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Impact of Sugarcane Delivery Schedule on Product Value at Raw Sugar Factories

Michael E. Salassi, Mercedes Garcia, Janis B. Breaux, and Sung C. No

Conversion to combine harvesters has resulted in Louisiana sugarcane growers delivering a more perishable product to raw sugar factories. Dextran formation increases as the time between harvest and milling is extended. Milling of freshly cut sugarcane reduces the formation of dextran and associated economic losses. One approach available to factories to reduce dextran formation is to extend the harvested sugarcane delivery schedule to the mill. A simulation model was developed to evaluate alternative delivery schedules at raw sugar factories. Economic losses in product value associated with dextran formation were estimated and compared for various extended delivery schedules.

Key Words: dextran, milling, product value, raw sugar factories, scheduling, sugarcane industry

The sugarcane industry is an important contributing factor in the performance of the Louisiana agricultural economy. In 2001, sugarcane was grown on 493,773 acres by 773 producers in 24 Louisiana parishes. An estimated 454,271 acres were harvested for sugar, with a total production of 1.5 million tons of raw sugar. Raw sugar produced per harvested acre was 6,298 pounds. The total value of the 2001 sugarcane crop in Louisiana (after milling) was $619.7 million. This value was the highest for a single crop commodity in the state and represented 31.2% of the total value of crops produced in 2001 (Louisiana State University Agricultural Center, 2001).

Recent years have seen increases in yield and production acreage and reductions in the number of farms and raw sugar factories in Louisiana. Low prices for competing crops fueled the increase in acreage, and increases in yield are due primarily to higher yielding varieties such as LCP 85-384 that require the use of more efficient combine harvesters. The number of raw sugar factories in Louisiana decreased from 43 in 1971 to 17 in 2001. Although existing factories have been upgrading their facilities to increase capacity, total milling capacity in the state is still somewhat

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Michael E. Salassi is professor, Mercedes Garcia is graduate research assistant, and Janis B. Breaux is research associate, all in the Department of Agricultural Economics and Agribusiness, Louisiana State University Agricultural Center, Baton Rouge, LA; Sung C. No is assistant professor, Department of Economics and Finance, Southern University, Baton Rouge, LA.

restrictive relative to the amount of acreage being harvested. Seventeen factories ground a total of 14.9 million tons of sugarcane in 2001 (*Sugar Journal*, 2002). Daily capacity in tons of cane ground vary greatly among the factories, ranging from approximately 4,000 tons per day to close to 20,000 tons per day.

A switch by producers to higher yielding varieties has created a shift in harvesting methods from wholestalk harvesting to combine harvesting. Previously used wholestalk harvesters would cut the sugarcane stalk at its base, leaving the entire stalk intact. Harvested stalks would then be loaded and shipped to the mill for grinding. With only two exposed ends, the time between harvest and milling could be as long as several days with no significant deterioration in cane quality. In contrast, the new combine harvesters cut the sugarcane stalk into several smaller pieces, called billets. These billets are loaded into a wagon running beside the harvester in the field. A stalk of sugarcane, cut into several pieces, now has many exposed ends through which dextran-producing bacteria can enter and start to cause a deterioration of cane quality. Raw sugar produced from sugarcane with high levels of dextran results in raw sugar price reductions, paid by refiners purchasing the raw sugar, as well as a reduction in the actual amount of raw sugar produced. As a result, sugarcane harvested with combine harvesters must be milled in a matter of hours, not days, after harvest in order to minimize any potential economic losses due to poor cane quality from dextran formation.

Currently, many sugarcane growers and raw sugar factories in Louisiana are considering the option of extending the hours in a harvest season day over which sugarcane is harvested and delivered to the mill for grinding. This change in harvest and delivery time could result in decreases in the time between harvest and milling, significant increases in cane quality, and could help to reduce economic losses resulting from delays in grinding due to harvest scheduling and delivery inefficiencies. This article presents results from a study which evaluated the impact from alternative sugarcane delivery schedules to raw sugar factories on the change in final product value associated with dextran formation.

Scheduling

Scheduling can be defined as the establishment of the timing of the use of resources in an organization. Scheduling occurs in every organization, as managers need to schedule uses of equipment, facilities, or human labor. In a manufacturing environment, scheduling relates to the allocation of machines to the different tasks required for the production of the different products. But before scheduling of resources takes place, other decisions regarding system design and operation are made. Consequently, in the decision-making hierarchy, scheduling is usually the final step before actual production starts. Because other decisions take place first, scheduling must meet the constraints set by these previous decisions. Scheduling is usually set to achieve a tradeoff among conflicting activities.

The basic scheduling problem assigns a number of jobs to be carried out in a period of time using the available resources. This problem accounts for a set of constraints that must be met in order to achieve the goal of the planner. The most important types of constraints involve the sequence of operations or process plan, the availability of resources, and the admissibility of assigning particular operations to particular machines. The main issues are resource constraints and their availability through time. For example, *renewable* resources are assumed to be available with constant capacity. Other types of constraints include due dates. These due dates are considered "soft" constraints because they can be adjusted to meet the requirements of the production process.

Once a schedule has met all of the constraints, it is considered feasible. Other measures for evaluating schedules are objective functions. These objective functions generally measure utility by meeting the economic goal set by the planner. In scheduling problems with due dates, the objective criteria would involve a performance measure based on lateness or tardiness. Scheduling performance measures have usually involved only lateness criteria. However, these criteria ignore the consequences of finishing a job early. Some of the costs involved with finishing a job early include storage costs (e.g., product deterioration, insurance, opportunity costs). On the other hand, the costs of finishing a job late include customer dissatisfaction, contract penalties, loss of sale, and potential loss of reputation. Just-in-time (JIT) production aims to discourage both earliness and tardiness. With JIT, the ideal schedule would mean finishing all the jobs on their assigned due date.

A quantitative criterion for measuring earliness and tardiness is the minimization of total penalty costs (Hall and Posner, 1991; Hall, Kubiak, and Sethi,1991). Baker and Scudder (1990) explain that the main role of penalties is to guide solutions toward exactly meeting due dates. If due dates are met exactly in an ideal schedule, one may see the use of penalty functions as a measure of less-than-optimal performance. Baker and Scudder provide a detailed review of the different models using some form of penalty measures. The first involves the minimization of total absolute deviation from a common due date. Under this model, both earliness and tardiness are penalized at the same rate. In an alternative model, earliness and tardiness are penalized at different rates. Other models include due date penalties and flowtime penalties.

Previous Work

Raw sugar factories face intense price/cost pressure to improve efficiency and competitiveness. Improving supply schedules in this industry involves a complex set of interrelationships among field productivity, mill-crushing capacity, transportation resources, and storage capacity. Higgins and Muchow (1998) developed an operations research methodology to explore the options available in cane supply scheduling. In that paper, the authors provided guidelines for on-farm and off-farm considerations and data to be taken into account when developing such a project. Their research found that both field productivity and crop maturity influence harvest schedules when the optimal harvest date is based on maximizing the theoretical recoverable sugar (TRS) in cane. However, maximizing TRS alone does not determine supply schedule, as it is highly influenced by mill-crushing capacity, the amount of transportation resources, and storage capacity available in the factory. The ability to consider all these elements and include all the constraints they involve would determine how well a supply delivery schedule fits the complexity of the system. Therefore, the optimal supply delivery schedule would consider crop yield and TRS as well as transportation, grinding, and storage capacities. Developing this type of schedule would be challenging since it would require gathering tremendous amounts of data to account for the complexities in the system, but simplifying assumptions and relaxing constraints could help the researcher create a schedule that still describes the system and generates optimal results.

Semenzato, Lozano, and Valero (1995) focused on a simulation of the operations that take place between pre-harvest burning and processing (grinding), presenting a simulation algorithm for scheduling harvesting operations, and available resources to minimize the time between the end of cane burning and start of grinding. In order to provide a decision support system, the authors took into account several factors, such as availability of resources, distance from field to factory, and maximum field area that should be burned, so the cane can be milled within 15 days. The algorithm they presented accounts for randomness in operation times, equipment breakdowns, and repair times (Semenzato, 1995). Semenzato, Lozano, and Valero concluded that such an algorithm can help in the cultivation phase to choose suitable field sizes, and in the harvesting phase to minimize resource use. Van Vliet, Boender, and Rinnoy (1992) examined delivery optimization based on the creation of an interactive system for planning bulk deliveries of sugar in a farming cooperative. In this case, development of such a system led to improvements in the efficiency and quality of planning procedures.

Loss in Sugarcane Quality from Formation of Dextran

Dextran is a polysaccharide formed during decomposition of sugar when the sugar is attacked by the bacterium *Leuconostoc mesenteroides*. This microorganism is always present in the environment and it usually thrives under warm and humid conditions. *Leuconostoc* secretes the enzyme dextran-sucrase, which is the major cause of dextran synthesis from sucrose. Research on sugarcane deterioration has found it is affected by burning, climatic conditions, billet length, and by the time elapsed from burning to cut to crush (Batta et al., 1992; Jolly and Prakash, 1987; Sharma, Batta, and Singh, 1994). Specifically, burning and climatic conditions affect sugarcane deterioration. Billet length and cane condition affect deterioration rate, and the longer cane is exposed after burning, the more it deteriorates. Dextran formation begins after burning takes place, indicating the microorganism penetrates the sugarcane stalk after the protective wax covering is destroyed (Alvarez and Cardentey, 1988).

Dextran is formed in the sugarcane stalk. Once the cane enters the milling process, no further amounts are generated in the juice, molasses, or sugars. Therefore, post-harvest management needs to be improved to optimize juice quality. Legendre and

Richard (1998) found that deterioration rate and dextran concentration were higher in billeted cane than in wholestalk cane, and higher in burned than in green cane. Chopping (cutting the harvested stalk into billets) appeared to have a greater effect on juice quality than burning, making burn-to-crush management crucial to juice quality when harvesting by combine. Legendre, Birkett, and Stein (2000) also verified that unburned billeted cane should be crushed within 20 hours after cut. Burned billeted cane should be crushed sooner. Therefore, cane held in sleeper (overnight) loads for at least 12 hours should be processed within five to eight hours to avoid further cane juice deterioration.

Dextran formation presents many problems for the raw sugar factory. First, it leads to a decline in sugar recovery, translating to economic losses for the sugar industry. It has been estimated that every one part per million (ppm) units of dextran in sugar juice results in a loss of 0.0025 pounds of raw sugar produced per ton of sugarcane (Day, 1994). Dextran formation also creates processing difficulties by increasing juice viscosity, poor clarification, and crystal elongation. Elongated sugar crystals result in sugar loss to molasses. Dextran affects processing by decreasing boiling house performance.

In addition to creating processing problems, dextran has a significant impact on the resulting market value of the final processed product. Raw sugar contracts offered to factories by sugar refiners include specific price penalties related to the level of dextran in the raw sugar. The dextran penalties are usually stated in terms of percentage reduction in price based upon the dextran level. Higher levels of dextran in the processed raw sugar result in higher price penalties. Figure 1 provides an assessment showing how significant these economic losses can be at typical raw sugar price levels of 18¢, 20¢, and 22¢ per pound.

Estimation of Dextran Levels

To evaluate the impact of alternative daily delivery schedules at raw sugar factories on the value of raw sugar produced, it was necessary to project dextran levels on an hourly basis over a 24-hour period. Raw data on which to base these projections were relatively scarce. Data sources from only two recent research studies in Louisiana were found which estimated hourly dextran levels on sugarcane harvested with combine harvesters. Legendre and Richard (1998) compared green versus burned cane and whole versus billeted cane of the varieties CP 70-321 and LCP 85-384 to evaluate post-harvest management and its effect on cane juice quality. Whole and billeted stalks were milled within 24, 48, 72, and 98 hours. Samples for delayed milling were kept at 80°F and high humidity (60–100%). Later, samples were analyzed for dextran concentration. In a subsequent study, Legendre, Birkett, and Stein (2000) evaluated the deterioration of sugarcane held in overnight sleeper loads. The objective of their study was to quantify the effects of billeted cane stored as sleeper loads on the dextran concentration of juice obtained in the factory core laboratory. Dextran levels were measured for cane milled at 1, 14, 17, 20, and 24 hours after harvest.

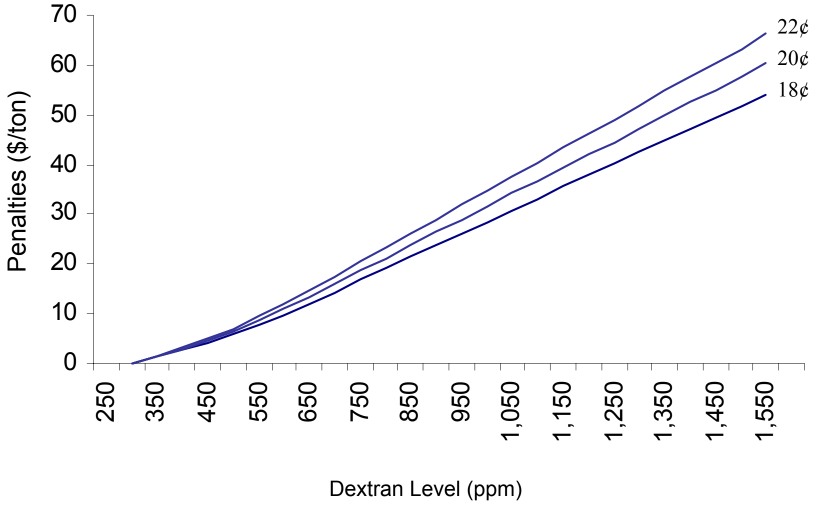

Figure 1. Dextran penalties on raw sugar for alternative price levels

Dextran concentrations reported in the Legendre, Birkett, and Stein (2000) study were used to estimate dextran formation on an hourly basis for the sugarcane delivery simulation model presented here. For purposes of projecting dextran formation on an hourly basis, the following functional forms were evaluated using ordinary least squares (OLS) estimation:

- Model 1: $Dextran = \$_0 + \$_1 \ (\ Hour$,
- Model 2: $\log(Dextran) = \$_0 + \$_1 \ (\ Hour$,
- Model 3: $Dextran = \$_0 + \$_1 \ (\ \log(Hour)$,
- Model 4: $Dextran = \$_0 + \$_1 \ (\ Hour + \$_2 \ (\ Hour^2$,
- Model 5: $Dextran = \$_1 \ (\ Hour + \$_2 \ (\ Hour^2$,

where *Dextran* is the dextran level measured in parts per million (ppm), *Hour* represents the hours of sugarcane age between harvest and milling, and $Hour^2$ is hours of cane age squared.

Various model selection criteria were adopted for the analysis, such as R^2, the Akaike Information Criterion (AIC) (Akaike, 1981), and the Schwarz Bayesian Criterion (SBC) (Schwarz, 1978), in order to identify the best model for the data. The results presented in table 1 indicate Models 1 and 2 are better in comparison to the others, given the adjusted R^2, AIC, and SBC selection criteria. Notice, however, that the comparison is not valid because of different regressands for Model 1 and Model 2. Thus, more meaningful tests were conducted for choosing between Model 1 (linear model) and Model 2 (log-linear model): the Box-Cox test (Box and Cox, 1964), the BM test (Bera and McAleer, 1982), the PE test (Mackinnon, White, and

Table 1. Model Selection Criteria Among the Nonnested Models

Selection Criteria[a]	Model 1	Model 2	Model 3	Model 4	Model 5
Adjusted R^2	0.7566	0.8826	0.7290	0.7345	0.7482
AIC	62.79	−5.06	63.30	63.20	62.96
SBC	62.01	−5.84	62.13	62.03	62.18

[a] AIC is the Akaike Information Criterion; SBC is the Schwarz Bayesian Criterion.

Table 2. Results of Tests for Selection Between Model 1 and Model 2

Models	Box-Cox Test	BM Test	PE Test	R-squared
Model 1 (linear model)	Rejected	Accepted	Accepted	0.9655
Model 2 (log-linear model)	Preferred	Accepted	Accepted	0.9744

Davidson, 1983), and "R-squared." The results of these tests are reported in table 2. The BM and PE tests indicate both Model 1 and Model 2 are preferable models for the data. In contrast, the Box-Cox and the R-squared tests choose Model 2 over Model 1 as the best model for the data. Thus, for this study, Model 2 is considered to be the best model for the data.

Given this model specification, some concerns arose due to the small sample size ($n = 5$). This issue was examined using a bootstrapping procedure. Regression coefficients were bootstrapped 5,000 times via the resampling of residuals. Table 3 clearly reveals that the OLS coefficients and standard errors in regression Model 2 are much closer to the bootstrapped mean of OLS coefficients and standard errors compared to those of the other regression models. This finding is an indication that the OLS coefficients in Model 2 are fairly stable, especially with the small sample size of the data. Therefore, Model 2 was chosen to be used in the simulation model to help project hourly dextran formation because it adequately met model specification criteria among the nonnested models considered in this study.

Since Model 2 contains the log of dextran as a dependent variable, OLS estimation of Model 2 results in an unbiased estimate of log(*Dextran*). However, the predicted value of the actual dextran level, *Dextran*, is biased. This prediction bias was reduced by using the prediction adjustment presented by Kmenta (1986, p. 511), resulting in the predicted value of dextran defined as follows:

$$Dextran_a = e^{\log(Dextran) + s^2/2},$$

where $Dextran_a$ is the predicted dextran level adjusted for estimation bias, log(*Dextran*) is the predicted value of the dependent variable, and s^2 is an unbiased estimate of the variance of residuals. Once the appropriate equation was determined and dextran levels were projected over a 24-hour period, price penalties currently specified in raw sugar contracts were used to assign a market price penalty to the hourly dextran concentrations in the final raw sugar product.

Table 3. Bootstrapped Mean (resamples = 5,000) of OLS Coefficients for the Dextran Data (*n* = 5)

	OLS Estimates (Standard Errors)			Bootstrapped Mean of OLS Estimates (Standard Errors)		
Model	b_0	b_1	b_2	b_0	b_1	b_2
Model 1	118.61	43.20	—	28.31	38.53	—
	(201.52)	(11.78)		(106.05)	(6.20)	
Model 2	5.37	0.074	—	5.27	0.069	—
	(0.228)	(0.013)		(0.12)	(0.007)	
Model 3	178.40	256.23	—	7.725	233.59	—
	(282.97)	(108.41)		(165.46)	(63.39)	
Model 4	223.11	6.44	1.55	102.44	!24.17	180.36
	(242.61)	(44.19)	(1.79)	(67.92)	(13.88)	(92.26)
Model 5	—	34.58	0.73	—	2.30	137.86
		(31.05)	(1.52)		(19.71)	(129.13)

The Simulation Model

A simulation model was developed which simulated the hourly delivery of harvested sugarcane to a raw sugar factory over a 24-hour period. The model kept track of the quantity and hourly age of cane ground, hourly age of cane stored in the factory yard, as well as the dextran price penalties and loss of sugar due to dextran formation hourly throughout the day. A representation of the model is presented in figure 2.

The simulation model was based on the operating conditions at one of the smaller raw sugar factories in Louisiana. This factory has a grinding capacity of 7,500 tons of sugarcane every 24 hours, providing for a milling rate of about 312.5 tons of cane per hour. Each truck and trailer delivering harvested sugarcane to the factory carries 28 tons of billeted cane. This means the factory would need 268 truck deliveries daily to keep the mill in constant operation over a 24-hour period.

In Louisiana, sugarcane must be harvested and sent to the factory for grinding over a relatively restricted harvest season to avoid the risk of freezing weather. Generally, sugarcane harvest in Louisiana will begin in September and continue through the end of December. Once the raw sugar factories start operations, they will run 24 hours per day throughout the season, only stopping grinding operations for breakdowns and major repairs.

The simulation model starts by determining random hourly truck deliveries. The number of truck deliveries each hour depends on the total number of hours when deliveries to the mill are allowed. In the research results presented here, deliveries were simulated over a 12-hour period, an 18-hour period, and a 24-hour period. The simulation model simulates truck deliveries and sugarcane grinding on an hourly basis for a single day during the harvest season. Just prior to the start of the harvest season, each raw sugar factory in Louisiana estimates the projected level of sugarcane

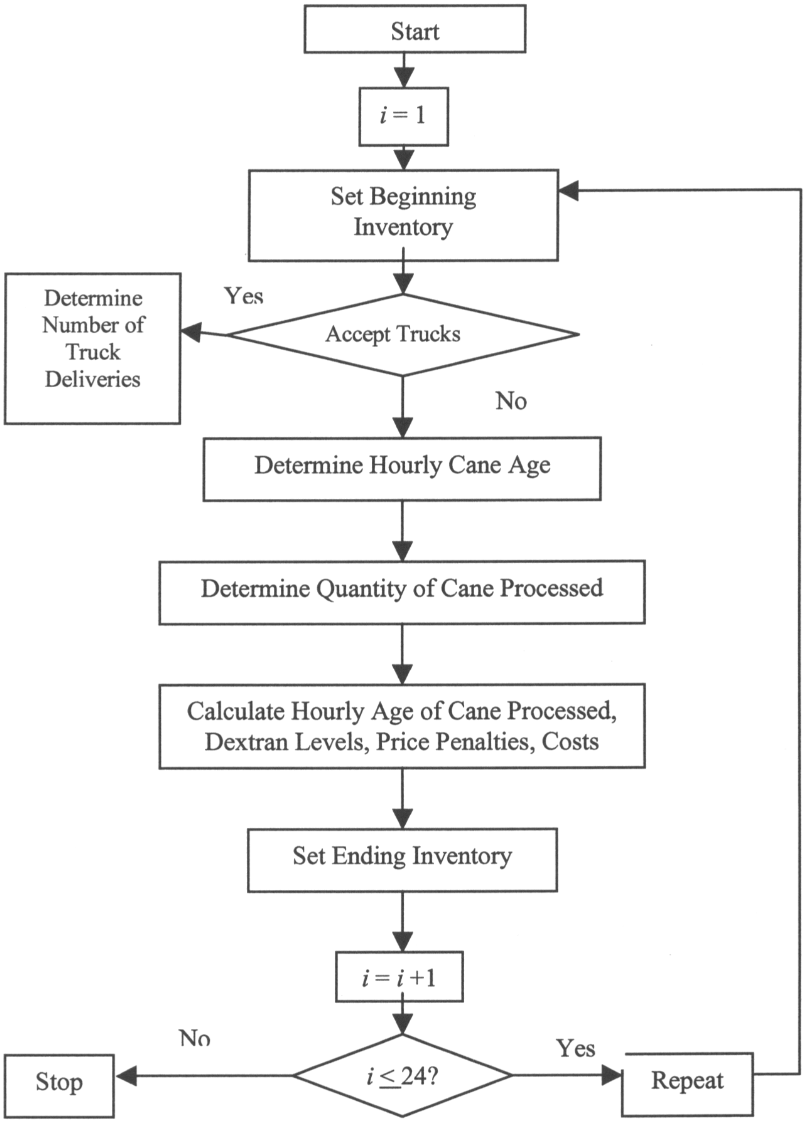

Figure 2. Simulation model flow chart

to be delivered to the mill during the upcoming milling period and assigns a daily delivery quota to each sugarcane grower. The focus of the research presented here was on determining the reduction in economic losses resulting from extending the delivery schedule to more than 12 hours per day. Therefore, it was assumed that 268 truckloads of harvested sugarcane would be delivered to the mill daily to supply the grinding operation. Lesser or greater numbers of daily truckload deliveries were not considered in this analysis.

To determine random daily truck deliveries, a Poisson distribution was used to generate the number of trucks arriving at the mill during each hour of the three delivery schedules evaluated in this study. This type of distribution assigns probabilities to the number of occurrences of the event within a set time interval based on the mean value of occurrences per time period. The model used in this study simulated the arrival of 268 trucks at the sugar factory during one 24-hour period. The trucks were allowed to deliver harvested cane during a 12-, 18-, or 24-hour period within the day. The mean number of hourly truck arrivals used to generate random truck arrivals was 22 trucks per hour for the 12-hour schedule, 15 trucks per hour for the 18-hour schedule, and 11 trucks per hour for the 24-hour schedule. Each daily delivery schedule generated was adjusted to the 268 total truck deliveries based on the generated percentage hourly distribution of trucks. A total of 100 different random sets of truck arrival occurrences were simulated for each delivery schedule evaluated.

After the number of trucks arriving hourly is determined, the model continues by setting the beginning cane inventory in the factory yard at the start of the 24-hour grinding period. For the scenarios where deliveries are only allowed for a 12- or 18-hour period, there is assumed to be enough cane from the previous grinding period in the yard to start grinding until new cane arrives. In this case, the beginning inventory would be delivered during the last hours of deliveries in the previous period (day) so that the cane sits in the yard the least possible amount of time. Once the milling period starts, the model updates beginning inventory in the yard by hourly age of cane. This model sets the amount of cane in the yard at the end of the hour as the beginning inventory at the start of the next hour. The simulation model allows five trucks each hour to deliver cane directly to the mill table (the platform on which cane is washed before entering the mill), with cane from any additional trucks arriving that hour to be dumped directly in the mill yard.

The next step in the model is determining the amount and the hourly age of the cane ground every hour under the assumption that the oldest cane is milled first. Therefore, the grinding rate determines the amount of cane needed every hour, and age of cane is determined by calculating beginning inventories plus truck deliveries minus the amount of cane ground every hour. Three scenarios were evaluated in this study related to the age of harvested cane as it arrives at the mill. Travel time from farm to mill scenarios were evaluated at one, three, and six hours between harvest and arrival at the mill.

After hourly mill operations over the 24-hour period have been simulated, the model then calculates resulting economic losses based on the age of cane ground.

Adapting bootstrapping procedures from Prescott and Stengos (1987), 100 random sets of 24-hour dextran values were generated to simulate random sucrose deterioration in the harvested sugarcane. Using the values on hourly dextran formation estimated from the regression model, the simulation model estimates dextran price penalties per pound of sugar at specified raw sugar prices. To do this, the regression model first estimates dextran formation in cane every hour after it has been harvested. Using this value, together with price penalties in contract sales based on dextran concentration, dextran penalty values can then be calculated.

Another cost from dextran formation is the cost associated with sugar loss for every unit of dextran formed in the harvested cane. It is estimated that for every ppm of dextran formed, there is a loss of 0.0025 pounds of sugar per ton of cane. The value of this sugar loss was then calculated as the total weight of sugar lost due to dextran formation times the per pound price of the sugar. The estimated price penalties plus the value of sugar loss together comprise the economic impact on product value evaluated in this study.

Results

Estimated mean daily economic losses from dextran formation in raw sugar produced for alternative delivery schedules and time intervals from harvest to arrival at mill are reported in table 4. These values represent the mean level of economic losses based on 100 daily truck arrival simulations and a 20¢ raw sugar market price. With the current 12-hour delivery schedule, estimated mean economic losses were $8,413 per day, assuming a one-hour time interval from harvest to mill. Of this amount, dextran price penalties totaled $6,668 per day, and the value of sugar losses from dextran formation was $1,745 per day. Extension of the daily delivery window to 18 hours per day dropped the estimated mean economic losses by 50%, down to $4,205 per day. The largest decrease was in the price penalties, decreasing by 56.9% to $2,868 per day. Economic value of sugar loss dropped only slightly, to $1,337 per day. A 24-hour delivery schedule resulted in a substantial decrease in economic losses. Dextran price penalties decreased to an estimated mean of $512 per day, a decline of 92.3%. Sugar loss values dropped by 45.8% to $945 per day. Resulting total economic losses using a 24-hour delivery schedule were estimated to be $1,457 per day, a decrease of 82.6% from the current 12-hour schedule.

The majority of harvested sugarcane in Louisiana is not usually delivered to the mill within one hour of harvest. A more realistic situation is where several hours elapse between the time of harvest and the delivery of the harvested cane to the mill. This situation is depicted in table 4 for the two additional scenarios of three and six hours travel time from farm to mill. The hourly age of the cane ground in this scenario is the sum of the hours between harvest and delivery plus the number of hours the cane waits at the mill to be ground. The estimated mean daily economic losses under the six-hour travel time scenario for a 12-hour delivery schedule were $16,203 at a 20¢ per pound market price. Dextran penalties were $13,673, and the economic value of sugar losses was estimated to be $2,530. Extending the delivery

Table 4. Estimated Mean Daily Economic Losses from Raw Sugar Produced for Alternative Delivery Scenarios at a 20¢/Pound Market Price

	Hours Mill Accepts Delivery of Sugarcane					
	12-Hour Schedule		18-Hour Schedule		24-Hour Schedule	
Type of Cost	Mean ($)	C.V. (%)	Mean ($)	C.V. (%)	Mean ($)	C.V. (%)
	<! ! ! ! ! ! ! ! ! ! ! ! 1-Hour Travel Time from Farm to Mill ! ! ! ! ! ! ! ! ! ! ! !>					
Dextran Penalty	6,668	13.8	2,868	20.1	512	66.0
Sugar Loss	1,745	6.3	1,337	7.4	945	11.7
Total Loss	8,413	12.2	4,205	15.9	1,457	30.3
	<! ! ! ! ! ! ! ! ! ! ! ! 3-Hour Travel Time from Farm to Mill ! ! ! ! ! ! ! ! ! ! ! !>					
Dextran Penalty	9,198	13.2	4,529	19.1	1,230	50.1
Sugar Loss	2,043	6.6	1,567	7.6	1,109	12.1
Total Loss	11,241	12.0	6,096	16.1	2,339	31.9
	<! ! ! ! ! ! ! ! ! ! ! ! 6-Hour Travel Time from Farm to Mill ! ! ! ! ! ! ! ! ! ! ! !>					
Dextran Penalty	13,673	11.1	7,658	15.9	2,785	37.6
Sugar Loss	2,530	6.3	1,938	7.4	1,370	11.7
Total Loss	16,203	10.4	9,596	14.2	4,155	29.1

Notes: C.V. is coefficient of variation. Mill grinding capacity = 7,500 tons per 24-hour period.

window to 18 hours reduced total economic losses by 40.7%, to $9,596. Price penalties for dextran decreased by 43.9% to $7,658 per day. The value of sugar loss declined to $1,938 per day, a decrease of 23.4%. Extension of the mill delivery schedules to a 24-hour period reduced daily economic losses due to dextran formation by 74.3%. Mean daily economic losses were estimated to be $4,155 per day of mill operation during the grinding season. This significant decline in economic losses resulted from the reduction in hourly age of cane ground, as the time period between delivery and grinding was reduced.

The levels of total daily price penalties and sugar losses are related to the level of raw sugar market price. The impact of alternative delivery schedules on net product value of raw sugar produced is presented in table 5 for three alternative raw sugar price levels. The daily estimated mean economic losses for farm to mill delivery times of one, three, and six hours were converted to a net price reduction in cents per pound of raw sugar. Daily economic loss values were converted to net price reductions using the daily mill grinding rate of 7,500 tons per day and an average raw sugar conversion rate of 200 pounds of raw sugar per ton of cane. Under the current 12-hour delivery schedule, the reduction in final product value due to dextran formation ranged from 0.504¢ to 1.188¢ per pound for raw sugar market prices of 18¢ to 22¢. Extension of the delivery window at the mill to 18 hours per day lowers this price reduction by approximately one-half, ranging from 0.252¢ to 0.703¢ per pound. A 24-hour delivery schedule further lowers these net price reductions to approximately 0.087¢ to 0.304¢ per pound, representing an approximate decrease in net price reductions of 74% to 83% compared to the 12-hour delivery schedule.

Table 5. Reduction in Net Price of Raw Sugar Produced Daily at Alternative Raw Sugar Market Prices

	Hours Mill Accepts Delivery of Sugarcane		
Travel Time (farm to mill)	12-Hour Schedule	18-Hour Schedule	24-Hour Schedule
	<! ! ! ! Net Price Reduction at 18¢/Pound Price (¢/lb.) ! ! ! !>		
1 hour	0.504	0.252	0.087
3 hours	0.674	0.365	0.140
6 hours	0.972	0.575	0.249
	<! ! ! ! Net Price Reduction at 20¢/Pound Price (¢/lb.) ! ! ! !>		
1 hour	0.560	0.280	0.097
3 hours	0.749	0.406	0.155
6 hours	1.080	0.639	0.276
	<! ! ! ! Net Price Reduction at 22¢/Pound Price (¢/lb.) ! ! ! !>		
1 hour	0.616	0.308	0.106
3 hours	0.824	0.447	0.171
6 hours	1.188	0.703	0.304

Conclusions

The adoption and widespread planting of the high-yielding sugarcane variety LCP 85-384 has resulted in the conversion of the harvest system used by sugarcane growers in Louisiana. The newly adopted combine harvester cuts harvested sugarcane stalks into small billets, rather than leaving the entire stalk intact as under the previous wholestock harvest system. Sugarcane stalks cut into billets have a greater number of exposed ends which can allow bacteria to enter, resulting in the formation of dextran. The formation of dextran in processed raw sugar can have a significant impact on the selling price of the processed raw sugar product which is sold to sugar refiners. Dextran formation creates processing problems in raw sugar factory operations and leads to a decline in sugar recovery, translating into economic losses for the sugar industry. In addition to processing problems, dextran has a significant impact on the resulting market value of the final processed product. Raw sugar purchase prices offered to raw sugar factories by buyers from sugar refiners include specific price penalties related to the level of dextran in the raw sugar.

This study has evaluated the impact of alternative sugarcane delivery schedules to raw sugar factories on the final product value associated with dextran formation. A simulation model was developed to evaluate the hourly delivery of harvested sugarcane to a mill over a 24-hour period. The hourly age of the unmilled sugarcane in the mill yard was determined and projected dextran levels were estimated. Three alternative sugarcane delivery schedules were evaluated in the study: delivery to the mill over a 12-hour period, an 18-hour period, and a 24-hour period. Dollar value of sugar lost due to dextran as well as the value of dextran price penalties in the final processed product were determined.

The general conclusion of this study is that raw sugar mills can reduce economic losses resulting from the processing of sugarcane with high levels of dextran by extending delivery hours at the mill from a 12-hour period, which most mills are currently using, to a longer delivery period. Dextran price penalties decreased substantially when delivery time was extended from 12 hours to 18 or 24 hours per day. These economic savings could be significant to the financial position of a raw sugar mill over an entire grinding season. For example, the economic savings per day in switching from a 12-hour to a 24-hour delivery schedule were estimated to be $12,048 with a 20¢ market price and a six-hour elapsed time between harvest and delivery at the mill. Over a 100-day grinding season, these savings would total $1.204 million.

However, extending the delivery time to the mill does have some disadvantages. The mill would incur some increased labor costs associated with unloading and sampling harvested cane arriving at the mill. Second, extension of the delivery schedule to 24 hours, for example, raises issues related to potential nighttime harvest and hauling operations. Currently, most sugarcane in Louisiana is harvested in the morning hours and shipped to the mill by truck in the afternoon hours. Although the combine harvesters have the capability to operate at night, it is unlikely that many growers would choose to do so, primarily for safety reasons. The more likely scenario is that harvest operations would be extended to later in the day, shifting much of the hauling operations to nighttime hours. Although such a change in harvest operations would not have much impact on cost, it would require much more coordination between the raw sugar mill and growers to schedule harvest and delivery of cane in a timely and efficient manner.

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