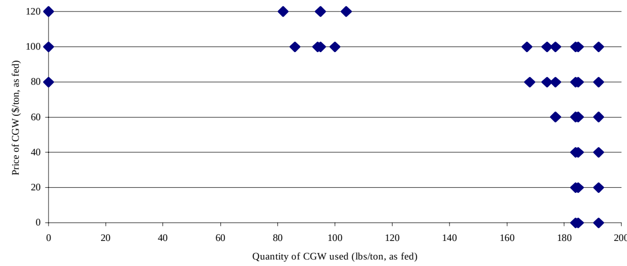

Figure 2. Price and quantity of CGW from LP simulation, using 1991-97 monthly price data for alfalfa, cottonseed hulls, and corn silage.