THE EFFECT OF TOPS AND TRASH ON CANE MILLING BASED ON TRIALS AT MAIDSTONE

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Abstract

The SMRI and the SASA Experiment Station commenced an area of research during 1988 which required the collaboration of milling and agricultural expertise. The initial requirement was to investigate the cost of producing biomass as a raw material for by-products. The first stage of this research involved harvesting, loading, transporting and milling of cane which had been subjected to four different types of harvesting system from burning and/or topping to no cleaning (i.e. the whole plant).

This paper covers the milling results of this first stage of the project. The operation and performance of the Maidstone milling tandem were observed while 200 ton batches of the different types of cane were being milled. The main effect of whole plant cane on the performance of the mill was the reduction in throughput of up to 30% in respect of cane and 45% in respect of pol. An evaluation of the quality of the juice and bagasse and the possible effect of this quality on factory performance and sugar quality are discussed. It was calculated that the A sugar colour for unburned and untopped cane would be double that for burned and topped cane and that the recovery would be over 8 percentage points lower. The impact of this project on several aspects of cane quality is analysed and a rough estimate of the true cost of production of additional biomass is given.

Introduction

The question of the true cost of bagasse as a raw material for by-product manufacture has not been fully explored in this country. It is appreciated that this question can only be satisfactorily answered by starting with the agricultural implications, and it was therefore appropriate that the SASA Experiment Station (SASEX) and the SMRI were prepared to enter into a collaborative project entitled "Whole crop harvesting and biomass utilisation".

It was agreed that the initial project would take the form of a series of harvesting and milling trials on cane subjected to different harvesting treatments, with large enough batches to provide representative samples and data at every stage of the trial.

The co-operation of a mill was sought and Maidstone (MS) kindly agreed to participate in the milling trials, which took place at two-weekly intervals from 11th June to 25th July 1988. The assistance of the mill and Sugar Industry Central Board (SICB) laboratories were sought for the many tests required.

Table 1

Test dates and harvesting systems

Test	Starting date	Harvesting System	Milling Date
1	9 June	UT - unburnt, topped.	13 June
2	23 June	BT - burnt, topped.	27 June
3	7 July	UU - unburnt, untopped.	11 July
4	21 July	BU - burnt, untopped.	25 July

Four different harvesting treatments were carried out as shown in Table 1.

The harvesting and transport of this cane is fully covered in the paper by AG de Beer, *et al*[2].

Milling Trials

It was agreed at the start that the milling train at MS should be used rather than the diffuser because of the shorter residence time of the former. The variables measured were as follows:

- Duration of test
- Tonnage processed
- Imbibition quantity
- First mill torque
- Steam flow to turbines
- Motor loads on cane knives.

The following samples were taken throughout the test:

- Cane stalks from cane carrier
- Shredded cane from SICB hatch
- Mixed juice from SICB sampler
- Final bagasse from full-width hatch
- Mixed juice for settling tests.

The cane was delivered to MS in hilo trucks in the same order in which it was loaded. This was assumed to be the same as the order in which the cane was harvested. The start of the milling trial was clearly marked by dumping approximately 20 kg of lime onto the cane just before it was conveyed into the first knives. This lime gave the cane and the subsequent bagasse a distinctive yellow colour which was easily detected at any point along the milling train and which provided an accurate measurement of the time taken to process the cane.

During the trial 90 sticks of cane were taken from the cross carrier in such a way that the sample was evenly distributed amonst the eight hilo loads. These sticks were then hand cleaned, topped and subsampled according to recommended practice (Anon[1]) and a juice sample was obtained from them by the SICB direct analysis of cane (DAC) method. This extract was subjected to the same analyses as the mixed juice samples from the mill.

The results of all the milling tests are given in Tables 2 to 6.

Table 2

Basic milling details

Test no	Date	Duration min	Duration sec	Imb % fibre	Tons cane/ hour	Tons pol/ hour	Stops min	1st mill Torque kNm
Test 1	13 June	69	36	269,1	140,1	16,2	0	600
Test 2	27 June	67	00	342,7	180,6	24,5	1	530
Test 3	11 July	68	38	344,7	127,0	13,5	7	580
Test 4	25 July	63	00	363,4	190,2	25,5	0	620

Table 3

SICB Lab test results on DAC, clean stick and bagasse samples

Test	Pol % cane	Brix % cane	Purity %	Moisture	Fibre % cane	Ash % cane
DAC						
Test 1	11,53	13,61	84,63	65,16	21,22	2,48
Test 2	13,57	15,35	88,40	70,25	14,40	1,13
Test 3	10,63	13,23	80,36	65,48	21,58	2,76
Test 4	13,39	15,50	86,37	69,82	14,68	2,11
Clean Stick						
Test 1	14,70	16,19	90,79	71,58	12,23	0,40
Test 2	13,98	15,61	89,55	71,34	13,06	0,80
Test 3	15,00	16,50	90,88	71,31	12,19	0,40
Test 4	14,46	16,17	89,38	71,26	12,58	0,40
Bagasse						
Test 1	0,89	1,98	45,26	53,45	44,57	
Test 2	1,32	1,94	68,18	54,71	43,25	
Test 3	0,79	1,97	40,21	54,39	43,64	
Test 4	0,92	1,92	47,92	54,13	43,96	

Table 4

SICB Mixed Juice analysis

Test no	Pol	Brix	Purity	Total flow, kg
Test 1	11,20	13,13	85,30	148 055
Test 2	11,80	13,47	87,59	203 000
Test 3	8,38	10,16	82,49	173 060
Test 4	11,60	13,46	86,12	195 490

Table 5

SMRI lab test results

Test	Clear juice		Mixed juice		Colour	Nitrogen % brix
	Turbidity	Colour	Brix	Sulphated ash		
1	3 800	22 090	12,50	0,55	23 660	0,257
2	1 600	14 970	12,94	0,40	15 860	0,198
3	9 030	30 730	10,09	0,41	32 980	0,305
4	2 250	15 000	13,44	0,55	16 240	0,223

Table 6

SMRI GC test results

Test	Mixed juice			
	% Fructose	% Glucose	% Sucrose	Fru + glu % sucr
Test 1	0,55	0,56	10,04	11,06
Test 2	0,26	0,23	11,69	4,19
Test 3	0,33	0,32	8,12	8,00
Test 4	0,26	0,25	11,61	4,39

Effect on mill performance and capacity

All the results consistently indicate that tops and trash lower the quality of the cane for efficient milling.

Capacity

The capacity of the mill was affected even though its speed was maintained at a constant level for all four trial runs. The throughput with UU cane was 30% less than that with BT cane, while that with UT cane was 22% less. The capacity of the mill relative to the pol or sucrose throughput was even more dramatically affected. In the UU case the pol throughput was 13,5 tons per hour, compared with 24,5 per hour in the BT case and 25,5 in the BU case (see Table 2). The effect of the trash might have been less serious if some attention had been given to better conveying and feeding of the cane. It was noticed, for example, that the untrashed cane caused a hold up at the point where the cross carrier discharges into the main cane carrier. This hold up was quickly cleared, and it was apparent that a small design modification would have avoided the problem if this cane was regularly delivered to the mill. The results quoted above are nevertheless significant. The throughput with BU cane was in fact 5% higher than BT cane, indicating that it was trash rather than tops that inhibited throughput.

Mill performance

Although the extraction was calculated for each trial, (see Table 14) the results should not be regarded as conclusive since it is believed that it cannot be accurate for short runs. The imbibition was maintained at the same flow for each test but the flowmeter was suspect. The figures quoted in Table 2 are therefore based on integrator readings corrected by the daily mass balance imbibition tonnages. As a consequence it is unfortunately not possible to draw any conclusions from the normal indicators of mill performance such as extraction, bagasse moisture and pol % bagasse. If it was necessary to measure the extraction accurately with the different types of cane, the experiment would have to be repeated with careful control of imbibition and throughput and for a much longer period for each trial.

Effect on factory performance and sugar quality

Because of the short milling runs a direct assessment of the effects of the cane quality on performance and sugar quality is not possible. The following comments are therefore based on extrapolations from clear juice quality.

Colour

Samples of mixed juice were subjected to a laboratory clarification test. Both the mixed and clear juices were analysed for colour at 420 nm, pH 7, using a filtration step with a 0,45 micron membrane.

Juice colours are shown in Table 7.

Table 7

Mixed and clear juices colour, laboratory clarification

Test	Mixed juice	Clear juice	% colour change
1	23 660	22 090	−7
2	15 860	14 970	−6
3	32 980	30 730	−7
4	16 240	15 000	−8

Clear juice colour is thus less than the mixed juice colour by about 7%. This drop appears independent of the level of colour in the mixed juice, and is lower than the 20% drop reported by Scott[4] under industrial conditions.

A colour increase from clear juice to syrup is expected, due to heat, pH and retention in the evaporators.

Getaz (personal communication) carried out surveys at various mills and found an increase of about 10% while Scott[4] reports a 6% increase under normal factory conditions at Amatikulu. A 10% increase has been used to calculate syrup colour.

Evaporator syrup and remelt are used as pan feed. It is thus necessary to consider pan feed and not syrup alone. Getaz (personal communication) found a 10% increase in colour from syrup to pan feed. This value has been used to estimate pan feed colour. Clear juice, syrup and pan feed colours are shown in Table 8.

Table 8

Syrup, pan feed and sugar colours

Test	Clear juice	Syrup	Pan feed	Affinated crystal	A-sugar
1	22 090	24 300	26 730	642	1 284
2	14 970	16 470	18 117	435	870
3	30 730	33 800	37 180	892	1 784
4	15 000	16 500	18 150	436	872

The range of syrup colours is interesting. Syrups around 17 000 units were found at UC, (Lionnet[3]) which was considered to have an excellent cane quality, while syrups averaging 23 000 units, were found at AK and SZ, two factories which have had difficulties in meeting the A sugar colour specification of 1 350 units. Syrup from tests 2 and 4 fits into the excellent cane quality category, while that from test 1 fits into the colour problem area and that from test 3 is extremely bad.

To predict sugar colour from pan feed colour, a transfer factor is needed. Laboratory pan boilings have shown (Lionnet[3]) an average transfer of 0,012, which was considered to be about half the value found industrially (Scott[4]). A factor of 0,024 has been used.

A sugar colour can now be calculated if a ratio is assumed for VHP sugar colour to affinated crystal colour. Again from Scott's results and from many measurements available at the SMRI, a ratio of 2 has been assumed.

The results are shown in Table 8.

The results in Table 8 show also that the presence of trash in the cane increases the sugar colour by 76%. The corresponding value for tops is 23%. Untopped and untrashed cane would yield sugar of very high colour.

Recovery

The mixed juices obtained were analysed for sucrose, glucose, fructose and ash. A target molasses purity can be calculated using the formula:

$$\text{Target purity} = 33{,}9 - 13{,}4 \times \log \frac{(F + G)}{A}$$

to be used for calculating SJM recoveries.

Table 9

SJM recoveries based on mixed juice target purities and a sugar purity of 99,5

Test	Target molasses purity	Mixed juice purity	SJM recovery
1	29,8	80,3	89,8
2	32,7	90,3	95,0
3	31,2	80,5	89,2
4	34,3	86,4	92,0

This has been done in Table 9 where the recoveries are compared.

Both tops and trash have negative effects, reducing recovery by 1,9 and 4,3% respectively. This represents a loss of more than 5 000 tons of sugar, with trash alone, for a factory producing 120 000 tons of sugar per season.

Cane quality

Effect of delay between burning or cutting and crushing Samples were taken from the bundles of harvested cane in the field. Just before crushing, samples were also taken from the cross carrier. In both cases the cane was stripped of all trash and, if required, topped at the natural breaking point. The clean stalks were then analysed.

These two procedures thus yield clean stalk analyses for the fresh cane and for the cane at crushing. The delay between burning or cutting and crushing for most of the test cane was in excess of 80 hours. Thus some deterioration would be expected, decreasing purity. Cane purities are shown in Table 10.

Table 10

Cane purities in the field and at crush

	Clean stalk purities	
Test	Fresh	At crushing
1	91,5	90,8
2	92,7	89,6
3	90,9	90,9
4	91,8	89,4
Ave	91,7	90,2

On average the delay reduced cane purity by 1,5 units. This corresponds to about 0,8% drop in recovery, all else being the same. Apart from the drop in recovery in the factory the decrease in purity represents a loss of revenue to the grower. It can be calculated that, if he had delivered the fresh cane, his tons of sucrose would be about 2% higher. The tests were carried out in winter and the same delay in summer would have had much more pronounced effects.

Effect of tops and trash on cane quality The effect of tops and trash on the crushed cane quality is shown in Table 11.

Table 11

The effects of tops and trash on cane quality

	Purity	Fibre % cane	Ash % cane
Without trash	87,4	14,54	1,62
With trash	82,5	21,40	2,62
% change	−6	+47	+62
Without tops	86,5	17,81	1,80
With tops	83,4	18,13	2,44
% change	−4	+2	+36

Trash has the more pronounced effects. In particular the effect of trash on fibre and on ash are quite serious.

The clean stalk analyses for test 2 can also be compared to the DAC analysis for that particular test. This comparison gives an idea of the efficiency of burning and of topping under industrial conditions. This has been done in Table 12.

Table 12

Comparing burnt and topped cane to hand cleaned cane

	Purity	Fibre % cane	Ash % cane
Hand cleaned	89,6	13,06	0,80
Burnt and topped industrially	88,4	14,40	1,13
% change	−1,3	+10	+41

It appears that a significant amount of extraneous matter is left behind after industrial topping and burning.

Effect of tops and trash on mixed juice quality It is expected that the lowering of quality found with cane will persist in mixed juice. This is illustrated in Table 13.

Table 13

Effect of tops and trash on mixed juice quality

	Purity	Ash % brix	Colour
Without trash	86,8	3,6	16 050
With trash	83,9	4,2	28 320
% change	−3	+17	+76
Without tops	86,4	3,8	19 730
With tops	84,3	4,1	24 610
% change	−2	+8	+25

Again trash has the more pronounced effect. The magnitude of the effects on purity and on ash are lower than those with cane. The difference for ash can be explained by the fact that ash % cane is a "total" ash, i.e. it includes both the soluble ash and any insoluble ash such as sand particles. Ash in mixed juice on the other hand consists of dissolved ash only because the sample is filtered before analysis. Ash % cane causes mechanical damage to preparation equipment, conveyors, pipes, pumps, boilers etc. and is thus an important quantity. Ash in mixed juice has an important significance in terms of recovery. The difference for purity is probably caused by the differences in the extraction rates of pol and of the impurities in cane.

The cost of production of additional bagasse

The bagasse and sugar output rates are calculated for the four test runs and appear in Table 14. The boiling house recovery for each test has been estimated from the figures in Table 9 assuming that the target purity difference based on mixed juice is 6,0 undetermined loss is 2%, cake loss is 0,2% and the non-sucrose ratio is 1,0. The sugar output is seriously affected by the reduction in the milling rate and to a lesser extent by the reduced recovery. If it is assumed that the sugar mill would maintain its sugar production rate in the event of a change to whole stick cane, then the rate of production of bagasse would be according to the bagasse to sugar ratios in the last column of the table. However, this would require large capital expenditure and increased operating costs, which are difficult to estimate and would be in proportion to the increased cane rate required. It is estimated that the cane yard, cane preparation and milling train portion of the sugar mill would require R300 000 of capital expenditure to increase the throughput by 1 TCH and operating costs would be of the order of R1,60 per ton of cane. To maintain sugar production at 14,8 tons per hour, which is the estimated normal level for this milling train, the capacity will have to be increased by 36% for the UU (test 3) case. This increase is 43,1 TCH which will cost roughly R13 million of capital and R69,00 per hour. The increase in bagasse to be expected from this would be from 34 to 48% on cane or 22 tons per hour. If this is related to capital expenditure and increased operating costs, it is likely that the bagasse will cost about R25,00 per ton. In addition to this there will be substantial sugar recovery losses which should be taken into account.

Table 14

Calculated performance and recovery

Test	Bagasse % cane	Tons bagasse per hour	Extraction	Boiling house recovery	Overall recovery	Tons sugar per hr	Bag/sugar ratio
1	46,51	65,2	96,3	84,4	81,3	13,2	4,95
2	32,11	58,0	96,7	91,3	88,3	21,6	2,68
3	48,34	61,4	96,3	83,7	80,6	10,9	5,64
4	32,31	61,5	97,7	87,5	85,4	21,8	2,82

Conclusions

Although the amount of fibre being brought into the mill can be greatly increased by harvesting and transporting whole plant cane, these trials indicate that the costs of doing so will be high in terms of reduced payloads, mill capacity and factory performance. In addition, the sugar quality in terms of the VHP standards for pol and colour will be totally unacceptable.

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