REFEREED PAPER

IMPROVED EXTRACTION AT FELIXTON

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Abstract

Overall sucrose recovery is an aspect with which every sugar factory is concerned and extraction forms a major part of this factory performance figure. Felixton Mill has constantly achieved good extraction and has positioned itself well as the southern African sugar industry benchmark. This paper shows how performance parameters such as crush rate, diffuser operations and cane preparation contributed to improved extraction of 98.49% in the 2013 season. Although it is believed that good extraction requires high imbibition rates of up to 400% fibre, Felixton was able to achieve this with a lower imbibition rate of 333.54%. Factors such as diffuser stops and starts, diffuser start-up and liquidation are identified as important operational features. A good relationship between extraction and imbibition quantity in prepared cane and a residence time in the diffuser is shown. It can also be said with certainty that the preparation index in the range of 90-92 and imbibition quantities have a significant effect on extraction. It has been established that the bed, in a stable non-flooded condition and with consistent cane feed, yields optimum extraction performance. The benefit of paying attention to detail is highlighted as a key operational control measure.

Keywords: extraction, diffuser operations, imbibition, PI, consistent feed

Introduction

Felixton mill crushed 1 464 812 tons of cane, and achieved a pol extraction of 98.26% in the 2012 season, and 2 088 930 tons of cane was crushed at a pol extraction of 98.49% in the 2013 season. Felixton diffusers are each rated at 300 tons cane per hour (TCH), and each has two dewatering mills with pressure feeders. The 2012 length of milling season (LOMS) was 30 weeks at an average of 443.40 TCH, and 2013 consisted of 33 weeks at 429.85 TCH. The diffusers installed at Felixton are Huletts moving bed diffusers. These diffusers are counter-current extraction devices which operate on a staged basis and have a fixed screen. This paper gives some insight into the key operational philosophies which made a significant contribution towards improved extraction. A description of Felixton diffusers is shown in Table 1.

Table 1.Description of Felixton diffusers.

	A-diffuser	B-diffuser
Screen length (m)	64.7	64.7
Screen width (m)	12	12
Screen area (m^2)	776	776
Bed height (m)	1.6	1.6
Bed speed (m/min)	0.65 -0.70	0.65-0.70
No. of stages	14	14
No. of lifting screws	12 *2 sets at stages 4 and 12, respectively	12 *2 sets at stages 4 and 12, respectively
Press water drum	Yes	Yes
Design rating (TCH)	300	300

Parameters contributing to improved extraction

Preparation index

In Felixton, the measurement of the degree of cane preparation is done by means of the preparation index (PI). PI attempts to assess the degree of preparation by measuring how much of the sugar in cane is exposed to be washed out of the prepared cane sample (Rein, 1995). In South Africa it is considered that a PI of at least 92 is required if an extraction of over 97% is to be achieved in a diffuser (Rein, 1995). The method of expressing cane preparation as a function of how the brix can be extracted from the open cells rather than a fraction of open cells was trialled at the Sugar Milling Research Institute (SMRI), but was not used. Preparation index is dependent on the power consumption of the cane preparation equipment, which is also a function of fibre loading. Apart from monitoring the PI analysis, which is done once per shift in the mill laboratory, a visual inspection of cane preparation as well as the work done by the shredder, is closely observed. It has been found that for good preparation, the power absorbed in a heavy duty shredder per ton of fibre per hour (TFH) lies in the range of 30-40 kW/TFH (Rein, 1995) and hence a figure of above 30 kW/TFH was deemed good and monitored on a shift basis as part of the operational dashboard.

The shift superintendent checks the calculation of the power consumption on an 8-hourly basis. In addition, during the frequent plant walkabouts, the engineer and the superintendent check the shredder amp meter in the plant, which has been found to be effective when it reads anything between 300 and 400 A. However, the best measurement of cane preparation is visual, and must be such that it allows the required imbibition to be applied with sufficient wetting of the bed (Munsamy SS and Bachan L, 2006). A practice of adjusting the shredder washboard every Tuesday and Thursday was adopted. This adjustment is made after careful visual inspection of cane preparation and the juice level above the cane bed. If cane is too fine or over-prepared or if flooding occurred and the shredder is evidently working hard as deduced from the calculation, the washboard is not adjusted on that particular day. Power figures for a typical week, without and with the washboard adjustment, are given in Figures 1 and 2, respectively.

Figure 1 shows the performance of the shredder during a typical week when the washboard is not adjusted. It can be seen that the PI drops below 89 when the shredder power is calculated to be below 25 kW/TFH. Figure 2 shows that the PI remains stable at between 91-92 on most days of the week, with high shredder power consumption. The hammer wear effect is seen towards the end of the week.

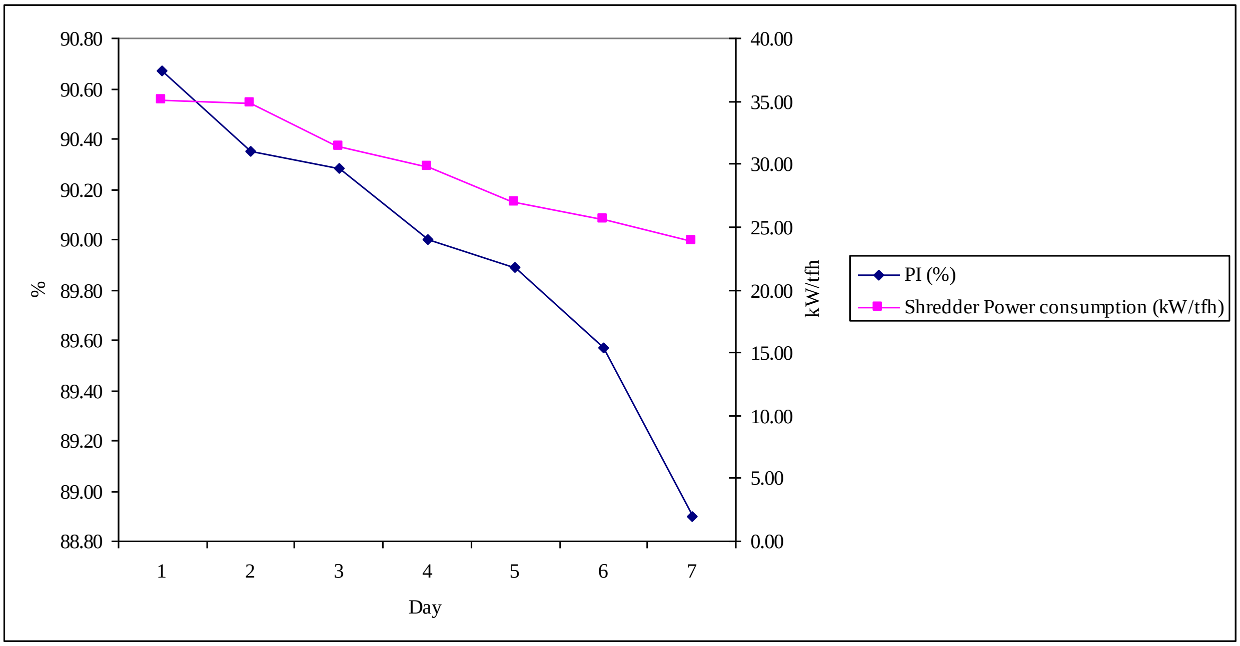

Figure 1.Preparation index vs shredder power consumption for a typical week without washboard adjustment.

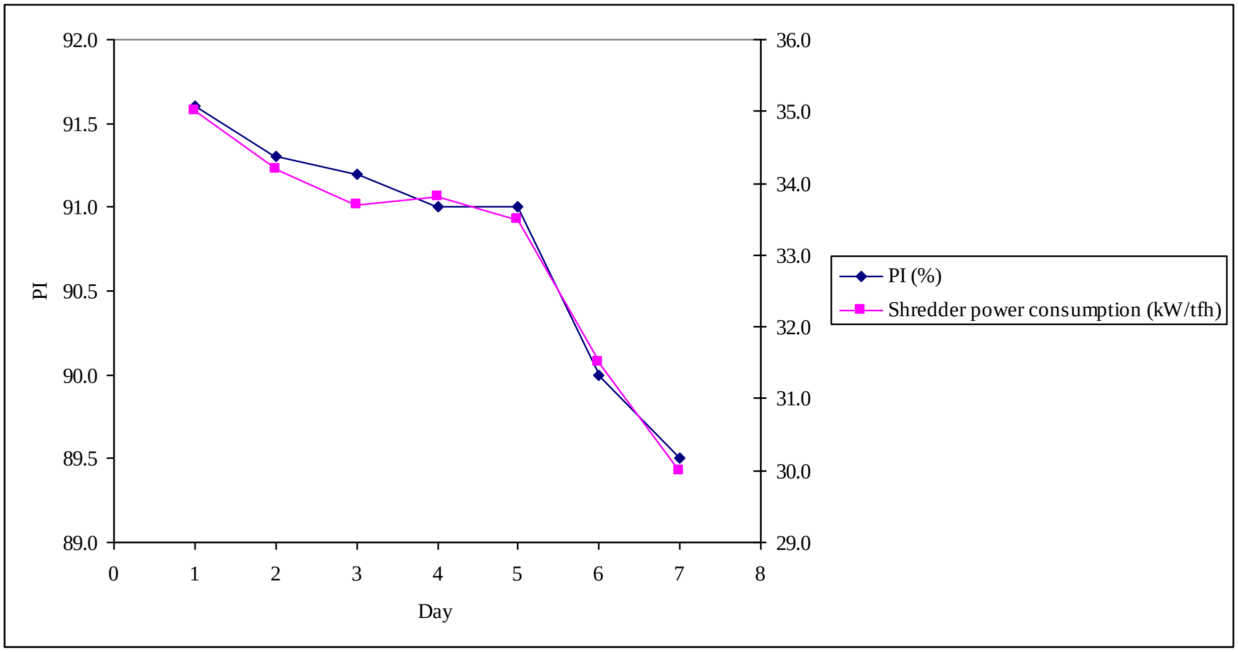

Figure 2.Preparation index vs shredder power consumption for a typical week with washboard adjustment.

From the trends, it can be said that the improvement in PI is a function of the power consumption of the shredder and the attention given to ensuring its efficiency. Table 2 shows a gradual improvement in PI over five years with an increase in extraction performance. The PI has improved over the past five years to an average of 90 in 2013, in comparison to 89 and a lower extraction in the previous four years. Felixton uses four methods of establishing the degree of preparation in cane, which are:

- Laboratory PI
- Visual inspection
- Shredder power consumption calculation
- Monitoring shredder amps in the plant.

Table 2. Felixton front end data from 2009 to 2013.

Year	Pol extraction	Fibre % cane	Imbibition % fibre	Pol % bagasse	Moisture % bagasse	Preparation index
2009	98.04	15.01	373.22	0.79	52.57	89.03
2010	98.09	15.19	350.98	0.8	51.77	88.50
2011	98.29	15.6	377.82	0.66	51.77	88.22
2012	98.26	16.16	369.3	0.66	51.68	88.55
2013	98.49	15.81	333.54	0.6	51.01	90.00

Juice percolation

Literature shows that the percolation of the liquid has an effect on the diffuser efficiency. Poor percolation results in flooding, hence a decrease in extraction (Lionnet *et al*., 2005). Flooding has adverse effects on extraction as it severely destroys the concentration gradients along the diffuser as it washes away the cane and juice. Flooding can be avoided by decreasing the throughput and imbibition of the diffuser, allowing more time for percolation (Lionnet *et al*., 2005). (Lionnet *et al.;* 2005) also suggests removing suspended solids from the cane bed to ensure efficient permeability. To overcome the problem of flooding due to a blinded bed, the functioning of every lifting screw in the area of press water return and mud return is not negotiable. The maintenance of the lifting screws is a critical part of operation. Promoting juice percolation by reducing imbibition water and smoothing out variation in PI (shredder adjustment) resulted in a reduction of more than 40% in lost time due to flooding in 2013.

Temperature and brix profile

Temperature affects the rate of pol extraction in the diffuser. (Rein, 1995) suggests that temperatures should be maintained above 75°C in order to attain high extraction rates. The average temperature of the diffuser should thus be maintained at 85°C (Rein, 1995). It is common practise to operate diffusers at an average temperature of about 85°C, as Felixton does. This ensures that the temperature at no stage drops below 75°C, which is considered to be the minimum operating temperature (Rein, 1995). High temperature result in an increase in juice colour (Rein, 1995). Lower temperatures expose the juice to microbiological breakdown and adversely affect extraction. This is illustrated in the temperature profile given in Figure 3, which shows a good control of temperature at approximately 85°C. In addition to doing the temperature profile on an 8-hourly shift basis, a continuous monitoring of temperature is automated by means of regulating the steam valve. Temperature is maintained by direct injection of vapour 2 into stages 3, 5, 7, 11, 12 and 13. Figure 4 depicts Felixton's brix profile across the diffuser stages with a steady decrease in the concentration of juice in the successive stages.

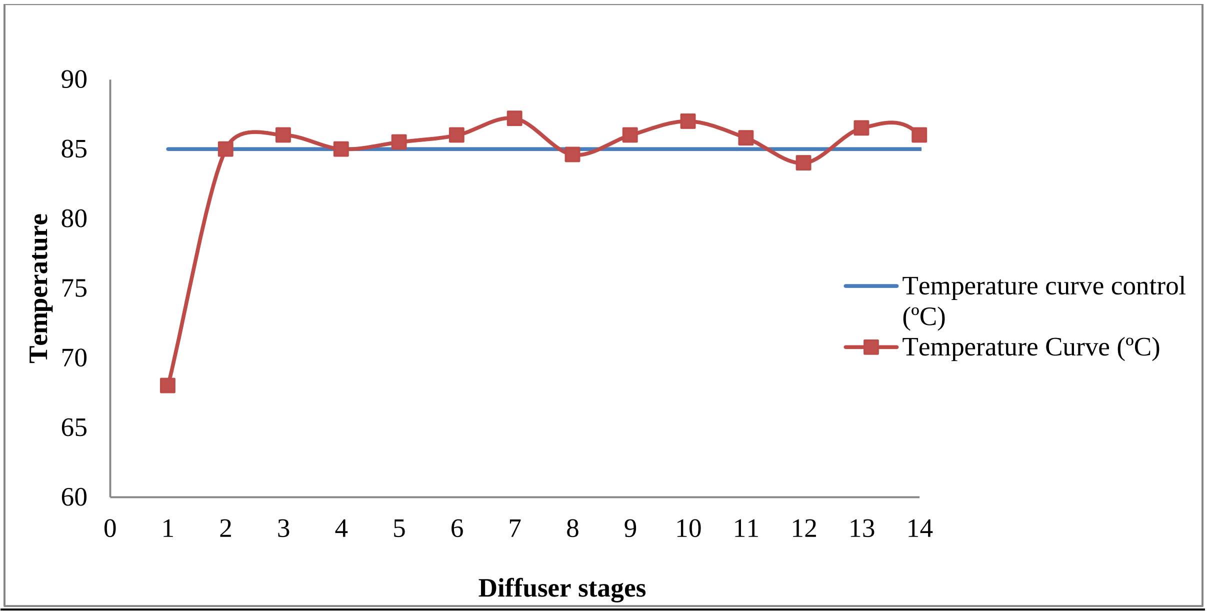

Figure 3. Felixton mill temperature profile across the diffuser.

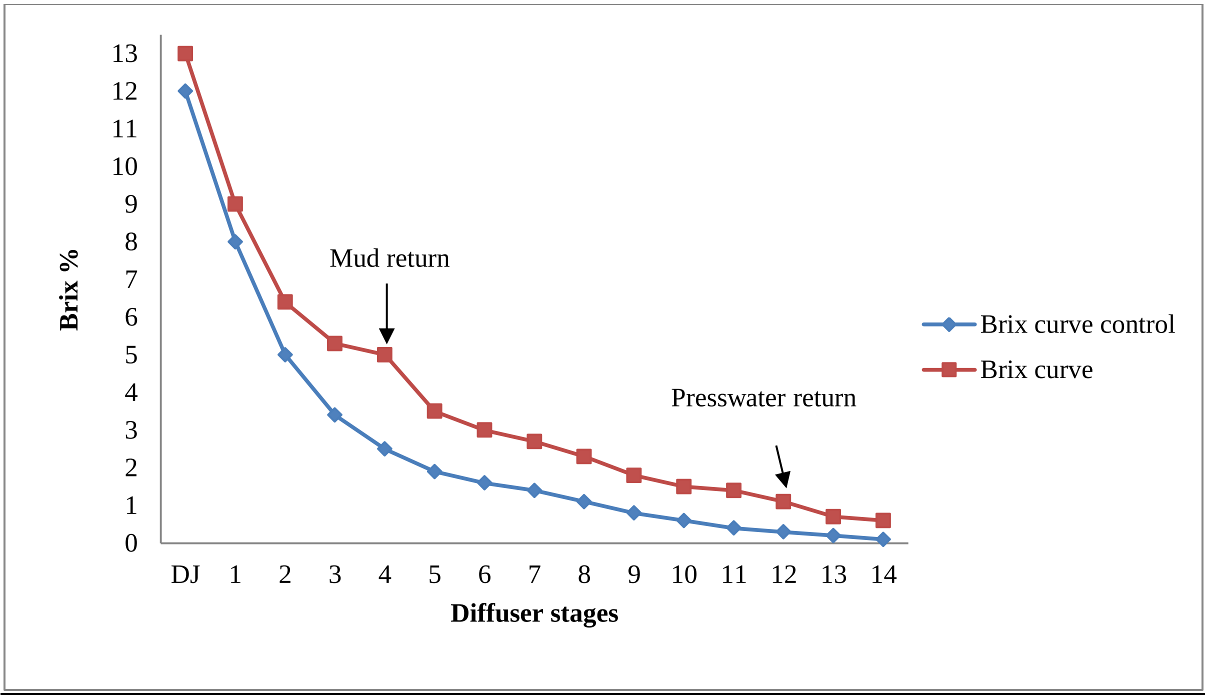

Figure 4. Felixton mill brix profile across the diffuser.

Retention time

It has been shown that in a moving bed type diffuser, extraction may be increased by increasing the amount of juice recirculation. The increased juice recirculation gives higher flow rates through the bed and thus increases the solid-liquid contact efficiency. This allows more of the sucrose to be extracted by washing and less by diffusion (Rein, 1995). In Felixton, diffuser stages 1 to 4 feed end spray pipes and angles are kept at maximum or recycle positions, whereas stages 5 to 14 are kept on forward or minimum positions. This favours percolation by increasing the juice retention time, it promotes pol extraction and prevents flooding at the feed end which drastically reduces extraction. From Table 3 and Figure 5, it can be seen that there is no conclusive relationship between the amount of cane crushed and pol extraction. In 2010 and 2012, almost the same amount of cane was crushed, but at 98.09 and 98.26% extraction, respectively. It would be expected that the lower the TCH, the better the extraction because of more retention time; however, the data below is not indicative of that.

Table 3. Felixton cane crush data from 2009 to 2013.

Year	Cane crushed	Tons cane/hour	Pol extraction
2009	1642988.25	437.12	98.04
2010	1468069.84	407.06	98.09
2011	1700474.73	492.78	98.29
2012	1464811.95	443.40	98.26
2013	2088929.86	429.85	98.49

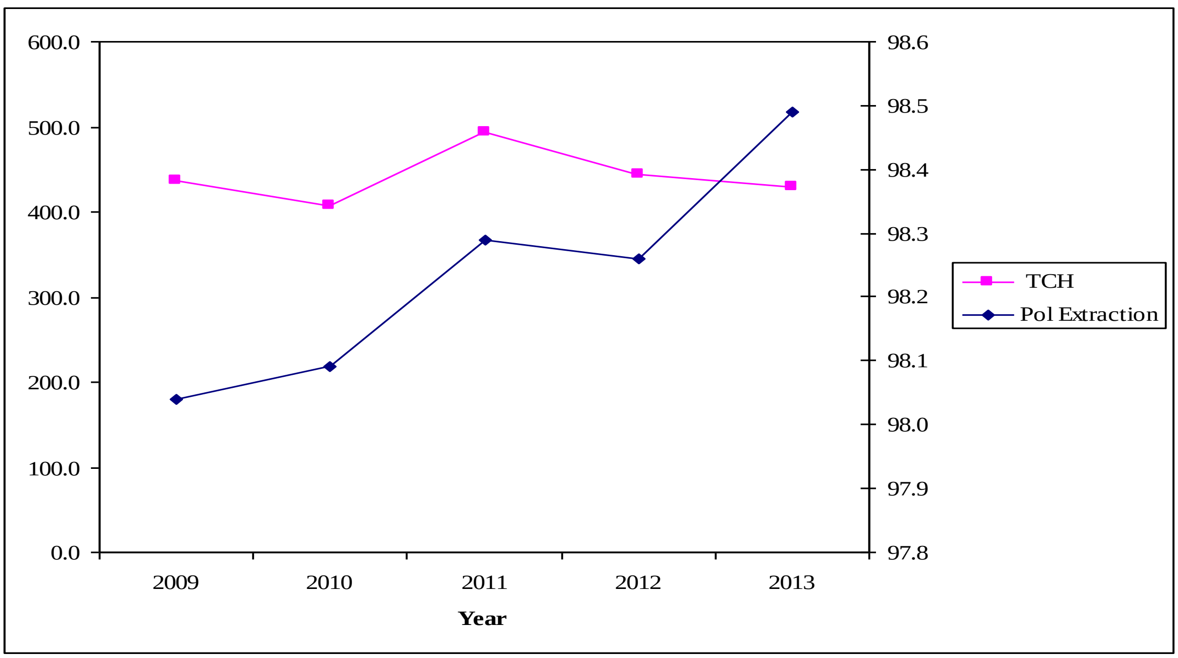

Figure 5. Tons cane/ hour vs pol extraction in 2009 -2013.

Bagasse moisture and pol % bagasse

It is generally accepted that the fibre % cane, brix % cane and imbibition% fibre affect the performance of the front end of the factory (Wienese, 1995). However extraction is also influenced by the characteristic of the bagasse from the diffuser. Felixton has two bagasse dewatering mills for each diffuser that operate in parallel. There is a gradual decrease in final bagasse moistures and a decrease in pol % bagasse and thus an improvement in extraction as shown in Table 2. In Felixton, all pressure feeder rolls were re-shelled in off-crop 2013. The mills were run strictly on automatic mode, which enabled better control of the cane level in the chute. The mill nozzle box pressures were closely monitored and recorded. Bagasse moistures show an improvement for the past five years as illustrated in Table 2. While it is important to reduce bagasse moisture to improve the value of bagasse fuel, the additional juice which is recovered promotes extraction. Another driving force to ensure lower moistures is the fact that Felixton exports bagasse to its neighbouring paper mill, where financial benefits are realised for low bagasse moisture. In 2012, the bagasse moisture was 51.68% and pol% bagasse increased to 0.7%. With decreasing bagasse moisture in 2013, pol% bagasse dropped to an average of 0.6%, resulting in improved extraction.

Diffuser Operations

Steady state operations

The diffuser is operated and controlled from a central panel in the Main Control room. The feed in the diffuser is controlled by measuring the depth of the cane on the conveyor belt by controlling the speed of the feeder table. The diffuser bed height is maintained by the use of a scratcher to ensure bed evenness. In the past, steady state operations were not easily achievable as there were always delays or ‘gaps’ between cane consignments and delays when changing over between rail and road cane. This has since been addressed through training. A camera monitor which aids in the monitoring of the flow of cane from the feeder tables and on the conveyor belts feeding the diffuser is installed in the control room. Challenges such as chokes and belt tracking are easily spotted before they result in unnecessary downtime. If there is a breakdown and the stop is anticipated to be longer than two hours, the strategy is to pump out all the ‘high brix’ juice from stages 1 to 7, while continuing to wet the bed with imbibition. If the stop is anticipated to be longer than four hours, the diffuser is liquidated to prevent the destruction of sucrose.

Control parameters

Particular attention was paid to the addition of imbibition water especially in the light of fuel saving, while not compromising extraction performance. A mixed juice % cane of 130% was found to be optimum, thus the superintendent calculates the tonnage of imbibition to be applied every hour. The calculated water tonnage to be added is monitored on the panel indication in the control room and verified on the flow meter reading in the plant. A pol% bagasse of <0.6% was tabled as the target. The water tonnage and pol % bagasse are recorded on an hourly basis, so that an increase or reduction in imbibition water can be done timeously. Figure 6 shows a trend between imbibition water and extraction over five years.

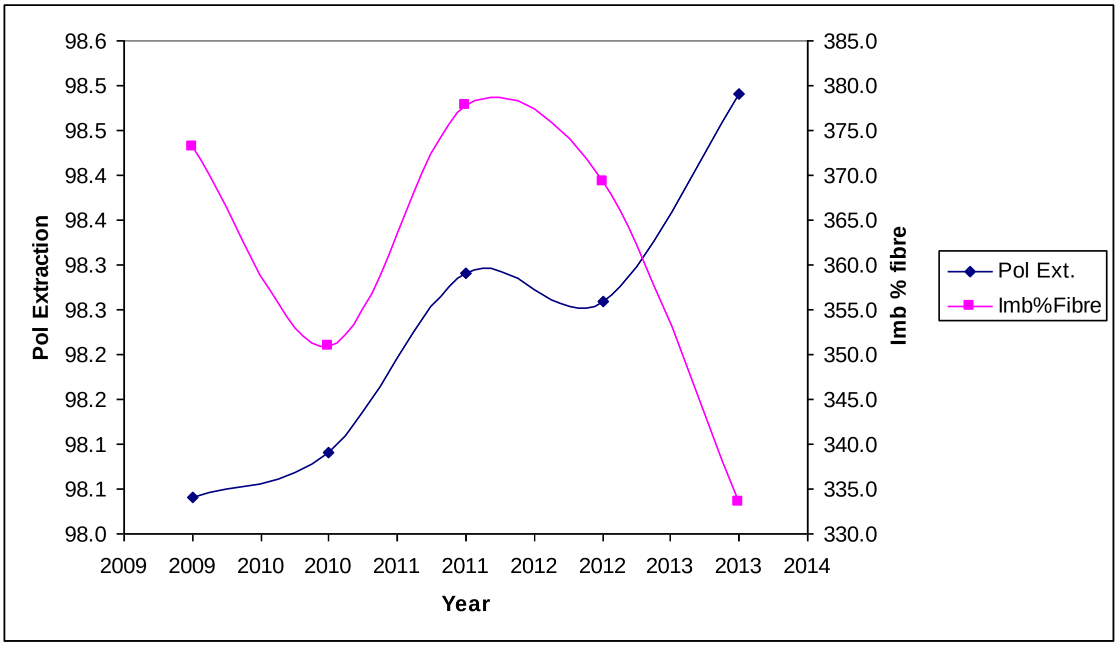

Figure 6. Relationship between extraction and imbibition % fibre in bagasse.

Note that extraction improved at a reduced imbibition rate in 2013. This improvement is attributed to the monitoring of the shredder efficiency for good PI and monitoring the dewatering mills for bagasse moisture and pol in bagasse.

Other practices adopted at Felixton

Diffuser hygiene

Diffuser hygiene is emphasised on a daily basis. During 2013 some changes were implemented, where the engineer increased the plant walkabout frequency with the focus on housekeeping.

Spray pipes and nozzles

Every stop day, the spray pipe flanges are opened and cleaned by flushing out with water. Spray nozzles are inspected for blockages and cleaned by pumping water from the trays, simulating diffuser operations. The engineer and superintendent stand inside the diffuser to witness these tests. This is to ensure that during operations juice is pumped from one stage tray to the preceding tray in a close to plug flow pattern of juice. Sideways dispersion due to worn nozzles would lead to juice bypassing trays and would affect percolation and hence extraction. Spray pipes are designed such that the direction of juice spraying position inside the diffuser can be varied. These spray pipe angles determine the minimum, bypass and maximum spray angles of juice in the different stages. The spray pipe angles are tested on stop days to observe whether they are indeed turning inside the diffuser as opposed to turning loosely outside. The engineer is actively involved with these inspections as they ensure retention time of juice in the diffuser.

Sight glasses

The importance of visual observation is emphasised through the cleaning of the sight glasses for internal diffuser observation.

Conclusions and Recommendations

The quest to improve extraction prompted a close look at those parameters known to affect extraction. Therefore, it is appropriate to conclude with a checklist for improving extraction as established in Felixton.

- PI is a function of the shredder power consumption and has the most significant effect on extraction performance. Adjusting the shredder washboard ensures a consistently good PI.
- Maximum juice percolation, juice recycling and the amount of imbibition applied improve extraction performance. Low moisture and low pol in bagasse have good correlations to pol extraction.
- Striving for steady state operations is key.
- Maintaining diffuser hygiene and attention to detail is critical.

For the above to be met, it is recommended that:

- A brix profile is done on a shift basis, to effectively monitor changes in operations such as:
  - stage juice temperature should be maintained at 86°C.
  - excessive mud return which will result in flooding.
- Control flooding by applying the four- finger rule on juice above the diffuser bed.
- Make use of clean water at start-up up in order to avoid microbiological losses.
- Raise the diffuser temperature before crushing by making use of direct injection of Vapour 2 bleed from the evaporators to avoid any sucrose losses.
- Ensure that juice is continuously pumped out to prevent the trays from overflowing into the drain which will need to be returned into the diffuser.
- Clean diffuser drains thoroughly on stop-days and continuously keep the cane yard and diffuser areas hygienic.

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