Proc S Afr Sug Technol Ass (2008) 81: 139 - 144

THE EFFECT OF SCALDING JUICE TEMPERATURE ON EXTRACTION IN A CANE DIFFUSER

MUNSAMY SS

Illovo Sugar Limited, PO Sezela, 4215, South Africa
smunsamy@illovo.co.za

Abstract

As part of an energy efficiency study, the temperature of the juice coming out of a cane diffuser was decreased from ±75 to ±50°C. The lower temperature would provide a greater temperature difference between the shell and tube side of the primary heaters and allow the factory to use a lower evaporator bleed for this purpose. To produce a lower temperature juice out of the diffuser, the scalding juice temperature needed to be lowered. In practice it is believed that high scalding juice temperatures produce good sucrose extractions. A plant level test was conducted over five days to assess the effect of lower scalding juice temperature on sucrose extraction. Dropping the scalding juice temperature from 97 to 57°C had no detrimental effect on extraction. The trial results are presented and diffuser theory is explored to try to understand this finding.

Keywords: cane diffuser, extraction, scalding juice, diffuser juice temperature, diffuser theory, primary juice heating.

Introduction

The Sezela sugar factory uses about 50 000 tons coal per season due to bagasse and steam export to an adjoining by-products plant. The sugar factory was redesigned in 1982 to use evaporator bleed, both vapour 1 (V1) and vapour 2 (V2), for heating and panboiling purposes. A turbine driven mechanical vapour compressor was also installed, but later decommissioned due to operational problems.

It is generally accepted that increasing the vapour bleed to include vapour 3 (V3) will improve the overall thermal efficiency of the plant. Singh and Albright (2000) used V3 for diffuser press water heating. If Sezela could drop its draft juice temperature from around 75ºC to around 50ºC then sufficient (ΔT) would be available to use V3 for primary heating of the mixed juice. At present, V2 is used for primary heating and V1 is used for final heating of the mixed juice to 103ºC.

To obtain a lower draft juice temperature the scalding juice temperature needs to be lowered. How would this affect extraction performance? A plant level trial was conducted to assess the effect of a lower scalding juice temperature on extraction.

Definition of various terminologies used in this paper

The various terminologies and parameters are described briefly for those who are not familiar with cane diffusion.

Scalding juice (SJ): That part of the high brix juice near the cane entry of the diffuser which is withdrawn, heated to 95-98ºC in shell and tube heaters and sprayed onto the prepared cane closest to the cane entry. The prepared cane is at ambient temperature. The SJ flowrate is 200-300% cane.

Draft juice (DJ): That part of the scalding juice which, after it has percolated through the incoming cane bed, is pumped to process via the juice scales. The flowrate is between 120-130% cane. Draft juice temperature is typically 65-75ºC.

Mixed juice (MJ): The draft juice is called mixed juice after it is weighed in the juice scales. This juice is heated to 103-104ºC before flashing and clarification.

Direct contact heating: Evaporator bleed vapour, typically V1, is injected into the diffuser juice cells for heating purposes.

Extraction: The mass of sucrose in mixed juice as a percentage of mass of sucrose in cane.

Press water (PW): The low brix juice squeezed out of the dewatering units and returned to the diffuser.

Vapour bleeding: The practice of using evaporator vapours for heating duties outside the multiple effect evaporators.

DRI: Diffusion rate index (Loubser and Gooch, 2004) is a measure of cane preparation.

Imbibition % fibre: Mass of imbibition water as a percentage of mass of fibre in bagasse. Typical values range from 200-450%.

The diffuser setup

The Sezela cane preparation, diffusion and dewatering setup is described by Hulley (1989). The equipment is summarised in Table 1. There are two identical diffusers at Sezela with identical auxiliary equipment.

Table 1. Summary of cane preparation, diffusion and dewatering equipment per diffuser.

Equipment/Parameter		Description
leveller knife		200 kW electric
primary knife		500 kW electric
secondary knife		1040 kW turbine
shredder		1840 kW turbine
diffuser:	type	Stationary screen, slat type, BMA design
diffuser screen:	length (m)	54
	width (m)	7.5
	no of stages	12
	screen area (m^2)	405
diffuser heating:	SJ	Shell and tube on V2
	direct injection	V1 sparges
	PW	Nil
Dewatering:	type	Conventional 3 roll with underfeed roll
	roll length (mm)	2134
	roll diameter (mm)	1067

Procedure

A seven-day trial on one of the two diffusers commenced on 17 September 2007 at 04h00. During the trial, the heating vapour (V2) was closed on the scalding juice heaters. All other parameters were kept at normal operating levels. The mass balance data was collected from the Cane Testing Services laboratory. The temperatures were recorded every hour from existing thermocouples connected to the central control system. The brix samples were collected at regular intervals throughout the trial.

Results

The average temperature profile across the diffuser during the trial is shown in Table 2, together with the typical operating profile.

Table 2. Average diffuser cell temperatures during the trial.

Diffuser cell	Average temperature for trial (ºC)	Typical operating temperature (ºC)
SJ	57	96-98
DJ	48	75
1	75	93
2	86	95
3	94	95
4	93	95
5	92	95
6	95	95
7	93	95
8	97	95
9	96	94
10	96	93
11	96	90
12	89	80
PW	70	65

Under normal operating conditions the SJ set point is 96-98ºC and the cell set points are 95ºC. The set points are not always achieved. During the trial the temperature controller towards the end of the diffuser was not controlling well and the temperature kept over-shooting the setpoint.

The average diffuser cell brixes during the trial (average of 37 sets) are shown in Table 3. The readings were obtained at regular intervals throughout the trial. The typical values are normal operating values.

The Table 3 data are shown graphically in Figure 1.

The average cane crush rate and the various extraction data are shown in Table 4. The trial was aborted after day five due to low mixed juice flash temperatures of around 94ºC and excessive carryover in the clear juice.

Table 3. Average diffuser cell brixes during the trial.

Cell	Average brix (%) during trial	Typical operating brix (%) values
SJ	10.63	10.50
1	6.89	6.90
2	5.26	5.50
3	3.88	4.00
4	2.88	3.00
5	2.32	2.20
6	1.92	1.80
7	1.59	1.50
8	1.34	1.30
9	1.18	1.00
10	1.07	0.80
11	0.91	0.70
12	0.73	0.60

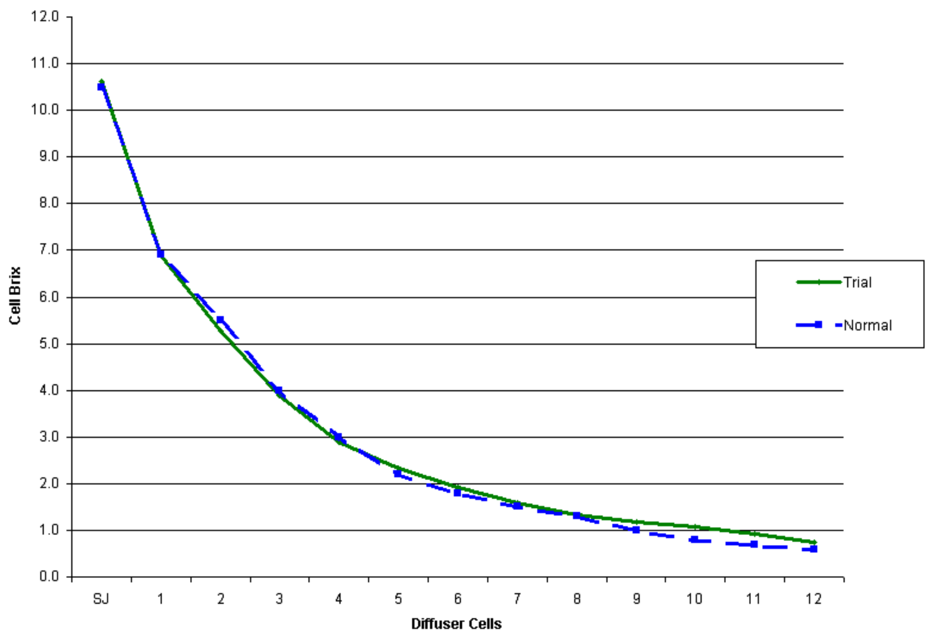

Figure 1. Average brix profile for the trial together with typical operating profile.

Table 4. Diffusion data during the trial.

Day	Tons cane/h	Pol % cane	Fibre % cane	Pol/fibre ratio	DRI	Imb % fibre	Pol % bagasse	Moist % bagasse	Extract (pol)
1	204	14.72	16.15	0.91	5	405	0.74	46.9	98.45
2	220	14.76	16.02	0.92	7	389	0.71	46.6	98.52
3	227	15.38	15.91	0.97	9	436	0.72	45.9	98.59
4	229	14.59	16.17	0.90	6	393	0.66	47.3	98.58
5	199	15.49	16.00	0.97	8	415	0.67	45.7	98.70
6	214	14.80	15.95	0.93	8	375	0.71	46.8	98.53
7	211	15.68	15.36	1.02	9	418	0.79	46.5	98.52
Wk Ave	214	15.06	15.94	0.95	7	404	0.72	46.5	98.55
Season to date	198	13.89	15.40	0.90	7	420	0.68	47.2	98.54

Discussion

Dropping the SJ temperature from 97 to 57ºC resulted in the DJ temperature dropping from 75 to 48°C. If V3 bleed is used for primary heating then the (ΔT) increases by a large margin with the lower DJ temperature. With the lower DJ temperature, V3 bleed (typically 98-102°C) could be used for the purpose of primary heating. Whilst an overall improvement in thermal efficiency is expected with the use of the V3 bleed, this needs to be carefully modelled.

During the trial, the existing MJ heater setup was unable to compensate for the lower DJ temperature, the flash temperature was not attained and mud carry-over into the clear juice was excessive and had a disastrous effect on performance and sugar quality. For this reason the trial was aborted after five days.

The effect of the lower SJ temperature on extraction was a surprise. There was no drop in extraction during the trial period. In practice the belief was that high scalding juice temperature was very important for good extraction. The author himself was a firm advocate of high SJ temperatures. To understand this finding one needs to look at the theory of cane diffusion.

Pioneering research into cane diffusion, by means of a mathematical model, was conducted by Rein (1971). Rein states that, "... the variation of the model parameters with temperature and degree of preparation is consistent with the postulate that extraction occurs by a combination of washing and diffusion." The paper continues, "Consequently, extraction is postulated to occur as follows: a fraction of the juice is readily extracted from broken cells by a simple washing-displacement process, and the remainder (consisting of juice in unbroken cells and in small capillary passages in the interior of the particles) is extracted according to a slower diffusion type process." The paper also shows that the washing-displacement process is very sensitive to degree of cane preparation (the number of open cells) and less sensitive to temperature. On the other hand the diffusion type process is more sensitive to temperature.

Using the above theory one could attempt to explain the Sezela trial results.

The rapid drop in the brix profile during the trial and under normal operating conditions suggests that a very large fraction of the brix (juice) in cane was displaced rapidly in the first few cells. This is an indication of the washing-displacement process which is related more to degree of cane preparation and amount of SJ to create turbulence and mixing in the bed. Sezela uses high SJ flowrates and the rate during normal operation and the trial was 600 tons per hour or approximately 300 % cane. The degree of cane preparation at Sezela is also fairly high with a DRI of around 7, or a Preparation Index (PI) of around 92. The heavy duty cane preparation equipment used is given in Table 1.

The remaining brix in the fibre was removed by the slower diffusion process and the higher temperatures towards the end of the diffuser improved the transfer rate of sucrose from the fibre to the liquid.

Conclusion

The trial results, supported by theory, suggest that the degree of cane preparation and SJ flowrate is more important than the SJ temperature with regards to sucrose extraction in a cane diffuser. A high temperature could be beneficial in the slower diffusion process towards the end of the diffuser. It is clear from a microbiological point of view that diffusers should not be operated below 85°C. The upper temperature limit must take into consideration the risk of increased colour formation in the diffuser juice.

The cane quality during the trial was exceptionally good by Sezela standards, with pol/fibre ratios between 0.90 and 0.97. The crush rate was below the design rate of the diffuser and the imbibition level was high. The above could have influenced the extraction during the trial.

The SJ and MJ heaters will need to be rearranged to provide the required heating surface with the lower DJ temperature.

Acknowledgements

The author gratefully acknowledges the sampling and data collection by Sezela's engineers-in-training, James Mhlongo, Navesh Kalua, Nadeem Shubrati and Milisha Pillay, who worked in shifts to collect the data.

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