

REFEREED PAPER

DEXTRAN: A REFINER'S PERSPECTIVE

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Abstract

The raw sugar that was processed by the Tongaat Hulett Sugar Refinery (Hulref) had low levels of dextran (<100 ppm). Over the past four years, however, the levels of dextran in the raw sugar have been increasing. As high levels of dextran have a deleterious effect on some of the unit operations in a refinery, investigative work was initiated in the following areas:

- Effects of high dextran on refinery operations.
- Carrying out a dextran balance in the refinery.
- Evaluating ways of reducing the high dextran.

Keywords: dextran, viscosity, dextranase, refined sugar quality

Introduction

Hulref, being a stand-alone refinery, receives raw sugar from multiple sources. In view of this, the quality of the raw sugar entering the refinery can vary widely. The main raw sugar quality parameter that was a challenge for refinery operations team to manage was colour. Although the raw sugar colour specification is <1350 icu, the colour of the raw sugar entering the refinery varied from 1300 to 3000 icu. This created major operation challenges for the operations team. In view of this, additional decolourisation (Moodley, 1993) has been implemented at the refinery to process the high colour raw sugar.

In 2013, however, it was observed by the refinery team that dextran, another raw sugar quality parameter, was increasing.

Dextran is a complex branched glucan (polysaccharide made of many glucose molecules) composed of chains of varying lengths (from 3 to 2000 kilo Daltons). The structure for dextran is given in Figure 1.

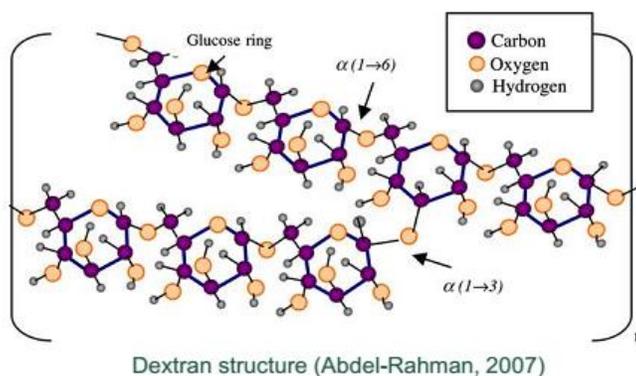


Figure 1. Dextran structure.

Ravno and Purchase (2005) did an excellent review on dealing with dextran in the South African sugar industry. Dextran is formed mainly during sugarcane deterioration, and is caused by microbial infestation of cane during transportation post-harvest and before crushing. It can also be formed in factories if there is inadequate attention to hygiene. Burnt cane is more prone to dextran formation than is unburnt cane (Ravno and Purchase, 2005).

The analysis of cane products to detect dextran is not easy: three methods are considered here. In 1959 Nicholson and Horsley proposed the 'Haze' method: Roberts (1983) introduced a procedure using copper sulphate named the Roberts method: Morel du Boil in 2000 published a procedure using hydrolysis and chromatography (HPAEC-PAD). Each method has its advantages and disadvantages (Lionnet, 2016). In South Africa the Haze method (Anon, 1994), is used to measure dextran in raw sugar on a routine basis.

Although dextran and its negative effects during cane processing were known for a long time, its importance was highlighted by the Australian industry when mechanical harvesting of cane was introduced in the early 1960s.

Unlike many of the other impurities present in the raw house, dextran is readily occluded in the raw sugar crystal (Ravno and Purchase, 2005). In South Africa Morel du Boil (2005) has reported on the high partitioning of dextran between juice and raw sugar for a number of South Africa mills. It was evident from that work that a significant level of dextran from a sugar mill will be transferred to a refinery. Dextran in raw sugar will also affect the filterability of the raw sugar (Ravno and Purchase, 2005). Dextran and many of its associated compounds show relatively high (17-25%) transfer from mother liquor to crystal (Morel du Boil, 2005).

The effects of high dextran on the refinery operations will now be discussed. High levels of dextran in raw sugar can have serious adverse effects on the operations of a refinery. High molecular weight dextran (1×10^7) at 1000 mg/kg brix, reduced the filterability from 63 to 7%, but dextran with molecular weight of 0, 1×10^6 and 2×10^6 , at the same concentration, had no effect (Hidi and McCowage, 1984). High levels of dextran (>1000 mau as measured by the Haze method) in the liquor did not cause any filtration problems at the Thames refinery (Donovan, 1993).

The evidence that sucrose crystal elongation is directly attributable to dextran is stated to be questionable by Morel du Boil (1991); but the other processing problems associated with polysaccharides or dextran should not be underestimated. Dextran formed by *Leuconostoc Mesenteroides* have high relative molecular masses (~2 million) and this is the type of dextran considered more troublesome in refining (Morel du Boil, 2000) and probably in raw sugar factories.

In addition to the processing difficulties caused by high dextran raw sugar, high dextran refined sugars can also cause other problems. High dextran refined sugars can be implicated in acid beverage floc (Ravno and Purchase, 2005). High levels of dextran in refined sugar can make it difficult to dry and condition (Fowler, 1981a) and cause distortion of 'hard candy' (Vane, 1981).

Ravno and Purchase (2005) have achieved much in quantify the losses due to dextran in the milling operations, with the more important findings listed below.

- *Sucrose destruction* – approximately four parts of sucrose are consumed for every one part of dextran produced.
- *Sugar Recovery* – high levels of dextran decreases the overall recovery of the mill.
- *Factory throughput* – high dextran levels will adversely affect throughputs.

One of the major conclusions from the review done by Ravno and Purchase (2005) was:

“If there is anything to be learned from the experiences of others, it is that dextran should be kept out of the boiling house if at all possible. This will require a concerted and coordinated effort from growers, harvesters, hauliers and millers, but is essential, if the local industry is to arrest and control the rise of dextran”.

Unfortunately, the recommendation made by Ravno and Purchase (2005) was not taken seriously by the South African sugar industry. Although the South African Sugar Terminals (SAST) maximum specification for dextran is 150 mg/kg, for the 2017 season the average dextran value that was sent to the terminal by the industry was 219 mg/kg (minimum of 12 and maximum of 994 mg/kg). In terms of mass, 77% of the sugar was out of specification for dextran, of which 17% was greater than 500 mg/kg. In view of this, the SAST team (¹personal communication) are struggling to find financially attractive markets for this raw sugar.

Besides addressing the problem at source, some method of reducing dextran levels in the refinery have been cited in the literature. Carbonatation is the only refining process found to achieve significant dextran removal (Fowler, 1981b). The use of the enzyme dextranase is used in other sugar producing countries to reduce the dextran levels in raw sugar (Inkerman, 1980). The addition of the enzyme to juice breaks down the dextran into lower molecular fractions that are not troublesome in the factory (Morel du Boil and Wienese, 2002). Ravno and Purchase (2005) strongly recommended that the South African Sugar Industry establish the practicability of applying dextranase on a production scale.

As Hulref drew a significant mass of the high dextran raw sugar from the terminal to process, the processing problems experienced will be discussed in this paper.

Procedures

Laboratory work

Dextranase tests

Laboratory tests were conducted to evaluate the effect of enzyme dosage on melt. The tests were done at a temperature of 65°C, on melt (66 brix) with a reaction time of 30 minutes. Dextran was estimated using the Haze method.

Dextran balance

Weekly composited samples of the various streams were sent to the SMRI for dextran analysis. Results of three sets of samples were averaged and inputted into a refinery mass and brix balance.

Results and Discussion

The dextran levels in raw sugar

The average dextran level in the four THS raw sugar mills that were sent to the South African Sugar Terminals for the past 15 years is given in Figure 2.

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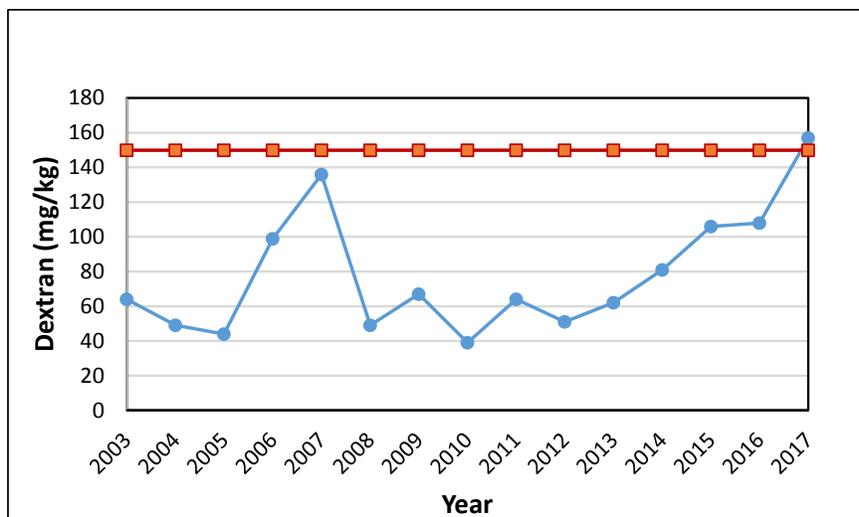


Figure 2. Tongaat Hulett Sugar mills dextran level for past fifteen years.

The following comments can be made from the results in Figure 2:

- There was a significant increase in dextran levels for the period 2005 to 2007. This was attributed to drought conditions.
- Since 2013 there was a steady increase in dextran levels, and in 2017 the refinery specification of 150 mg/kg brix was exceeded.

For the period from December to March, Hulref draws raw sugar from the terminal. The quality of the sugar that is stored there is of importance to Hulref. The dextran level of all raw sugar that was sent to the SAST for the past fifteen years is given in Figure 3.

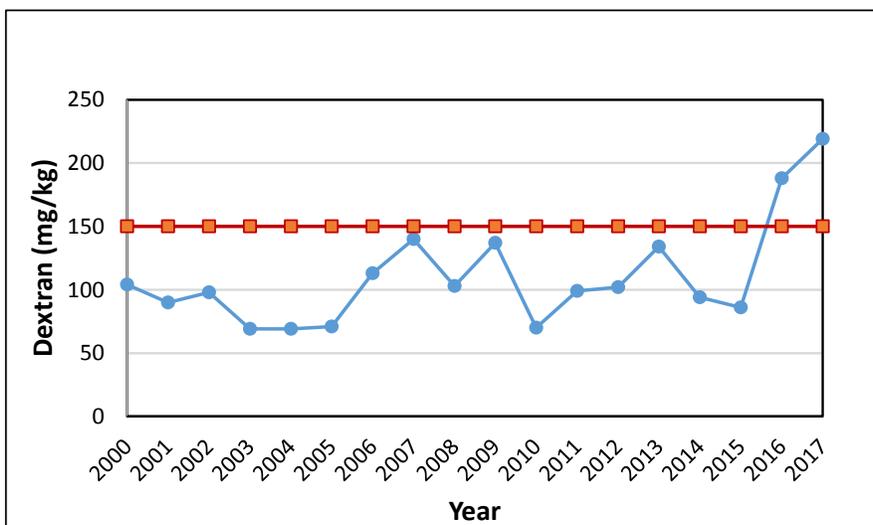


Figure 3. Dextran levels in all raw sugar sent to the terminal for the past fifteen years.

It can be seen that from 2015 the level of dextran in the raw sugar increased significantly. During the period November to March the refinery draws most of its raw sugar from the SAST.

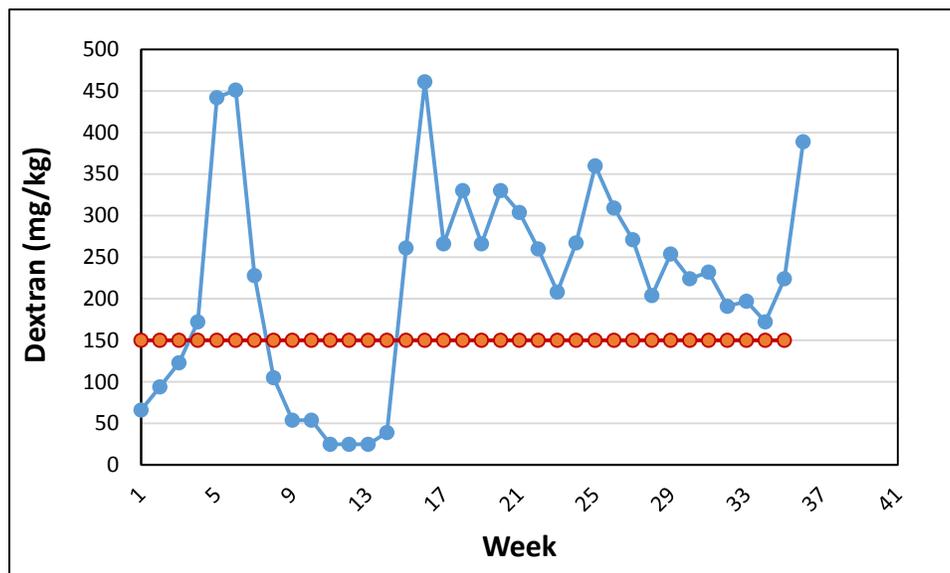


Figure 4. Dextran levels in raw drawn from SAST for 2017 season.

The following comments can be made from the results in Figure 4:

- For most of the weeks (except for 10 weeks; weeks 1 to 3 and weeks 9 to 14) the dextran levels were above the refinery specification.
- Some very high levels (>300 mg/kg) were recorded (weeks 5, 6, 16, 18, 20, 25 and 37).

The dextran and starch levels in raw sugar

The quality of the raw sugar from SAST in terms of starch, dextran and filterability is given in Table 1.

Table 1. Starch, dextran and filterability results in raw sugar from SAST for the 2017 season.

Month	Starch (mg/kg)	Dextran (mg/kg)	% Filterability
Mar-17	120	84	58
Apr-17	111	31	71
May-17	115	243	52
Jun-17	141	467	31
Nov-17	145	618	43
Dec-17	136	274	39
Jan-18	122	232	50
Feb-18	107	197	55
Mar-18	160	280	53

The following comments can be made from the results in Table 1:

- The starch values varied from 107 to 160 mg/kg. These levels are considered normal.
- Dextran levels varied from 31 to 618 mg/kg. The average (arithmetic) level of 270 mg/kg is considerably above the levels that the refinery normally processes.

Filterability is plotted against dextran concentrations in Figure 5.

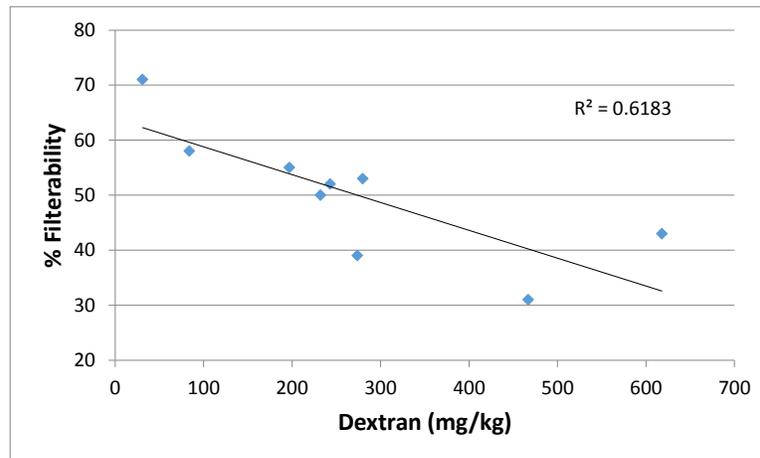


Figure 5. The effect of dextran on raw sugar filterability.

The results (Figure 5) show a reasonable correlation between dextran levels and the filterability of the raw sugar.

The effect of high dextran raw sugar on refinery operations

The following practical observations were made when the refinery was processing high dextran raw sugar (²personal communication).

Pan floor

- The first boiling pans which typically boil in 90 minutes had an average boiling time of about 120 minutes. This is approximately 33% longer which had a significant impact on the refinery throughput. Water was boiled in the pans more frequently as the steam flow worsened over time.

Centrifugal floor

- The grains felt 'soft' to the touch and were sticky at times. This made curing difficult. The centrifugal machines needed to be washed more frequently, i.e. every four or five batches compared to the norm of fifteen batches. There was an increase in the amount of vibration on the floor. The machine proxies and sensors as well as the holding down bolts had to be tightened more frequently. A visual look inside the basket showed that not all sugar was adhering to the sidewall (centripetal force) but to the main shaft in the centre of the basket – this was most unusual.

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Refined sugar driers

- The driers are typically washed every three months but these fouled at just over two months. The sugar also lacked sparkle. Although the grain size was met at most times, the sugar could be crushed by hand quite easily. The blowers struggled at times to pneumatically convey the sugar to the liquids plant.

Recovery house

- The overall pol purity profile in the recovery house increased.

Impact of high dextran on refined sugar quality

The refined sugar produced by Hulref has typical dextran values of <60 mg/kg. Weekly dextran results of both the raw sugar feeding the refinery and the refined sugar produced is given in Figure 6.

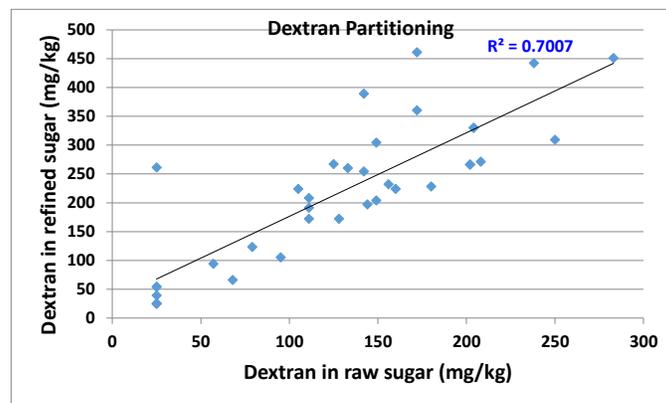


Figure: 6. Relationship between raw sugar and refined sugar dextran levels.

The results in Figure 6 show a strong correlation between the dextran level in raw sugar and the dextran level in refined sugar.

Dextran balance across the refinery

Various weekly samples were taken across the refining process and analysed for dextran. The main objective of this survey was to carry out a dextran balance across the refinery. The dextran results of the individual streams are given in Figure 7.

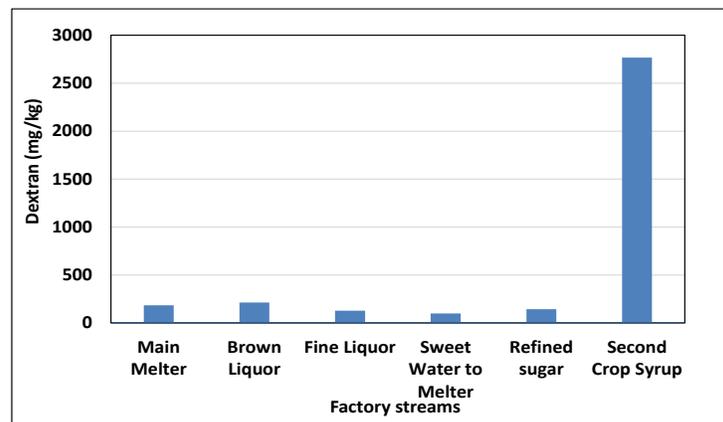


Figure: 7. Dextran levels in various refinery streams.

The dextran values from the individual streams (Figure 7) were inputted into a mass balance, and the following comments can be made from the mass balance:

- 75% of the dextran in raw sugar is transferred to refined sugar
- The balance of the dextran ends up in high test molasses (HTM).
- There was also a slight increase in dextran levels in the refinery.

More tests will be done in the 2018 refining season to verify the above observations.

Due to the serious adverse effects of high dextran on refinery operations and also on refined sugar quality, it was decided by the refinery team to investigate ways of reducing the level of dextran in the liquor feeding the crystallisation unit operation in the refinery.

Evaluation of methods to remove dextran

According to Fowler (1981b) carbonatation is the only refining process found to achieve significant dextran removal. The results of laboratory carbonatation tests (Figure 8) found this not to be true. In fact an increase in dextran levels was measured. No reason could be found for this and further laboratory work will have to be done to confirm this.

At Hulref, samples were taken from the carbonatation station and from the resin plant and analysed for dextran. The preliminary results showed that there was no change in the dextran levels across both the unit operations.

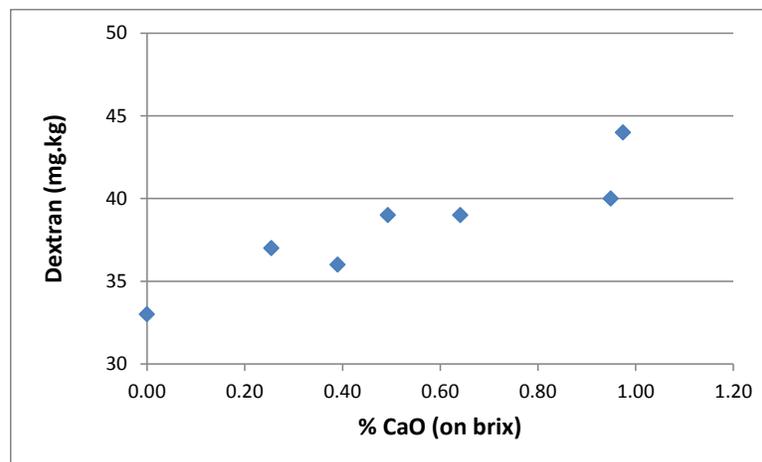


Figure 8. The effect of the quantity of CaO added on the level of dextran carbonated liquor (SternEnzymes, Germany).

Laboratory dextranase evaluations tests

A raw sugar sample with high dextran levels (725 mg/kg) was sent to SternEnzymes in Germany for laboratory evaluation tests with dextranase. The results from these tests are plotted in Figure 9.

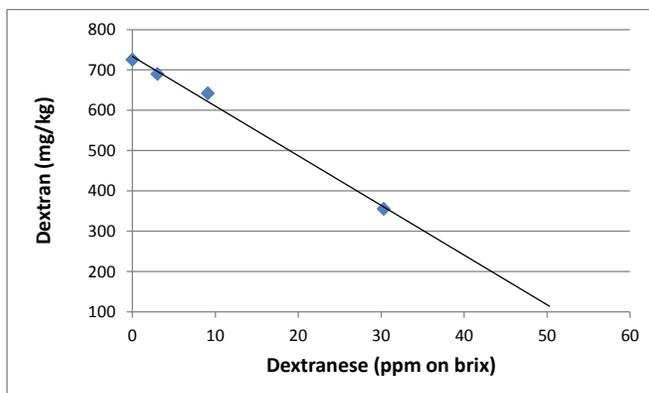


Figure: 9. The effect of the quantity of dextranase added on the level of dextran in melt (Hulref).

The results (Figure 9) showed that to reduce the level of dextran from 725 to 150 mg/kg about 50 mg/kg of dextranase was required. Further laboratory tests were done at Hulref. The results are plotted in Figure 10.

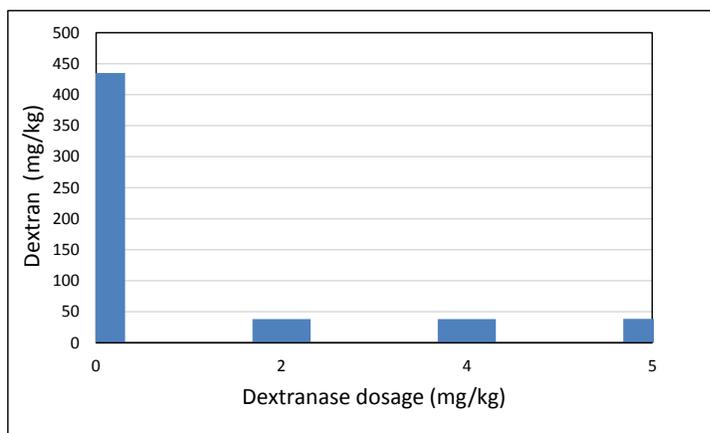


Figure 10. The effect of the quantity of dextranase added on the level of dextran in melt.

In this test, 2 mg/kg of dextranase reduced the dextran from 440 to 2 mg/kg. In view of the encouraging laboratory results a full scale trial is being planned for the 2018/2019 refining season. The cost of dosing dextranase to melt is given in Figure 11.

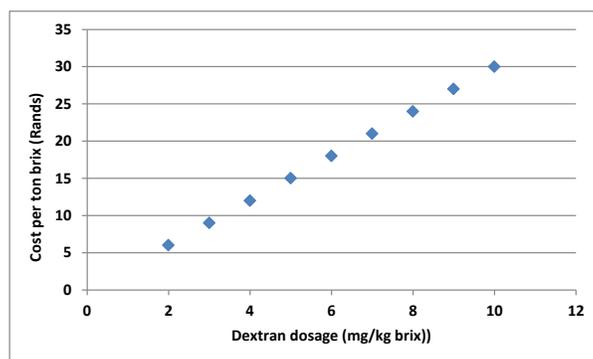


Figure: 11. The cost of dosing dextranase to melt.

To reduce the dextran levels to acceptable values in melt the cost would be between R6 and R10 per ton on brix. This is fairly expensive. In view of this, the use of dextranase can only be justified during periods of very high dextran levels in raw sugar.

Blending strategy

The other option Hulref can adopt to ensure that the raw sugar feeding the refinery has acceptable dextran values is a raw sugar blending strategy. During the season the refinery normally receives raw sugar from about six different sources (four THS mills, other millers and SAST). It has been observed that the quality of the raw sugar in terms of dextran levels can vary significantly between the different mills. In view of this, the raw sugar can be blended so the raw sugar feeding the refinery has acceptable dextran levels. This is shown in Figure 12.

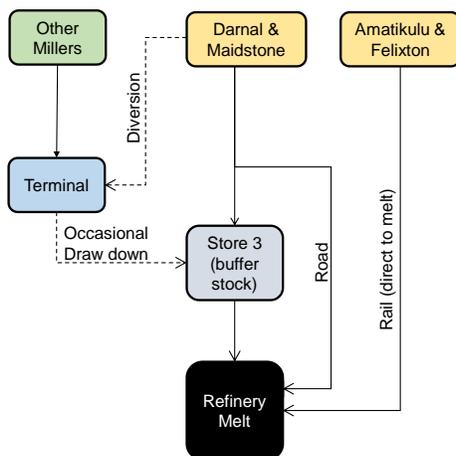


Figure: 12. Hulref season blending strategies.

During the period December to March the main supplier of raw sugar to Hulref is the SAST. This strategy is shown in Figure 13.

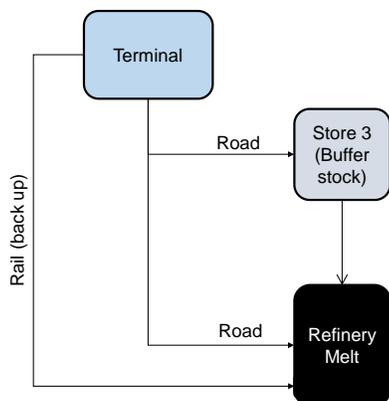


Figure 13. Hulref off-crop blending strategy.

A blending strategy can again be used to bring down the level of dextran in the raw sugar feeding the refinery.

The adverse effects of processing high dextran raw sugar at Hulref have been well documented in this paper. High dextran raw sugar caused a significant decrease in the refinery throughput which has a major negative financial impact on the refinery. In view of this the recommendation that dextran is included in the SAST penalty bonus system made by Ravno and Purchase (2005) is supported.

Conclusions

The following conclusions can be made from the investigations carried out by the refinery on dextran and its effect on the refinery unit operations refinery:

- From 2013 the dextran levels in the raw sugar entering the refinery has been increasing.
- Dextran decreases the filterability of the raw sugar
- Both carbonatation and ion-exchange do not remove dextran
- High levels of dextran (>150 mg/kg) has adverse effects on most of the unit operations in the refinery.
- The blending of raw sugar from the different sources can be used to lower the dextran levels in the raw sugar feeding the refinery.
- Laboratory tests have shown that the addition of dextranase can significantly reduce the dextran levels in melt.

In view of the encouraging results from the laboratory work with dextranase, a full-scale trial will be planned for the coming refining season.

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