M31 The use of NIR Spectroscopy in a Cane Quality Incentive Scheme

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Abstract

This paper will describe the cane quality program implemented at the Mulgrave Central mill during the 2001 season and the outcomes the scheme has achieved since its implementation. The aim of the program was to provide a financial incentive to improve the quality of cane delivered to the Mulgrave mill. High levels of extraneous matter were adversely affecting mill operations in the areas of cane haulage, crushing rate, maintenance requirements and factory downtime.

A cane analysis system using NIR spectroscopy provided the mill with an estimate of fibre and ash levels in cane on an individual consignment basis. In combination with the bin weights and laboratory CCS, these estimates were used in developing a cane quality scheme that provided sufficient incentive to change adverse field practices and improve the mills' bottom line. The quality scheme awarded bonus and penalty points based on the following key performance indicators; bin weight, ratio of fibre to CCS and ash content of the cane supply. The quality scheme was supported by rapid information feedback to the growers in the form of daily faxing, dial in phone services and a web site.

The results show a very strong response for all the key parameters and feedback from the growing and harvesting sectors has been positive, with most endorsing the program as both achievable and robust.

The program has been successful in reducing the levels of cane of poor quality from 47% of supply in 2000 to 18% in 2001, 3% in 2002 and 6 % in 2003, while increasing the levels of premium quality cane from 23% in 2000 to 59% in 2001, 86% in 2002 and 78% in the 2003 season.

Introduction

The Mulgrave district was experiencing record low CCS and high fibre levels during the mid to late 1990's. Pope (1997) identified the major factors contributing to this CCS decline as increased levels of extraneous matter, suckers and pest damage.

Historically the mill had an extraneous matter incentive scheme. However with a standard error of 3.5% in individual extraneous matter determinations, growers had little faith in the results and the scheme was deemed to be ineffective in delivering the desired outcomes.

Mulgrave was the first mill to install a Cane Analysis System (CAS) using NIR spectroscopy in 1996. The system was evaluated during the 1997 crushing season and cane payment based on individual fibre analysis was introduced for the 1998 season (Staunton et al., 1999). It was hoped that the determination of individual rake fibre for payment would provide the necessary financial incentive to reward best practice in harvesting. However because there is only a one-unit decline in CCS for every six-unit increase in fibre, individual fibre alone was not significant enough to change adverse practices and high levels of extraneous matter were still significant in the 1998, 1999 and 2000 seasons. The impacts of high extraneous matter levels, particularly trash, were increased fibre levels, decreased bin weights and a lowering of the biomass CCS through dilution. High fibre and dirt levels affected crushing rate, factory downtime and contributed to increased maintenance requirements.

The implementation of the CAS provided the mill with fibre and ash levels in cane on an individual consignment basis. Three parameters were targeted as a measure of cane quality. They were:

- Fibre to CCS ratio
- Bin weight
- Ash in cane

The variability of these performance indicators in a commercial cane supply was determined using productivity information and CAS data from the 2000 season. It was immediately apparent that some harvesting groups had superior performance with regard to the three parameters. It was also clear that some of the best performing groups were cutting in the wetter parts of the district.

This paper will describe the cane quality program implemented at the Mulgrave Central mill during the 2001 season and the outcomes the scheme has achieved since its implementation.

Cane Quality Program

The aim of the cane quality program was to provide a financial incentive to improve the quality of cane delivered to Mulgrave mill. The program had to deliver a quality scheme that was achievable using current best practice, provide a financial incentive that made required changes in practice an attractive option and structured so that full compliance would not be a financial burden to the mill.

The scheme awarded quality bonus and penalty points based on the key performance indicators; bin weight, fibre to CCS ratio and ash content of the cane supply, each of which is discussed below.

Bin weights

Low bin weights have an adverse effect on the crushing capacity at the Mulgrave mill. The factory can process a maximum of 136 bins per hour, and at lower bin weights it becomes impossible to achieve desired crushing rates. Table 1 contains year 2000 data showing the percentage of cane supply below given bin weights, and the predicted maximum achievable crushing rate possible under these conditions.

Table 1: Effect of bin weight on crushing capacity

Bin weight (tonnes)	% of cane supply	Crushing rate @136 bins/hr
< 3.00	5.86	408.0
< 3.10	10.50	421.6
< 3.20	17.40	435.2
< 3.30	26.39	448.8

The data shows that even at maximum tipping capacity, the mill could not achieve its target-crushing rate of 450 tonnes per hour for more than one quarter of its cane supply for the 2000 season.

Data collected from 1992 to 1996, (while the previous extraneous matter based cane quality scheme was in place), showed a very strong relationship between the levels of extraneous matter in the cane supply and the bin weight. Figure 1 shows the trend-line for the average bin weight against the extraneous matter level for over 100,000 individual determinations.

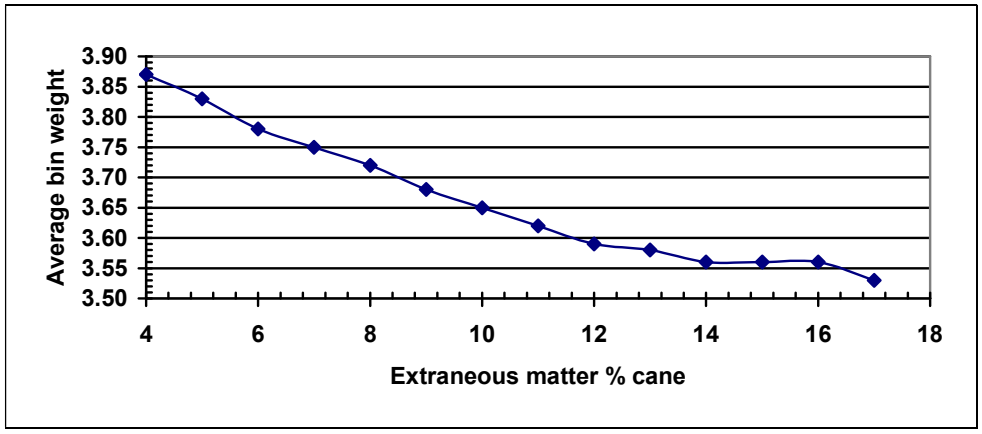

Figure 1: Average Bin weight trend-line for varying extraneous matter content.

The trend-line shows that overall, an improvement in cane quality will result in improved bin weights delivered to the factory, and as a result, a financial incentive linked to bin weight would act as a positive reinforcement in a scheme to improve cane quality. With this in mind the cane quality scheme for this parameter, shown in Table 2, allocates a relatively small amount of quality points.

Table 2: Quality point allocation for bin weight

Bin weight (tonnes)	Quality points
> 3.80	50
3.35 – 3.80	0

< 3.35	-50

Ratio of Fibre to CCS

Increases in the fibre content of cane can be linked historically to increases in CCS and is usually associated with moisture loss as the cane ripens. In this situation the ratio of fibre to CCS remains relatively constant, as it is independent of the moisture content of the cane. Increases in this ratio must involve the addition of material both high in fibre and low in CCS. Historical data, shown in Table 3, shows a dramatic increase in this ratio over the last decade.

Table 3: Historical trends for the ratio of fibre to CCS

Season	Fibre / CCS ratio	% Increase on 1983-92 decade
1983 - 1992	1.01	-
1993	1.22	20.8
1994	1.18	16.8
1995	1.25	23.8
1996	1.22	20.8
1997	1.34	32.7
1998	1.39	37.6
1999	1.33	31.7
2000	1.28	26.7

This increase prompted investigations into the effect of the addition of tops, trash and dirt on the CCS of the cane supply that are described by Crook et al. (1999) and Berding et al. (2002). Using data from the Crook investigation, shown in Table 4, the effect of the addition of these parameters on the ratio of fibre to CCS was calculated.

Table 4: Effect of Extraneous matter on Fibre/CCS ratio

Component	Fibre % cane	CCS	Fibre / CCS ratio
Cane Stalk	12.81	15.00	0.86
Stalk + Tops (6%)	12.81	13.67	0.95
Stalk + Tops + Trash (5%)	14.71	12.87	1.18
Stalk + Tops + Trash + Dirt (0.5%)	15.34	12.65	1.26

The results show the increases in this ratio over the last decade could be attributed to significant levels of tops, trash and dirt in the cane supply and that the large increases were due to trash and dirt. A financial incentive linked to the fibre to CCS ratio would limit trash levels and act as a positive reinforcement to reduce dirt levels in the cane supply. The cane quality scheme for this parameter, shown in Table 5, allows a greater range of values and allocates more quality points than for bin weight to reflect the greater importance of this parameter in achieving the desired outcomes.

Table 5: Quality point allocation for Fibre to CCS ratio

Fibre / CCS Ratio	Quality points
< 1.05	100
1.06 – 1.15	50
1.16 – 1.25	0
1.26 – 1.35	-50
> 1.35	-100

Ash in Cane

The total ash content of the cane supply can be used as an indicator of the dirt levels entering the factory. Analysis of clean whole stalk cane always gives total ash contents of less than 1 %. Increases in total ash over 1 % are due to the addition of tops, trash and dirt. Total ash contents over 2 % indicate the presence of significant quantities of dirt.

Dirt is by far the most damaging component of extraneous matter. Dirt contributes to increased sugar losses in both mud and bagasse, a reduction in crushing rate and significantly increased maintenance costs. Historical data, shown in Table 6, shows a doubling of the mud solids entering the factory over the last decade.

Table 6: Historical trends for mud solids % cane

Season	Mud Solids % cane
1992	0.68
1993	0.97
1994	0.63
1995	0.80
1996	0.80
1997	1.20
1998	1.06
1999	1.34
2000	1.32

A financial incentive linked to the ash levels in cane would act to limit the dirt levels entering the factory and have a significant impact on the costs associated with the processing cane.

The cane quality scheme for this parameter, shown in Table 7, heavily weights the ash parameter compared to the other quality parameters, this combined with the reinforcing effect of fibre/CCS ratio on dirt levels, gives this quality program a strong bias in encouraging a dirt free cane supply.

Table 7: Quality point allocation for ash % cane.

Ash % cane	Quality points
< 2.00	200
2.01 – 2.15	100
2.16 – 2.50	0
2.51 – 3.00	-50
3.01 – 3.50	-100
> 3.50	-200

Cane Quality Incentive Scheme

All that remains for the cane quality program to be complete is the financial incentive to be offered. As this is not a relativity scheme, where only the top performers would receive a bonus, it is possible for everyone supplying cane to participate if their cane quality meets all criteria. Finding the reward that encourages changes to adverse practices while not becoming a financial burden to the mill is a delicate matter that may require some iteration.

The quality points awarded for the three parameters described above are accumulated and the bonus/penalty scale for the accumulated points is shown in Table 8.

Table 8: Accumulated Quality points financial returns.

Quality Points	Bonus (cents/tonne)	Quality Points	Penalty (cents/tonne)
350	50	-150	10
300	40	-200	20
250	30	-250	30
200	20	-300	40
150	10	-350	50

Cane that has accumulated quality points between 150 and –150 fall within the null zone of the scheme and receives no bonus or penalty.

For any quality incentive scheme to be successful it must be supported by accurate assessments and rapid feedback to growers on the quality of cane received by the mill. The quality scheme was supported by rapid information feedback to the growers in the form of daily faxing, dial in phone services and a web site. Reports on harvester group performance with a ranking from first to last in each assessment parameter were produced weekly.

In addition to the quality points table, guidelines were established for providing incentives for wet weather harvesting (eg altering the penalty/bonus points), provisions for dealing with missed samples, sharing of sugar quality bonus payments and periodic review by the Local Area Negotiating Team.

Results

The cane quality program was introduced for the 2001 season. In conjunction with dry seasonal harvesting conditions, the program saw an immediate improvement in cane quality.

The improvement in quality had flow-on effects for mill and grower operations in:

- Increased CCS through reduced dilution of the biomass
- Lower transport costs and greater availability of bins
- Improved consistency in crushing rate
- Reduced factory down time
- Lower maintenance costs through reduced wear in the milling train and boilers.

The percentages of cane supplied in each bonus/penalty point category over a number of seasons are shown in Table 9. Data from the 2000 season show the percentages supplied in each category prior to the implementation of the cane quality scheme. The percentage of cane attaining a quality bonus increased from a starting value of 23% in 2000 to 59% in 2001, 86% in 2002 and 78% in the 2003 season.

Table 9: Quality point distributions percent of tonnes supplied

Quality points	Bonus/Penalty	2000	2001	2002	2003
-350 to -250	Penalty (30-50 cents/tonne)	31%	11%	1%	3%
-250 to -200	Penalty (10-20 cents/tonne)	16%	7%	2%	3%
-150 to 150	Null Zone	30%	23%	12%	16%
150 to 200	Bonus (10-20 cents/tonne)	7%	10%	9%	10%

250 to 350	Bonus (30-50 cents/tonne)	16%	49%	77%	68%

By far the biggest improvement has been the large reduction in cane of very poor quality. The scheme was implemented to target a reduction in the supply of cane that was adversely affecting factory operations. This cane was categorised as that which would attract from 150 to 350 penalty points. The program has been successful in reducing cane of poor quality from 47% in 2000 to 18% in 2001, 3% in 2002 and 6 % in 2003.

Table 10 shows the season average key performance indicators for the cane quality program from 2000 to 2003 seasons. The improvement in each indicator was calculated using the 2000 season data as the base.

Table 10: Quality Program key performance indicators

Season	Bin Weight	Fibre/CCS ratio	Ash % cane	Change in Bin Weight	Change in Fibre/CCS ratio	Change in Ash % cane
2000	3.65	1.28	3.13	-	-	-
2001	3.91	1.16	2.05	7.1%	-9.4%	-34.5%
2002	4.04	1.07	1.38	10.7%	-16.4%	-55.9%
2003	4.07	1.10	1.57	11.5%	-14.1%	-49.8%

These results could not have been achieved without a high level of participation in the growing and harvesting sectors. Feedback from these sectors has been generally positive, with most endorsing the program as both achievable and robust.

The program was also monitored using composite whole stalk cane samples, randomly selected from over the whole mill area and analysed by juice press on a weekly basis for the key parameters used in the quality program. These results set a baseline for the program in providing an estimate of the value of each parameter for cane free of extraneous matter. The seasonal average values of these parameters for whole stalk cane are shown in Table 11.

Table 11: Key parameter values for whole stalk cane

Season	Fibre % cane	CCS	Fibre/CCS Ratio	Ash % cane
2001	13.45	16.84	0.80	0.46
2002	13.72	17.31	0.80	0.44
2003	13.42	15.92	0.82	0.47

The results show very little variation in the key parameters for whole stalk cane from season to season, seasonal variation in these parameters must be due to the amount and type of extraneous matter in the cane supply. This baseline data can be used in interpreting the impact of extraneous matter in the commercial cane supply on cane quality.

Weather conditions over the three-year period the quality program has been in force have been very good for harvesting. This may lead some to believe that the program has yet to be tested under adverse conditions, and there may be some truth to this. Be that as it may, the program to date has met all criteria set for it and delivered on the expected benefits with little or no contention between stakeholders.

Conclusions

High levels of extraneous matter in cane were adversely affecting mill performance and reducing grower returns. Bin weights, CCS, fibre and ash levels in cane on an individual consignment basis in conjunction with on-line information systems and a financial incentive program have provided both the incentive and feedback to allow growers to optimise their cane quality.

The results show a very strong response for all the key parameters and feedback from the growing and harvesting sectors has been positive, with most endorsing the program as both achievable and robust.

The program has been successful in reducing the levels of cane of poor quality from 47% of supply in 2000 to 18% in 2001, 3% in 2002 and 6 % in 2003, while increasing the levels of premium quality cane from 23% in 2000 to 59% in 2001, 86% in 2002 and 78% in the 2003 season.

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