

REVIEW OF PROVEN TECHNOLOGIES AVAILABLE FOR THE REDUCTION OF RAW SUGAR COLOUR

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Abstract

Colour removal is the chief cost centre of sugar refineries, hence, by reducing the colour of the raw sugar to be processed, the level of processing and costs incurred by a refinery are also reduced. A lower colour raw sugar is thus highly marketable.

There are a number of proven technologies that can be applied in raw sugar mills to control and reduce raw sugar colour. These mechanisms are reviewed in order to identify effective and economically viable means of reducing the colour of South African raw sugars to a reasonable level, ca 1 000 ICUMSA units.

The technologies include:

- syrup flotation clarification
- juice and syrup sulphitation
- alternative boiling schemes
- double curing of C-massecurites
- additional washing in centrifugals
- the use of specialised chemicals and flocculants during clarification
- hydrogen peroxide in wash water during centrifugation.

Keywords: colour, raw sugar colour, colour removal, sulphitation, syrup clarification, hydrogen peroxide

Introduction

Producing low colour raw sugar is a common goal of most sugar mills, and many refiners are now specifically seeking to buy lower colour raw sugar. There are a number of proven technologies that can be used in raw sugar mills to control and reduce the raw sugar colour, and these technologies are reviewed. Technologies such as membrane filtration and ion exchange will not be considered, as they are most effective when seeking to achieve very low colours, such as for mill white or refined sugars, and are generally expensive.

Basic approach to sugar colour

Jullienne (1989) reported that the raw sugar manufactured by the partial remelt system consists of:

- the B-sugar nucleus (colour contribution of 5-10%)
- the A-crystal around the nucleus (approximately 45% of the colour)
- the A-molasses film adhering to the crystal (approximately 45% of the colour).

In reducing the colour of the raw sugar, the following approaches or combinations thereof can be used:

- Elimination of the B-nucleus from the A-crystal.
- Improvement in the quality of the medium from which the sugar is recovered. This would improve the colour of the crystal and the molasses film around it.
- Improvement in crystallisation technique and hence reduction in crystal colour.
- Removal of the maximum amount of molasses from around the sugar crystal and/or the replacement of the film by one of a lower colour.

Syrup flotation clarification

Syrup clarifiers are of necessity flotation clarifiers rather than settling clarifiers, because of the high density and viscosity of syrup (Rein *et al.*, 1987). Worldwide, flotation clarifiers are becoming a more popular means of improving syrup and raw sugar quality and, although originally used at mills where poor quality cane was received, their use has subsequently been extended to meet the following needs:

- Reduction of insoluble matter in direct consumption raw sugars.
- Further reduction of very high pol (VHP) sugar colour.
- Low cost purification of melt in a back-end refinery (Smith *et al.*, 2000).

In this process, residual suspended solids are floated to the surface of the clarifier by fine air bubbles (Figure 1), and are removed as a scum which is traditionally returned to the mixed juice tank. The treated syrup is drawn from the bottom of the clarifier. The use of anionic flocculants is essential, with an optimal dosage rate of 15 mg/kg dry solids (DS). With very poor quality syrup, higher dosage rates are required for best results (Rein, 2007). The dosage rates, however, should not be so high as to compromise sugar quality or the performance of processes downstream from its application.

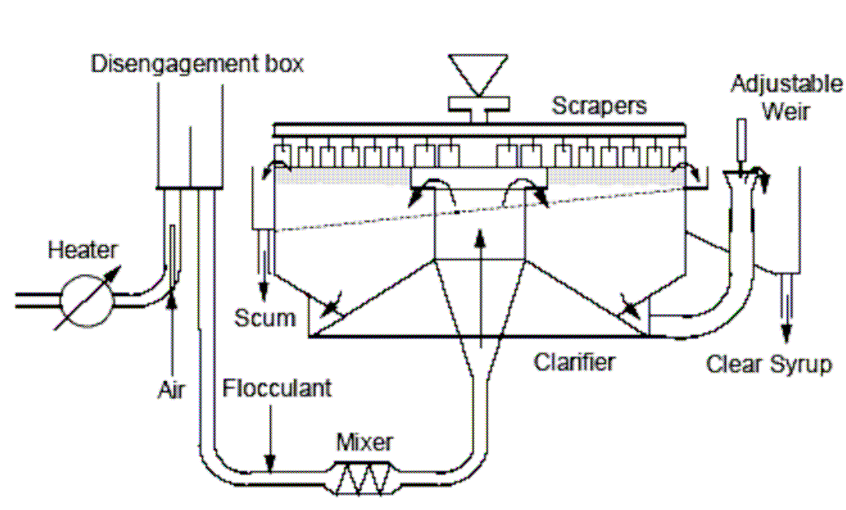


Figure 1. Typical flotation clarifier vessel (Smith *et al.*, 2000).

The major benefits obtainable from syrup clarification are improvements in syrup quality, with the turbidity of treated syrup decreasing by 80-95% and a reduction in massecuite viscosities, with the viscosity of final molasses boiled from treated syrup decreasing by as much as 25% (Rein, 2007). Colour removal may be enhanced when syrup clarification is

augmented with colour precipitants, sulphitation or phosphatation to achieve particular sugar quality criteria (Table 1).

The original Tate and Lyle patent required the primary flocculation of calcium phosphate. There are, however, unverified claims from sugar mills that the addition of lime and phosphate do not further improve clarification as compared to the process of adding only an anionic flocculant (Steindl and Doherty, 2005).

The colour removal across syrup clarifiers has been reported to be in the range of 5-10% (Rein *et al.*, 1987; Steindl and Doherty, 2005). Laboratory sulphitation of the syrup indicated that the syrup colour could be reduced by 20-25% as opposed to 7% without sulphitation (Rein, 2007). Full-scale trials using 2 000 mg sulphur dioxide/kg solids resulted in a 15% syrup colour reduction. The sugar colour, however, was reduced by 24%, suggesting that additional downstream benefits of syrup clarification are available (Smith *et al.*, 2000).

Table 1. Simple flotation vs sulflotation (Smith *et al.*, 2000).

Analyses	Simple flotation	Sulflotation
Sulphur dioxide on brix (%)	0	0.2
Feed syrup colour (ICUMSA)	24 700	23 300
Treated syrup colour (ICUMSA)	22 900	19 900
Colour reduction (%)	7	15
Turbidity reduction (%)	77	77
Sugar colour (ICUMSA)	1 210	920

Laboratory testing of syrup sulphitation in combination with syrup clarification (Getaz and Bachan, 1989) showed up to 30% colour removal, but at a high sulphur dioxide dosage rate (Figure 2).

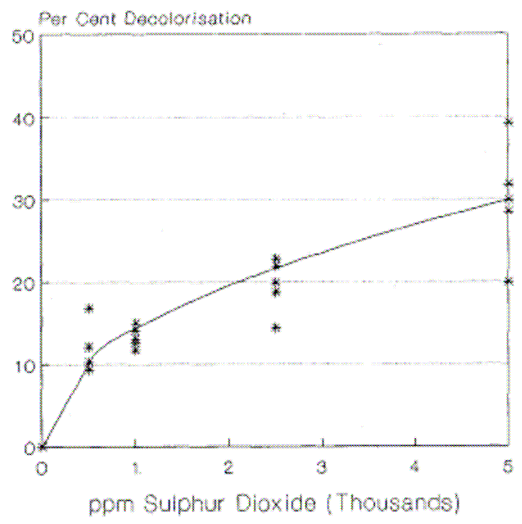


Figure 2. Laboratory testing of sulflotation of syrup (Getaz and Bachan, 1989).

It is evident from the literature survey that the conditions for flotation clarification need to be optimised for individual applications. There appears to be a wide range of turbidity and colour removal efficiencies that can be achieved.

Raw sugar factories in India that utilise phosphoflotation (lime, phosphoric acid and flotation flocculant) aided by a colour precipitant, claim colour removals of 25% with a boiling scheme where C-sugar is double cured and melted into syrup. The treated syrup is then sulphited. A further 8% colour is removed, but turbidity is increased. For a 5 000 ton cane/day factory, the syrup clarifier and peripherals, including automation, would cost approximately US \$150 000, excluding civil and structural expenditure. The cost of the chemicals is around US \$0.95 per ton of sugar produced (personal communication¹).

For 850 ICUMSA colour sugar to be produced by means of a colour balance, a typical syrup colour of 24 000 ICUMSA would have to be reduced to 15 600 ICUMSA to arrive at the required sugar colour (personal communication²). Syrup phosphatation clarification was recommended as the preferred colour removal mechanism, with the use of cationic colour precipitants as necessary. It was estimated that a syrup clarifier would cost about R4 million to install in 2003. Cake losses were expected to increase because of the recycling of clarifier scums. These losses would reduce the overall recovery by about 0.1%.

Juice and syrup sulphitation

Sulphur dioxide is commonly used as a decolourising agent, and is applied in gaseous or liquid state, with the former being preferred. It is commercially obtainable as a liquefied gas (R35/kg), and can be produced in-house from the combustion of sulphur. Not only does the sulphur dioxide aid in colour removal, it also prevents colour from being formed at a later stage (Getaz and Bachan, 1989).

Standard juice sulphitation processes

(a) Cold sulphitation

Mixed juice is sulphited to a pH of 3.8 and then limed to a pH of 7.0 before being heated to above its boiling point, flashed and clarified (Hugot, 1972). A variation of cold liming is to first lime the mixed juice (Mkhize and Davis, 2004), in which case about twice the quantity of milk of lime used for defecation is added to the mixed juice. Sulphitation, heating and clarification by subsidation then follows.

Cold sulphitation produces a calcium sulphite salt which fouls the tubes of the heaters following sulphitation, as the salt is more soluble cold than hot (minimum solubility occurring around 75°C). It is for this reason that hot sulphitation is preferred.

(b) Hot sulphitation

The drawback of cold sulphitation is avoided by modifying the standard sulphitation procedure. Typically, the mixed juice is heated to 70-80°C, followed by sulphitation, heating to boiling point and clarification. Hot sulphitation appreciably reduces the quantities of lime and sulphur dioxide required. A disadvantage is that the absorption efficiency of the sulphur dioxide is reduced.

The Java procedure (Perk, 1951) is widely recognised to be the best method for hot sulphitation from the point of view of colour and colloid elimination. Hugot (1972) reports the Java procedure to include heating of the mixed juice to 50°C, liming, sulphitation to a pH of 7.2, reheating to boiling point and then clarification. Perk (1951) reports that this practice is required to force the pH of the juice to follow a certain curve,

¹S Singhal, Chemical Systems, India (2007).

²K Koster, unpublished report (2003).

the course of which is prescribed by the properties of the juice. The process can be either continuous, or executed in an intermittent form. In both cases, the sulphur dioxide and lime (either milk of lime or lime saccharate) are added simultaneously to the juice.

(c) Fractional liming and sulphitation

The hot sulphitation process can be used with success in the clarification of refractory juices. However, better results are sometimes obtained with a modification to the procedure as developed in India (Hugot, 1972).

The mixed juice is pre-limed to a pH of 8. It is then heated to 50 or 70°C. A pH of 5.1 to 5.3 is targeted during the juice sulphiting process. Liming again takes place, in this instance to a pH of 7.0 to 7.2, after which the juice is heated and clarified.

In such modifications, a consideration is whether to utilise sulphitation before or after liming. The rapidity of settling and the volume of the mud depend on the reaction medium. When formed in an alkaline medium, the mud will be hydrated, hence an increase in the mud volume. When formed in an acid medium, the speed of settling will be greater and the mud will be more compact. In general, liming after sulphitation is preferable, particularly when processing immature cane. However, with contradictory points of view having been expressed on this subject, it is probable that the results obtained will alter according to circumstances, and it is best to try both methods (Hugot, 1972).

The Puna Sugar Company reported 25% less syrup and raw sugar colours with full scale juice sulphitation (Onna and Sloane, 1977). This was achieved with a 300 ppm sulphur dioxide dosage and a two step liming process that was later changed to one step (Francisco, 1978), i.e. liming to a pH of 9.5 just before sulphiting to a pH of 7.4. Reduced molasses purities and increased sugar recoveries were also reported. Following the work done at the mill, the Pioneer Milling Company also started full scale juice sulphitation. At a sulphur dioxide dosage of 150 ppm, the raw sugar colour was reduced by approximately 9% (Takenouchi, 1978).

The advantages of sulphitation are:

- Mud settles more rapidly
- Less viscous massecuites
- Marked reduction in colour
- Slight gain in the capacity of centrifugals
- Better elimination of phosphates and waxes, leading to better refining quality and filterability of the sugar produced.

The disadvantages of sulphitation are:

- Heavier fouling of heating surfaces
- Higher ash content of the sugar obtained; residual sulphur in the sugar is increased
- Increased costs.

Syrup sulphitation

A second sulphitation of the syrup ensures a low colour sugar. This is usually practised on the syrup from the final effect evaporator. In Hawaii, the syrup from the third effect was treated. Lime and sulphur dioxide were added simultaneously to a pH of 7.0. The quantity of lime was

typically 1.6 to 2.0 kg/ton cane, and the quantity of sulphur about 1.4 to 1.8 kg/ton cane. The syrup was treated in Vallez filters and the cakes obtained sent to the Oliver filters used in clarification. The pH entering the final effect was 7.1 (Hugot, 1972).

The processes for syrup sulphitation vary but generally involve heating, sulphiting and filtering. One such variation (Deerr, 1921) recommends the addition of milk of lime (2.0-2.5% on weight of syrup or 0.3-0.4% of quicklime). Sulphitation to a pH of 7.0 follows immediately. The precipitate is then filtered off and the juice re-sulphited to a slight acidity. In India (Hugot, 1972), the syrup is maintained between a pH of 5.5 and 6.0 and consumes only 0.11-0.18 kg of sulphur/ton of cane.

Getaz and Bachan (1989) indicate that mixed juice sulphitation, particularly at higher sulphur dioxide dosages, achieves better decolourisation than syrup sulphitation. The quantity of sulphur consumed depends on the type of clarification procedure adopted, the degree of colour removal to be achieved, the final acidity sought and the quantity of lime used in defecation. When sulphitation of juices is practised, the sulphur consumption is in the region of 0.25 to 0.5 kg/ton cane. If double sulphitation is used, i.e. sulphitation of the juice and of the syrup, then the sulphur usage can increase to 0.9 kg/ton cane (Rein, 2007).

Alternative boiling schemes

The recovery of sucrose by crystallisation may be achieved by a variety of pan boiling schemes. It is the purity of the syrup and the quality of the sugar to be produced that dictates the scheme best suited for this function. The most common crystallisation schemes used to produce raw sugar are:

- the two-boiling scheme
- the three-boiling scheme
- the double Einwurf scheme
- the VHP scheme.

Of these schemes, it is the VHP pan boiling procedure (see Figure 3) that yields the lowest sugar colour. The VHP sugar has a pol of 99.3-99.5°Z. B-sugar is used as a seed to boil the A-massecuite from which the VHP sugar is obtained. Slurry is added to the A-molasses from which a B-massecuite is boiled, producing B-sugar and B-molasses. A mixture of A-molasses and B-molasses is seeded with slurry and a C-massecuite is boiled from this. The final molasses and C-sugar are produced from this last stage of boiling. All of the C-sugar, and that fraction of the B-sugar not used to seed the A-massecuite, are remelted (dissolved in water or clarified juice) and recycled to syrup.

Modified boiling scheme

A variation of the VHP scheme described by de Robillard and van Hengel (1984) was implemented during a period of abnormal cane quality at the Illovo sugar mill and was found to significantly improve sugar quality. The A-massecuite and C-massecuite were grained, while the C-magma and A-molasses were used to boil the B-massecuite with the entire crop of B-massecuite being remelted into syrup (Figure 3).

Of the improvements noted, the most significant was that of the reduction of the wash water used in the A-centrifugals. Despite progressively reducing the wash from 37 to 12 seconds, an improvement in the sugar purity and colour was still noted (Table 2) with no disadvantages reported. It is likely, however, that the process consumes more energy. The influence of the

modified boiling scheme on boiling house recovery (BHR) was not evaluated. The BHR was reduced during the period of the trial but cannot be attributed solely to the boiling system used, as the mixed juice purities during this time were substantially lower than before the trial was performed.

Reduction in crystal size

A reduction in crystal size has a positive effect on crystal colour (Mann, 1987). With a crystal size consistent with the minimum specified, a reduction of 10% is likely in the crystal colour. The quality of the molasses film around the crystal is nevertheless unchanged, so the colour decrease in the raw sugar is limited to about 5%. This technique has the advantage of requiring a change in only the process control of the factory, and can be combined with other decolourising mechanisms to give a larger colour reduction.

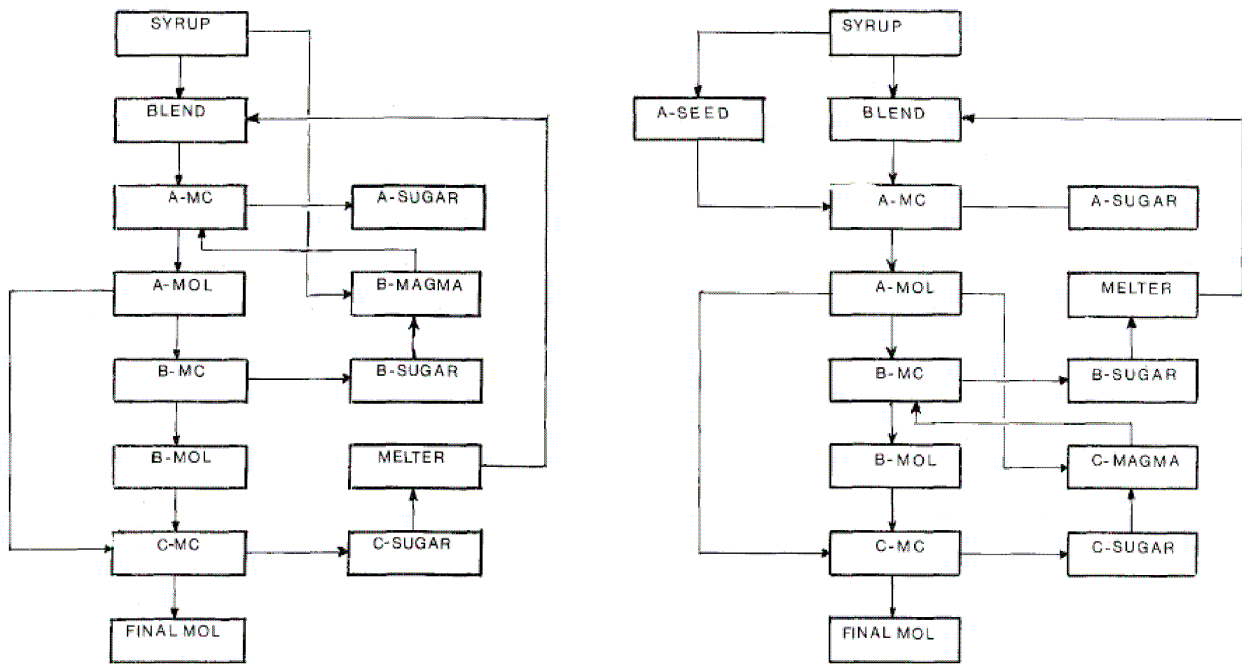


Figure 3. Very high pol (VHP) boiling scheme (left) and modified boiling system (right).

It should be noted, however, that whilst the quality of the molasses surrounding the sugar crystal is unchanged with the reduction in the crystal size, the quantity increases because the crystal surface area is increased. More wash water in centrifugals may be necessary, as the centrifuging of small crystals is generally more difficult. This would result in an increased recycle of sucrose.

Table 2. Comparative data between very high pol (VHP) and modified boiling system.

Product	Analysis	VHP scheme	Modified scheme	Significant at 5%
Raw sugar	Colour (ICUMSA)	1 871	1 575	Yes
	Purity (%)	99.45	99.54	
	Pol	99.29	99.40	
Affined sugar	Colour (ICUMSA)	1 233	1 015	No
Syrup	Colour (ICUMSA)	26 373	29 080	
Remelt	Colour (ICUMSA)	38 012	31 634	Yes
B-Sugar	Purity (%)	91.55	92.06	

Double curing of C-massecuites

Double curing of C-massecuites reduces the amount of final molasses being returned to syrup, thereby improving the quality of the medium from which the sugar is crystallised. Typically, about 15% of the final molasses is returned, but this recycle is limited to about 5% or less with double curing (Julienne, 1989).

Double curing is practised by first purging in a battery of centrifugals without any wash. The sugar is discharged into a mingler below the centrifugals and is mixed with either a higher purity molasses or syrup, or clarified juice or water. This mixture is then purged in a second battery of centrifugals with water and steam. In double curing C-massecuites, the C-sugar obtained from the first set of centrifugals is re-mixed into a massecuite with B-molasses (70 brix and 70°C). The C-sugar from the second set of centrifugals is mixed to a magma with syrup. The syrup obtained from the second set of centrifugals is returned to C-massecuite. This procedure is illustrated in Figure 4 (Julienne, 1989).

Both the operating and capital expenditure for double curing of massecuites are considerably higher than for conventional single centrifugation. Its usage can therefore be justified only where it significantly improves sugar quality or recovery.

Darnall, the last factory in South Africa to practise double curing of C-massecuite, reported the following in favour of the process:

- It was easier to meet raw sugar specifications with double curing of the C-massecuite. Shorter wash times and spin cycles resulted at the A-centrifugals.
- When single curing, a higher steam temperature was required.
- There was a slight reduction in sugar colour.

A disadvantage noted was that the back-end of the factory filled when double curing.

Lamusse (1986) compared single and double curing at the Darnall mill in the 1985-1986 season and concluded that tests on these purging methods showed no significant difference in boiling house recovery or sugar quality. Julienne (1989) reported a reduction in pan feed colour of about 10% (Table 3) and in A-sugar colour of 10-15% with double curing.

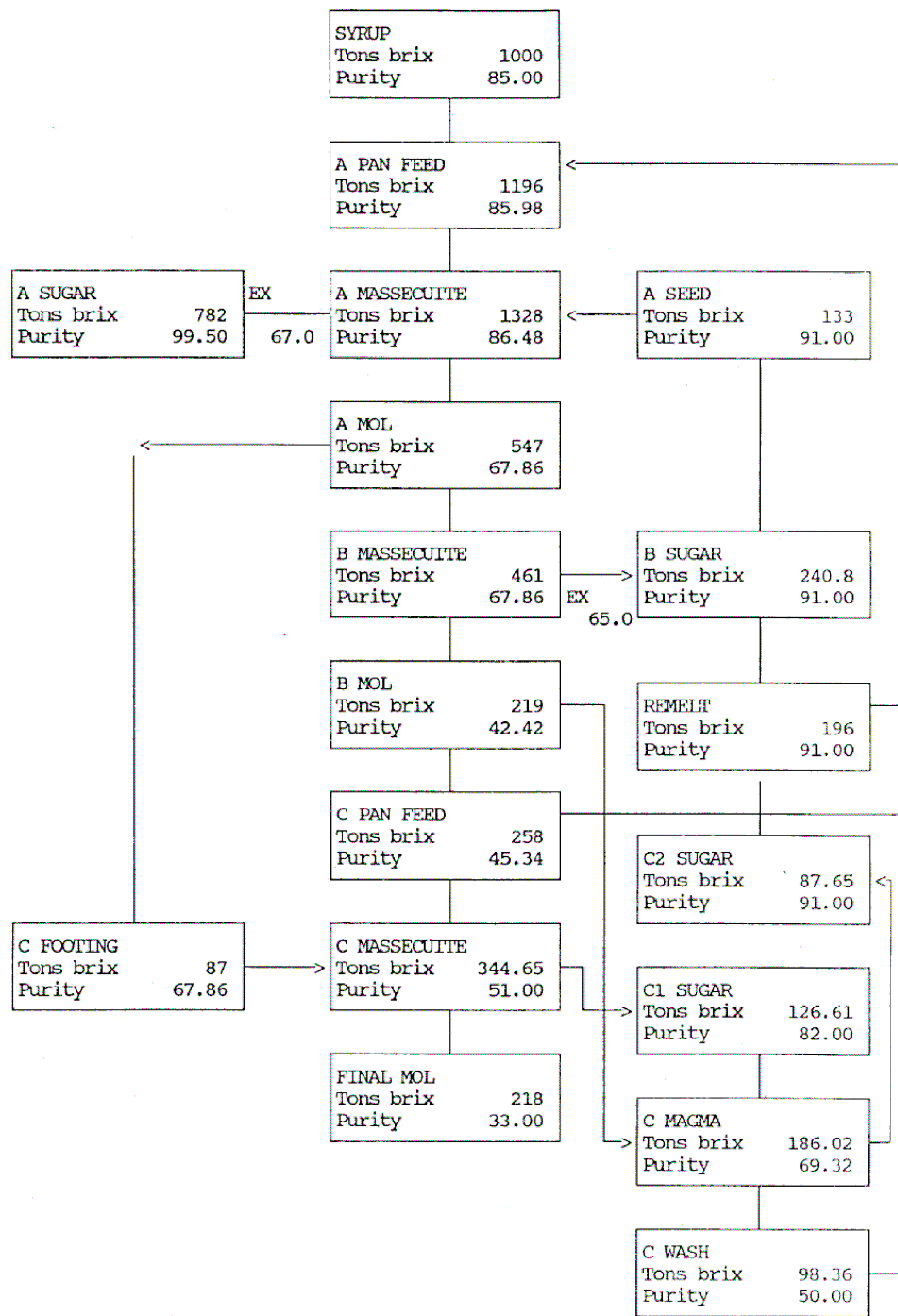


Figure 4. Partial remelt system with double curing of C-massecuite (Julienne, 1989).

Table 3. Colour and purity data for single and double curing schemes (Julienne, 1989).

Analysis	Single curing	Double curing
Syrup colour (ICUMSA)	25 000	25 000
B-sugar colour (ICUMSA)	20 000	20 000
C1-sugar purity (%)	82	82
C1-sugar colour (ICUMSA)	44 000	44 000
C2-sugar purity (%)	–	91
C2-sugar colour (ICUMSA)	–	20 000
A-Pan feed colour (ICUMSA)	26 150	23 750

Additional washing in centrifugals

A condensate wash is usually applied to the massecuite being purged in the A-centrifugals. This wash water aids in the separation of the mother liquor in the massecuite from the sugar crystal. By increasing the wash, a lower sugar colour can be achieved, as a greater proportion of the high colour molasses film surrounding the sugar crystal is removed. The extent of colour removal by increasing the centrifugal wash durations was investigated by Barker (2003) in the Sugar Milling Research Institute (SMRI) laboratory. It was found that, whilst the additional washing aids in reducing the colour of the sugar (Figure 5), a large degree of sugar loss by dissolution occurs (Figure 6), thereby reducing the A-exhaustion.

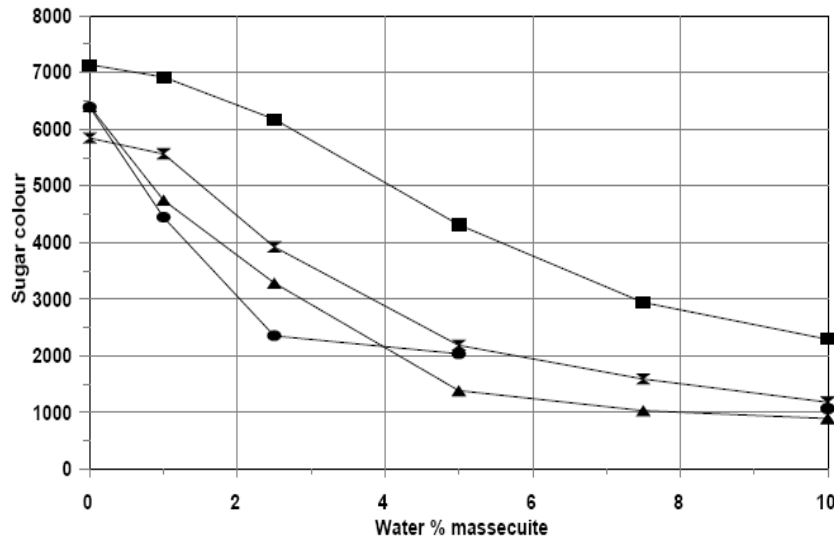


Figure 5. The decrease in sugar colour with increased washing in the Sugar Milling Research Institute laboratory centrifugal (Barker, 2003).

The amount of sugar dissolution shows fairly linear trends and is estimated at approximately 1.5% of the sugar lost for every 1% increase in the wash water. Barker (2003) reported no improvement in sugar quality from extending the purging time for massecuite.

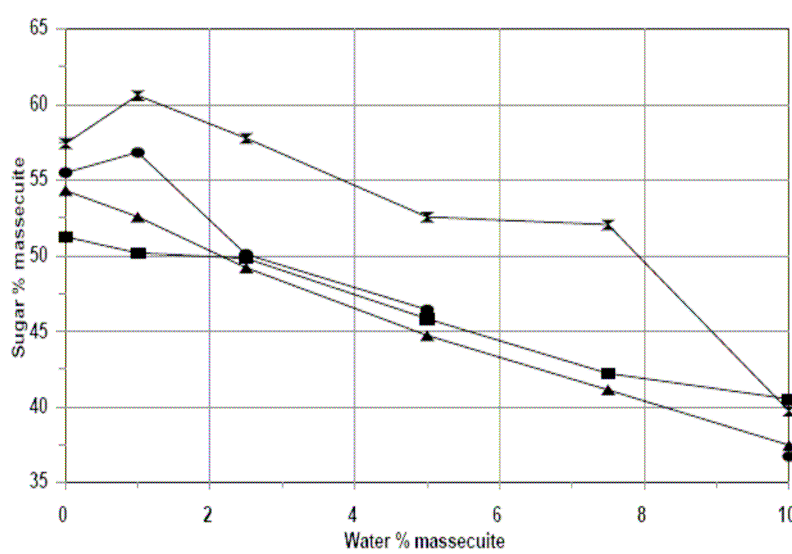


Figure 6. Amount of crystal dissolution with increased washing in the Sugar Milling Research Institute laboratory centrifugal (Barker, 2003).

Whilst these tests were conducted on mill massecuite samples, they were not tested at the mills under mill operating conditions. No records of such mill testing were found.

A model was developed by Koster (2003) to predict the effect of increased washing of VHP sugar in the A-centrifugals on a sugar factory's profit margin. It was estimated that any South African factory with an evaporator syrup colour of approximately 24 000 ICUMSA units, and making 1 350 ICUMSA colour VHP sugar at 99.3 pol, could make 850 ICUMSA colour sugar by increasing the wash in the centrifugals. Six South African mills were found to have suited this profile.

It was also reported that the water usage would be typically around 2% on massecuite. The additional water would incur an A exhaustion penalty of three units and would push up sugar pol of the dried sugar to 99.54%. The higher purity sugar and the lower exhaustion would reduce overall recovery by 0.23%, costing 498 tons of 99.3 pol VHP sugar over a 100 000 ton production run. A further cost, which would be applicable to coal burning factories, is an additional 1 494 tons of coal. A small gain in molasses revenue would be obtained in making the higher pol sugar.

Specialised chemicals and flocculants during clarification

Investigations into the use of chemical agents as clarification and decolourising aids in order to produce a lower raw sugar colour is ongoing, with the development of new products and the improvement of those currently in use. A brief report is given on the usage of bentonite, hydrogen peroxide, ozone, Multifloc®, polyaluminium chloride and some sulphurous acid salts, *viz.* sodium sulphite, sodium bisulphite, sodium hydrosulphite and sodium hypochlorite.

Bentonite

Clay has been widely used in the history of sugar manufacture as an auxiliary defecant in clarification. Bentonite, a special technical clay, was found to remove 10-15% of the turbidity from clear juice when used as an aid in mixed juice clarification at a dosage of 0.2% (Getaz and Bachan, 1989). At a cost of R0.70 per ton cane (or about R2 present value), its use was not economically promising. At a cost of R1.10 per ton sugar (or about R3.14 present value), its use was also not justifiable as an aid in syrup clarification, only removing a further 2-4% turbidity.

In 2006, two samples of activated clay were tested by the SMRI to determine their effect on colour during clarification. Colour removal of 21% from mill juice and 14% from diffuser juice were achieved with one sample, compared to 19% and 7% respectively, using another sample. The clays increased the mud levels in the diffuser juice only (from 2% to 9%). It was concluded that, at these levels of colour reduction, the cost of the clays would dictate whether further trials would be justified. Estimated costs of delivered clay were R3 700 per ton for the imported clay and R2 350 per ton for the SA clay (dosing rate: 0.2% m/v juice – of the order of R80 and R50 per ton of raw sugar, respectively).

Hydrogen peroxide

The decolourising effect of hydrogen peroxide is reported to be more effective than that of sulphur dioxide. At a cost of 60 times that of sulphur dioxide though, its usage is limited (Getaz, 1989). Patel and Moodley (1991) conducted some preliminary experiments on the use of hydrogen peroxide on syrup. The results are given in Table 4. The low decolourisation achieved at higher dosages suggests that the use of hydrogen peroxide addition to syrup in the rawhouse is not economically viable.

Table 4. Decolourisation of syrup with hydrogen peroxide and hydrogen peroxide + air blowing with no pH control at 50°C (Patel and Moodley, 1991).

ppm H ₂ O ₂ on syrup	H ₂ O ₂		H ₂ O ₂ + air blowing	
	% decolourisation	Final pH	% decolourisation	Final pH
250	+2*	6.4	+3*	6.5
500	+3*	6.1	11	6.4
1 000	5	6.0	8	6.2
1 500	8	5.8	13	5.8
2 500	11	5.6	–	–
5 000	14	5.4	–	–
7 500	16	5.2	–	–

*denotes an increase in colour

Ozone

On an industrial scale, ozone is produced by passing very dry atmospheric air or oxygen through a high voltage electric discharge. It is a powerful oxidising agent and its use is growing rapidly, particularly in water treatment plants, where it is used as an alternative to chlorine.

Figure 7 shows a schematic diagram of a typical production plant. The ozone generator is built close to the point of application because bulk production and transport of the ozone is difficult owing to the rapid chemical reversion of ozone to oxygen. The cost of ozone production can be measured in terms of power consumption (20-24 W.h/g).

The decolourisation achieved with ozonation of clear juice and syrup at 32, 43 and 68 brix, at a pH of 7, is given in Table 5 (Patel and Moodley, 1991). Further experiments showed that during ozonation of the 43 and 68 brix syrups, there is a drop in purity of 2.4 and 0.7% respectively. It is likely that the purity drop will increase, the more dilute the sucrose solution and the greater the exposure to the ozone. More tests are required to determine the optimal pH at which to dose the ozone.

Davis (1995) reports colour removal of up to 69% on mixed juice and 72% on syrup with ozonation. This was achieved, however, with high ozone dosage rates (4900 ppm on brix for syrup, with 72% colour removal and 12 500 ppm on brix for mixed juice for 60% decolourisation). He concluded that these ozone dosages were too high to be economically justifiable.

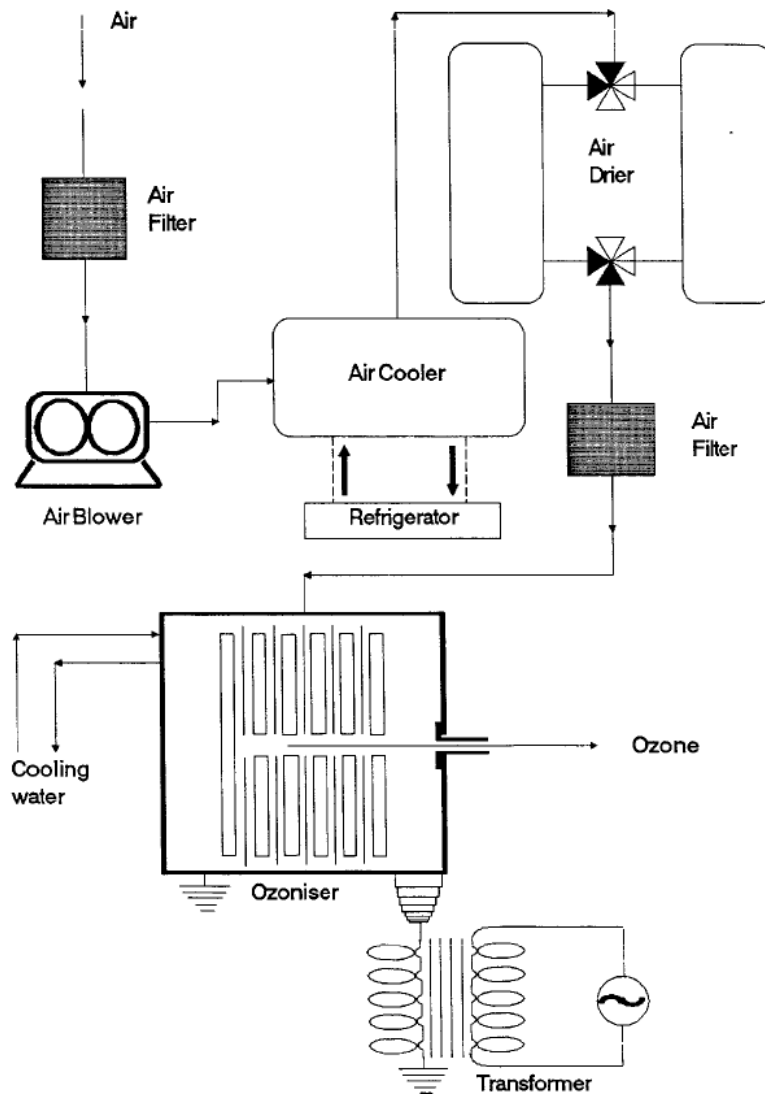


Figure 7. A typical ozone production plant (Getaz, 1989)

At present the implementation of ozone technology appears unattractive, due to the large capital expenditure required (Gomez *et al.*, 1980). Patel and Moodley (1991) report the cost of a 20 kg/h ozone plant as R6 122 899 in 1990 (approximately R17 476 548 present value).

Table 5. Percentage decolourisation achieved with ozonation with pH control (Patel and Moodley, 1991).

Ozonation time (min)	Clear juice 12 brix	Syrup 32 brix	Syrup 43 brix	Syrup 68 brix
10	42	10	9	5
20	63	30	19	17
30	76	48	36	25
40	77	65	49	41
50	88	73	57	52
60	90	85	71	64

Sulphurous acid salts

Sodium hydrosulphite (SHS), sodium bisulphite and sodium sulphite were tested on a laboratory scale to measure the decolourisation that can be achieved when applied to factory products (Getaz and Bachan, 1989). The results obtained are shown in Figure 8.

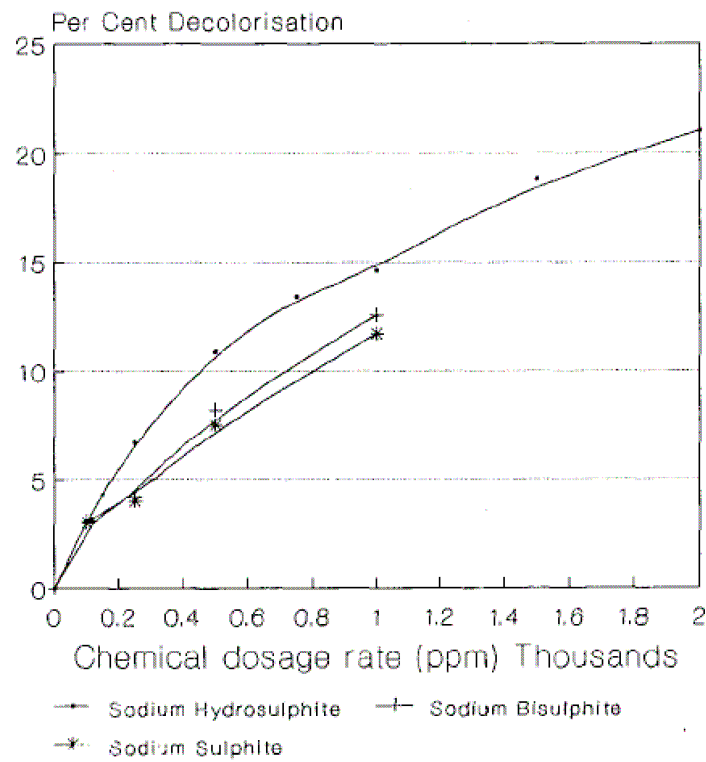


Figure 8. Results of laboratory decolourising tests using various sulphurous acid salts (Getaz and Bachan, 1989).

Factory trials were performed at the Umzimkulu mill to determine the decolourising ability of SHS on remelt. At a dosage of 500 ppm SHS on remelt (cost of R0.60 per ton of sugar in 1989 or R1.71 present value), the colour removal achieved was small and not significant.

SHS was also dosed into vacuum pans at the Sezela and Umzimkulu mills (Getaz and Bachan, 1989). The results are shown in Table 6. As with the remelt, the colour differences in using SHS in the pans were small, generally being within analytical error.

Table 6. Effect of sodium hydrosulphite on A-massecurite boiling colours (Getaz and Bachan, 1989).

Product	Colour without SHS (ICUMSA)	Colour with SHS (ICUMSA)	Difference (%)
Footing	19 522	19 223	1.5
Pan feed	21 243	19 892	6.4
Massecurite at strike	21 762	19 365	11.0
Affinated sugar at strike	427	407	4.6
Nutsch molasses	47 147	43 681	7.4

Multifloc

Multifloc® is a clarifying agent marketed by AEB Africa, that consists of a mixture of bentonite, activated carbon and polyacrylamide flocculant. It is claimed to improve clarification and reduce juice colour and turbidity with a recommended dosage of 5-50 ppm on juice. The product has been tested at two South African mills and one Malawian mill. Each of these mills have reported good results and lower costs, with a 15-20% reduction in colour (from mixed juice to clear juice) achieved in the factory in one of the South African mills and a 15-35% reduction in colour in the Malawian mill.

Polyaluminium chloride

Polyaluminium chloride (PAC) solutions have long been used in water treatment for clarification purposes, and their use has been tested at high levels (400 to 1 000 ppm) in India and Brazil for the production of direct consumption white sugar (mill white). Godshall (2006) reported a factory trial in the USA at the end of the 2005 season, dosing at a rate of 90 ppm on brix into mixed juice. An improvement in colour reduction of 19% was reported, with a small decrease in ash and turbidity. The SMRI is currently conducting laboratory trials on the effect of PAC on South African juices.

Tannin-based flocculants

Flocculants made from extracts of wattle tree bark have long been used for water treatment, but recently modified flocculants have been developed for use in cane sugar clarification. These are being used at some Brazilian factories to reduce the chemical requirements of sulphitation and are claimed to be effective in reducing colour and improving juice turbidity (Fava, 2006).

Samples of this flocculant were tested in the SMRI laboratory, and initial results were promising, with up to 40% colour reduction in juice being achieved (Schoonees and Davis, 2006). On this basis, a full scale trial of limited duration was undertaken at a South African factory; however, the trial was conducted towards the end of the milling season, when cane quality was declining. The results from this trial were inconclusive (Schoonees and Davis, 2006), and a number of further laboratory trials were conducted to try to determine the best conditions for application of the flocculant (Schoonees *et al.*, 2006 and Gwegwe *et al.*, 2007). The results of all further trials were disappointing, despite collaboration with the suppliers to ensure that the correct conditions were being used, and the good performance reported from Brazil could not be replicated. Hence, no further work has been done at the SMRI using such flocculants. However, their success at certain mills in Brazil for reduction of raw sugar colour, suggests that they could still have potential application in South Africa. At the time of undertaking the South African factory trial (November 2005), the cost of dosing the flocculant at the recommended rate was estimated to be around R7.00 per ton of sugar.

Hydrogen peroxide in wash water during centrifugation

The application of hydrogen peroxide on raw sugar, for the purpose of colour removal, was investigated by Saska (2007).

The initial, simple laboratory trials included mixing of diluted hydrogen peroxide with raw sugar samples of low colour, under vacuum, and treatment of a raw sugar sample with hydrogen peroxide, as it was then and after three sequential affinations, with a saturated refined sugar liquor. Sufficient colour removal was achieved with these simple laboratory trials to warrant factory scale testing. It was further observed during the laboratory tests that the hydrogen peroxide oxidised the reducing sugars to acids and, when used in high

concentrations, lowered the pH of the sugar. In these cases, the use of sodium hydroxide was suggested to increase the pH. With low dosages of H₂O₂, however, the pH of the sugar remained largely unchanged.

The storage of the treated sugar was a concern, and therefore the colour measurement was repeated on some samples stored in plastic bags in the laboratory after six months and then after 24 months of storage. The results suggest that the pH drop is not proportional to the colour reduction. The colour advantage of the treated sugars was maintained after six months of storage. After two years of storage, the colour of the affined sugars with and without bleaching equalised. A 1 000 ICUMSA advantage was still held with the bleached sugar over the unbleached sugar after this period.

Some of the results from the factory trials are given in Table 7 and illustrated in Figure 9. In these trials, diluted hydrogen peroxide was dosed into the centrifugal wash water and applied during the high spin cycle.

Table 7. Effect of wash water with varying concentrations of H₂O₂ on sugar colours.

H ₂ O ₂ concentration in dosing tank (%)	Amount of H ₂ O ₂ applied (ppm sugar)	pH at 20°C and 20 brix	Colour (ICUMSA)
0 (water)	0	7.0	1 838
6	300	6.5	899
11	560	6.3	893
17	860	6.0	776

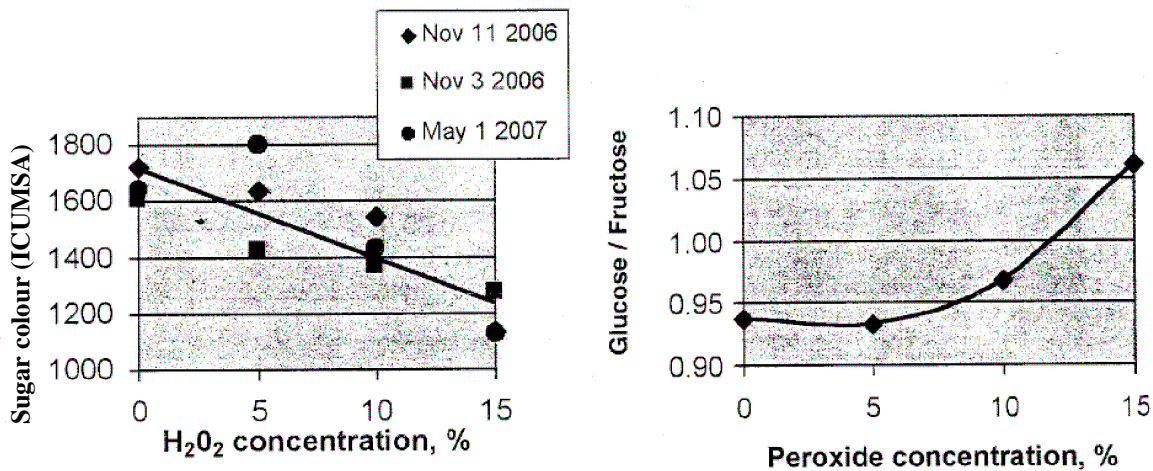


Figure 9. Effect of H₂O₂ concentration on sugar colour and glucose/fructose ratio with a constant wash volume of 1.2 litres/cycle.

It was concluded that a 20-30% colour reduction can be achieved with the direct bleaching of raw sugar with hydrogen peroxide. The 35% hydrogen peroxide is too strong an oxidant, apparently causing some invert sugar degradation, but the 5-6% peroxide is still effective for colour reduction, without significant effects on pH of the sugar. The slight pH drop from peroxide action can be offset with 10-20 mg/kg sugar of sodium hydroxide. The ash increase is insignificant compared to indigenous ash in the sugar. A partial or full replacement of wash water in the centrifugals with dilute hydrogen peroxide is possible, at a cost that compares favourably with the expected savings from the reduced load on the refinery decolourising station. It could be well worthwhile testing this method under South African conditions.

Storage tests performed on samples from the factory trials showed no significant colour rise in the sugar after six months, when stored in the laboratory in plastic bags.

Discussion

The colour of raw sugar has been the subject of many investigations and trials throughout the cane sugar producing world. It is also evident that high colours are usually periodic or seasonal in nature, and generally colour specifications can be met during the peak of the season, in most South African sugar mills, when the best cane quality is being experienced.

However, when high colours are experienced, additional measures need to be taken to control the colours. The available technologies fall into one of two categories:

- Physical control, by such means as increased centrifugal wash water or modified boiling schemes, or
- Chemical control, by the addition of suitable chemicals into the clarification process.

Both measures come with additional costs, either directly from the purchase of chemicals, or indirectly as the result of higher sugar losses, increased energy consumption and reduced throughput. In addition, extra capital equipment is required for many of these technologies, and it is difficult to justify this extra capital when it is only likely to be utilised for a portion of the season, namely when high colours are experienced.

In this respect, the use of additional clarification agents is of greater interest, as many of them are available in bulk and may be simply added to mixed juice at a desired rate when the colour problem is experienced, and discontinued when colours return to acceptable levels. However, these agents are generally costly, and care must be taken to ensure that other processes are being operated correctly in the factory to minimise colour formation and transfer before spending money on a 'miracle cure'. Hence, very few of these chemicals are routinely used for raw sugar production anywhere in the world. Only where plantation white, mill white or so-called direct consumption white sugars are produced from cane, are such chemicals routinely used, as the colour removals required are beyond the scope of normal raw sugar production processes. It should also be noted that many of these chemicals used in mill white sugar production have been developed to reduce the dependence of these factories on the use of sulphitation, which has been associated with health and safety risks.

Conclusions

A number of proven technologies and chemicals for the reduction of raw sugar colour have been discussed in this review. In the South African context, with the application of a VHP boiling house scheme and generally good raw sugar colours, in the majority of the mills, given good cane quality, the better options for colour control at the beginning and end of the crushing season would seem to lie with additional chemical clarification agents. A number of these are readily available, and their use, after the conventional processing methods have been tried, will be on an economic basis, depending on the unit cost and dosage required. However, the costs of the chemicals are generally high and their use can rarely be justified.

REFERENCES

- Barker B (2003). Low colour sugar by extra washing. Sugar Milling Research Institute Technical Note No. 32/03 (RC).
- Davis SB (1995). Decolourisation of sugar liquors with ozone – additional laboratory trials. Sugar Milling Research Institute Technical Report No. 1728.
- de Robillard JPM and van Hengel A (1984). Preliminary results of a modified boiling system at Illovo factory. *Proc S Afr Sug Technol Ass* 58: 47-50.
- Deerr N (1921). *Cane Sugar*. Norman Rodger, London, UK.
- Fava F (2006). BIOSUGAR and BIOCLIN: A natural solution for cane juice clarification and disinfection. Presented at Sugar Processing Research Institute, Inc. Conference, Aguas de Sao Pedro, Brazil, 17-20 September 2006.
- Francisco RD (1978). Update of sulfitation at Puna Sugar Company. Hawaiian Sugar Technologists 1978, 96-97.
- Getaz MA (1989). Chemical methods for lowering the colour of A-sugar. Part 1: An introductory review. Sugar Milling Research Institute Technical Report No. 1533.
- Getaz MA and Bachan L (1989). Some ideas of the use of chemical methods for improving the colour of A-sugar. *Proc S Afr Sug Technol Ass* 63: 76-80.
- Godshall MA (2006). Studies on the action of polyaluminum coagulants. ISSCT Processing Workshop, Baton Rouge, Louisiana, 29 May to 1 June 2006.
- Gomez M, Perez P and Ramos R (1980). Method of sugar refining with ozone. *Proc Int Soc Sug Cane Technol* 17(3): 2066-2071.
- Gwegwe B, Barker B, Schoonees BM and Davis SB (2007). Further investigations into the use of bioflocculants for colour removal during clarification. Part 2. Sugar Milling Research Institute Technical Note No. 06/07 RC.
- Hugot E (1972). *Handbook of cane sugar engineering – sugar series 7*. Elsevier, Amsterdam, The Netherlands.
- Jullienne LMSA (1989). Double curing of C-Sugar: Why not? *Proc S Afr Sug Technol Ass* 63: 100-103.
- Lamusse JP (1986). Comparison of single and double curing of C-massecuite at Darnall during the 1985-1986 season. Sugar Milling Research Institute Technical Report No. 1434.
- Mann GF (1987). Modifications to the boiling procedures at Sezela in an attempt to reduce VHP sugar colour. *Proc S Afr Sug Technol Ass* 61: 83-85.
- Mkhize SC and Davis SB (2004). Juice and syrup sulphitation: A brief literature review. Sugar Milling Research Institute Technical Note No. 20/04 (RC).
- Onna K and Sloane GE (1977). 1977 Juice sulfitation tests at Puna Sugar Company. Hawaiian Sugar Technologists 1977, 26-28.
- Patel MN and Moodley M (1991). Decolourisation with hydrogen peroxide, ozone and other chemicals: some preliminary experimental work. Sugar Milling Research Institute Technical Report No. 1598.
- Perk CGM (1951). The Java method of juice sulphitation. Sugar Milling Research Institute Comms 8, 6 pp.
- Rein PW (2007). *Cane Sugar Engineering*. Bartens, Germany.
- Rein PW, Cox MGS and Montocchio G (1987). Syrup clarification in raw sugar mills. *Proc S Afr Sug Technol Ass* 61: 22-31.

- Saska (2007). Reducing sugar colour by washing and bleaching with dilute hydrogen peroxide. *Int Sugar J* 109(1306): 616-622.
- Schoonees BM and Davis SB (2006). Colour removal using a bioflocculant. Sugar Milling Research Institute Technical Report No. 1977 RC, 28 pp.
- Schoonees BM, Gwegwe B and Davis SB (2006). Further investigations into the use of bioflocculants for colour removal during clarification. Sugar Milling Research Institute Technical Report No. 1990 RC, 24 pp.
- Smith IA, Schumann GT and Walthew DC (2000). Some developments in flotation clarification. *Proc S Afr Sug Technol Ass* 74: 263-266.
- Steindl RJ and Doherty WOS (2005). Syrup clarification for plantation white sugar to meet new quality standards. *Int Sug J* 107(1282): 581-589.
- Takenouchi G (1978). Sulfitation to improve recovery. Hawaiian Sugar Technologists 1978, p 98.