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Final Report

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MODIFIED ROTARY-PINCH CHOPPER SYSTEM FOR IMPROVED HARVESTING EFFICIENCY

FINAL REPORT SRDC PROJECT HGP003

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EXECUTIVE SUMMARY

Bin weight is becoming an increasingly topical issue for the Australian sugar industry, with millers and haul-out contractors seeking to improve the efficiency of their operations by hauling more cane per trip using existing infrastructure. This has meant that there is considerable pressure within the industry to reduce billet length.

This program of work aimed to facilitate the adoption of feedtrain/chopper synchronisation through the development of a modified rotary-pinch chopper system. The design principle is based on the concept of obtaining variable length billets through one revolution of the chopper drum, not through manipulating feedtrain roller speed.

The conceptual design of the proof-of-concept modified rotary-pinch chopper system was developed and presented to Corradini Engineering for review, detailed design and manufacture. After fabrication the 'Corradini' proof-of-concept chopper system was installed on a harvester that is used to cut billets for planting and as a backup commercial machine.

Initial comparative trials were successfully undertaken at Fairymead Plantation in Bundaberg during the 2006 harvest season. A standard 15-inch chopper system with unsynchronised (variable) and synchronised (uniform) feedtrain setup was compared with the 'Corradini' proof-of-concept rotary-pinch chopper system (MRPCS) with synchronised feedtrain setup.

The functionality of the 'Corradini' proof-of-concept MRPCS was assessed with no differences in operational performance observed or noted by the machine operator when compared with a standard 15-inch chopper system. This included no recirculation of billets and a throw velocity identical to that of a standard 15-inch system.

In the 2006 trials, the 'Standard' chopper variable billet length treatment resulted in the greatest packing density, with 380 kg/m³ and the uniform length billets the lowest with 365 kg/m³. The packing density of the 'Corradini' proof-of-concept MRPCS variable length billet treatment was found to be 375 kg/m³. The corresponding average reduction in bin weight from the standard chopper variable length billets was found to be 1%. Alternatively, an increase in bin weight of 2.7% was found when compared with the standard chopper uniform length billets.

The results of the 2006 trial program justified further development and testing of the 'Corradini' MRPCS. Hence, further comparative trials were undertaken in Bundaberg during the 2007 harvest. A standard 15-inch chopper system with synchronised feedtrain setup was compared with the 'Corradini' MRPCS with synchronised feedtrain setup on bin weights and mill realised CCS.

In the 2007 trials, the 'Corradini' MRPCS variable length billet treatment resulted in the greatest packing density with an average 380 kg/m^3 . The standard chopper system uniform length billet treatment resulted in a reduced packing density with an average of 372 kg/m^3 . Theoretically, the increase in bin weight recorded from the standard to the 'Corradini' MRPCS was an average of 2.1%. No clear trends from the measured CCS levels in each replicate were evident.

The results demonstrate that it is possible to increase the packing density of billeted cane with variable length billets obtained through the design of the chopper system rather than manipulation of the feedtrain/chopper relationship. This would minimise cane and juice loss, whilst maximising packing density and minimising transport costs. This concept would be of most benefit to a 15-inch 3 blade per drum chopper system.

The opportunity for widespread adoption of the chopper system developed within this project appears limited given the sugar industry and harvesting sectors' lack of awareness and interest in reducing sugar losses during harvesting. Hence, it is recommended SRDC continue to support participative approaches which include application of current knowledge and implementation of improved harvesting practices. This should include heightened awareness of the concepts to increase the recovery of sugar during the harvesting operation, such as feedtrain/chopper optimisation.

1 BACKGROUND

Bin weight is becoming an increasingly topical issue for the Australian sugar industry, with millers and haul-out contractors seeking to improve the efficiency of their operations by hauling more cane per trip using existing infrastructure. This has meant that there is considerable pressure within the industry to reduce billet length.

In previous studies, factors influenced by billet length have been studied in isolation. However this approach does not allow the overall impact of changing billet length to be determined. These studies have focused on a number of aspects including the effect of billet length on bin weight, cane deterioration, extraneous matter (EM) and cane and sugar loss.

Cane transport and associated maintenance costs constitute a significant portion of a mill's operations budget and are largely driven by bin weights (Pope 1998). Bin weight is primarily affected by factors such as EM, billet length, cane variety, and field transport method (Vitale & Domati 1997).

Pope (1998) found bin weight reduction ranged from 2.5-5.5% for every 5% increase in EM level. Pope (1998) found cane class also affects bin weights with a distinct decrease in bin weight from plant through to third ratoon, with bin weights then tending to level out. This trend is most likely the result of a corresponding increase in EM content from plant to older ratoons (Pope 1998). Pope (1998) hypothesised that the increase in EM level from plant to older ratoons is a result of the billets being lighter in weight as age of ratoons increases.

The deterioration of sugar cane during the delay between being cut and crushed (cut-to-crush delay) has been a popular topic for investigation since the introduction of chopper harvesters. This deterioration is primarily due to *Leuconostoc* bacteria breaking down sucrose to produce dextran, acids and other products (Vitale & Domati 1997). It is unclear how billet length alone affects cane deterioration.

Shaw and Brotherton (1992) in a survey in the Mulgrave mill area established that an optimum cleaning level was available where both cane loss and extraneous matter levels were minimised. They found that trash was the most readily removable form of extraneous matter but as the extractor works to remove heavy trash loadings, billets are drawn out the extractor. In one case, reducing EM by one percent, cane loss was increased by 4.2 t/ha in Q120 and bin

weight reduced by 0.45 tonne. This led to their conclusion that there is little evidence of an optimum harvester setting which minimises both loss and EM. This result may also reflect the preferential removal of smaller billets and fragments by the extractor. This preferential removal in effect skews the billet length distribution towards a longer mean billet length.

Whiteing (2002) undertook trials over a four year period in North Queensland which defined the performance of late model machines with respect to extraneous matter and cane loss under a range of operational settings and field conditions. Over fifteen machines were assessed covering 1996-1998 Austoft and Cameco model machines. They found that EM is predominantly controlled by harvester pour rate and cane loss is primarily determined by fanspeed, with the crop having some influence. Typically, big increases in fanspeed cause big increases in cane loss with minimal reduction in trash levels. However, the interaction of billet length on these outcomes was not assessed.

Ridge and Dick (1987) identified two sources of cane loss during the billeting process. The first results from chipping or fragments and secondly moisture loss was hypothesised as a significant component of loss. Ridge and Dick (1987) found a chopper component loss of approximately 3% of the cane harvested.

Crook et al. (1999) indicated that total cane and juice losses associated with the chopping process could be in the order of 6% at the high harvester pour rates and with the billet length settings being used. It was hypothesised that juice was typically deposited on the surface of the extraneous matter (EM) and that significant proportions were then lost during the cleaning process (Davis & Norris 2002a).

Studies by Norris et al. (2000), Hockings et al. (2000) and Davis et al. (2003) into the interactions between the feedtrain and chopper system found that losses during the chopping process varied between 1.2% and 4.5% depending on cane variety, pour rate, chopper system and chopper setup. These losses are principally determined by the mismatch between the surface speeds of the chopper system and the feedtrain rollers.

Few studies have been undertaken into the effect of billet length on bin weight. James (2002) investigated the impact of billet length on biomass yield, CCS, tonnes of sugar per ha, and bin weight in commercial harvester trials. He demonstrated that increasing billet length from 'short' to 'long' increased the biomass per hectare yield and decreased bin weight. These increases

ranged in estimated magnitude (as percent of trial mean) from 2.2 to 5.5% additional tonnes biomass per hectare. As these increases were not met by corresponding increases in measured percentage trash or fibre levels, it could be hypothesised that these yield increases were due to a net decrease in the magnitude of associated cane and juice loss with the 'long' billet treatments. Bin weight was found to be inversely proportional to observed billet length. This decrease was estimated between 4.4-15.4% additional weight per bin with shorter billets (James 2002). James (2002) also found that a small reduction in mean billet length led to a significant decrease in sugar yield of up to 10%.

James (2002) also investigated the effect of fan speed on bin weight. He found that fan speed had a significant effect upon bin weight, and this effect was additive to the billet-length effect. The magnitude of the effect was approximately 3.7-4.4% increase with increasing fan speed. He hypothesised that increasing fan speed increases the bulk density of material in the bin, effectively due to the less dense billets being removed by the extractor fan.

Vitale and Domanti (1997) examined the effect of billet length on bin weight, cane deterioration, EM and cane loss. Most historical data supports the argument that reducing billet length increased bin weights and decreases EM levels. The main costs influenced by billet length are cane transport, cane deterioration, EM and cane loss.

Vitale and Domanti (1997) attempted to collate all available data pertaining to the effect of billet length on factors such as bin weight, EM levels and cane loss. Using these relationships, they developed a model to predict the cost of different billet lengths to the industry. The billet length/bin weight interactions component of the model was an adaptation of the model developed by Parkhouse and Kelly (1995) to estimate the effect of the length and thickness of randomly packed fibres of a given density upon packing density. The conclusion of the model was that the 'optimum' billet length was around 190 mm.

The model attempted to help the sugar industry make informed decisions regarding billet length and assumptions were based on the best available data at the time. However, further research by Davis and Norris (2001), Berding et al. (2002) and Hockings et al. (2000) has demonstrated that some of the assumptions in the model were flawed. The model assumed:

- Extraneous matter levels were significantly affected by billet length. Data reported by Henderson and Kirby (1972) were used to provide a relationship between billet length

and EM. This analysis concluded that there is approximately a 2% change in total EM for a 1% change in billet length. James (2002) found no significant differences between billet length and EM levels.

- Extraneous matter are totally devoid of sugar, and as such has a purely deleterious effect upon mill efficiency. Davis and Norris (2002b) found that 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. These results are supported by Whiteing (2002) where recorded CCS reductions at high leaf and trash levels in the cane supply (with low extractor speeds or extractors turned off) were not large and the work by Berding et al. (2002).
- Billet length has no effect on cane loss from the extractor. Whiteing et al. (2001) and James (2002) found that significant decreases in biomass yield per hectare as primary extractor fan speed increased. James (2002) found the magnitude of this decrease in biomass yield ranged from 2.7% to 10.9% and could not be explained by decreases in trash or fibre levels, thus it is likely that these results represent increased loss of millable cane through the primary extractor fan.
- Juice losses from the chopping process were substantially less than determined by Hockings et al. (2000) and James (2002).

The model also failed to include billet diameter as a significant factor affecting bin weight. Parkhouse and Kelly (1995) found that the combination of thickness (diameter) and length of randomly packed fibres of a given density have a large affect upon packing density.

A sensitivity analysis of the model showed that cane loss during harvesting and the cost of EM to be the two most influential variables impacting on the outcome of the model (Vitale & Domanti 1997).

In light of further research, the assumptions used within the Vitale and Domanti (1997) model could be redefined and it is reasonable to assume that the true 'optimum' billet length for the industry would be substantially longer than 190 mm. James (2002) work suggests that, if the relative losses recorded were consistent across the entire industry, moving to a longer billet

setting could lead to a conservative 5% increase of whole of industry net returns. This equates to about \$50 million per year for the Queensland industry.

The benefits of harvester feedtrain/chopper synchronisation are well defined (Hockings et al. 2000; Davis et al. 2003; James 2002). Feedtrain/chopper optimisation includes the reconfiguring of the harvester feedtrain and chopper system so that the surface speed of the feedtrain rollers are all identical and then setting this surface speed to be approximately 60-70% of the chopper tip speed. Feedtrain/chopper optimisation produces uniform billet lengths, which decrease bin weight.

Currently, to increase bin weights, harvester operators reduce billet lengths by reducing the speed of the last group of seven feed rollers. This in effect increases the mismatch in feedtrain/chopper speed ratio, effectively achieving a greater billet length distribution and reduces the mean billet length at the expense of cane and juice loss. Whilst minimising cane and juice loss, through feedtrain/chopper synchronisation, if bin weight could be increased with no change to the mean billet length, then, significant economic advantages for the industry could result.

This research has adopted a novel approach to obtain a varying billet length during one revolution of the chopper drum, not through varying the mismatch in feedtrain/chopper speed ratio which is currently undertaken.

2 PROJECT OBJECTIVES

This project aims to facilitate the adoption of feedtrain/chopper synchronisation through the development of a modified rotary-pinch chopper system. This will be achieved by:

- Undertaking proof-of-concept trials to assess the impact of variable length versus uniform length billets on packing density and bin weight.
- Developing a proof-of-concept modified rotary-pinch chopper system (MRPCS) design for a 15-inch, three or four blade per drum system where the blade configuration per drum is set at a varying angle on the circumference.
- Fabrication of the proof-of-concept design by a commercial after-market manufacturer.
- Installation of the proof-of-concept MRPCS design on a commercial harvester and field trialed.

3 METHODOLOGY

3.1 Stage One - Proof-of-Concept Evaluation

3.1.1 2005 Trial harvester

The harvester used in the 2005 trials was a standard 1996-built production model Austoft 7000. The machine is fitted with a Komatsu SA6D125 engine @ 2100rpm, rated in excess of 240 kW and has an electronic cabin. The harvester is fitted with leg basecutters and Austoft 15-inch differential rotary-pinch chopper system with 3 blades per drum.

A billet length selector valve is fitted to the machine and is activated by a dial knob located in the gauge panel in the cabin. This valve controls the amount of oil supplied to the last group of seven rollers to infinitely vary the speed of the rollers (Rollers 5-11 in Table 1). This change in roller speed varies the billet length. This machine was assessed and modified to BSES Limited specifications, such that when the 'long' billet is selected on the dial, the speed of the feedtrain rollers are more closely synchronised with the speed of the chopper system at a ratio of 0.64. BSES Limited recommends a feedtrain/chopper ratio between 0.65 and 0.70 for optimum harvester performance (Hockings et al., 2000). However, due to their initial hydraulic configuration, not all machines can be modified to reach a 'optimum' ratio between 0.65 and 0.70, so modifications aim to get as close as possible to this ratio within practical and economic constraints. Conversely, when 'short' billet is selected the feedtrain/chopper ratio reduces, resulting in further unsynchronisation of the feedtrain/chopper system at a ratio of 0.53. In factory standard harvesters with 15 inch chopper systems (assessed by BSES Limited in their feedtrain/chopper optimisation program) typically have a feedtrain/chopper ratio ranging from around 0.46 to 0.56 for 'short' and 'long' billet settings depending on year model and configuration (C Whiteing pers comms, 2005).

This harvester is owned and operated by Bundaberg Sugar Ltd and is used to cut billets for planting and as a backup commercial machine. Photograph 1 illustrates the Austoft 7000 cane harvester used in the 2005 trials.



PHOTOGRAPH 1 - THE AUSTOFT 7000 CANE HARVESTER USED IN THE 2005 TRIAL PROGRAM

The crop-handling system components and speed specifications for the trial harvester with synchronised feedtrain/chopper system are presented in Table 1. With this configuration the feedtrain/chopper ratio is 0.64 and the target billet length range is approximately 250 – 265 mm.

TABLE 1 - CROP-HANDLING SYSTEM COMPONENTS AND SPEED SPECIFICATIONS FOR TRIAL HARVESTER SETUP WITH SYNCHRONISED FEEDTRAIN/CHOPPER SYSTEM

Component	Model (Eaton Series)	Displacement (cubic inch)	Oil Flow (US gpm)	Speed (rpm)	Surface speed (km/h)
LHS Spiral	2000	18	15.5	185	7.0
LHS Outer Spiral	2000	18	15.5	185	7.0
RHS Spiral	2000	18	15.5	185	7.0
RHS Outer Spiral	2000	18	15.5	185	7.0
Knockdown	2000	2*24	15.5	150	8.8
Finned	2000	2*24	15.5	150	8.8
Basecutters	-	-		667	-
1 Buttlifter	2000	2*24	24	146	8.2
2 1st top	2000	18	15.5	193	7.9
3 2nd top	2000	18	15.5	193	7.9
4 1st bottom	2000	18	15.5	193	7.9
5 2nd bottom	2000	2*18	15.5	193	7.9
6 3rd top	2000	18	15.5	193	7.9
7 3rd bottom	2000	18	15.5	193	7.9
8 4th top	2000	18	15.5	193	7.9
9 4th bottom	2000	18	15.5	193	7.9
10 5th top	2000	18	15.5	193	7.9
11 6th bottom	2000	18	15.5	193	7.9
Chopper	10000	2*40.6	32	175	3.5
15 inch					

*Surface speed at first point of contact with cane (Spiral diameter 200mm).

The speed of the feedtrain and chopper can be unsynchronised by dialing the in-cab billet length selector control to 'short' billet. This controls the 'valvistor'-a hydraulic oil flow control valve that bleeds oil from the last group of seven feed rollers-slowng their speed. (Rollers 5-11 in Table 2).

The crop-handling system components and speed specifications for the trial harvester with unsynchronised feedtrain/chopper system are presented in Table 2. With this configuration, the feedtrain/chopper ratio is 0.53 and the target billet length range is approximately 200 – 235 mm.

TABLE 2 - CROP-HANDLING SYSTEM COMPONENTS AND SPEED SPECIFICATIONS FOR TRIAL HARVESTER SETUP WITH UNSYNCHRONISED FEEDTRAIN/CHOPPER SYSTEM

Component	Model (Eaton Series)	Displacement (cubic inch)	Oil Flow (US gpm)	Speed (rpm)	Surface speed (km/h)
LHS Spiral	2000	18	15.5	185	7.0
LHS Outer Spiral	2000	18	15.5	185	7.0
RHS Spiral	2000	18	15.5	185	7.0
RHS Outer Spiral	2000	18	15.5	185	7.0
Knockdown	2000	2*24	15.5	150	8.8
Finned	2000	2*24	15.5	150	8.8
Basecutters	-	-	-	667	-
1 Buttlifter	2000	2*24	24	146	8.2
2 1st top	2000	18	15.5	193	7.9
3 2nd top	2000	18	15.5	193	7.9
4 1st bottom	2000	18	15.5	193	7.9
5 2nd bottom	2000	2*18	15.5	148	5.8
6 3rd top	2000	18	15.5	148	5.8
7 3rd bottom	2000	18	15.5	148	5.8
8 4th top	2000	18	15.5	148	5.8
9 4th bottom	2000	18	15.5	148	5.8
10 5th top	2000	18	15.5	148	5.8
11 6th bottom	2000	18	15.5	148	5.8
Chopper 15 inch	10000	2*40.6	32	175	3.5

*Surface speed at first point of contact with cane (Spiral diameter 200mm).

The trial harvester can be operated with either a synchronised or unsynchronised feedtrain/chopper system. This flexibility makes this harvester ideally suited for this work,

allowing control and treatments to be undertaken with an identical machine forward-feeding and extractor configurations.

3.1.2 Trial Program 2005

The 2005 proof-of-concept trial program was undertaken at Fairymead Plantation in Bundaberg. Trials were undertaken in erect, Q188 variety cane yielding approximately 100 t/ha and harvested green and in both directions.

The flexibility in the setup of the trial harvester's feedtrain/chopper system allows it to be used for both uniform and variable length billets treatments. Variable length billets result from the unsynchronised feedtrain/chopper setup and uniform length billets result from the synchronised feedtrain/chopper setup. A third treatment, comprising mixture of uniform and variable billet lengths from both the synchronised and unsynchronised feedtrain/chopper setups, was also evaluated. In all trials the primary extractor fan speed was set at a constant no load speed of 1300 rpm.

Trial designs were setup to maximise data quality within the physical and operational constraints. Replicated trials were undertaken at a nominated harvester ground speed of 6 km/hr. This corresponds with a nominal pour rate of 90 t/hr. Plot lengths corresponding with the paddock size were utilised and were 300 m in length.

Each treatment consisted of 10, 6 tonne bin rakes to allow mill realised CCS and individual bin weights to be recorded. The packing density of the middle 6 bins of each treatment rake was determined by carefully levelling the material with a pitchfork and the corresponding height recorded. This allowed the volume of each individual bin to be determined.

The mass of material from each bin is in the order of 5500 kg. It was not feasible to sample every billet from this mass to determine billet length distribution and EM level. Therefore billet length distribution and EM level was assessed through a program of subsampling the mass of material from each bin. Work by McRae et al. (1998) has indicated that a sample size of 20 kg gives representative data for this assessment and this sample size was adopted for this work.

The billet length distribution and EM level assessment procedure included collecting two 20 kg samples from each of the middle 6 bins of each treatment rake, weighing the sample, then

sorting the sample into billet length categories and EM. The procedure for determining billet length categories was modified from the guidelines set out by De Beer et al. (1985) for quantifying billet length distribution. To provide a more detailed analysis of billet lengths, nominal increments of 25 mm were used, with this reducing to 12 mm increments around the target billet length. Thus billets were sorted into categories of 0-125 mm, 125-150 mm, 150-175 mm, 175-200 mm, 200-212 mm, 212-225 mm, 225-237 mm, 237-250 mm, 250-262 mm, 262-275 mm, 275-300 mm and longer than 300 mm. Each category was then weighed, and a weighted mean billet length recorded. EM was then weighed and recorded. No billet damage assessment was undertaken.

3.2 Conceptual design of proof-of-concept modified rotary–pinch chopper system

The conceptual design of the proof-of-concept modified rotary–pinch chopper system was developed through an investigation into the correlation between billet length and bin weight. This was based on data sourced from literature, private communications, unpublished work of specialists at various mills and the results of the Stage 1 - Proof-of-concept evaluation.

The current design of rotary-pinch chopper systems incorporate two, three or four blades per drum equi-spaced around the circumference at 180, 120 and 90 degrees respectively. Thus, during one revolution of the drum, two, three or four billets are produced all of equal length (in the case of a synchronised setup) depending on the blade configuration.

Rotary-pinch chopper systems with two blades per drum are only available in 12-inch and are not currently commercially manufactured. In this system, the diameter of the top and bottom drums are identical. Two bladed systems are commonly used in machines dedicated for cutting plants and are not used in machines for cutting commercial cane due to the length of billet cut.

Rotary-pinch chopper systems with three blades per drum are available in 12-inch and 15-inch. Currently 15-inch systems are commercially manufactured. Both systems have unequal drum diameters to allow for alternative blade entry dynamics. These systems are commonly referred to as differential chopper systems. Three bladed systems are commonly used in machines dedicated for cutting plants and for cutting commercial cane.

Rotary-pinch chopper systems with four blades per drum are only available in 15-inch. Currently four bladed 15-inch systems are commercially manufactured. These systems also have unequal drum diameters and are referred to as differential chopper systems. Four bladed systems are commonly used only in machines dedicated for cutting commercial cane.

Figure 1 illustrates the configuration of rotary-pinch choppers systems with two blades, three blades and four blades per drum respectively. Table 3 illustrates the nominal billet length from two, three and four bladed systems.

TABLE 3 - BILLET LENGTHS FROM VARIOUS CONFIGURATIONS OF ROTARY-PINCH CHOPPER SYSTEMS

Chopper System (inch)	No blades per drum	Nominal Billet length (mm)	Nominal Billet length (inch)
12	2	325	12.8
15	3	265	10.5
15	4	200	8

A modified rotary-pinch chopper system with three bladed drums was selected as the system for modification due to its flexibility in cutting both billets for planting and commercial cane. In addition, a three bladed system has lower cane and sugar losses when compared with a system with four blades per drum (Hockings et al. 2000). Lower cane and juice losses result from the reduction in chops per unit length of material or correspondingly the larger average billet length.

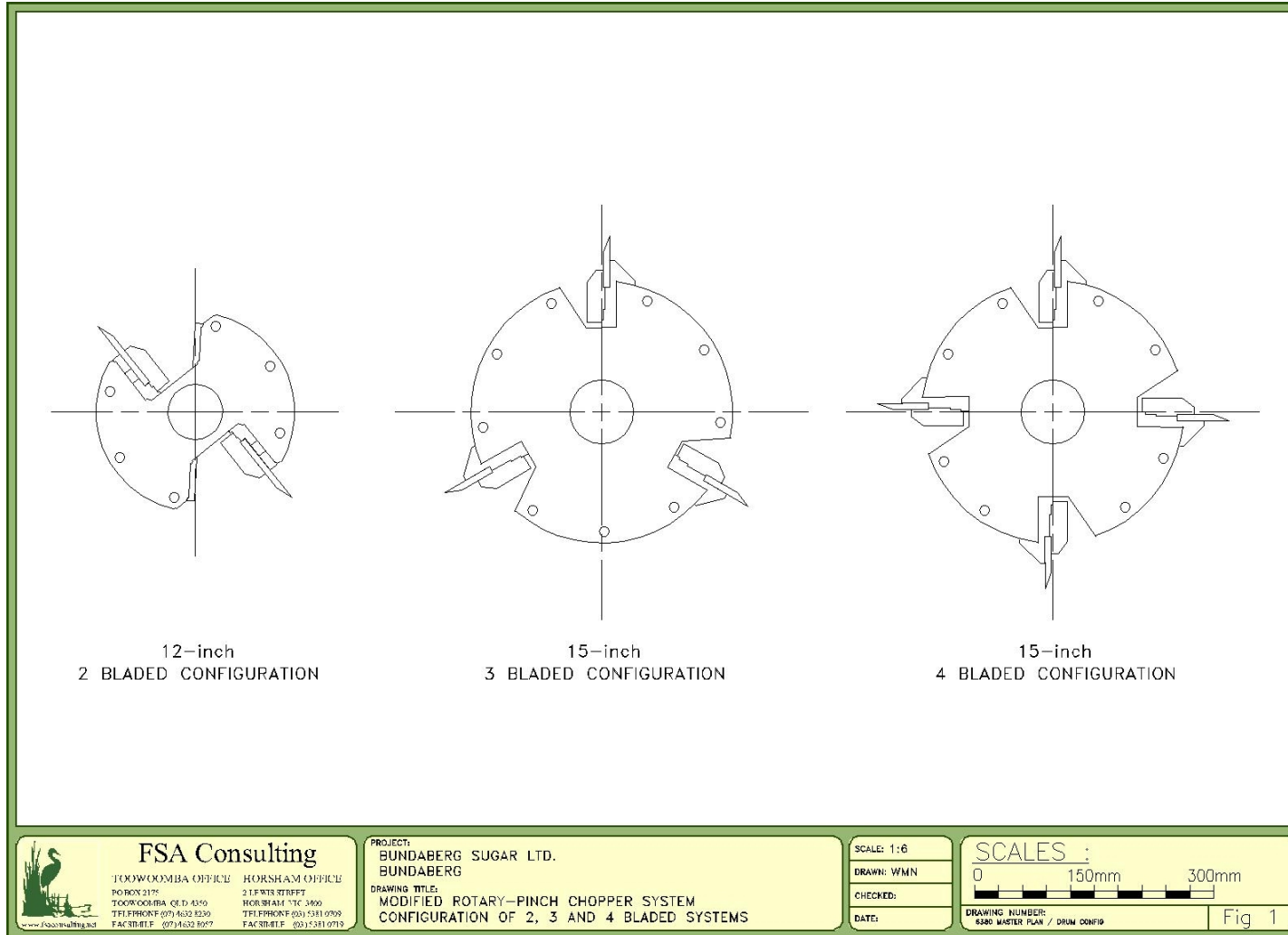


FIGURE 1 - CONFIGURATION OF TWO, THREE AND FOUR BLADED ROTARY-PINCH CHOPPER SYSTEMS

The Parkhouse and Kelly (1995) model adapted for cane billets by Vitale and Domanti (1997) was utilised to determine how bin weight changed with billet length. The packing characteristics of different length billets can be predicted using a relationship that considers the random three dimensional packing of long straight fibres (Vitale & Domanti 1997).

The bin weight of clean cane was estimated using the following equation:

$$\text{Bin Weight} = \kappa \times (\rho_c/1000) \times V_f \times V_b \quad \text{Equation 1}$$

Where:

κ = calibration constant, 0.6

ρ_c = the density of cane billets (kg/m^3)

V_f = is the volume of fraction of fibres and;

$V_f = (2 \ln \lambda)/\lambda$

λ = slenderness of the fibre. Slenderness is the ratio of length to diameter.

V_b = Volume of the cane bin

This equation does not account for changes in bin weight as a result of changes in EM. In addition, the billet density and diameter are considered constant. A clean cane billet density of 1100 kg/m^3 was used. The dimensions of the nominal 6 t railway cane bin used by Bundaberg Sugar Ltd in Bundaberg measures 2.35 m wide by 3.60 m in length by 1.85 m in height. These dimensions give a calculated volume of 15.8 m^3 per bin.

A spreadsheet model was developed to evaluate the effect of varying slenderness ratio on bin weight. Hence, slenderness ratios were assessed based on a 30 mm billet diameter and billet lengths ranging from a nominal length of 200mm (4 Blade) to 325 mm (2 blade).

A finite number of billet length combinations are obtainable with a chopper system with three-blades per drum whilst restricting the billet length between 200 mm and 325 mm. These include combinations of (265 mm; 265 mm; 265 mm), (305 mm; 265 mm; 225 mm), (305 mm; 240 mm; 240 mm), (325 mm; 265 mm; 205 mm) and (295 mm; 295 mm; 205 mm). The aim was to maximise the bin weight as predicted from the model from the above combinations of billet length. The modelling demonstrated that a billet length combination of 295 mm; 295 mm;

205 mm maximises bin weight. The relationship between billet length and bin weight developed in the model suggests that a 1% change in billet length produces a 0.5% change in bin weight. The theoretical increase in bin weight achievable from this combination was estimated to be 3%.

A conceptual design was developed with blade angles such that nominal billet lengths of 295 mm; 295 mm; 205 mm could be attained. This design was then presented to Corradini Engineering for review and detail design.

3.3 Detailed design of proof-of-concept modified rotary–pinch chopper system

Corradini Engineering of Ingham undertook the detailed design of the proof-of-concept modified rotary–pinch chopper system. A number of steps were undertaken in the design process and included:

- 1) Preparation of a short design brief outlining the major criteria for the design
- 2) The mechanical function of existing rotary–pinch chopper systems was researched
- 3) A patent search was undertaken for similar or existing designs
- 4) Preparation of a preliminary design based on existing components
- 5) A 3D ‘Solidworks’ model was developed and motion simulated to ensure correct cutting action (See Figure 2)
- 6) A field trip to gather additional information on existing chopper systems and gather information from users was undertaken
- 7) The 3D model was refined with information obtained during field trip
- 8) The 3D model was reviewed by management as part of an internal quality assurance check prior to approval for fabrication
- 9) Refined the 3D model after review by management if required
- 10) Detailed workshop drawings were produced for manufacture and/or quotation of parts or assemblies if required.

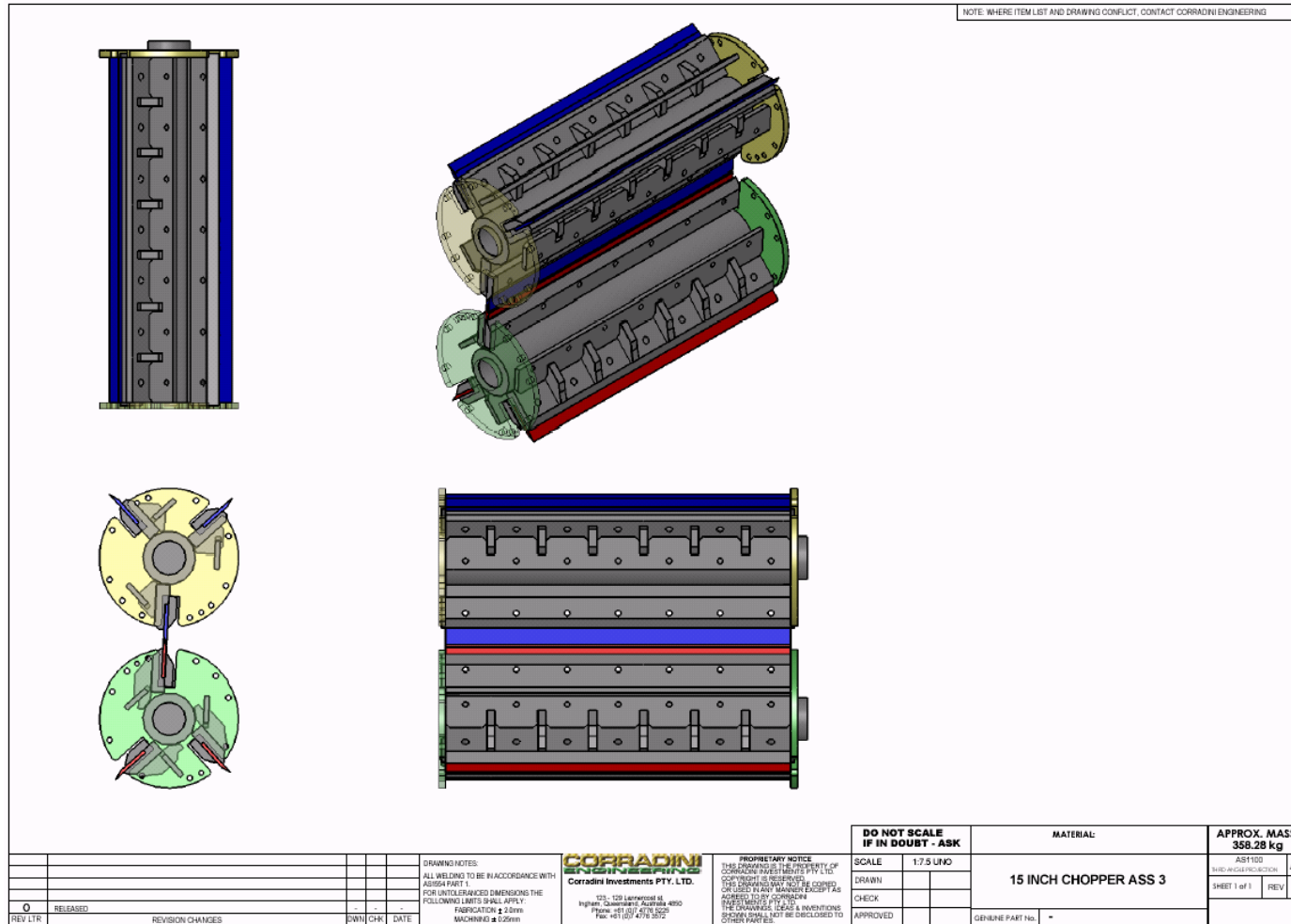


FIGURE 2 - END, SIDE AND ISOMETRIC VIEWS OF 3D ‘SOLIDWORKS’ MODEL OF PROTOTYPE ROTARY PINCH CHOPPER SYSTEM – CORRADINI ENGINEERING

3.4 Manufacture of proof-of-concept modified rotary–pinch chopper system

Corradini Engineering of Ingham undertook the manufacturing of the proof-of-concept modified rotary-pinch chopper system. A number of steps were undertaken in the manufacturing process and included:

- Suitable material was sourced, cleaned and processed into required sizes
- End plates and centre tube were individually machined using a CNC lathe
- End plates and centre tube were assembled and welded in a specifically designed jig. This included preheating components, welding then post heating to minimise distortion
- Blade locations on drums were milled in vertical milling machine
- Drums were face machined to length in a centre lathe.
- Drums balanced

Photograph 2 illustrates the fabrication of the bottom drum of the proof-of-concept modified rotary-pinch chopper system in the specifically designed jig.



PHOTOGRAPH 2 - FABRICATION OF THE BOTTOM DRUM OF THE PROOF-OF-CONCEPT MODIFIED ROTARY-PINCH CHOPPER SYSTEM

Photograph 3 illustrates the fabricated bottom drum of the proof-of-concept modified rotary-pinch chopper system prior to machining of the blade locations and face machining.



PHOTOGRAPH 3 - FABRICATED BOTTOM DRUM OF THE PROOF-OF-CONCEPT MODIFIED ROTARY-PINCH CHOPPER SYSTEM PRIOR TO MACHINING

3.5 Stage Two - Proof-of-Concept modified rotary-pinch chopper system evaluation

3.5.1 2006 Trial Harvester

The proof-of-concept modified rotary-pinch chopper system was freighted from Ingham to Bundaberg in preparation for field testing. Bundaberg Sugar Ltd made available the same harvester as used in the 2005 trial program. The specifications of the harvester are outlined in Section 3.1.1. In 2006 this harvester was used to cut billets for planting and as a backup commercial machine.

Photograph 4 illustrates the Austoft 7000 cane harvester used in the 2006 trials.



PHOTOGRAPH 4 - THE AUSTOFT 7000 CANE HARVESTER USED IN THE 2006 TRIALS

The 2006 trial harvester's crop-handling system components and speed specifications were configured identical to that of the 2005 trial program. Table 1 presents the crop-handling components and speed specifications as set during the 2006 trial program. This configuration results in a feedtrain/chopper ratio of 0.64 and a nominal target billet length range between 250 – 265 mm.

The speed of the feedtrain and chopper can be unsynchronised by dialing the in-cab billet length selector control to 'short' billet. This controls the 'valvistor'-a hydraulic oil flow control valve that bleeds oil from the last group of seven feed rollers-slowing their speed.

For the variable length billet treatment with the standard chopper system, the crop-handling system components and speed specifications were set identical to that of the 2005 trial program for the same treatment. Table 2 outlines the crop-handling system components and speed specifications for the trial harvester with unsynchronised feedtrain/chopper system. This configuration, results in a feedtrain/chopper ratio of 0.53 and a nominal target billet length range between 200 – 235 mm.

The trial harvester can be operated with either a synchronised or unsynchronised feedtrain/chopper system. This flexibility makes this harvester ideally suited for this research

work, allowing control and treatments to be undertaken with an identical machine forward-feeding and extractor configurations.

The ‘Corradini’ proof-of-concept modified rotary-pinch chopper system was installed on the trial harvester by an experienced harvester mechanic who specialises in chopper system installations (Photograph 5). No problems were experienced during the installation process. The blades were timed, with no issues in the timing of the blades.



PHOTOGRAPH 5 - ‘CORRADINI’ PROOF-OF-CONCEPT MODIFIED ROTARY–PINCH CHOPPER SYSTEM INSTALLED ON 2006 TRIAL HARVESTER

3.5.2 Trial Program 2006

The 2006 proof-of-concept trial program was undertaken at Fairymead Plantation in Bundaberg. Trials were undertaken in erect, 1st ratoon Q205 variety cane, yielding approximately 120 t/ha and harvested green and in both directions.

The flexibility in the setup of the trial harvester's feedtrain/chopper system allows it to be used for both uniform and variable length billets treatments. Variable length billets result from the unsynchronised feedtrain/chopper setup and uniform length billets result from the synchronised feedtrain/chopper setup. In all trials the primary extractor fan speed was set at a constant no load speed in the order of 1300 rpm.

Comparative trials using a commercial harvester were successfully undertaken at Fairymead Plantation in Bundaberg. Trials evaluated the impact of the proof-of-concept modified rotary pinch chopper system with synchronised feedtrain setup when compared with the standard 15-inch chopper system with unsynchronised and synchronised feedtrain setup on billet length, packing density and bin weight.

Trial designs were setup to maximise data quality within the physical and operational constraints of commercial harvesting operations. Replicated trials were undertaken at a nominated harvester ground speed of 5 km/hr. This corresponds with a nominal pour rate of 90 t/hr. Plot lengths corresponding with the paddock size were utilised and were 400 m in length.

Each treatment consisted of 15, 6-tonne bin rakes to allow mill realised CCS and individual bin weights to be recorded. The packing density of all bins in each treatment rake was determined by carefully levelling the material with a pitchfork and the corresponding height recorded. This allowed the volume of each individual bin to be determined.

The billet length distribution and EM level was assessed through a program of subsampling the mass of material from each bin. The billet length distribution and EM level assessment procedure included collecting two 20 kg samples from each bin of each treatment rake, weighing the sample, then sorting the sample into billet length categories and EM. The procedure for determining billet length categories was modified from the guidelines set out by De Beer et al. (1985) for quantifying billet length distribution. To provide a more detailed analysis of billet lengths, nominal increments of 25 mm were used, with this reducing to 12 mm increments around the target billet length. Thus, billets were sorted into categories of 0-125 mm, 125-150 mm, 150-175 mm, 175-200 mm, 200-212 mm, 212-225 mm, 225-237 mm, 237-250 mm, 250-262 mm, 262-275 mm, 275-300 mm and longer than 300 mm. Each category was then weighed and a weighted mean billet length recorded. Extraneous matter was then weighed and recorded. No billet damage assessment was undertaken.

The same personnel undertook the assessment of billet quality for all samples. This ensured that the interpretation of qualitative assessment criteria was repeatable and consistent.

3.6 Stage Three - Prototype modified rotary-pinch chopper system evaluation

3.6.1 2007 Trial Harvester

In 2007, Bundaberg Sugar Ltd made available the same harvester as used in the 2005 and 2006 trial program. The specifications of the harvester are outlined in Section 3.1.1. This harvester is used to cut billets for planting and as a second commercial machine when not utilised for plant cutting. Photograph 6 illustrates the Austoft 7000 cane harvester used in the 2007 trial program.



PHOTOGRAPH 6 - THE AUSTOFT 7000 CANE HARVESTER USED IN THE 2007 TRIAL PROGRAM

The crop-handling system components and speed specifications for the 2007 trial harvester with synchronised feedtrain/chopper system are presented in Table 1. With this configuration the feedtrain/chopper ratio is 0.64 and the target billet length range is approximately 250 – 265 mm.

The crop-handling system components and speed specifications for the trial harvester with unsynchronised feedtrain/chopper system are presented in Table 2. With this configuration, the feedtrain/chopper ratio is 0.53 and the target billet length range is approximately 200 – 235 mm.

The trial harvester can be operated with either a synchronised or unsynchronised feedtrain/chopper system. For plant cutting the harvester is operated on the synchronised chopper setting and when used for commercial cane harvesting, the chopper system is set on the unsynchronised setting. For the 2007 trial program, the chopper system was set on the synchronised setting and in all treatments and replications the primary extractor fan speed was set at a constant no load speed in the order of 1400 rpm.

3.6.2 Trial Program 2007

The 2007 trial program was undertaken on FARM 30193 (Fulcher), a Bundaberg Sugar Ltd, Elliott River Farm in Bundaberg. Two blocks were used for the trials, Block 89-A and 91-A. Both blocks were erect, even, 1st ratoon Q205 variety cane, yielding approximately 75 and 85 t/ha for Block 89-A and 91-A respectively (Photograph 7). The treatments were harvested green and in both directions. Replications 1 and 2 were completed in Block 89-A and Replication 3 in Block 91-A.



PHOTOGRAPH 7 - 2007 TRIAL PROGRAM CROP CONDITIONS – VARIETY Q205

Comparative trials evaluated the impact of the proof-of-concept modified rotary pinch chopper system with synchronised feedtrain setup when compared with the standard 15-inch chopper system with synchronised feedtrain setup on billet length, packing density, bin weight and CCS.

Trial designs were setup to maximise data quality within the physical and operational constraints of commercial harvesting operations. Replicated trials were undertaken at a nominated harvester ground speed of 7 km/hr which suited the crop and ground conditions at the time. This ground speed corresponds with a nominal pour rate of 80 and 90 t/hr for Blocks 89-A and 91-A respectively. The replicate sizes corresponded with the nominated block row lengths and number of rows with average replications comprising 23-25 rows and row lengths of 400m in length.

Each replication consisted of between 20 and 25, 6 tonne nominal bin rakes to allow mill realised CCS and individual bin weights to be recorded. The volume of all bins in each replication rake was determined by carefully levelling the material in each bin with a pitchfork and the corresponding height recorded (Photograph 8). This allowed the packing density of each individual bin to be determined for comparative purposes.



PHOTOGRAPH 8 - LEVELLING THE CANE IN EACH RAILWAY BIN TO DETERMINE BIN VOLUME

Billet length distribution and EM level was assessed through a program of subsampling the mass of material from each bin. The billet length distribution and EM level assessment procedure included collecting one 20 kg sample from each bin of each treatment rake, weighing the sample, then sorting the sample into billet length categories and EM.

Billets were sorted into categories of 0-125 mm, 125-150 mm, 150-175 mm, 175-200 mm, 200-212 mm, 212-225 mm, 225-237 mm, 237-250 mm, 250-262 mm, 262-275 mm, 275-300 mm and longer than 300 mm. Each category was then weighed and a weighted mean billet length recorded. Extraneous matter was then weighed and recorded. No billet damage assessment was undertaken.

Bundaberg Sugar Ltd employee, Nancy Rincon and FSA Consulting's Rod Davis undertook the assessment of billet quality for all samples. This ensured that the interpretation of qualitative assessment criteria was repeatable and consistent.

4 RESULTS AND DISCUSSION

4.1 Stage One - Proof-of-Concept Evaluation: 2005 Trial Program

Comparative trials using a commercial harvester were successfully undertaken at Fairymead Plantation in Bundaberg to evaluate the impact of variable length versus uniform length billets on packing density and bin weight. The results were collated and analysed and are presented in the following sections. Table 4 illustrates the average mill realised bin weight, CCS and dirt in juice from each treatment. EM levels were measured from the samples collected. These results illustrate that the cane supply in all treatments was consistent.

TABLE 4 - BIN WEIGHT, EM LEVEL AND CCS FOR 2005 TRIALS

Treatment	Average Bin Weight Kg	EM Level %	CCS	Dirt in Juice %
Variable Length	5790	1.95	12.0	3
Uniform Length	5360	1.73	12.0	3
Mixed Length	5780	1.97	12.4	4

4.1.1 Variable Length Billets

The average billet length distribution from samples taken from the unsynchronised ('short') billet length setting treatment is presented in Figure 3. The 'short' billet length setting results in 42% by weight of billets falling within the range of 225 to 237 mm. The length distribution closely represents a normal distribution around this mean target length within approximately 80% of billets within 50 mm of this length. The billet lengths ranged from 200 mm to 300 mm. Billet lengths less than 175 mm typically represent the top and base ends of stalk and depend on the starting point of the chopping process and the stalk length, not the characteristics of the chopper system. They are therefore not considered in the overall distribution assessment.

Factory-standard harvesters with 15-inch chopper systems (assessed by BSES Limited in their feedtrain/chopper optimisation program) typically have a feedtrain/chopper ratio ranging from around 0.46 to 0.56 for 'short' and 'long' billet settings respectively (C Whiteing pers comms,

2005). The 'short' billet setting in this harvester results in a feedtrain/chopper ratio of 0.52. Therefore the resultant mean length and distribution would be similar to the typical industry standard length and distribution for 15-inch, 3 blade chopper systems in commercial situations.

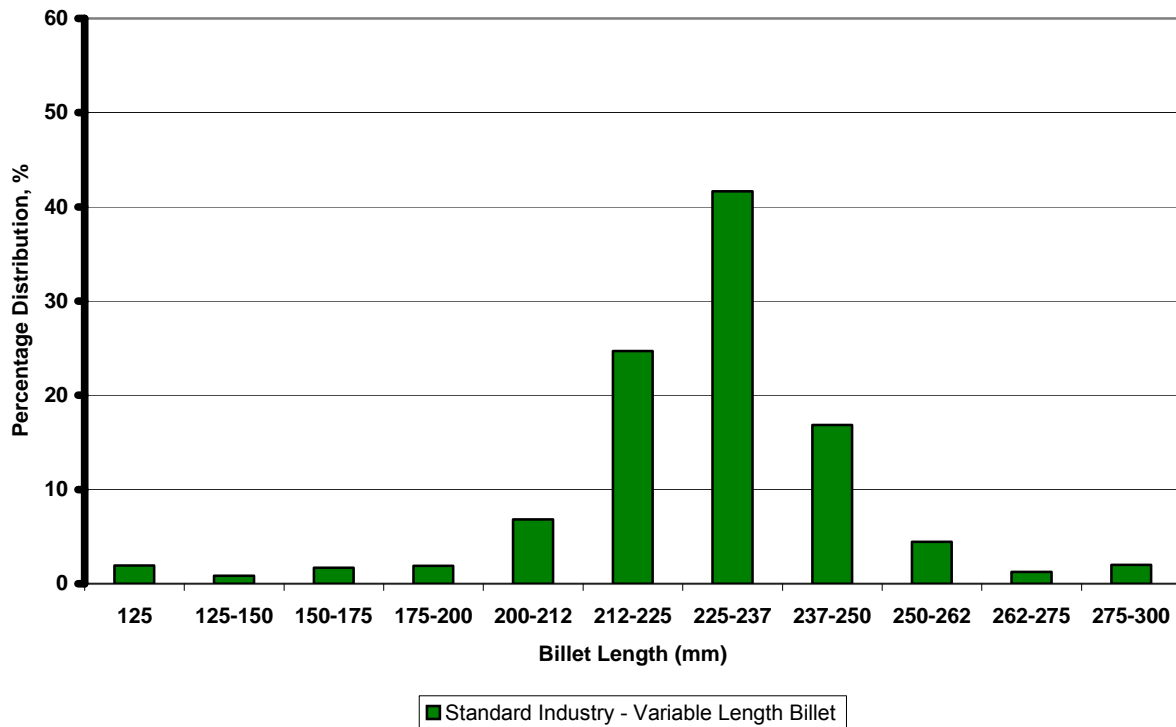


FIGURE 3 - VARIABLE LENGTH BILLET DISTRIBUTION

4.1.2 Uniform Length Billets

The average billet length distribution from samples taken from the synchronised ('long') billet length setting treatment is presented in Figure 4. The 'long' billet length setting results in 57% by weight of billets falling within the range of 262 to 275 mm. The length distribution closely represents a left skewed distribution around this mean target length, with approximately 85% of billets within 50 mm of this length. The billet lengths ranged from 250 mm to 300 mm. Billet lengths less than 237 mm typically represent the top and base ends of stalk and depend on the starting point of the chopping process and the stalk length, not the characteristics of the chopper system. They are therefore not considered in the overall distribution assessment. BSES Limited have measured up to 85% of billet lengths falling within 25 mm of the mean billet length target for 15-inch machines with feedtrain/chopper ratios between 0.65 and 0.70 (C. Whiteing pers comms, 2005).

The 'long' billet setting in this harvester results in a feedtrain/chopper ratio of 0.64 and is therefore close to the optimum BSES Limited feedtrain/chopper ratio range of 0.65 to 0.70. The slightly reduced feedtrain/chopper ratio in this harvester is a plausible explanation for the wider distribution found with the synchronised 'long' billet setting.

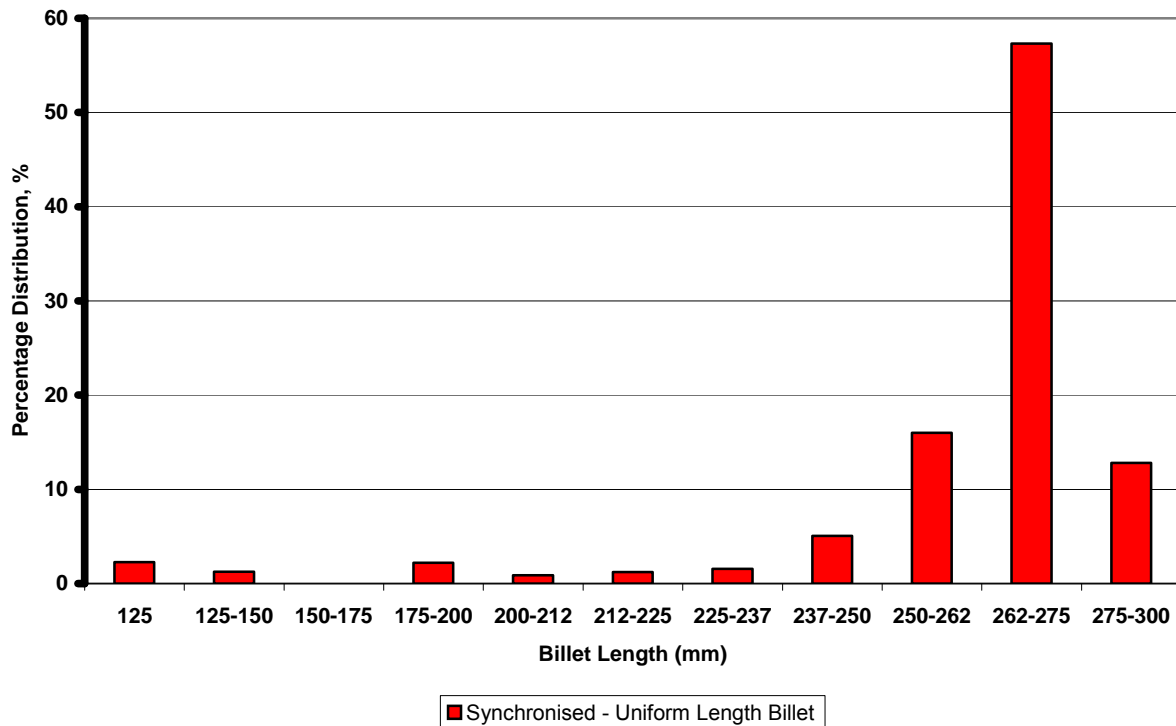


FIGURE 4 - UNIFORM LENGTH BILLET DISTRIBUTION

The average billet length distribution for 'long' billets setting is narrower than that measured for 'short' billets. At the 'long' billet length setting it is expected that sugar and cane losses are at their lowest and billet quality at it's highest. These parameters were not quantified in the proof-of-concept trials.

4.1.3 Mixed Length Billets

The average billet length distribution from samples taken from the mixed billet length setting treatment is presented in Figure 5. This treatment was undertaken to simulate the expected length distribution from the modified rotary-pinch chopper system. As expected, Figure 5 shows two distinct billet length peaks; one at the 'long' billet setting and one at the 'short'. The

resultant length distribution from the modified rotary-pinch chopper system is expected to have a similar distribution, with three mean target lengths. Figure 6 illustrates the billet length distribution for variable, uniform and mixed length billets.

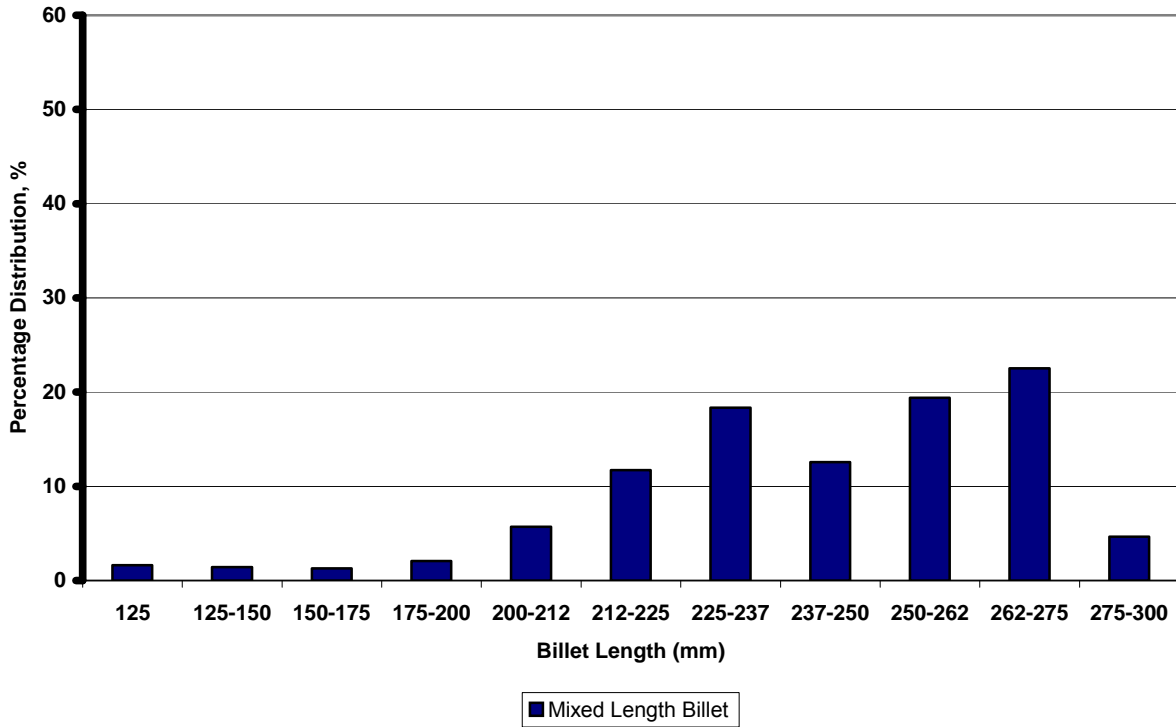


FIGURE 5 - MIXED LENGTH BILLET DISTRIBUTION

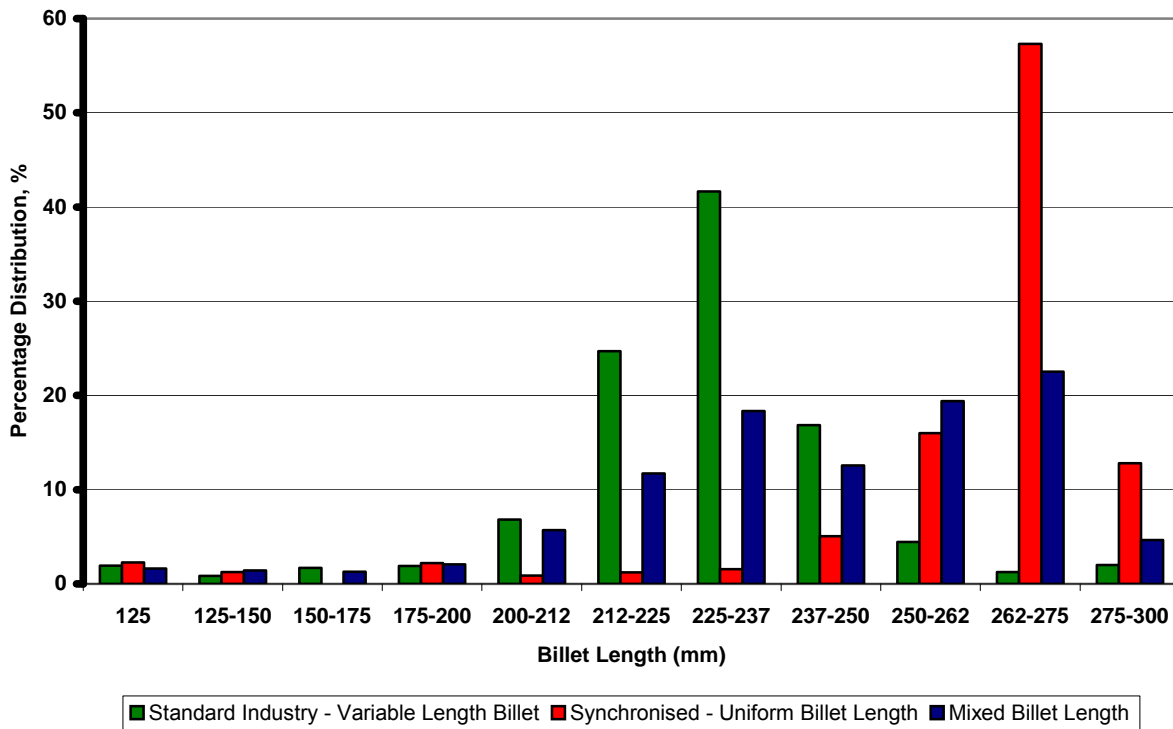


FIGURE 6 - LENGTH DISTRIBUTION OF VARIABLE, UNIFORM AND MIXED LENGTH BILLETS

Photograph 9 illustrates the billet length distribution for the three treatments with uniform length billets on the far left, variable length in the middle and mixed length billets on the far right.



PHOTOGRAPH 9 - UNIFORM, VARIABLE AND MIXED BILLET LENGTH DISTRIBUTION

4.1.4 Packing Density and Bin Weight

The packing density of the variable, uniform and mixed length billet treatments and the corresponding mill realised bin weights were assessed. The bin volume of a standard 6t nominal Bundaberg Sugar, Bingera mill cane railway bin was calculated to be 15.8 m³. For any given EM level and billet length distribution, two criteria limit the amount of material that can be placed in a transport bin. These include the packing density within the bin and the natural piling of material above the sides of the bin.

Table 5 illustrates the results of average bin volumes, bin weights, packing density and nominal 6t bin weight for each treatment respectively.

TABLE 5 - PACKING DENSITY AND BIN WEIGHT – VARIABLE AND UNIFORM LENGTH BILLETS

Treatment	Bin Volume m ³	Actual Bin Weight Kg	Packing Density Kg/m ³	Nominal 6t Bin Weight Kg	% Reduction
Variable Length	14.7	5790	393	6200	-
Uniform Length	14.8	5360	363	5725	8.1
Mixed Length	15.5	5780	371	5865	4.8

The average trash levels were found to be 1.9, 1.7 and 2.0 percent for variable length, uniform length and mixed length billet treatments respectively. The trash level decreased with uniform billet lengths, however this did not translate in an increase in packing density. This results supports the theory hypothesised by Davis and Norris (2002a) that a more even flow of material from the synchronised feedtrain/chopper system to the cleaning chamber would result in improved cleaning performance. This contradicts the work by Vitale and Domanti (1997) who found that reducing billet length decreased EM levels.

The variable billet length treatment resulted in the greatest packing density, with 393 kg/m³ and the uniform length billets the lowest with 363 kg/m³. Packing density was translated into a weight for a nominal 6 t railway bin for direct comparison. Theoretically, an average reduction in bin weight from variable to uniform length billets was calculated to be 8.1%. This result supports the work of James (2002) who found bin weight reduction of 10% in similar trials.

The packing density of the mixed length billet treatment was found to be 371 kg/m³ which is greater than uniform length billets, but less than variable length billets. The corresponding average reduction in bin weight from variable length billets is 4.8%. Therefore, it is possible to increase the packing density with variable length billets. This result justifies the rationale for the development of a rotary-pinch chopper system whereby variable billet lengths could be produced at an optimum feedtrain/chopper ratio. This would minimise cane and juice loss, whilst maximising packing density and minimising transport costs.

Photograph 10 and Photograph 11 illustrate the typical in-situ billet packing distribution of the variable length and uniform length treatments respectively as delivered by the haulout into a railway bin. These photographs aid in illustrating the causal effects of the differences in packing density between the treatments. Photograph 10 shows that the variable length billets naturally pack together with little voids, whereas the uniform length billets can naturally form random

pockets of voids within the bin (Photograph 11). If these voids can be redistributed through the use of mechanical agitation or similar process, then additional material can be added. Photograph 12 illustrates the natural piling of material above the bin sides. Similarly, if this pile could be redistributed by mechanical means to the sides and corners of the bin, then further material could be added to the bin.



PHOTOGRAPH 10 - VARIABLE LENGTH BILLETS PACKING DISTRIBUTION IN CANE RAILWAY BIN



PHOTOGRAPH 11 - UNIFORM LENGTH BILLETS PACKING DISTRIBUTION IN CANE RAILWAY BIN



PHOTOGRAPH 12 - PILING OF MATERIAL ABOVE SIDES OF CANE RAILWAY BIN

The development of a machine to provide mechanical levelling and/or agitation may be especially important to effect an increase in the amount of material in the bin to improve the efficiency of the transport network. This may be of critical importance in operations where railway bins are transferred onto road transport for delivery to the mill.

4.2 Stage Two - Proof-of-Concept modified rotary-pinch chopper system evaluation: 2006 Trial Program

Comparative trials using a commercial harvester were successfully undertaken at Fairymead Plantation in Bundaberg in 2006. The impact of a standard 15-inch chopper system with unsynchronised and synchronised feedtrain setup versus 'Corradini' proof-of-concept rotary pinch chopper system with synchronised feedtrain setup was evaluated. The trials were aimed at assessing the functionality of the proof-of-concept system including target billet lengths and recirculation. In addition, a preliminary assessment on the effect on billet length, packing density and bin weight was undertaken. The results were collated and analysed and are presented in the following sections.

4.2.1 Standard Chopper System

4.2.1.1 Variable Length Billets

The average billet length distribution from samples taken from the unsynchronised ('short') billet length setting treatment is presented in Figure 7. The 'short' billet length setting results in 37% by weight of billets falling within the range of 225 to 237 mm. The length distribution closely represents a normal distribution around this mean target length within approximately 75% of billets within 25 mm of this length. The billet lengths ranged from 200 mm to 300 mm. Billet lengths less than 175 mm typically represent the top and base ends of stalk and depend on the starting point of the chopping process and the stalk length, not the characteristics of the chopper system. They are therefore not considered in the overall distribution assessment.

Factory-standard harvesters with 15-inch chopper systems (assessed by BSES Limited in their feedtrain/chopper optimisation program) typically have a feedtrain/chopper ratio ranging from around 0.46 to 0.56 for 'short' and 'long' billet settings respectively (C Whiteing pers comms, 2005). The 'short' billet setting in this harvester results in a feedtrain/chopper ratio is 0.52. Therefore, the resultant mean length and distribution would be similar to the typical industry standard length and distribution for 15-inch, 3 blade chopper systems in commercial situations.

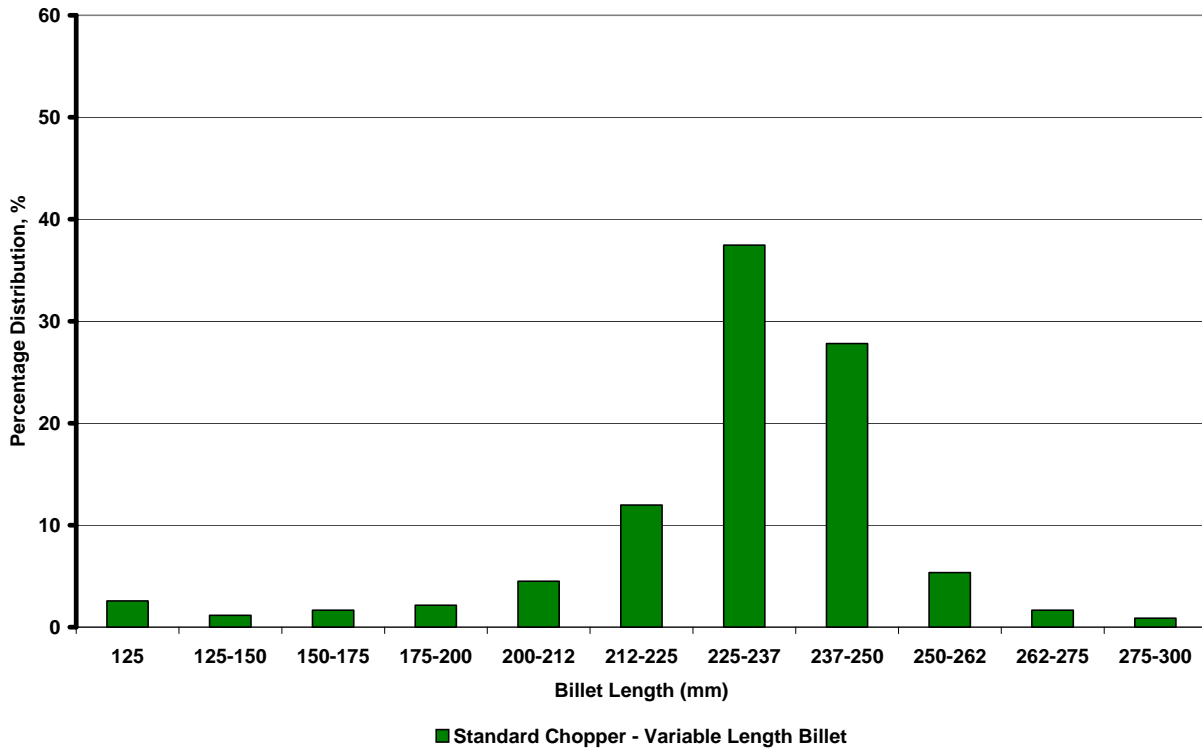


FIGURE 7 - STANDARD CHOPPER - VARIABLE LENGTH BILLET DISTRIBUTION – 2006 TRIALS

4.2.1.2 Uniform Length Billets

The average billet length distribution from samples taken from the synchronised (‘long’) billet length setting treatment is presented in Figure 8. The ‘long’ billet length setting results in 39% by weight of billets falling within the range of 262 to 275 mm. The length distribution closely represents a left skewed distribution around this mean target length, with approximately 75% of billets within 25 mm of this length. The billet lengths ranged from 250 mm to 300 mm. Billet lengths less than 237 mm typically represent the top and base ends of stalk and depend on the starting point of the chopping process and the stalk length, not the characteristics of the chopper system. They are therefore not considered in the overall distribution assessment. BSES Limited have measured up to 85% of billet lengths falling within 25 mm of the mean billet length target for 15-inch machines with feedtrain/chopper ratios between 0.65 and 0.70 (C. Whiteing pers comms, 2005).

The ‘long’ billet setting in this harvester results in a feedtrain/chopper ratio of 0.64 and is therefore close to the optimum BSES Limited feedtrain/chopper ratio range of 0.65 to 0.70. The

slightly reduced feedtrain/chopper ratio in this harvester is a plausible explanation for the wider distribution found with the synchronised ‘long’ billet setting.

The average billet length distribution for ‘long’ billets setting is narrower than that measured for ‘short’ billets. At the ‘long’ billet length setting it is expected that sugar and cane losses are at their lowest and billet quality at it’s highest. These parameters were not quantified in the proof-of-concept trials.

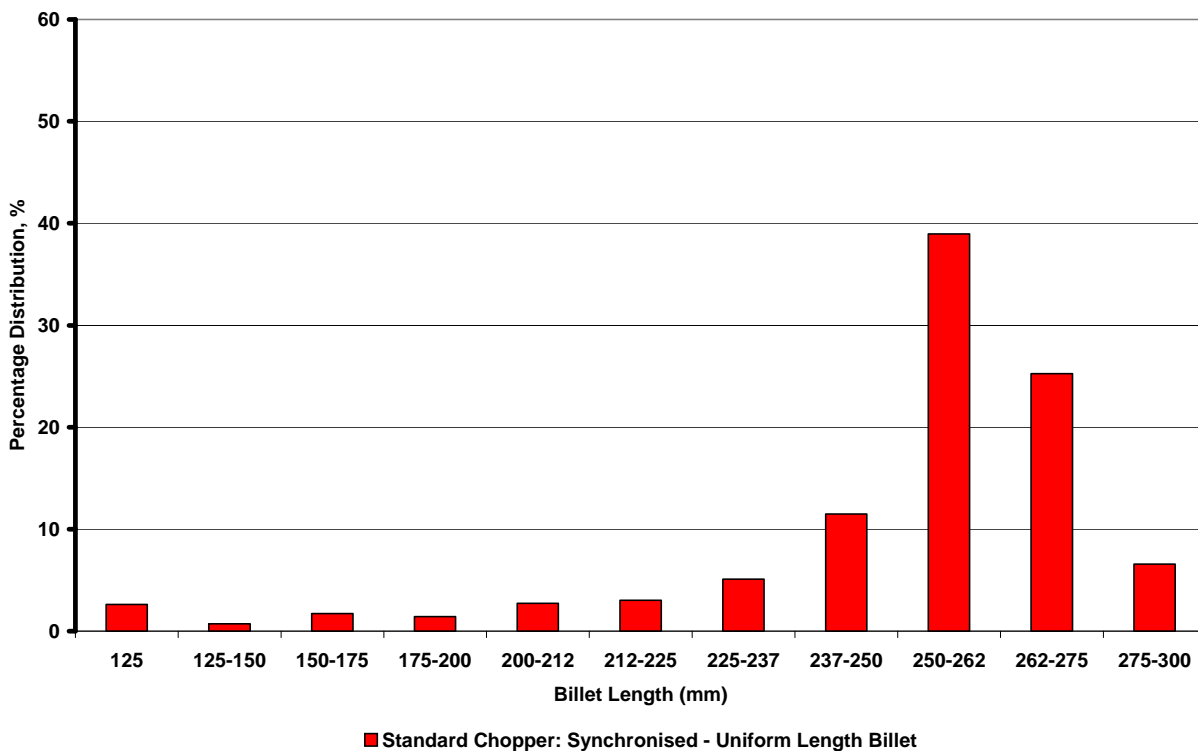


FIGURE 8 - STANDARD CHOPPER - UNIFORM LENGTH BILLET DISTRIBUTION – 2006 TRIALS

4.2.2 Proof-of-Concept Chopper System

4.2.2.1 Functionality

The functionality of the ‘Corradini’ proof-of-concept chopper was assessed in an initial field evaluation prior to commencement of the trial program. No differences in operational performance were observed or noted by the machine operator when compared with a standard 15-inch chopper system. This included no recirculation of billets and a throw velocity identical to a standard 15-inch system. Hence, for operational purposes the proof-of-concept system can be considered identical to that of a standard 15-inch chopper system.

4.2.2.2 Variable Length Billets

The average billet length distribution from samples taken from the synchronised ('long') billet length setting treatment of the 'Corradini' proof-of-concept chopper is presented in Figure 9. The target billet lengths from the proof-of-concept chopper were designed to be 295 mm; 295 mm and 205 mm. The results shown in Figure 9 illustrate that the design target billet were reached with approximately 24% by weight of billets falling within the range of 200 to 225 mm and 48% falling within the range of 275-300 mm.

The length distribution around each target billet length represents a normal distribution around each respective target length. Approximately 27% of billets are within 25 mm of the 205 mm target length and 67% within 50 mm of the 295 mm target length. The billet lengths ranged from 175 mm to 350 mm. Billet lengths less than 175 mm typically represent the top and base ends of stalk and depend on the starting point of the chopping process and the stalk length, not the characteristics of the chopper system. They are therefore not considered in the overall distribution assessment.

At the 'long' billet length setting, it is expected that sugar and cane losses are at their lowest and billet quality at it's highest. These parameters were not quantified in the proof-of-concept trials.

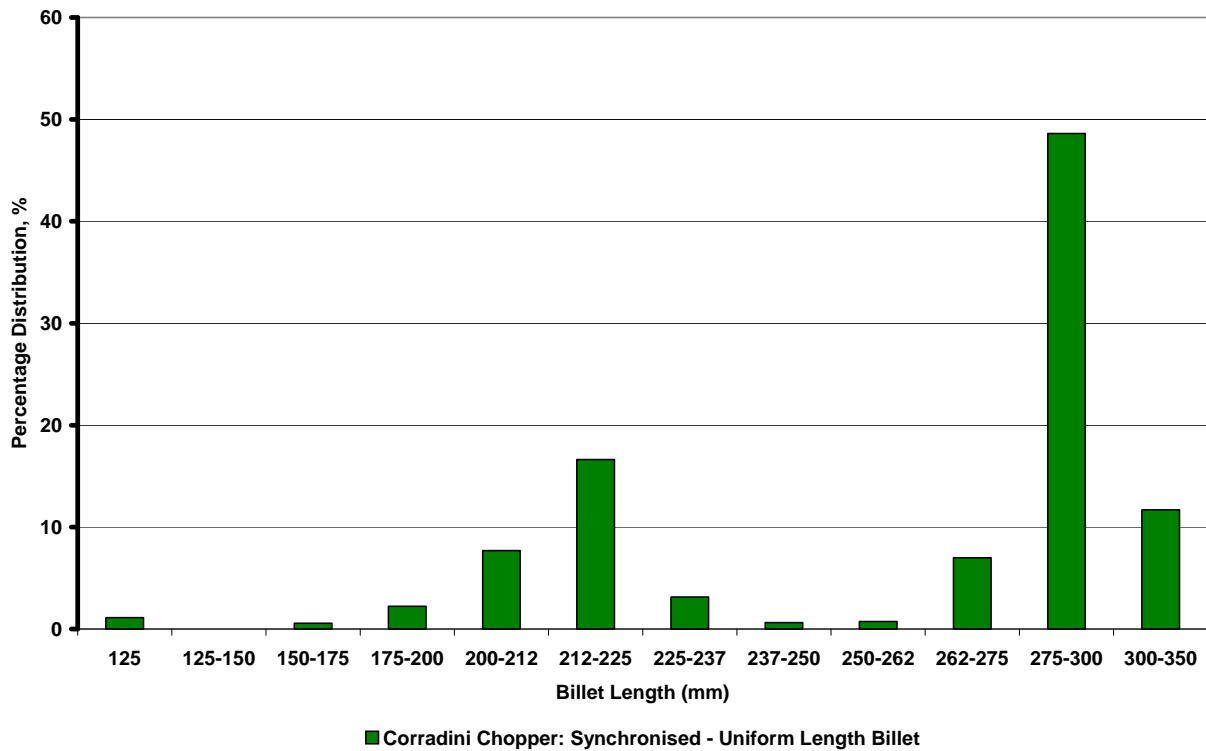


FIGURE 9 - ‘CORRADINI’ PROOF-OF-CONCEPT MRPCS – VARIABLE LENGTH BILLETS – 2006 TRIALS

4.2.3 Packing Density and Bin Weight

The packing density of the treatments and the corresponding mill recorded bin weights were assessed. The bin volume of a standard 6 t nominal Bundaberg Sugar, Bingera mill cane railway bin was calculated to be 15.8 m³. For any given EM level and billet length distribution, two criteria limit the amount of material that can be placed in a transport bin. These include the packing density within the bin and the natural piling of material above the sides of the bin.

Table 6 illustrates the results of average bin volumes, bin weights, packing density and nominal 6 t bin weight for each treatment respectively.

TABLE 6 - PACKING DENSITY AND BIN WEIGHT – ‘STANDARD’ VS ‘CORRADINI’ PROOF-OF-CONCEPT MRPCS

Treatment	Bin Volume m ³	Actual Bin Weight Kg	Packing Density Kg/m ³	Nominal 6t Bin Weight Kg	% Reduction
Standard chopper - Variable Length	14.6	5541	380	6000	-
Standard chopper - Uniform Length	14.6	5345	365	5770	4.0
‘Corradini’ Proof-of- concept chopper – Uniform Length	14.0	5275	375	5918	1.0

The average trash levels were found to be 2.9%, 2.3% and 1.4% for standard variable length, standard uniform length and ‘Corradini’ proof-of-concept chopper treatments respectively.

The trash level decreased with uniform billet lengths. However this did not translate to an increase in packing density. This results supports the theory hypothesised by Davis and Norris (2002a) that a more even flow of material from the synchronised feedtrain/chopper system to the cleaning chamber would result in improved cleaning performance. This contradicts the work by Vitale and Domanti (1997) who found that reducing billet length decreased EM levels.

The standard chopper variable billet length treatment resulted in the greatest packing density, with 380 kg/m³ and the uniform length billets the lowest with 365 kg/m³. Packing density was translated into a weight for a nominal 6 t railway bin for direct comparison. Theoretically, an average reduction in bin weight from variable to uniform length billets was calculated to be 4%.

The packing density of the ‘Corradini’ proof-of-concept MRPCS variable length billet treatment was found to be 375 kg/m³ which is greater than the standard chopper uniform length billets, but less than the standard chopper variable length billets. The corresponding average reduction in bin weight from the standard chopper variable length billets was found to be 1%. Alternatively, an increase in bin weight of 2.7% was found when compared with the standard chopper uniform length billets. This result is similar to the 3% increase in bin weight predicted by the packing density model. Therefore, it is possible to increase the packing density with variable length billets obtained through the design of the chopper system rather than manipulation of the feedtrain/chopper relationship.

This result justifies the rationale for the development of a rotary-pinch chopper system whereby variable billet lengths could be produced at an optimum feedtrain/chopper ratio. This would minimise cane and juice loss, whilst maximising packing density and minimising transport costs.

4.3 Stage Three - Prototype modified rotary-pinch chopper system evaluation: 2007 Trial Program

Comparative trials using a commercial harvester were successfully undertaken on FARM 30193 (Fulcher) a Bundaberg Sugar Ltd, Elliott River Farm in Bundaberg. These trials evaluated the impact of the standard 15-inch chopper system with synchronised feedtrain setup versus 'Corradini' prototype MRPCS with synchronised feedtrain setup. The trials were aimed at quantifying the effect of the two chopper systems on billet length, packing density, bin weight and CCS. Three replications were undertaken with each chopper with a total cane harvested of 540 and 576 t for the standard chopper system and 'Corradini' prototype MRPCS respectively. The total bin requirement for each replication was consigned as 8-10 bin rakes to determine mill realised CCS levels. The results were collated and analysed and are presented in the following sections.

4.4 Standard Rotary-Pinch Chopper System - Uniform Length Billets

Figure 10 shows the average billet length distribution from samples taken from the synchronised ('long') billet length setting treatment. The 'long' billet length setting resulted in 46% by weight of billets falling within the range of 237 to 250 mm. The length distribution closely represents a right skewed distribution around this mean target length, with approximately 85% of billets within the 237-262 mm range. The billet lengths ranged from 225 mm to 262 mm. Billet lengths less than 225 mm typically represent the top and base ends of stalk and depend on the starting point of the chopping process and the stalk length, not the characteristics of the chopper system. They are therefore not considered in the overall distribution assessment. BSES Limited have measured up to 85% of billet lengths falling within 25 mm of the mean billet length target for 15-inch machines with feedtrain/chopper ratios between 0.65 and 0.70 (C. Whiteing pers comms, 2007). Photograph 13 shows the billet length distribution for the standard chopper system.

The 'long' billet setting in this harvester results in a feedtrain/chopper ratio of 0.64 and is therefore close to the optimum BSES Limited feedtrain/chopper ratio range of 0.65 to 0.70. At

the 'long' billet length setting it is expected that sugar and cane losses are at their lowest and billet quality at it's highest. Mill realised CCS levels for each replication were obtained and are presented in Table 7.

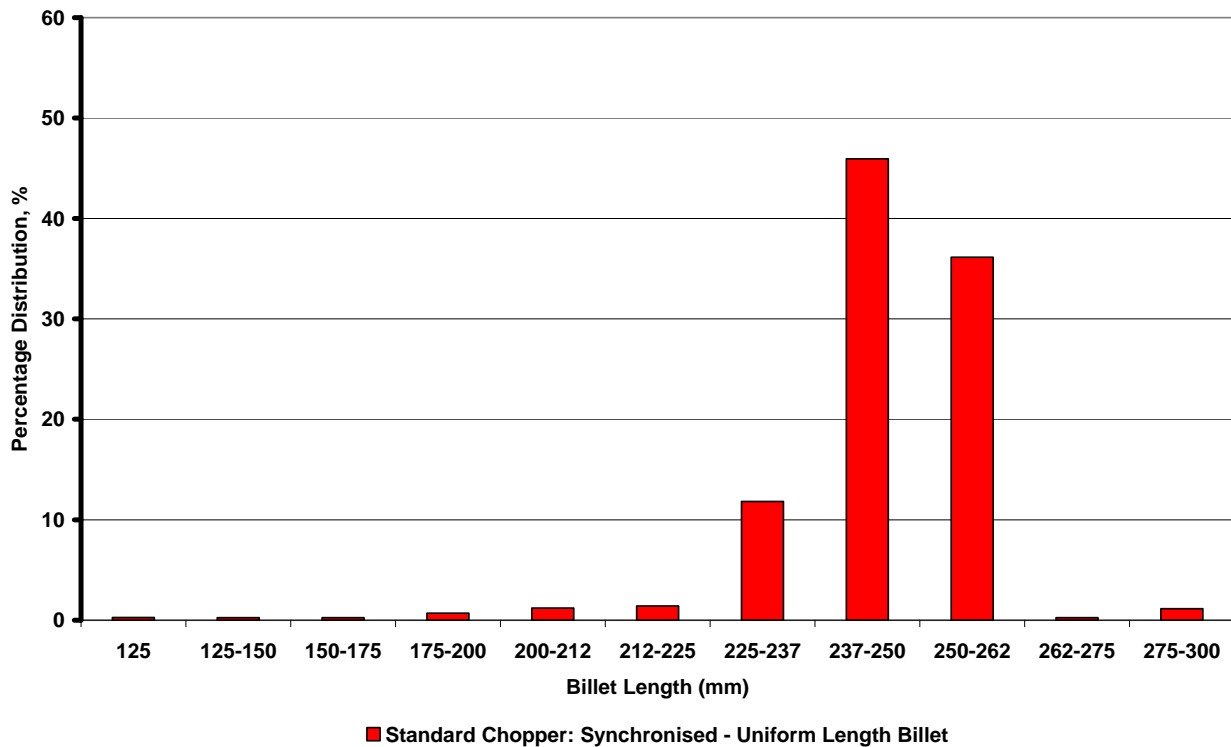


FIGURE 10 - STANDARD ROTARY-PINCH CHOPPER SYSTEM – UNIFORM LENGTH BILLETS – 2007 TRIALS



PHOTOGRAPH 13 - BILLET LENGTH DISTRIBUTION – STANDARD CHOPPER SYSTEM

4.5 ‘Corradini’ Modified Rotary-Pinch Chopper System – Variable Length Billets

Figure 11 shows the average billet length distribution from samples taken from the synchronised (‘long’) billet length setting treatment of the ‘Corradini’ MRPCS. Figure 11 illustrates the target billet lengths reached with approximately 20% by weight of billets falling within the range of 200 to 225 mm and 60% falling within the range of 262-300 mm.

The length distribution around each target billet length represents a normal distribution around each respective target length. Approximately 25% of billets are within 25 mm of the 205 mm target length and 73% within 50 mm of the 295 mm target length. The billet lengths ranged from 175 mm to 350 mm. Billet lengths less than 175 mm typically represent the top and base ends of stalk and depend on the starting point of the chopping process and the stalk length, not the characteristics of the chopper system. They are therefore not considered in the overall distribution assessment.

At the ‘long’ billet length setting, it is expected that sugar and cane losses are at their lowest and billet quality at it’s highest. Mill realised CCS levels for each replication were obtained and are presented in Table 8.

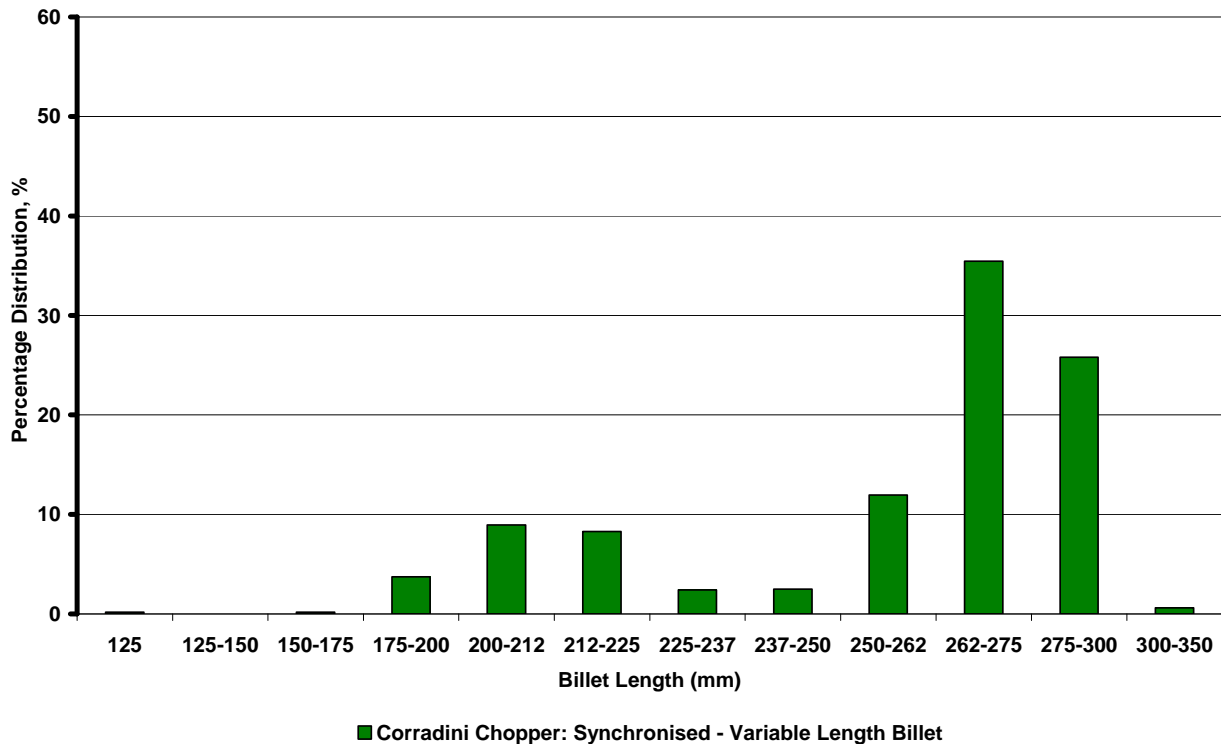


FIGURE 11 - 'CORRADINI' MRPCS – VARIABLE LENGTH BILLETS – 2007 TRIALS



PHOTOGRAPH 14 - BILLET LENGTH DISTRIBUTION OF 'CORRADINI' MRPCS

4.6 Packing Density and Bin weight

The packing density of the treatments and the corresponding mill recorded bin weights were assessed. The nominal internal dimensions of a standard 6 t nominal Bundaberg Sugar, Millaquin mill cane railway bin are 2.35 m in width, 3.65 m in length and 1.83 m in height. This gives a nominal bin volume of 15.6 m³. For any given EM level and billet length distribution, two

criteria limit the amount of material that can be placed in a transport bin. These include the packing density within the bin and the natural piling of material above the sides of the bin.

Table 7 and Table 8 illustrate the results of average bin volumes, bin weights, packing density, nominal 6 t bin weight, CCS and trash level for each treatment respectively.

TABLE 7 - PACKING DENSITY, BIN WEIGHT AND CCS – STANDARD ROTARY-PINCH CHOPPER SYSTEM

Treatment	Replication	Bin Volume m ³	Actual Bin Weight Kg	Packing Density Kg/m ³	Nominal 6t Bin Weight Kg	CCS	Trash Level %
Standard Chopper System - Uniform Length Billets	1	15.2	5650	371	5820	10.1	0.6
	2	15.5	5750	371	5820	9.8	0.6
	3	15.5	5780	374	5850	11.2	1.2

TABLE 8 - PACKING DENSITY, BIN WEIGHT AND CCS – ‘CORRADINI’ MRPCS

Treatment	Replication	Bin Volume m ³	Actual Bin Weight Kg	Packing Density Kg/m ³	Nominal 6t Bin Weight Kg	CCS	Trash Level %
‘Corradini’ MRPCS - Uniform Length Billets	1	15.2	5830	382	5990	9.7	0.5
	2	14.9	5650	379	5950	9.9	0.7
	3	15.3	5800	378	5885	11.9	1.3

The average trash levels for the standard chopper system were found to be 0.6, 0.6 and 1.2 percent for Replication 1, 2 and 3 respectively. Similar levels were found with the ‘Corradini’ MRPCS with 0.5, 0.7 and 1.2 percent measured for Replication 1, 2 and 3 respectively. Differences in crop conditions (trash levels etc) are plausible explanations of the differences between trash levels found in the replications.

The ‘Corradini’ MRPCS variable length billet treatment resulted in the greatest packing density with 382, 379 and 378 kg/m³ found for Replications 1, 2 and 3 respectively. The standard chopper system uniform length billet treatment resulted in a reduced packing density with 371, 371 and 374 kg/m³ for Replications 1, 2 and 3 respectively. Packing density was translated into a weight for a nominal 6 t railway bin for direct comparison. Theoretically, the increase in bin weight recorded from the standard to the ‘Corradini’ MRPCS was 2.9%, 2.4 and 1.1% for Replications 1, 2 and 3 respectively.

A reduction of 0.4 units of CCS was measured with the 'Corradini' MRPCS in Replication 1 when compared with the standard chopper system. An increase in CCS of 0.1 and 0.7 units for Replications 2 and 3 respectively were measured with the 'Corradini' MRPCS when compared with the standard chopper system. Differences in crop conditions (trash levels etc) between the blocks are plausible explanations of the differences between CCS levels found in the replications.

5 CAPACITY BUILDING

The participative approach implemented in this research work has enhanced Bundaberg Sugar's capacity for and acceptance of harvesting research and development and the use of rigorous methodologies. Hence, their capacity to conduct R&D has been enhanced.

The harvesting personnel capacity-for-change was enhanced through exposure to both the technologies available for reducing sugar losses and first hand assessment of the effects of manipulating machine component settings on billet length.

6 OUTCOMES

The outcomes to date resulting from the project are as follows:

- **A greater common understanding within Bundaberg Sugar Ltd of sugar losses associated with the harvesting process.** Prior to HGP003, Bundaberg Sugar Ltd had acknowledged the issue of sugar losses during the harvesting operation and were actively involved in quantifying the magnitude of the problem. However, there had been limited activity in implementing improvements to machine setup and operational practices within their own commercial harvesting fleet.
- **An enhanced awareness of current knowledge and implementation of improved harvesting practices for reducing sugar losses.** HGP003 has enhanced Bundaberg Sugar's knowledge of technologies developed for reducing sugar losses. These include the concept of feedtrain/chopper optimisation and resulting effect on billet quality and

length. HGP003 highlighted these opportunities and enhanced their understanding and how they would work in practice.

- **Development of a modified rotary-pinch chopper system.** The design principle is based on the concept of obtaining variable length billets through one revolution of the chopper drum. A conceptual design was developed and presented to Corradini Engineering, Ingham to undertake the detailed design and manufacture the proof-of-concept modified rotary-pinch chopper system. No issues were experienced with the functionality of the design in terms of blade timing and recirculation of billets.

We expect following future benefits and legacies as a result of HGP003:

- **Adoption of technologies for reducing sugar losses during harvesting, in particular feedtrain/chopper optimisation.** Initially, this outcome is anticipated within Bundaberg Sugar's own commercial harvesting enterprises. Bundaberg Sugar Ltd have already implemented feedtrain/chopper optimisation within their plant cutting harvester fleet. It is expected that this concept will be further promoted regionally due to local industry initiatives to reduce sugar losses during the harvesting operation.

7 ENVIRONMENTAL IMPACT

The project has had no known adverse environmental impacts and this is unlikely to change in future outcomes generated by the project. The application of current knowledge and the implementation of improved harvesting practices to reduce sugar losses during harvesting such as those outlined in this work will have a positive impact on the environmental performance of the sugar industry.

8 COMMUNICATION AND ADOPTION OF OUTPUTS

Communication outputs have included:

- Discussions were held with Neville Toft, John Deere Cameco after the proof-of-concept trials. The rationale for the project was outlined, funding sources acknowledged (SRDC) and expected duration of the project. John Deere Cameco were interested in alternative chopping systems potentially for energy cane. However, the concept was not divulged as discussions had been held and a relationship developed with Corradini Engineering on the concept and proof-of-concept prototype manufacture.
- Discussions have been held with Corradini Engineering regarding the development of alternative chopping systems. The commercial viability of this chopper system will be evaluated based on this report and recommendations.
- Articles have been prepared and published in the Australian Sugarcane Magazine (2). SRDC's funding of the project has been acknowledged in the usual manner (logos, statement).
- Ongoing discussions with Bundaberg Sugar Ltd regarding the progress and outcomes of the project.
- Bundaberg Sugar Ltd has a greater awareness of feedtrain/chopper optimisation and has ensured that this configuration remains incorporated within harvesters used for plant cutting.

9 RECOMMENDATIONS

This work highlighted the lack of awareness of the concept of feedtrain/chopper optimisation within the context of commercial harvesting operations.

The key recommendation for future Research and Development is the continued support by SRDC of participative approaches which include application of current knowledge and implementation of improved harvesting practices. This should include heightened awareness of the concepts embodied within Harvesting Best Practice to increase the recovery of sugar during the harvesting operation, such as feedtrain/chopper optimisation. Previous constraints to optimised three blades per drum 15-inch systems in commercial harvesting have largely been overcome with the adoption over the past two seasons of four blades-per-drum 15-inch chopper systems.

It is unlikely that this system would be commercially viable at this stage, given the resistance/lack of awareness in the industry of feedtrain/chopper optimisation in the context of reducing sugar losses during harvesting. Industry resources would be better targeted at awareness campaigns which demonstrate the magnitude of sugar losses during harvesting. This system would then be more marketable in the Industry as a potential solution to the problem.

However, new harvester component developmental work still remains an important area especially with respect to emerging technologies and their implementation to maintain a profitable and sustainable harvesting system.

10 PUBLICATIONS

Two publications resulted from this work. A copy of the two articles submitted to Australian Sugarcane magazine are attached in Appendix A.

11 CONCLUSIONS

Bin weight is becoming an increasingly topical issue for the Australian sugar industry, with millers and haul-out contractors seeking to improve the efficiency of their operations by hauling more cane per trip using existing infrastructure. This has meant that there is considerable pressure within the industry to reduce billet length.

BSES Limited extended the concept of harvester feedtrain/chopper optimisation to industry. Feedtrain/chopper optimisation includes the assessment and reconfiguring of the harvester feedtrain and chopper system so that the surface speed of the feedtrain rollers are all identical and then setting this surface speed to be approximately 65-70% of the chopper tip speed. Feedtrain/chopper optimisation produces uniform billet lengths of good quality and minimises cane and juice loss.

However, bin weight is an important economic factor when analysing the impact of feedtrain optimisation on commercial harvesting. The uniform billet lengths produced decrease bin weight.

This program of work aims to facilitate the adoption of feedtrain/chopper synchronisation through the development of a modified rotary-pinch chopper system. The design principle is based on the concept of obtaining variable length billets through one revolution of the chopper drum, not through manipulating feedtrain roller speed.

The conceptual design of the proof-of-concept modified rotary-pinch chopper system was developed through an investigation into the correlation between billet length and bin weight. This was based on data sourced from literature, private communications, unpublished work of specialists at various mills and the results of the Stage 1 - Proof-of-concept trials.

A spreadsheet model was developed to evaluate varying billet lengths on bin weight. The modelling demonstrated that combination of billet lengths including two at 295 mm and one at 205 mm maximises bin weight. The theoretical increase in bin weight achievable from this combination was estimated to be 3%.

A conceptual design was developed and presented to Corradini Engineering for review and detailed design. Corradini Engineering of Ingham undertook the detailed design and manufacturing of the proof-of-concept modified rotary-pinch chopper system. After fabrication the 'Corradini' proof-of-concept chopper system was installed on a harvester that is used to cut billets for planting and as a backup commercial machine.

Initial comparative trials were successfully undertaken at Fairymead Plantation in Bundaberg during the 2006 harvest season. A standard 15-inch chopper system with unsynchronised and synchronised feedtrain setup was compared with the 'Corradini' proof-of-concept rotary-pinch chopper system (MRPCS) with synchronised feedtrain setup. The trials were aimed at assessing the functionality of the proof-of-concept system including target billet lengths and recirculation. In addition, a preliminary assessment on the effect on billet length, packing density and bin weight was undertaken.

The functionality of the 'Corradini' proof-of-concept MRPCS was assessed in an initial field evaluation prior to commencement of the trial program. No differences in operational performance were observed or noted by the machine operator when compared with a standard 15-inch chopper system. This included no recirculation of billets and a throw velocity identical to a standard 15-inch system. Hence, for operational purposes the proof-of-concept MRPCS system can be considered identical to that of a standard 15-inch chopper system.

In the 2006 trials, the standard chopper variable billet length treatment resulted in the greatest packing density, with 380 kg/m^3 and the uniform length billets the lowest with 365 kg/m^3 . Packing density was translated into a weight for a nominal 6 t railway bin for direct comparison. Theoretically, an average reduction in bin weight from variable to uniform length billets was calculated to be 4%.

The packing density of the 'Corradini' proof-of-concept MRPCS variable length billet treatment was found to be 375 kg/m^3 , which is greater than the standard chopper uniform length billets, but less than the standard chopper variable length billets. The corresponding average reduction in bin weight from the standard chopper variable length billets was found to be 1%. Alternatively, an increase in bin weight of 2.7% was found when compared with the standard chopper uniform length billets. This result is similar to the 3% increase in bin weight predicted by the packing density model.

The results of the 2006 trial program justified further development and testing of the 'Corradini' MRPCS. Hence, further comparative trials were undertaken in Bundaberg during the 2007 harvest. A standard 15-inch chopper system with synchronised feedtrain setup was compared with the 'Corradini' MRPCS with synchronised feedtrain setup on bin weights and mill realised CCS.

In the 2007 trials, the 'Corradini' MRPCS variable length billet treatment resulted in the greatest packing density with an average 380 kg/m^3 . The standard chopper system uniform length billet treatment resulted in a reduced packing density with 372 kg/m^3 . Theoretically, the increase in bin weight recorded from the standard to the 'Corradini' MRPCS was an average of 2.1%. No clear trends from the measured CCS levels in each replicate were evident.

The results demonstrate that it is possible to increase the packing density of billeted cane with variable length billets obtained through the design of the chopper system rather than manipulation of the feedtrain/chopper relationship. This would minimise cane and juice loss, whilst maximising packing density and minimising transport costs. This concept would be of most benefit to a 15-inch 3 blade per drum chopper system.

The opportunity for widespread adoption of the chopper system developed within this project appears limited given the sugar industry and harvesting sectors' lack of interest in reducing sugar losses during harvesting. The benefits of harvester feedtrain/chopper synchronisation are well documented (Hockings et al. 2000; Davis et al. 2003; James 2002) and are one such mechanism available for minimising sugar losses during harvest. Contributing to the situation is the current harvest payment system which provides no incentives for the harvesting sector to minimise sugar losses during harvest. The resultant reduction in bin weight translates into increased transport costs which are a direct disadvantage to the harvesting sector.

To maximise bin weight the industry has changed to 15-inch chopper systems with four blades per drum and shorter billets. This translates into higher cane and sugar losses when compared with 15-inch three bladed systems based on more cuts per unit length. Some operators still seek even higher bin weights by operating these in an unsynchronised setup, which results in further increases in associated cane and sugar loss.

A 15-inch chopper system with four blades per drum modified in the same way as the 15-inch three blades per drum system investigated in this work has the potential to achieve higher bin weights without the increased cane and sugar loss associated with unsynchronised feedtrain/chopper setups.


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13 APPENDIX A - PUBLICATIONS

13.1 Article 1 - Australian Sugarcane: December 2005 – January 2006, Volume 9, No. 6



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Variable billet length packs on the weight

By Gary Alcorn

Harvesting operators are always looking for new ways to increase bin weights and minimise loss of cane and juice loss.


Research being conducted by staff from FSA Consulting, Bundaberg Sugar Ltd and Corradini Engineering Ltd aims to develop and field test a modified rotary-pinch chopper system.

FSA Consulting senior project engineer Rod Davis said the design principle was based on the concept of obtaining variable length billets through one revolution of the chopper drum, while maintaining feedtrain/chopper synchronisation and not through manipulating feedtrain roller speed.

Initial work included proof of concept trials to assess the impact of variable length billets and uniform length billets on packing density and bin weight.

The design of the modified rotary-pinch chopper system is currently under development.

This work is part of a harvesting inno-

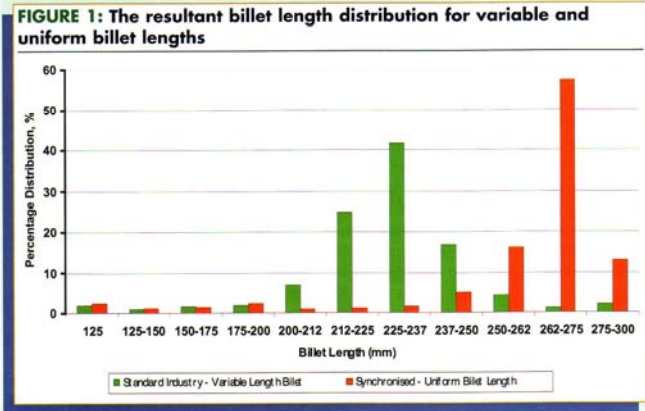


Maximising bin weights while minimising cane and juice loss, is a major focus for harvester operators.

vation group research project funded by the Sugar Research and Development Corporation.

Over the past four years, BSES Limited

FIGURE 1: The resultant billet length distribution for variable and uniform billet lengths



Billet Length (mm)	Standard Industry - Variable Length Billet (%)	Synchronised - Uniform Billet Length (%)
125	2	2
125-150	1	1
150-175	2	2
175-200	3	3
200-212	8	1
212-225	25	1
225-237	42	1
237-250	18	5
250-262	5	18
262-275	2	58
275-300	3	15

has extended the concept of harvester feedtrain/chopper optimisation to industry.

"Feedtrain/chopper optimisation includes reconfiguring the harvester feedtrain and chopper system so that the surface speed of the feedtrain rollers are all identical and then setting this surface speed to be approximately 65-70 per cent of the chopper tip speed," Rod said.

Feedtrain/chopper optimisation produces uniform billet lengths of good quality and minimises cane and juice loss.

But producing uniform billet lengths, decreases packing density, hence bin weight.

Rod and his counterpart, Bundaberg Sugar Ltd's Craig Baillie, undertook field trials in August to evaluate the packing density and resulting bin weights from variable and uniform billet length distributions.

Bundaberg Sugar's 1997 Austoft 7000 with a feedtrain/chopper system synchronised to BSES Ltd specifications was used.

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FIGURE 2: Variable length billets packing distribution in bin



At the 'short' and 'long' feedtrain settings the feedtrain/chopper system was unsynchronised and synchronised respectively.

The 'short' billet length setting produced billets of variable length, with the length distribution ranging from 200–300 mm. In this machine when the 'long' billet setting was selected the feedtrain/chopper system was synchronised and produced uniform length billets of 270 mm.

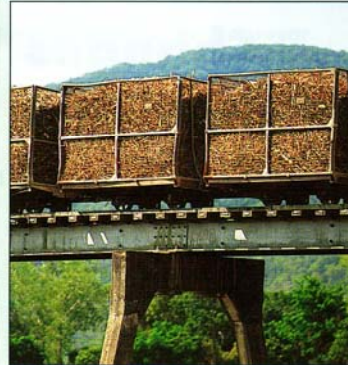
Figure 1 shows the resultant billet length distribution for variable and uniform billet lengths.

The variable billet length resulted in a higher packing density, 393 kg per m³ compared to uniform billets, 363 kg per m³.

Figures 2 and 3 illustrate the typical insitu billet packing distribution of the variable length and uniform length treatments respectively as delivered by the haulout into a railway bin.

These figures aid in illustrating the causal effects of the differences in packing density between the billet lengths.

Figure 2 shows that the variable billets naturally pack together with small little voids, whereas the uniform billets can nat-



Variable billet lengths, with higher packing density, could increase rail bin weights by around eight per cent.

urally form random pockets of voids within the bin (Figure 3).

If these voids can be minimised through a combination of variable length billets obtained through a synchronised feedtrain/chopper system, then bin weight can be increased.

Packing density was translated into a weight for a nominal six tonne railway bin for direct comparison.

Theoretically, an average increase in bin weight of 8.1 per cent can be achieved from uniform to variable length billets.

So increased bin weight can be achieved from a variable billet length distribution.

For further information please contact: Rod Davis, Senior Project Engineer, FSA Consulting, Ph: 07 4632 8230, Email: Rod.Davis@fsaconsulting.net.

FIGURE 3: Uniform length billets packing distribution in bin



Australian Society for Engineering in Agriculture

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13.2 Article 2 - Australian Sugarcane: December 2007 – January 2008



LEADING EDGE

Leading Edge, supported by the Society for Engineering in Agriculture and the Australian Centre for Precision Agriculture, provides a local and worldwide window on engineering and PA research.

Odds beat evens when optimising bin weight

By Gary Alcorn

Capturing more sugar per tonne of cut cane was the main reason engineer Rod Davis of FSA Consulting, Toowoomba spent a lot of time last harvest observing billets produced by a modified rotary-pinch chopper system (MRPCS).

He wanted to demonstrate that it is possible to increase the packing density of billeted cane with variable length billets by modifying the design of the chopper system rather than by manipulating the feedtrain/chopper relationship.

FSA Consulting was engaged by Bundaberg Sugar Ltd to undertake an SRDC funded project titled 'Modified Rotary-

Pinch Chopper System for Improved Harvesting Efficiency'.

"The background to this challenge of packing more billets per bin using the optimum number of cuts is an increasingly topical issue for the Australian sugar industry.

"Millers and haul-out contractors are seeking to improve the efficiency of their operations by hauling more cane per trip using existing infrastructure. This has meant that there is considerable pressure within the industry to reduce billet length.

"Similarly, increasing the recovery of sugar during the harvesting operation, is an imperative to deliver profitable and sus-

tainable regional sugarcane industries," he said.

As every grower knows critical sugar losses are caused by complex interactions between the crop and the inherent design characteristics of the harvester and by the operational settings during harvesting.

Cane and sugar losses of up to five per cent have been measured in the feedtrain and rotary pinch chopper system. This represents a significant sucrose loss during harvesting. The feed train delivers whole stalks of cane to the chopper system, which cuts the stalks into segments or billets nominally of equal length.

"Synchronisation of the feedtrain rollers and the chopper system reduces these losses. But bin weight is an important economic factor when analysing the impact of feedtrain optimisation on commercial harvesting.

"The uniform billet lengths produced decreased bin weight," Rod said.

This program of work aims to facilitate the adoption of feedtrain/chopper synchronisation through the development of a modified rotary-pinch chopper system (MRPCS). The design principle is based on the concept of obtaining variable length billets through one revolution of the chopper drum, not through manipulating feedtrain roller speed.

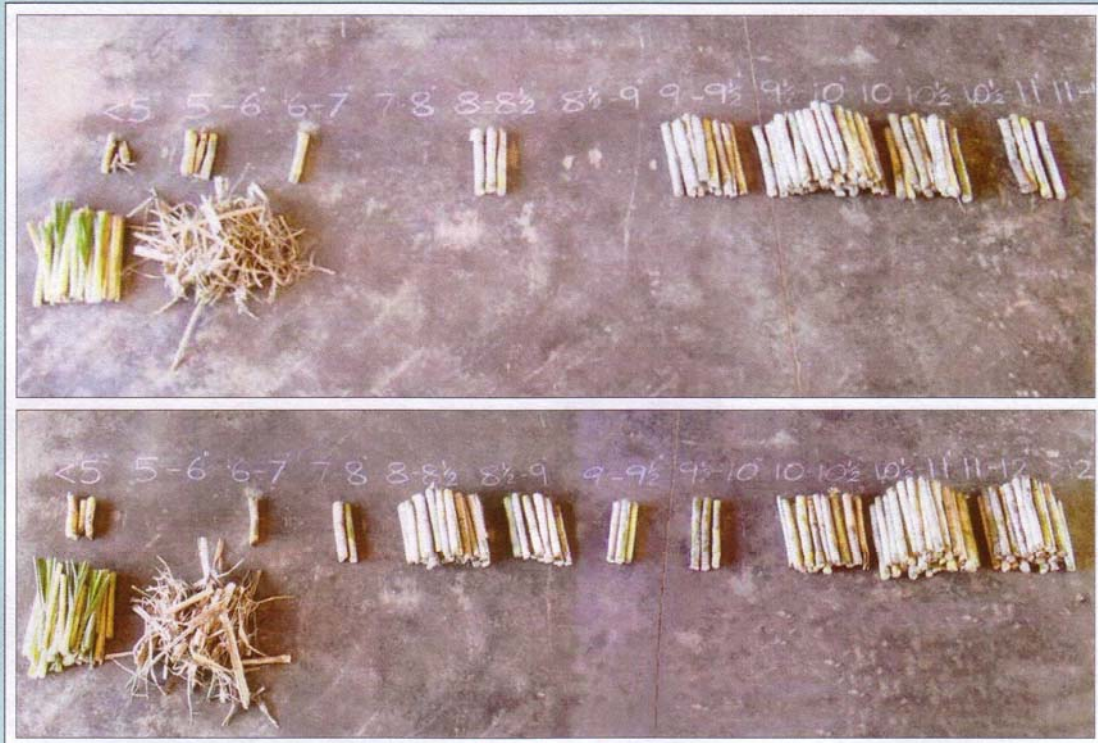
MODIFIED CHOPPER SYSTEM

The development of the modified chopper system was undertaken in a number of steps. Firstly, the team produced a conceptual three blade per drum design of the chopper system by investigating the correlation between billet length and bin weight based on data sourced from literature and the results of the initial trials.

Secondly, a spreadsheet model was developed to evaluate varying billet lengths on bin weight.



Modified rotary pinch chopper setup in an Austoft harvester.



Billet length distribution –
TOP: Synchronised standard 15-inch chopper system.
BOTTOM: Synchronised modified 15-inch chopper system.

“From this base a conceptual design was produced and presented to Corradini Engineering of Ingham for review and detailed design. They undertook this brief to manufacture a proof-of-concept MRPCS.

“After fabrication, the ‘Corradini’ proof-of-concept MRPCS was installed on a commercial harvester for evaluation under field conditions during July 2007,” he said.

Field trials compared a standard 15-inch three blade per drum chopper system with synchronised feedtrain setup with the ‘Corradini’ MRPCS with synchronised feedtrain setup on bin weights and mill-realised CCS.

The ‘Corradini’ MRPCS variable length billet treatment produced the greatest packing density, with an average of 380 kg/m³, while the standard chopper system uniform length billet treatment produced a packing density of 372 kg/m³.

Packing density was translated into a weight for a nominal six tonne cane railway bin for direct comparison. Theoretically, the increase in bin weight recorded from the standard to the ‘Corradini’ MRPCS was two per cent.

The results demonstrate that it is possible

to increase the packing density of billeted cane with variable length billets obtained through the design of the chopper system rather than by manipulating the feedtrain/chopper relationship, he said.

This advance would minimise cane and juice loss, while maximising packing density and minimising transport costs. This concept would be of most benefit to a 15-inch three blade per drum chopper system.

Rod said however, previous bin weight related constraints to optimised three blades per drum 15-inch systems in commercial harvesting operations have largely been overcome with the adoption over the past two seasons of four blades per drum 15-inch chopper systems.

“These systems, when synchronised have the ability to produce a uniform 8-inch billet, which provides an increase in bin weight when compared with a synchronised or unsynchronised three bladed system.

“But harvesters with four-bladed systems are still operated with an unsynchronised chopper/feedtrain set up which translates into further increases in bin weight and su-

crose losses,” he said.

He claimed the outcomes of this work have demonstrated a lack of awareness by the sugar industry and harvesting sector in reducing sugar losses during harvesting.

“As a result of this research I see a great opportunity for the sugar industry to take a whole-of-industry approach to maximise returns to all industry sectors through the application of current knowledge and implementation of improved harvesting practices.

“This should include heightened awareness of the concepts to increase the recovery of sugar during the harvesting operation, such as chopper/feedtrain optimisation,” Rod said.

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