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**FINAL REPORT - SRDC PROJECT BS244S
IMPACT OF CHOPPER HARVESTING
ON THE TRANSLATION OF
FIELD CCS TO FACTORY REALISED CCS**

by

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SD01007

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SUMMARY

This project was designed to investigate the impact of chopper harvesting on CCS at the mill relative to measured CCS levels of cane in the field, as part of the reason behind declining CCS. Background for the project was provided mainly by field trials evaluating harvesting best practice, and sugar balance studies in the Mulgrave Mill area. These projects identified significant losses in cane CCS during the harvesting process, and an increase in CCS of leaf and trash between the field and the factory. They also indicated less depression of CCS than expected at low harvester cleaning intensities where extraneous matter levels in the cane supply were high. The exact magnitude of the losses, the mechanisms causing losses, and the fate of lost sugar have not been clearly identified, and this project was designed to clarify these issues. The chopper test rig developed for research on chopper performance was used in the project to help clarify the role of the chopper system in loss of sugar during harvesting.

The project included harvester trials in the field, and trials with the chopper test rig located at BSES, Bundaberg. The field trials were conducted in both erect and lodged cane, using the SRDC-BSES harvester. The harvester is fitted with a differential chopper system, which is currently fitted as standard equipment, and was operated with standard feed train roller speed set-up. Cane from the same trial blocks was used for the test rig studies. Both sharp and blunt blades were compared for all field and test rig cane loss and CCS measurements. Progressive sampling of standing cane in the field was carried out to determine base yield and cane composition for comparison with mill, field trial and test rig measurements.

The field trials were conducted with and without the harvester cleaning system operating. In the clean cane trials, composition and relative levels of cane and extraneous matter in the elevator boot after chopping and cleaning were measured, together with composition and quantity of leaf and trash and cane discharged from the primary extractor. This was collected on a tarpaulin placed beside the harvester. Rakes of cane corresponding to each harvester treatment were analysed at the mill to determine brix and pol of juice, and individual fibre levels in prepared cane. CCS of cane and tops was determined on cutter-ground material with juice being extracted using a hydraulic press. CCS of leaf and trash was determined by water extraction from cutter-ground samples using a tumbler technique.

Where the cleaning system was turned off, relative levels and composition of cane and leaf and trash were determined for a feed train slug sample, and for material collected from the elevator boot. Samples were also collected to estimate quantity and CCS of cane lost in the basecutter and feed roller areas during harvesting.

The test rig studies were conducted with the standard chopper speed used on current harvesters (field), and a slower speed (optimum) giving closer matching of chopper and roller peripheral speed. In these trials, cane loss was estimated from mass balance calculations, and composition and proportions of cane and leaf and trash were recorded.

The field trials showed a significant loss in CCS of cane between standing cane and cane in the feed train prior to chopping, cane in the elevator boot after chopping and cane in the elevator boot after chopping and cleaning by the primary extractor. There was no clear evidence of a progressive lowering of cane CCS as it progressed through the harvester, but there was a trend to higher CCS of leaf and trash at each stage. Leaf and trash at each stage within the harvester, and in material discharged from the primary extractor, had a significantly higher CCS than in standing cane prior to harvest. Mass balance calculations indicated that increased CCS of leaf and trash accounted for only a small proportion of the apparent sugar loss from cane stalk during harvesting. There were no consistent differences in apparent CCS loss from cane and CCS increase on leaf and trash between lodged and erect cane, or between sharp and blunt chopper blades.

The test rig CCS values for cane and leaf and trash were similar to those for the corresponding field trials, and again only a small proportion of the apparent CCS loss from cane was recovered on the leaf and trash. As for the field samples, this suggests that the sampling technique is not reflecting the potential CCS at the mill if the cleaning system is non-operational.

CCS values recorded at the mill represent the combined CCS of clean cane and extraneous matter in the cane supply. The mill CCS (individual fibres) for rakes harvested with the extractors operating was compared firstly with calculated CCS based on sampling of cane and extraneous matter from the elevator bowl. This showed relatively good agreement between actual and calculated CCS. However, the mill CCS of cane in rakes harvested with the extractors off was significantly higher than that calculated from sample cane CCS and extraneous matter analysis.

Conversely, calculated CCS at the mill, based on CCS of cane and extraneous matter prior to harvest and measured EM levels in the cane supply, was higher than the recorded mill figure with the extractors on. A similar calculation of CCS with extractors off, again based on measured EM levels, showed good agreement with actual mill CCS.

The combination of these two findings suggests that most of the CCS loss from cane as a result of damage during harvesting can be recovered at the mill, provided the cleaning extractors are not operating. In this case, CCS at the mill can be estimated from pre-harvest cane and extraneous matter CCS, and measured extraneous matter levels. If extractors are operating, mill CCS is similar to that calculated from post-harvest cane and extraneous matter CCS samples collected at the harvester, and reflects the loss of potential CCS resulting from cane damage.

The mill CCS showed no apparent effect of chopper sharpness on CCS, but extraneous matter levels at the mill were higher with blunt blades, reflecting poorer cleaning of leaf and trash if it is not cut cleanly by the choppers.

The assessment of cane losses during basecutting, passage through the feed train and chopping and cleaning showed substantial, but highly variable losses. It appears that basecutter losses are more substantial than previously thought, and this is supported by the low CCS of cane recovered in feed train slugs. Estimates of block cane yields in the field and at the mill showed an apparent clean cane yield loss of approximately 21 t/ha during harvesting, or 16.5%. Only 6 t/ha of this loss are accounted for by the tarpaulin estimates of primary extractor losses. If both the CCS and cane losses during conventional harvesting with extractors on are taken into account, the sugar loss is 27.8%, rather than 16.5% based on cane loss alone. This provides a strong incentive for addressing the factors contributing to cane damage and losses of cane and juice during harvesting.

The estimated cane loss in the chopper system was in the range 0.8 to 4.0 t/ha with a trend to higher losses with blunt blades than sharp blades, and an apparent reduction in cane loss with the 'optimum' chopper speed. The billets were significantly longer with the slower chopper speed, as expected, and marginally longer in lodged cane than in erect cane. These results suggest that there is some scope for reducing cane loss through optimum operation of the chopper system, as noted in previous research.

The data obtained from instrumentation of the harvester in the field, and of the test rig, show that power consumption by the chopper system is dependent on material throughput rate, relative chopper and roller speeds, chopper blade sharpness, and mechanical strength of the cane under test. It was also noted that the current setting of relative chopper and feed roller speeds in commercial harvesters gives approximately one third increase in chopper power consumption, compared to an 'optimum' setting with better matching of peripheral speeds. This is an important consideration for harvester design.

1.0 BACKGROUND

With the introduction of chopper harvesters in the 1960s, issues such as billet length and billet damage were researched to minimise losses and maximise the sugar quality within the constraints of development of a viable mechanised harvesting system. The losses associated with chopper harvesting were deemed inevitable and thus acceptable, given the available alternatives of whole-stalk harvesting or hand cutting. The adoption of green cane harvesting appeared to offer significant gains in cane quality compared to burning prior to harvest, and generally led to the relaxation of billet length standards.

The primary focus of recent harvester research has been on the improvement of primary cleaning systems, although some fundamental research has been undertaken on the gathering and feeding of cane and on basecutting. The cleaning system research has shown that the chopper harvesting process itself has a significant impact on the loss of CCS, other than by the dilution effects of extraneous matter and dirt.

Data from replicated trials undertaken as part of BS189 clearly demonstrated that the reduction in CCS from treatments producing high extraneous matter levels was significantly less than would have been expected from the addition of trash to clean cane. Similarly, a series of 42 ‘scoping’ trials funded by BSES as part of the ‘Low CCS program’ in north Queensland and undertaken by Mulgrave Mill during 1998 demonstrated the following:

- Very significant levels of juice on trash, with a CCS increase of up to 3 units between trash on standing cane and trash in harvested cane.
- An average depression of greater than 0.75 unit of CCS between sound whole-stalk cane (pre-harvest) and sound billets in harvested cane. The magnitude of the CCS change was greatest in high yielding crops harvested green.

Detailed investigation of cane losses during the chopping process was carried out in project BS188. Current chopper designs were evaluated in a chopper test rig with sharp chopper blades and recommended blade-meshing configurations. The major findings in this research were:

- The loss of mass during the chopping process was between 1.2% and 4.5%, varying with cane variety, pour rate, chopper system and chopper set-up. Whilst it would be expected that losses in the field would be at the higher end of this range, this loss would not account for increases in CCS of trash noted in sugar balance trials at Mulgrave, or the reduced impact of trash on CCS found in BS189 trials.
- Billet quality achieved by chopper systems in the test rig was significantly better than typical billet quality of chopper systems in the field.
- Power consumption of the chopper systems in the test rig was significantly below that observed with identical choppers operating at similar pour rates in the field.

It is apparent that further clarification of the mechanisms impacting on billet quality, billeting energy, losses and the transfer of juice from the stalk to the trash is required. It is believed that stalk damage in the gathering process, basecutting and passage through the feed train has a significant impact on the magnitude of losses during the gathering, feeding and chopping processes and the transfer of juice onto trash. In the test rig, the cane bundles are ‘ideally’ presented to the choppers (even presentation, straight

undamaged cane, active feed into the feed train). Similarly, it can be argued that the impact of factors such as blunt blades or poor blade adjustment will be greater under field conditions than in the test rig.

This trial program was designed to investigate these interactions and the magnitude of losses from factors other than the billeting process. This will enable informed decisions not only on the best method of harvester operation to reduce losses, but also the best direction for future research into harvester design and operation.

2.0 OBJECTIVES

The objectives of this project were to:

- identify the mechanisms causing losses during gathering, feeding, billeting and cleaning by the harvester;
- quantify these losses and the effect on CCS of cane delivered to the mill.

3.0 METHODS

The project included a field study of cane losses during gathering, basecutting, feeding, chopping and cleaning by a current model harvester, together with CCS changes in cane and leaf and trash during passage through the harvester. Parallel studies of the performance of the feed train and chopper system were carried out using the BSES test rig developed for project BS188, and closely matched operating parameters to the field trials. Both the field harvester and test rig were instrumented to allow comparison of power consumption of the feed roller and chopper system between the field harvester and the test rig. The field and test rig studies were supported by a substantial laboratory phase to measure CCS changes in crop components and assess billet quality corresponding to different treatments. To assist with interpretation of results, crop characteristics such as stalk strength were assessed at intervals throughout the project.

3.1 Preliminary studies

Preliminary trials were carried out to determine the most suitable technique and define sampling protocols for measuring sugar in juice deposited on leaf and trash during passage through the harvester and test rig.

Consultations with former and current BSES staff¹ and Bundaberg Sugar staff² identified key considerations to be addressed in the development of protocols. Key considerations for field collection and storage of samples in the field included:

- To prevent deterioration - the industry preference is to snap-freeze samples rather than use preservatives and, especially in the case of trash, the samples should be collected and frozen within one hour of sampling to minimise deterioration. This was achieved through the use of dry ice. Long-term storage of samples requires the temperature to

¹ Phil Atherton, Graham Leonard, Graham Kingston, Don Mackintosh, Dave Sanders, Nils Berding and Mike Cox

² Clyde Garson, Neil Sichter and Gary Longden

be kept below minus 20°C. Common practice is to store samples between minus 20°C and minus 70°C.

- To prevent contamination and evaporation it was seen as essential that the samples were stored in an airtight container. Strong plastic bags were seen to be a suitable container for this purpose.

The processes involved in the determination of appropriate protocols for determination of sucrose levels on trash were somewhat more difficult. Previous research by Crook *et al.* (1999) and Ivin and Doyle (1989) had indicated that CCS values could be obtained from the cane trash by using standard hydraulic juice press techniques, although some difficulty was encountered with drier trash. These trials were conducted on cane trash from the northern regions of the Queensland sugar industry, where a high percentage of trash is green leaf and the relative humidity results in high moisture content of the trash, enabling juice extraction. In the southern region, the trash can typically be expected to be much drier. Three procedures were evaluated:

- Juice press trial procedure –The protocol was developed by Crook (Mulgrave Central Mill) using a juice press to extract juice from dry trash.
- Wet disintegration – The use of a wet disintegrator was evaluated as a method of determining total sucrose in the material. It was believed that the difference in the total sucrose in samples taken before harvest versus those taken after harvest would be one method of determining the transfer of sucrose between cane components during the harvesting phase.
- Tumbler extraction - Although predominantly used to indicate the pol in open cells of prepared cane or bagasse, it was believed that use of a tumbler and known water quantities would potentially give an indication of sucrose deposition on the trash and leaf surfaces during the harvesting operation.

The three systems were evaluated to determine their potential to quantify the sucrose deposition on trash during the harvesting operation.

The juice press trial procedure proved unsuccessful because the trash was too dry and no liquid was recovered. Further experimentation with the addition of known quantities of water to the trash samples was then undertaken. The results from this were not promising, with less than 50% of the added water recovered for analysis. This indicated that the retrieved liquid may not represent the true concentration of sugars in the sample, especially due to the low level of sugars expected.

A total of 88 samples, consisting of 43 ‘before harvest’ samples and 45 ‘after harvest’ samples, was then collected to evaluate the other options to determine sucrose transfer onto the trash. The before harvest trash was sampled directly from the cane stalks in the field and placed into plastic bags, sealed and snap frozen on dry ice. The after harvest samples were collected by assigning quadrates of trash deposited on the ground by the primary extractor, immediately after the passing of the harvester. Trash was collected and quickly sorted to remove all green leaves (tops), dirt and cane fragments, then sealed in a plastic bag and snap frozen. Both sampling techniques appeared to work well; however, some modification to procedures was identified to reduce the time taken from sampling to freezing.

The samples were then stored at a temperature below minus 20°C until required for analysis. Each sample was subsampled into sufficient quantities for the tumbler, wet disintegrator and fibre analysis, as per the standard procedures. The disintegration procedure was slightly modified to accommodate the higher fibre content of the trash. After completion of the tumbler and wet disintegration tests, the liquid was filtered and sampled for precision pol and brix analysis. Similar procedures have applied to the sampling of the other harvested cane components (billets, tops, cane fragments). These two procedures appeared to be suitable for determining the low levels of sugar on trash.

To evaluate the wet disintegration trial procedure, a trial was conducted for comparative analysis of pol and brix from the wet disintegrator and tumbler between sample types, and to assess the suitability of laboratory instruments and procedures. The wet disintegrator is used to determine the extraction of sucrose from cane by successive mills, and hence generally uses bagasse or prepared cane samples. Each disintegrator test requires a minimum of 30 minutes operation. The tumbler is used in conjunction with the wet disintegrator to determine the pol in open cells of a prepared sample, and requires 10 minutes.

During the determination of pol and brix, fluctuations in the readings of the Polartronic (precision polartrometer) located at the Bundaberg BSES laboratory were noted between replications. Two possibilities for this were:

- a fault in the Polartronic, to a small extent due to either worn components or fluctuations in the power supply;
- inadequate inherent accuracy of the unit. This was not considered, because the readings were within the advertised accuracy of the unit.

This work demonstrated that the critical factors in maximising the data integrity were the time difference between collecting, sorting and freezing of the samples, and the precision of the laboratory analysis.

The preliminary work and results indicated that wet disintegration and tumbling were the best procedures available to determine the levels of sugar levels on trash, and hence also on billets, tops and cane fragments.

Test program protocols were developed and recorded to ensure reliable determination of sugar levels on trash.

All of the standard procedures to be used for the testing phase of this project were initially devised by past BSES researchers; therefore, most of the necessary equipment was available through BSES. However, a tumbler had to be fabricated and Figure 1 illustrates the machine developed specifically for use in this project.



Figure 1 - Tumbler arrangement

From the literature review and preliminary trials conducted, it is concluded that the wet disintegration test is only necessary for the calculation of CCS in the samples of cane fragments and cane billets. There are two predominant reasons for this:

- (a) Measurement of relatively small concentrations of sugar, translocated to the external area of billets and fragments is “swamped” in the tumbler procedure by the high level of leaching or washing of sugar from the exposed pith region (open cells).
- (b) Testing billets in the wet disintegrator gives the added advantage of comparing the CCS of sound regions of billets (middle of billet) with the exposed, damaged ends of billets (more susceptible to deterioration). This gives greater insight to an area highly suspected as a major cause of the reduction of mill CCS from field CCS, and is in addition to the comparison of sound billet CCS with the in-field whole-stalk CCS.

The tumbler procedure was used to assess the quantity of sugar translocated to the surface of trash and tops by “washing” samples taken before and after harvest. Current procedures for determining the CCS of in-field crops are adequate for the purpose of this program. Additional whole-stalk samples are taken for the comparative wet disintegration tests of CCS reduction in billets and cane fragments. Other protocols discovered and applied for the previous milestone, relating to the sampling of all

elements, have proven to be successful. All of these protocols and procedures provide sufficient consistency to maintain data integrity and, together with the improved reliability of the polarimeter, will ensure reliable determination of the sugar levels in the various elements produced in the harvesting of sugarcane.

The critical factor in maximising data integrity was the precision of the laboratory analysis. The preliminary results indicated that the use of the wet disintegration and tumbler techniques are the best procedures available for determining the low concentrations of sugar translocated onto trash, billets, tops and cane fragments during the harvesting process. Using the wet disintegrator has also opened an avenue for more detailed analysis to aid in achieving the ultimate goal of this project: determine the factors in the harvesting process that cause a reduction of mill CCS from field CCS.

3.2 Field trials

3.2.1 Selection of the test variety

Field trials were conducted in both erect and lodged cane, with the same cane blocks being used for both the field and test rig trials. The erect block was third ratoon spring plant, and the lodged block first ratoon autumn plant cane. The trial blocks both contained the variety Q124, and estimated yields were 112 and 150 t/ha, respectively. The variety Q124 is considered to be a non-brittle variety, with similar behaviour during harvesting to the average cane delivered to Bundaberg mills.

3.2.2 Varietal characteristics during trial period

Previous experience has shown that varietal characteristics may change during the season, and regular sampling was carried out to determine stalk length, diameter, node length, and mechanical strength characteristics. At each time of sampling, 20 stalks were cut from a randomly selected section of the part of the field to be harvested. Stalk length, and stalk diameter at the top, middle and base of the each stalk, were recorded. From the selected stalks, four were used for measuring mechanical strength characteristics with the pendulum device developed for project BS188. This device determines impact and shear strength of both the nodes and internodes of stalks. Figure 2 illustrates the pendulum testing device.

Both transverse and longitudinal impact tests were conducted at the node and internode of stalks. For the transverse impact tests, the stalk was held vertical and the pendulum impacted in a transverse direction. In the longitudinal impact tests, a small section of stalk (20 mm) was cut and held horizontally, so that the pendulum would impact the sample at the midpoint of the cross-section and parallel to the longitudinal axis of the stalk. The average cross-sectional area of all samples was measured before testing for calculation of the impact strength of cane. Care was taken in preparing samples to ensure that there were no splits or growth cracks in test samples.



Figure 2 - Pendulum testing apparatus illustrating typical transverse impact testing mode

3.2.3 Harvester parameters

The BSES Austoft 7000 harvester used in the field phase of the project represented an industry standard machine. It has 1995 specifications and is fitted with a Cummins LTA10 engine rated in excess of 225 kW, and electric over hydraulic cabin controls. It also has a standard leg basecutter, and this was fitted with standard five-blade discs and 4 mm thick standard blades. The basecutter angle was factory set at 11 degrees. Figure 3 illustrates the harvester used in the trials.



Figure 3 - The SRDC/BSES 7000 research harvester

An Austoft 12-inch differential chopper system, used previously in the BS188 project, was refitted for the current project. This system has become standard on new machines and is used as a common retrofit on older harvesters. It features 12-inch drum centres and three cutting blades per drum. The diameters of the top and bottom drums are 360 and 305 mm, respectively (when fitted with blades). Further information on differential chopper systems can be obtained by reference to Norris *et al.* (1999).

Standard 65 mm chopper blades were fitted. New blades were used for ‘sharp blade trials’. These have a bevel length of approximately 30 mm and are sharpened with a machined edge. Worn blades used in the ‘blunt blade trials’ were discarded, used blades machined back to an even blade depth, usually corresponding to that at the middle of the blade. The resulting bevel width of the cutting edge was approximately 3 mm.

The operating speed of the chopper drums was nominally 260 rpm, which gave a tip speed of the top and bottom drums of 4.9 and 4.2 m/s, respectively.

The harvester feed train was set up as per factory specifications for the 1995 machine, with the buttlifter operating at 104 rpm, lower four rollers at 135 rpm, and the last six rollers at 185 rpm. For a nominal roller diameter of 220 mm, and a buttlifter diameter of 250 mm, this gives surface speeds of 1.1, 1.3 and 2.1 m/s, respectively, for these nominal roller speeds.

The harvester field operating speed was 4 kph and cane was untopped. This is equivalent to pour rates of approximately 67 t/h and 90 t/h in erect and lodged cane, respectively. The extractor speed when operational was 1450 rpm, set with the extractor unloaded and the harvester at high idle. The loaded speed was approximately 1150 rpm, which is indicative of the speed droop experienced with the type of extractor speed control system.

3.2.4 Data acquisition during trials

Key components of the crop handling areas of the harvester were instrumented with sensors to allow measurement of hydraulic pressure and feed roller displacement during tests. Hydraulic pressure was measured across the chopper system to allow quantification of the work done during processing of material. Displacement of the first top feed roller (top roller after buttlifter) and the last top feed roller (adjacent to chopper) was also measured. This allowed the pour rate and evenness of feed to be quantified. Ground speed was also measured to ensure that trials were conducted at identical ground speeds, and to allow calculation of pour rates.

All data were recorded on a laptop computer using a high-speed data acquisition system. Full details of the sensors and data acquisition system are given in Appendix 1.

3.2.5 Field trial details

Two series of trials were conducted, one with and one without the primary and secondary extractor fans operating.

3.2.5.1 Fans on tests- conventional harvesting

The fans on tests were carried out at two separate times with sharp and blunt chopper blades, respectively. In the fans on tests, samples of cane, tops and leaf and trash were collected from the harvester elevator bowl (approximately 20 kg), and cane, leaf and trash and tops from a 4.8 m tarpaulin positioned to collect material discharged from the primary extractor (blue tarp test). The harvester was stopped at a randomly selected spot to facilitate sample collection from the elevator bowl. The 20 kg sample size was based on the work of McRae *et al.* (1998) which indicated that this is sufficient to provide representative data on CCS and billet quality. These elevator bowl samples were designed to measure the change in CCS and proportions of cane, tops and leaf and trash from the combined process of basecutting, passage through the feed train, chopping and cleaning by the primary extractor. The blue tarp test was designed to determine the quantity and CCS of cane discharged by the primary extractor, and also the CCS of the trash discharged. The blue tarp test was developed for field assessment of cane loss during harvesting (Shaw and Brotherton, 1992; Linedale *et al.*, 1993).

One sample per bin was taken for each bin of a three-bin rake, with three rakes each for sharp and blunt chopper blades. This gave a total of nine samples per chopper blade treatment.

At the mill, prepared cane samples were taken from the three-bin rakes to allow use of individual fibres for recalculation of mill CCS determined using class fibres.

All trial samples were sorted into their separate components where relevant and snap frozen for later analysis.

3.2.5.2 Fans off tests- no cleaning by the harvester

The second series of trials, with the cleaning extractors turned off, involved stopping the harvester (forward motion, gathering spirals, basecutter and feed train) during cutting while it was full of cane, raising the front of the machine and placing a tarpaulin under the harvester. The following samples were then collected.

- A sample from the area immediately adjacent to the basecutter where cane had been severed, but not yet fully fed into the harvester, was collected to determine loss of cane during basecutting and CCS of this cane.
- A feed train sample collected by rewinding the feed train slug onto a tarpaulin. This sample was comprised of approximately 0.5 m of cane immediately adjacent to the chopper. This was sorted into whole cane, cane fragments, tops and leaf and trash. This sample was designed to determine cane loss in the feed rollers and change in CCS of cane and leaf and trash. This CCS change could be attributed to a combination of basecutter and feed train action.
- A ground loss sample collected under the tarpaulin, representing a combination of basecutter damage fragments and cane loss through the roller system.
- An elevator bowl sample of approximately 20 kg, which was sorted into billets, cane fragments, tops and leaf and trash. This sample was considered to indicate the combined effect of the basecutter, feed train and chopper on CCS of cane and leaf and trash.

Where possible, mill CCS values were also obtained for the small rakes cut with the cleaning extractors turned off.

In addition, samples were cut from standing cane to provide a reference for pre-harvest cane yield and proportions of cane, tops, green leaf and trash. At the same time, cane was cut for test rig trials. All trial samples were snap frozen for later analysis after sorting into the relevant components (cane, tops, trash and green leaf) and weighing. The only exception was for whole cane and billet samples, which were processed fresh.

All frozen samples were subsequently partially thawed and then cutter ground (Jeffco cutter-grinder) for analysis. The cutter-ground material was subsampled for fibre, brix and pol analysis. Extracts from cane and tops for brix and pol analysis were obtained using the hydraulic press technique, and leaf and trash extracts using a specially constructed stainless steel tumbler as discussed earlier. A ratio of 300 g of material to 5 L of water was used in tumbler extractions, with a 10 minute extraction time. Standard techniques were used for brix, pol and fibre determinations. Since only fibre and not moisture content was determined on leaf and trash samples, it was necessary to use an iteration technique to calculate moisture, brix and pol % of material for CCS calculation. An Excel spreadsheet was used for iteration calculations.

3.3 Test rig studies

3.3.1 Test rig description and settings

The chopper test rig used in this project was developed for project BS188. It is a stationary rig duplicating the feed train of an Austoft 7000 harvester. The feed rollers in the test rig are powered hydraulically in a similar manner to a standard harvester, with the exception that speed of different roller groups can be varied between 100 and 250 rpm. The buttlifter was set at a speed of 133 rpm, compared to 104 rpm in the field harvester, to enhance evenness of feed off the elevator, thus reducing error of effective feed rate.

The chopper system in the test rig is identical to the harvester, with the exception that the chopper drums are mounted in a discrete module, and secured to the feed train via load cells and tie rods.

For these trials, two settings were used to simulate, firstly, the standard harvester configuration in the field, and secondly an 'optimum' chopper setting to give closer matching of feed roller and chopper peripheral speeds. In the 'field setting' trials, the feed roller speed was 185 rpm and the chopper speed 260 rpm (flywheel 800 rpm). The 'optimum' settings were 185 rpm for feed rollers and 190 rpm for choppers (flywheel 581 rpm). The 'optimum' setting is based on findings in project BS188, which indicated an optimum chopper speed of 190 rpm, and the same peripheral speed for all feed rollers, set at approximately two-thirds of the chopper peripheral speed. In this case, the peripheral speed of the feed rollers was 2.1 m/s and of the top and bottom chopper drums 3.6 and 3.1 m/s, respectively.

Cane was fed into the test rig using a 12 m, rubber belt conveyor. The cane was stacked in overlapping bundles with the butt end facing the test rig, to simulate the manner of cane presentation to the harvester in the field. For these trials, the belt speed was 7.7 kph, giving a feed rate of approximately 190 t/h. Figure 4 illustrates the test rig used in this work.

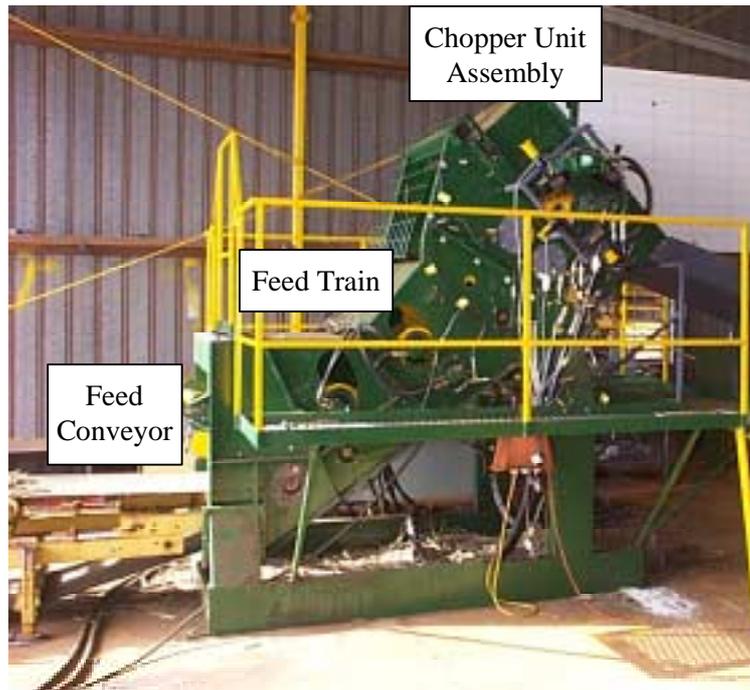


Figure 4 - The chopper test rig with conveyor feed system

3.3.2 Test rig instrumentation

The instrumentation used for measuring hydraulic pressure in the chopper circuit and displacement of the first and last top feed roller is similar to that described for the harvester in the field.

In addition, magnetic pick-up transducers were utilised to record the speed of the chopper drums and the last top and bottom feed rollers. The transducers were located to sense teeth on a gear wheel attached to the appropriate component. The alternating voltage signal produced by the sensors was converted to frequency-time domain using a fast Fourier transform in the DASyLab[®] software. To achieve accuracy with this approach data were acquired at a sampling rate of 7000 Hz, and recorded at this frequency.

3.3.3 Test rig trial details

The test rig trials were conducted with erect and lodged cane from the field trial blocks. Three replicates of approximately 300 kg of cane were processed with sharp and blunt chopper blades for each cane category. This cane was cut in the field when the corresponding test was being conducted with the harvester. As mentioned above, the trials were repeated with chopper speeds equivalent to the field harvester, and an 'optimum' chopper setting giving closer matching of feed roller and chopper peripheral speeds. The blunt blades used in these trials were those used in the harvester in the field.

To quantify the losses associated with the chopping process, a 'mass balance' approach was used. Cane cut in the field was first stripped of trash, and the initial mass of cane and trash determined. It was then stacked on the conveyor with approximately half the trash under the cane bundles and half on top. This placement of trash is consistent with field observations during project BS165, where trash was noted to be concentrated towards the bottom of cane in the feed train.

After processing, the billets and trash were collected in a bin and weighed. Two sets of representative subsamples of approximately 20 kg were then taken for determination of proportions of cane and leaf and trash and CCS of these components, and for assessment of billet size distribution and billet damage.

The remaining material was then cleaned by passing it through a specially designed cleaning system, and the residual mass of cane and tops, leaf and trash was determined by weighing. The change in mass of cane during chopping was then calculated to estimate cane loss during chopping.

One subsample was sorted into cane, tops and leaf and trash and the separate components were frozen for later CCS analysis as described for the field trials. The second subsample was also frozen for later assessment of billet size distribution and billet damage. Billets were sorted into size categories similar to those set out by De Beer *et al.* (1985), with the exception that after the initial category of 0-100 mm subsequent categories were in 25 mm increments. After weighing each category the cane was then sorted into sound, damaged and mutilated billets using the criteria set out by De Beer *et al.* (1985).

4.0 RESULTS AND DISCUSSION

4.1 Preliminary studies

The preliminary trials were hampered by problems with the polarimeter, which resulted in excessive variability of results and low precision. The polarimeter problems were subsequently resolved, improving the precision of analyses. The specifications for the Schmidt and Haensch Automatic Refractometer used in these studies indicate an accuracy of $\pm 0.05^\circ$ brix, compared to brix readings in the order 0-0.1 in cane leaf and trash extracts prior to harvest, and of the order 0.1-0.6 post-harvest. Similarly the Polartronic Universal used for measuring pol of leaf extracts has an accuracy of $\pm 0.01^\circ$ S. This compares to pol levels of 0.01-0.05 in leaf and trash pre-harvest, and 0.4-0.8 post-harvest. The accuracy of the instrumentation was therefore considered adequate to detect changes in sugar levels on leaf and trash.

Despite the initial problems, the trials indicated some difference in brix and pol of leaf and trash extracts between the wet disintegrator and tumbler extraction techniques, and also a difference in brix and pol between trash sampled before and after harvest. Comparative results for leaf and trash to water ratios of 400 g and 300 g to 6,000 g water, respectively, are given in Table 1.

TABLE 1
Preliminary comparisons of wet disintegrator and tumbler techniques in trash collected pre- and post-harvest

Trash type	Wet disintegrator		Tumbler	
	Pol	Brix	Pol	Brix
Pre-harvest	0.11	0.33	0.05	<0.1
Post-harvest	0.56	0.58	0.26	0.15

There was no clear cut agreement between the wet disintegrator technique and the tumbler extraction technique in the magnitude of the increase in brix and pol of trash extracts from pre-harvest to post-harvest. The reason for this is uncertain but it could in part be related to the difference in sample to water ratios. Bearing this in mind, the tumbler technique was adopted for subsequent leaf and trash extractions to allow more rapid processing of large numbers of samples. A ratio of 300 g of material to 5,000 g water was used to improve precision at low brix and pol levels.

4.2 Characterisation of trial cane

The physical characteristics of the cane stalks over the trial period are summarised in Table 2. Measurements were taken of the average diameter of the stalks at the base, mid stalk and the top, average length of stalks to the dewlaps and average node length.

Transverse and longitudinal impact tests were conducted on the node and internode at three locations (base, middle and top) on the cane stalk. Average results for the two tests in both the node and internode regions are shown in Figures 5 and 6, respectively.

TABLE 2
Cane physical characteristics for crop material utilised in the trials

Sampling date	Variety	Condition	Diameter (mm)			Stalk length (m)	Node length (mm)
			Base	Middle	Top		
24/10/00	Q124	Erect	27.0	23.7	20.2	2.4	133
24/10/00	Q124	Lodged	27.1	24.6	20.3	2.6	131
06/11/00	Q124	Erect	27.5	24.4	20.3	2.5	123
06/11/00	Q124	Lodged	26.8	24.8	20.1	2.7	128
13/11/00	Q124	Erect	27.1	24.0	20.4	2.5	132
13/11/00	Q124	Lodged	28.1	24.2	19.9	2.6	124

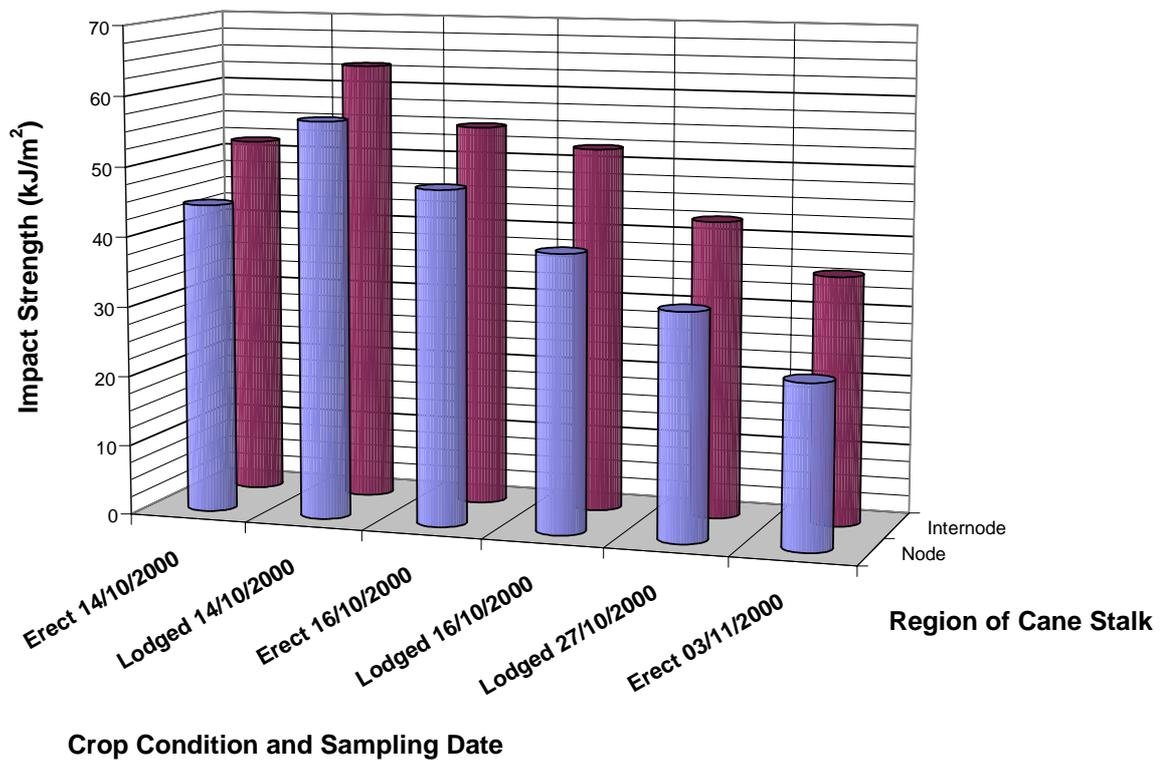


Figure 5 - Relationship between transverse impact strength, region of stalk, crop condition and sampling date

The internode region has a higher transverse impact strength than the node region for both crop conditions and all sampling dates. These results indicate that impact strength varies during the season, and there is no consistent difference between erect and lodged cane. Lodged cane appeared to lose strength to a greater extent than erect cane following rainfall between the first and second sampling dates. This may have been due to slower drying out of the lodged crop. In addition, the strength of the stalks further decreases at the last sampling date following further rainfall events. This could be expected to affect stalk damage and chopper power requirements during harvesting.

Figure 6 illustrates the relationship between longitudinal impact strength, region of the stalk, crop condition and sampling date. Longitudinal impact strength is an order of magnitude lower than transverse impact strength and therefore less energy is required for this mode of failure. The pattern of change in longitudinal strength during the season does not correspond to that for transverse strength, and the reason for this is uncertain. Again lower power consumption would be expected when processing lower strength material.

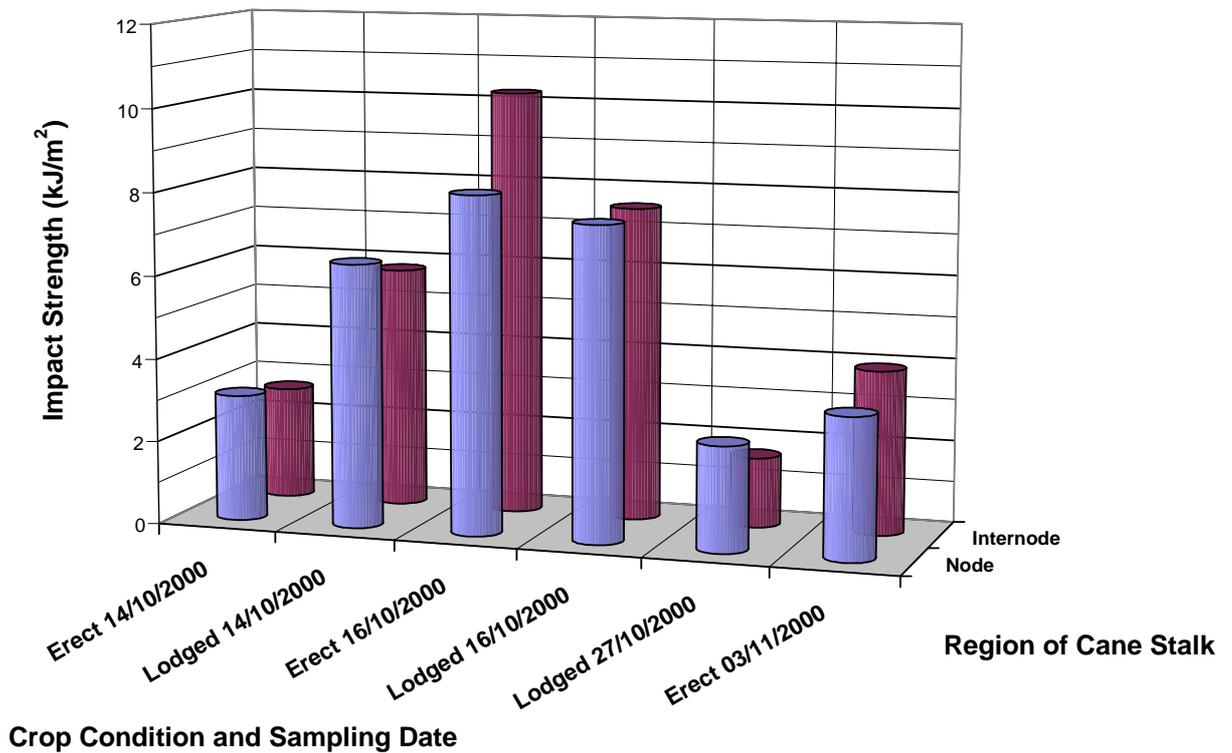


Figure 6 - Relationship between longitudinal impact strength, region of stalk, crop condition and sampling date

4.3 Field trials

4.3.1 Initial crop characteristics

The estimated initial crop yields, extraneous matter composition, and CCS of components for the lodged and erect cane blocks are summarised in Table 3.

Table 3 indicates that the lodged block had higher initial potential yield and extraneous matter levels than the erect block, and higher cane CCS. The CCS of green leaf and trash was negative in both cases. Later sampling indicated some changes in extraneous matter levels during the test period.

TABLE 3
Estimated initial crop yield and extraneous matter composition
for the lodged and erect trial blocks

Crop characteristic	Crop type	
	Lodged	Erect
Sample yield estimate t/ha	146.8	108.0
Tops %	7.18	4.66
Green leaf %	6.41	3.91
Trash %	9.64	7.25
EM %	23.23	15.82
Cane CCS	17.75	16.67
Tops CCS	2.12	2.07
Green leaf CCS	-0.28	-0.34
Trash CCS	-0.1	-0.29

4.3.2 Trial results for full cleaning

Data collected from the elevator and blue tarpaulin samples are summarised in Table 4. It is evident from Table 4 that final extraneous matter levels are higher for lodged cane than for erect cane, reflecting higher initial field values. In both lodged and erect cane, leaf and trash levels in the elevator boot sample are significantly higher with blunt chopper blades than with sharp blades. This supports the general belief that cleaning of leaf and trash is less efficient with blunt chopper blades that do not cut trash efficiently.

There is a small and non-significant trend to lower cane loss in the 'blue tarp' test with blunt blades, and this is contrary to expectations. If the measured cane loss of around 2 t/ha is adjusted by a factor of three for non-detected juice and fine fragment losses at the high extractor speeds used in the trials, the estimated loss becomes 6 t/ha. Both blue tarp cane losses and percentage cane fragments in the elevator samples are higher for lodged cane than erect cane. This may reflect the higher pour rates when harvesting lodged cane.

Cane CCS is reduced significantly in the elevator boot samples compared to pre-harvest cane samples, and this reduction is highest with blunt chopper blades. Similarly, there is a further reduction in CCS in cane fragments collected on the blue tarp and this reduction is highest with blunt chopper blades.

CCS of leaf and trash samples is significantly higher in both elevator boot and blue tarp samples than for the pre-harvest samples (Table 3 data). However, the CCS of leaf and trash is apparently lower for blunt blades than for sharp blades. This is contrary to expectations of greater loss of juice with blunt blades, the trend to higher levels of cane fragments in elevator samples, and the data indicating a greater loss in cane CCS with blunt blades. CCS of leaf and trash is higher for the elevator boot samples than the blue tarp samples. In both cases, it is evident that some of the juice lost as a result of cane billeting, and cane damage during basecutting and conveying, has been transferred onto the leaf and trash.

TABLE 4
Extraneous matter levels, cane fragment levels and CCS of components for elevator boot and blue tarpaulin samples collected with sharp and blunt chopper blades

Characteristic measured	Lodged cane				Erect cane			
	Elevator		Blue tarp		Elevator		Blue tarp	
	Sharp	Blunt	Sharp	Blunt	Sharp	Blunt	Sharp	Blunt
Tops %	3.38	4.08			3.24	3.51		
Leaf and trash %	1.80	3.01			1.66	2.70		
EM %	5.18	7.08			4.90	6.21		
Cane frag. %, t/ha*	2.7	3.3	2.16*	1.85*	1.9	2.3	1.66*	1.60*
Cane CCS	15.91	15.76	12.09	11.52	14.83	14.61	9.78	8.37
Tops CCS	2.4	2.6			2.6	2.7		
Leaf and trash CCS	2.26	1.1	1.51	0.18	1.39	0.87	0.83	-0.08

* t/ha estimated from blue tarp test, no adjustment for juice and small fragment loss

4.3.3 Trial results with extractors turned off

The data collected with the extractors turned off include cane and leaf and trash analyses, and the level of cane fragments, for feed train slug and elevator boot samples (Table 5); cane analysis for basecutter loss samples; estimates of the cane loss during basecutting; and cane found beneath the harvester resulting from basecutter and feed train losses (Table 6).

The data in Table 5 show no clear change in cane CCS as it passes from the feed train through the chopper system, and between sharp and blunt chopper blades in the elevator boot samples. However, CCS is significantly lower than that recorded in standing cane prior to harvesting. In contrast, there is a trend for CCS of leaf and trash to increase between the feed train and elevator boot, and for CCS of leaf and trash in the elevator boot to be higher with blunt chopper blades than for sharp blades. The chopper blade effect is in conflict with the extractor on results discussed above, and the reason for this is uncertain. In both cases, the CCS of leaf and trash is significantly higher than that recorded for leaf and trash prior to harvest.

There is no consistent change in the percentage of fragments present in cane between the feed train and the elevator boot, and no apparent effect of blunt chopper blades on the level of cane fragments in the elevator boot. In general, the level of fragments is significantly higher for lodged cane than erect cane.

As indicated in Table 5, there was a change in extraneous matter levels recorded for the lodged cane between sharp and blunt chopper blade tests conducted two weeks apart in a different section of the trial block, but no apparent change in the erect block.

TABLE 5
Assessment of cane and leaf and trash CCS and cane fragments in feed train slugs and elevator boot samples in trials with the cleaning extractors turned off

Characteristic measured	Lodged				Erect			
	Feed train slug		Elevator		Feed train slug		Elevator	
	Sharp	Blunt	Sharp	Blunt	Sharp	Blunt	Sharp	Blunt
Cane CCS	15.32	15.84	15.43	15.63	15.49	15.02	15.71	15.50
Leaf and trash CCS	0.60	0.48	0.41	1.06	0.29	0.28	0.42	0.57
Leaf and trash %			16.1	11.4			11.2	11.2
Tops %			7.2	6.2			3.8	3.8
EM %			23.3	17.6			15.0	15.0
Cane fragments %	7.2	4.3	4.5	1.8	0.8	2.9	2.4	2.1

TABLE 6
Estimated basecutter loss, feed train loss potential as cane fragments, ground loss in tonnes per hectare and CCS measured for these components.

Loss type	Lodged		Erect	
	CCS	Est t/ha	CCS	Est t/ha
Basecutter loss	10.02	9.7	12.59	3.0
Feed train loss	12.40	7.0	9.66	5.3
Ground loss	14.88	3.0	11.07	4.1

The figures given in Table 6 are based on extremely variable data and indicate only general trends in CCS of cane and estimated cane loss, the latter being based on measured cane loss for an approximate row length of 1 m. However, it is evident that the CCS of cane loss components is significantly lower than sound cane CCS, and that there is a significant amount of cane loss attributable to basecutter damage and breakage in the feed train. The lower CCS in fragments also indicates preferential loss of high pol juice as a result of cane damage. The combined extractor and other losses indicate both the magnitude of the physical loss of sugar as cane loss and the potential for additional juice loss.

4.3.4 Comparison of extractors on/extractors off results

CCS trends, fibre, moisture, brix and pol comparisons for all phases of the field tests and for the test rig studies are given in Table 7. These figures are averaged over lodged and erect cane and sharp and blunt chopper blades. The test rig results correspond to the field results for the elevator boot samples with the extractors turned off. Full results of the test rig trials are given later.

The fibre and moisture values for leaf and trash indicate some preferential removal of trash compared to leaf with the cleaning extractors operating, with lower fibre and higher moisture in elevator boot samples than for the feed train slug or for the elevator boot samples with the extractors turned off.

Cane CCS is lower for all harvester samples than for the pre-harvest cane samples, with no clear trends between feed train slug, elevator boot (extractor off) and elevator boot (extractor on) samples. The apparent CCS loss of 1.6-2.1 units (11%) is significantly higher than the average change of 0.9 unit (6%) recorded by Crook *et al.* (1999) between sound cane in the field and clean cane at the mill. The reason for this is uncertain.

Brix, pol and CCS of leaf and trash show a significant increase with the extractors operating, and all three harvester samples have higher values than determined for standing cane. The brix and pol levels of leaf and trash are much lower than would be expected if a significant proportion of sugar lost from cane was retained on the trash. This may reflect some inadequacies in the sampling procedure for the extractor off samples in representing the retention of sugar in juice on the leaf and trash (see later discussion). It may also reflect the relatively low pour rates used in the field trials, giving lower interception of lost juice. Similar scoping trials in the Mulgrave Mill area in 1998 (Crook *et al.*, 1999), with sampling at the mill rather than from the harvester, gave leaf and trash CCS increases of 1.8 units from standing cane to harvested cane. In the current study the increase is of the order 0.8-1.6 units.

The test rig results are similar to those for the feed train slug and elevator boot (extractors off) results in the field trials, as would be expected.

TABLE 7
CCS trends, fibre, moisture, brix and pol comparisons for all phases
of the field tests and for the test rig

Trial comparisons	Fibre %	Water %	Brix %	Pol %	CCS
Cane					
Pre-harvest	11.12				17.21
Feed train slug	11.06				15.42
Elevator boot (extractor off)	10.73				15.57
Elevator boot (extractor on)	10.13				15.28
Test rig	10.09				15.08
Green leaf					
Pre-harvest	31.6	67.4	0.98	0.15	-0.31
Trash					
Pre-harvest	80.7	18.4	0.88	0.33	-0.21
Leaf and trash					
Feed train slug	56.2	41.7	1.86	0.87	0.41
Elevator boot (extractor off)	57.5	41.2	1.37	0.76	0.61
Elevator boot (extractor on)	38.2	58.1	3.74	2.18	1.41
Test rig	64.4	33.3	2.3	1.03	0.39

4.3.5 Mill data

The mill records for the trial blocks show final clean cane yields of 126 and 87 t/ha, for lodged and erect cane, respectively. These compare to sample clean cane yield estimates of 147 and 108 t/ha, respectively. While sample yields are an approximate estimate only of block yields, the apparent cane loss during harvesting is of the order of 21 t/ha or an average of 16.5% between lodged and erect cane.

Mill CCS data for trial rakes of cane are given in Table 8. The mill CCS data include figures calculated with actual fibres and class fibres. These data show no apparent effect of blunt blades on CCS, but a significant depression of CCS with the extractors turned off. The CCS depression is much less than expected with the high extraneous matter levels in the extractors off treatments (Table 5). Mill CCS is higher for the lodged cane block than for the erect block, and significantly lower than the CCS measured by sampling prior to harvest (Table 3).

Estimated CCS values at the mill based on elevator boot samples and pre-harvest samples are compared with actual mill CCS in Table 9. In estimating mill CCS from the pre-harvest samples, a weighted average CCS of cane and extraneous matter was calculated, assuming that the CCS of leaf and trash, tops and cane had not changed during harvesting, but using the proportions of cane and extraneous matter cane delivered to the mill (Tables 4 and 5). Similarly, in estimating mill CCS from elevator boot samples, a weighted average CCS of cane and extraneous matter collected from the elevator boot was calculated. Mill CCS was calculated using individual fibres.

TABLE 8
Mill CCS data, fibre values and corresponding EM % for trial rakes
of both lodged and erect cane

Treatment details	Mill Fibre %	Sample Fibre %	CCS Mill fibre	CCS sample fibre	Sample EM %
<i>Lodged cane</i>					
Sharp blades- Extract. On	12.6	11.57	15.13	15.24	5.18*
Extract. Off	12.6	13.74	14.8	14.53	17.54*
Blunt blades- Extract. On	12.1	11.88	15.13	15.03	7.08*
<i>Erect cane</i>					
Sharp blades- Extract. On	12.0	10.06	14.57	14.72	4.90*
Extract. Off	12.0	10.76	14.15	14.28	14.96*
Blunt blades- Extract. On	13.0	11.17	14.43	14.68	6.20*

* Based on samples taken from the elevator boot with and without extractors operating

In general, the calculated CCS based on the elevator samples is only slightly below the measured value at the mill for trials with the extractors turned on, but significantly underestimates mill CCS if the extractors are turned off. In contrast, calculated CCS based on the pre-harvest samples significantly overestimates the mill CCS with extractors on, but gives close agreement with mill values with the extractors off.

TABLE 9

**Comparison of mill and calculated final CCS based on component analysis
for lodged and erect blocks**

Treatment	Mill CCS		Est. CCS (elev. sample)		Est. CCS (pre-harv. sample)	
	Sharp	Blunt	Sharp	Blunt	Sharp	Blunt
<i>Lodged</i>						
Extractors on	15.24	15.03	15.20	14.78	16.90	16.57
Extractors off	14.53		12.92		14.75	
<i>Erect</i>						
Extractors on	14.72	14.68	14.21	13.82	15.91	15.70
Extractors off	14.28		13.50		14.22	

This suggests firstly that the apparent loss in clean cane CCS during processing by the harvester is not registered at the mill if the cleaning extractors are turned off. It could be assumed that most of the sugar ‘lost’ from the clean cane, as a result of billeting and damage, is retained within the cane and leaf and trash delivered to the mill bins, and recovered at the mill. The elevator boot sampling procedure was not able to represent the apparent retention of lost sugar from the sound cane within the trash and leaf material in this case. These observations are supported by project BS189, where recorded CCS reductions at high leaf and trash levels in the cane supply (with low extractor speeds or extractors turned off) were not as large as expected.

Secondly, since the pre-harvest samples overestimate sugar levels at the mill when cleaning extractors are operating, and the elevator samples give a relatively accurate representation of mill CCS, it could be assumed that a majority of juice lost from the cane passes out through the cleaning extractors rather than going to the mill. This has important implications for harvester design and operation. If mills require low extraneous matter levels to reduce processing costs, it is extremely important to minimise cane damage during basecutting and chopping and subsequent loss of high pol juice.

If both the CCS and cane losses during conventional harvesting with extractors operating are taken into account, the sugar loss is 27.8%, rather than the loss of 16.5% as cane alone. This provides a strong incentive for measures to reduce both CCS and cane losses.

4.3.6 Harvester instrumentation results

The main data collected from the harvester instrumentation were chopper pressure and feed roller displacement. An example of processed data from displacement and pressure sensors is given in Figure 7.

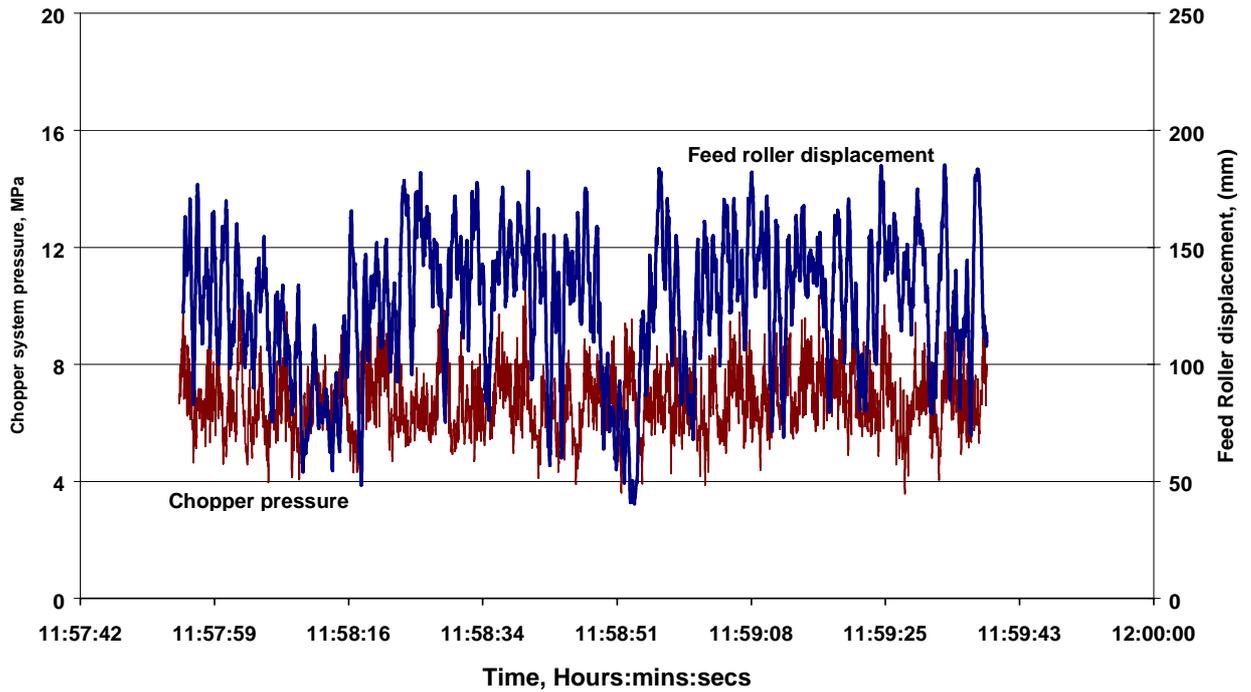


Figure 7 - Sample of calibrated instrumentation data from the instrumented harvester used in the field trials

The chopper hydraulic pressure data were used to calculate chopper motor torque and power during trial runs using the following equations.

$$\text{Motor torque, } M = \frac{p \times V}{2\pi} \quad \dots (1)$$

$$\text{Motor power, } P = \frac{M \times n}{9550} \quad \dots (2)$$

Where:

M = torque, Nm

p = oil pressure, MPa

V = motor displacement ml/rev

P = motor power, kW

n = speed of rotation, rpm

The average chopper motor power consumption for each treatment replicate was calculated, and average data for all replicates are given in Table 10.

Table 10 illustrates that power consumption is dependent on crop condition, blade condition and harvester pour rate. Both peak chopper power and average chopper power are higher for lodged cane than erect cane, as expected from the higher pour rates in lodged cane. In erect cane, peak chopper power and average chopper power consumption are higher with blunt blades than with sharp blades. This is in agreement with earlier testing during project BS188. However, in the lodged cane trials power consumption is

less with blunt blades than with sharp blades. Referral to Figures 5 and 6 shows that stalk strength was significantly lower at the time of the blunt blade tests late in the season, and this may explain the lower power consumption.

TABLE 10
Average chopper motor power during field harvesting trials

Variety	Crop condition	Blade condition	Nominal chopper speed (rpm)	Nominal feed train speed (rpm)	Pour rate (t/h)	Peak chopper power (kW)	Average chopper power (kW)
Q124	Erect	Sharp	260	185	70	27.7	16.8
Q124	Erect	Blunt	260	185	70	33.6	17.8
Q124	Lodged	Sharp	260	185	100	40.2	22.2
Q124	Lodged	Blunt	260	185	100	33.0	20.1

The average power consumption for the worst case scenario is approximately 22 kW. This is much less than that for commercial harvesters, and this is probably due to the relatively low pour rates used in these trials. Commercial harvesters have in the order of 125 kW (170 Hp) available for processing material under extreme conditions where instantaneous pour rates between 250 and 400 t/h can be encountered. Under these conditions even these power levels are often insufficient to prevent stalling.

4.4 Test rig results

4.4.1 CCS trends

Cane and trash CCS results for the different treatment combinations in the test rig trials are given in Table 11. These include comparison of ‘field’ and ‘optimum’ chopper speeds in lodged and erect cane with sharp and blunt chopper blades. Results are the mean of three replicates in each case.

The CCS results making up these means are extremely variable and there is no significant difference between treatments. There is a trend for CCS of leaf and trash to increase in the blunt chopper blade treatment, but as for the field trials this is not significant. Again CCS of cane is reduced compared to pre-harvest standing cane, and CCS of leaf and trash is higher than that prior to harvest. The apparent CCS change of cane is higher than would be expected from cane loss figures (section 4.4.2) and mass balance calculations, assuming cane lost has the same CCS as the cane prior to harvest. While some caution is required in interpreting the variable and unexpectedly low CCS values for cane in Table 11, *the magnitude of the CCS loss suggests that there is preferential loss of high pol juice during chopping.*

TABLE 11
Comparison of cane and leaf and trash CCS values for ‘field’ and ‘optimum’ chopper speeds in lodged and erect cane with sharp and blunt chopper blades

Treatment	Field setting		Optimum setting	
	Cane CCS	Trash CCS	Cane CCS	Trash CCS
<i>Lodged</i>				
Sharp	14.36	0.07	14.47	0.66
Blunt	15.44	0.68	15.71	0.75
<i>Erect</i>				
Sharp	14.69	0.17	15.47	0.15
Blunt	15.85	0.39	15.35	0.65

4.4.2 Cane loss and billet quality trends

Cane loss calculated from the mass balance of test rig runs, and mean billet length for test runs are given in Tables 12 and 13. Table 12 gives mean values for three replicates of each treatment combination. Table 13 gives overall mean losses and billet lengths for field and optimum chopper speeds, sharp and blunt chopper blades and lodged and erect cane, together with statistical significance of any differences.

TABLE 12
Cane loss and billet length data for lodged and erect cane, with sharp and blunt chopper blades, and ‘field’ and ‘optimum’ chopper speed settings

Test conditions	‘field’ setting		‘optimum’ setting	
	Cane loss %	Billet length mm	Cane loss %	Billet length mm
<i>Sharp blades</i>				
Lodged cane	1.80	189.3	0.87	225.3
Erect cane	3.30	186.7	1.57	223.3
<i>Blunt blades</i>				
Lodged cane	3.97	190.3	3.27	223.7
Erect cane	2.83	187.0	1.53	220.0

It is evident from Table 13 that the ‘optimum’ setting for chopper speed gave a reduction in cane loss that is close to significance at the 5% level. There was also a significant increase in billet length of the order of 19% as would be expected with a slower chopper speed. The proportional change in chopper speed was approximately 27% suggesting a possible increase in slippage at the slower chopper speed. The reduction in cane loss is around 65%, so this may not be purely due to the reduction in the number of cuts during billeting.

Sharp blades gave reduced cane loss compared to blunt blades, and the reduction was close to significance at the 5% level. Blade sharpness did not affect billet length.

TABLE 13
Mean cane loss and billet length for each chopper setting, chopper sharpness
and crop habit and statistical significance of differences

Treatment	Mean cane loss %	Mean billet length mm
Field setting	2.98	223.1
Optimum setting	1.80	188.3
lsd 5%	1.24 (n.s.)	2.7
Sharp blades	1.88	206.2
Blunt blades	2.90	205.3
lsd 5%	1.03 (n.s.)	n.s.
Lodged cane	2.48	207.2
Erect cane	2.31	204.3
lsd 5%	n.s.	2.9

There was no difference in cane loss due to chopping between lodged and erect cane, but billet length was increased by a small but significant amount in lodged cane. This may reflect greater slippage in the feed rollers.

Samples taken for measuring billet length distribution were also sorted to determine billet damage, but damage was severe and erratic due to a combination of severe growth cracking in the cane and the need to freeze samples before processing took place. These data have therefore been omitted from the report.

4.4.3 Test rig instrumentation results

Typical data on hydraulic power consumption and last top roller displacement for a test rig run are given in Figure 8.

4.4.3.1 Power consumption

In the test rig, direct measurement of both the chopper motor hydraulic pressure and the speed of rotation was carried out as described in section 3.3.2 and Appendix 1, to allow calculation of power consumption as for the field trials.

Average data recorded for the chopper rig trials are presented in Table 14. The main feature of these data is the reduction in chopper power consumption when there is matching of the chopper and feed roller peripheral speed in the 'optimum' setting (chopper speed 190 rpm) as opposed to the 'field' setting (chopper speed 260 rpm). Power consumption is approximately one-third lower with the optimum setting, and this is an important consideration for harvester design.

In the erect cane trials, power consumption is higher with blunt blades than with sharp blades, but as for the field harvester trials, the reverse is true for lodged cane. This may again be due to lower cane strength late in the season when the lodged cane, blunt blade trials were conducted.

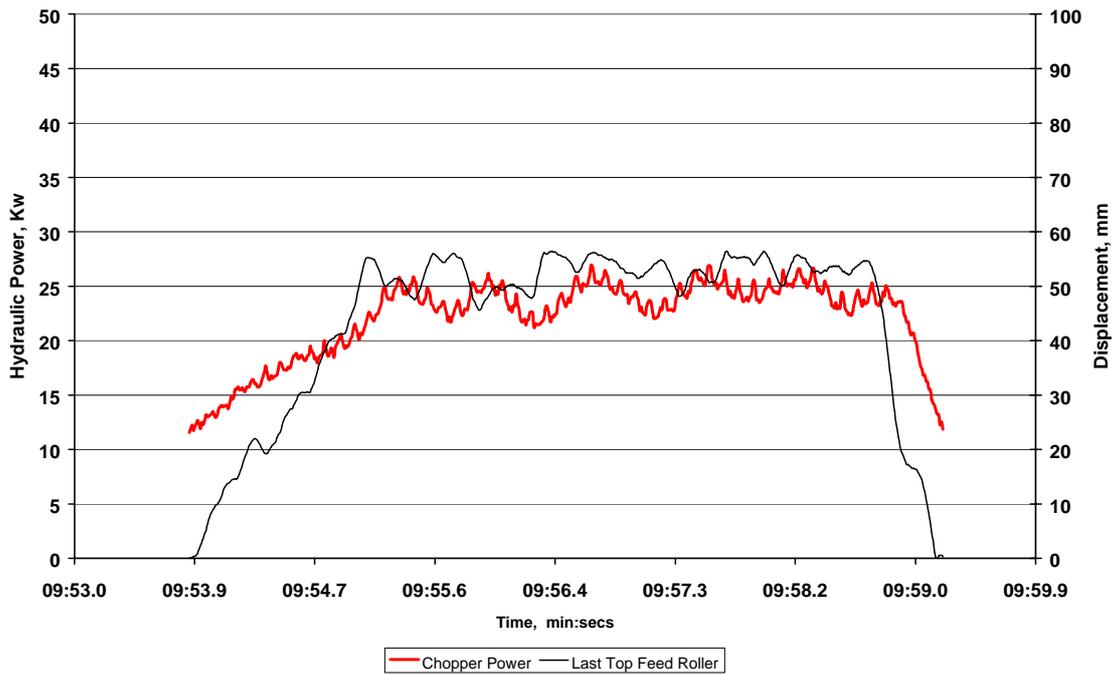


Figure 8 - Sample of calibrated instrumentation data from a test rig run

TABLE 14
Average chopper motor power for test rig trials

Variety	Crop condition	Blade condition	Nominal chopper speed (rpm)	Nominal Feed train speed (rpm)	Pour rate (t/h)	Peak Chopper Power (kW)	Average Chopper Power (kW)
Q124	Erect	Sharp	190	185	180	16.8	12.4
Q124	Erect	Blunt	190	185	180	20.8	16.2
Q124	Lodged	Sharp	190	185	180	23.6	16.0
Q124	Lodged	Blunt	190	185	180	19.0	12.6
Q124	Erect	Sharp	260	185	180	23.4	18.4
Q124	Erect	Blunt	260	185	180	26.6	19.7
Q124	Lodged	Sharp	260	185	180	35.5	25.7
Q124	Lodged	Blunt	260	185	180	26.7	17.6

4.4.3.2 Rotational speed measurements

The relationship between chopper drum speed and last top roller speed for a typical test rig run is presented in Figure 9. This case represents the set-up of the harvester for commercial harvesting (field setting). During processing of cane, the chopper speed fluctuates as the rate of flow of material fluctuates, falling below its nominal speed

under increased load. In contrast, there is periodic acceleration of the top feed roller speed by around 10% due to the aggressive feeding action of the chopper. This is partly responsible for the high power consumption in the ‘field’ configuration of the test rig, and would increase wear on the mechanical components of the hydraulic motors.

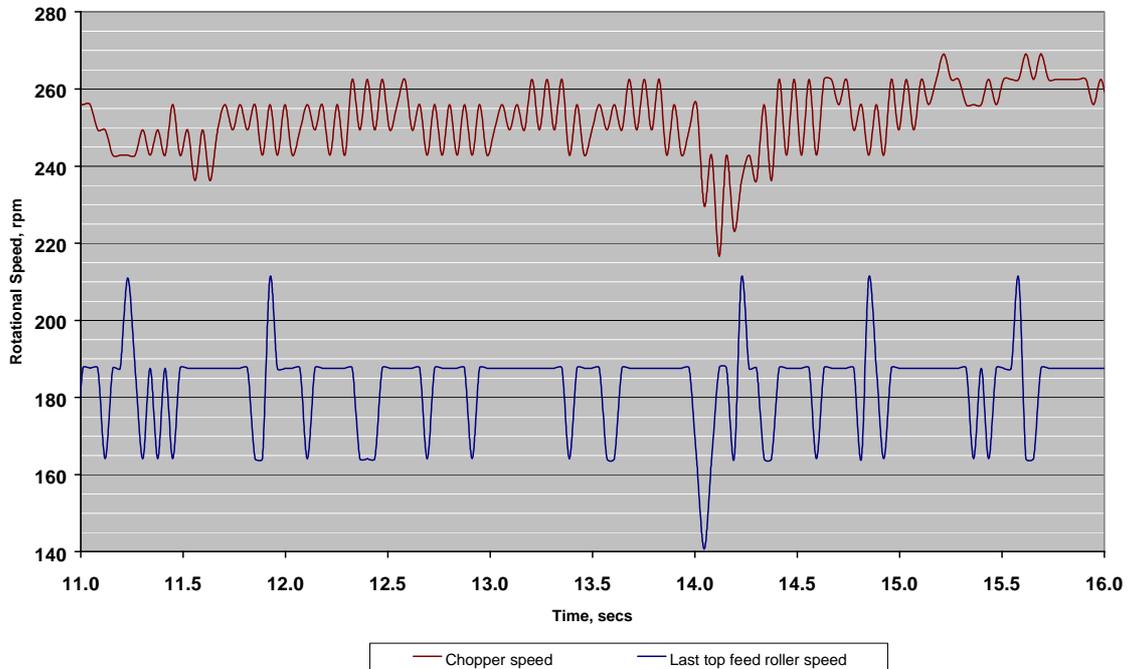


Figure 9 - Relationship between chopper and last top feed roller speed during processing of a cane bundle at ‘field’ settings: variety Q124, pour rate 180 t/h

In contrast, Figure 10, representing the ‘optimum’ setting of chopper speed, shows that both chopper and feed roller speeds reduce below their nominal value during cane processing, and there are no higher peaks in feed roller speed. This indicates that cane is moving through the rollers at a similar speed to the chopper blades, and explains the lower power consumption in the ‘optimum’ setting.

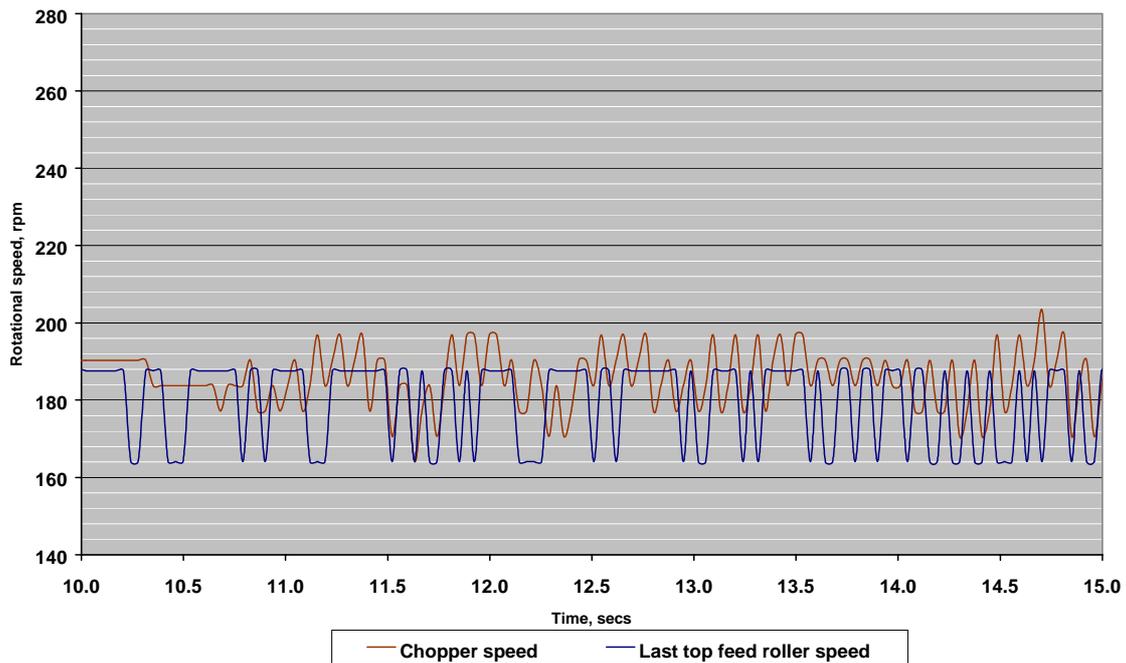


Figure 10 - Relationship between chopper and last top feed roller speed during processing of a cane bundle with ‘optimum’ settings: variety Q124, pour rate 180 t/h

5.0 DIFFICULTIES ENCOUNTERED DURING THE PROJECT

The principal difficulties encountered in the project included the following:

- (a) Techniques used by previous researchers in extracting juice from leaf and trash for CCS analysis were found to be unsuitable for cane in the Bundaberg area, and it was necessary to develop an alternative technique for extracting sugar from leaf and trash. Preliminary trials with tumbler and wet disintegrator techniques were not conclusive due to polariscope problems, and because of time constraints it was decided to use the tumbler technique with minimal prior evaluation. It is uncertain whether this contributed in any way to lower CCS values in leaf and trash than earlier studies in north Queensland.
- (b) There were also some logistical problems in processing the large number of samples collected from concurrent field and test rig trials. There were limits to the number of samples that could be processed fresh each day, and a majority of samples were snap frozen, and stored in a cold room freezer for later analysis. The effects of freezing, storage and thawing for analysis may have compromised the quality of the limited sets of CCS and billet quality data.

6.0 RECOMMENDATIONS FOR FURTHER RESEARCH

This research demonstrates the significant loss in CCS of cane during basecutting, chopping and cleaning by the harvester. The loss is linked to damage to cane during each stage of processing by the harvester, physical loss of damaged cane, preferential loss of high pol juice from cane as result of damage, and loss of this high pol juice during cleaning by the harvester extractors. Further research is therefore warranted to minimise cane damage (basecutter, feed rollers and chopper) and to optimise the level of cleaning to minimise loss of high pol juice during cleaning.

7.0 APPLICATION OF RESULTS TO THE INDUSTRY

The project has potential application in the industry through the improvement of harvester design and operation to minimise cane damage and CCS loss during harvesting, and changes in cleaning strategies to reduce loss of sugar from the cane supply during cleaning. Both this project and the earlier project, BS188, demonstrate the potential benefits from better matching of chopper and feed roller peripheral speeds in commercial harvesters.

8.0 PUBLICATIONS

There have been no publications to date arising from this project

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APPENDIX 1 - Detail of data acquisition and sensors

Data acquisition system

The high-speed acquisition of data is facilitated by a 16-channel 100 kHz PCMCIA slot analog and digital input/output computer board. Operation of the computer board is controlled by the proprietary Windows-based software DASyLab[®] that allocates acquired data directly to specified files. Data are recorded directly on the hard drive of the laptop computer.

Pressure measurement

Hydraulic pressure was measured using Genspec GS4200 series pressure transmitters. These transmitters feature a compact, rugged design and generate a 4 to 20 mA output proportional to applied pressure. Accuracy in terms of stability, repeatability and non-linearity hysteresis is less than 0.25% of full scale output with a response time of 1 ms. The transmitter output is interrogated by the computer software data acquisition system at 100 Hz, averaged and recorded on disk at 25 Hz.

The pressure transmitters were interfaced into the hydraulic circuits via a dedicated 5 mm diameter pilot tube and a tee-section fitting. This allowed the transmitters to be centrally located for protection. Figure 11 illustrates pressure transmitter pilot tube arrangement.



Figure 11 - Pressure transmitter pilot tube arrangement

Feed roller displacement measurement

The position of the floating feed rollers was monitored by measuring the rotation of the feed roller cradle. The system developed used a dedicated roller cradle pin, rotary position sensor and shaft. The shaft was attached to the inside of the roller cradle tube and extended out through the roller cradle pin to the rotary position sensor.

The sensor is a compact, rugged design, has a regulated power supply, and provides a zero to 5 volt output proportional to the degree of rotation. The sensor was interrogated by the data acquisition system at 100 Hz, the signal averaged, and recorded at 25 Hz. Figure 12 illustrates the feed roller displacement sensor arrangement.



Figure 12 - Feed roller displacement sensor and pilot tube arrangement

Pour rate measurement

Pour rate can be described as the mean material processing rate of the harvester, and it is the primary method of benchmarking the load ‘seen’ by the harvester components.

To determine pour rate, the harvester ground speed was measured using a Dicky John ground speed radar. This unit has a regulated 12-volt power supply, is rugged in construction, and provides a frequency output proportional to the speed of travel. The frequency output is converted to a voltage output by means of a digital to analogue board for input into the analog data acquisition system. Similar signal averaging was used to that for the other sensors.

The radar unit was mounted at the rear of the harvester engine bay and aimed at the tyre surface in the case of the wheeled harvester. Figure 13 illustrates the ground speed radar set-up.



Figure 13 - Ground speed radar system