Proc S Afr Sug Technol Ass (2008) 81: 160 - 164

SHORT COMMUNICATION

THE USE OF POLYALUMINIUM COAGULANTS FOR THE REMOVAL OF COLOUR DURING CLARIFICATION

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Abstract

South African raw sugar factories face continuous pressure to improve both the quality and quantity of raw sugar produced. Many non-sucrose impurities, both organic and inorganic, adversely affect the extraction, recovery and final quality of sucrose recovered. Melassigenic compounds inhibit the recovery of sucrose. If some of these impurities could be more completely removed earlier in the process it is possible that sucrose recovery costs could be reduced.

Polyaluminium chloride (PAC) type chemicals are used as coagulants in water purification and waste water treatment. Some work done in the USA showed promise in using PAC as auxiliary flocculants in the clarification of sugarcane juice.

A number of different PAC samples were obtained from local chemical suppliers for screening in laboratory clarification trials specifically for evaluating the effect on juice colour. Results were encouraging, with the best colour reduction being 46% compared to a control sample. Effects on mud levels and the mud settling rates were observed for some of the products.

Keywords: clarification, colour, polysaccharides, turbidity, non-sucrose, coagulants

Introduction

Any non-sucrose impurities (both organic and inorganic) adversely affect the extraction, recovery and quality of sucrose recovered in a raw sugar factory. The South African sugar industry currently uses heat, lime and polyacrylamide flocculants for clarification to remove many of these impurities, and applies crystallisation to recover the pure sucrose. Melassigenic compounds inhibit the recovery of some of the sucrose through crystallisation. If some of these impurities could be more completely removed earlier in the process, it is possible that sucrose recovery costs could be reduced and the quality of the final product be improved.

There are generally two classes of colourants in a cane sugar factory: those which come from the plant itself and those which are made in the factory. The light-absorbancy of the plant pigments is generally highly pH sensitive, while that of the types of colourants that are made in a factory is not. Analysis of colours at various pH values can therefore potentially be used to measure the relative contribution of the various colour types to the final colour value. To this end an Indicator Value (IV) is defined as the ratio of the colour measured at 420 nm after adjusting the sample pH to 9.0 to the colour measured after adjusting the sample pH to 4.0 (Clarke *et al.*, 1985; Davis, 2001; Kennedy and Smith, 1976).

Polyaluminium chloride (PAC) chemicals are a class of soluble aluminium products in which aluminium chloride has been partly reacted with a base. PAC products with low (0-17%) and medium (17-50%) basicity are generally used in the paper making industry to boost drainage rates, and those with higher (>50%) basicity in the water and wastewater treatment industries as coagulants for the precipitation of impurities (http://www4.ncsu.edu/~hubbe/PAC.htm).

Studies were conducted in the USA during the past decade on the use of PAC products in the cane sugar raw house to remove colour, turbidity and polysaccharides (Anon, 2004; Anon, 2005b; Anon, 2006). Reports indicate that the use of PAC achieved double the colour removal when compared to conventional clarification, and an even greater increase in polysaccharide removal as well as some turbidity removal.

This communication reports on initial results obtained during the screening of a set of PAC products specifically for colour removal during clarification. Future work will be expanded to evaluate the effects of the PAC products on other non-sucrose entities such as polysaccharides and inorganics. All of the products were obtained from local suppliers.

It is not possible to closely simulate the process of continuous clarification used in the sugar industry on a laboratory scale. The Sugar Milling Research Institute (SMRI) uses a method that attempts to keep conditions as close as possible to conditions in a factory, recognising that the results of such clarification tests are comparable only to those of similar tests and control tests. Results are therefore compared only to each other and are used to make predictions on the behaviour of the evaluated parameters in a factory.

Experimental

Laboratory scale clarification – SMRI apparatus

A sample of mixed juice was heated to the temperature of the draft juice at a particular factory (e.g. 65°C) and 50 ppm of phosphoric acid was added. The auxiliary product, PAC, was introduced and the juice was mixed for five minutes to allow for interaction. The juice was heated to 95°C and limed to a pH of 6.7, recording the amount of lime needed for the adjustment. The juice was boiled for 30 seconds to expel any dissolved air and decanted into volumetric cylinders already containing flocculant LT027 (3 ppm); this was done carefully to ensure that no air was entrained during the transfer. The cylinders were placed in a 95°C water bath for 30 minutes to allow complete settling of the solid mud particles. The volume of mud was recorded as a percentage of the volume of liquid in the cylinders, and the clarified portion of the liquid was analysed for colour.

Colour analyses

The colours of the juices were determined at pH 4, 7 and 9 using the SASTA method for juice colour determination (Anon, 2005a). This colour analysis is loosely based on the International Commission for Uniform Methods of Sugar Analysis (ICUMSA) method for the determination of the colour of raw and speciality sugars in solution at pH 7 (Anon, 2003). The colour values at pH 7 were used for general comparison, while the colour values at pH 4 and 9 were used to calculate the IV values.

Auxiliary products tested

Thirteen PAC products were tested at low (250 ppm on sample) and high (1000 ppm on sample) dosage rates using the method described above. Limited information on the PAC products was obtained, as shown in Table 1.

Table 1. Some information on the polyaluminium chloride (PAC) products screened for clarification properties at the Sugar Milling Research Institute.

No.	Description	Cost (R/kg)
1	Blend of cationic aluminium polymers with ± 50% poly-quaternary amine	21.50
2	Blend of cationic aluminium polymers with ± 25% poly-quaternary amine	19.35
3	Blend of cationic aluminium polymers with ± 10% poly-quaternary amine	18.40
4	Not highly polymerised cationic aluminium salts blend	18.10
5	Not highly polymerised cationic aluminium salts blend	16.90
6	Blend of cationic aluminium polymers with ± 50% poly-quaternary amine and less complex salts	20.15
7	Medium molecular weight cationic polymer	15.00
8	Medium molecular weight cationic polymer with aluminium species	8.00
9	Aluminium chlorohydrate	9.70
10	unknown	14.50
11	unknown	18.55
12	unknown	unknown
13	unknown	13.00

Results and Discussion

Results for clarification using low and high dosages of PAC products are given in Tables 2 and 3 respectively. Data were sorted in descending order based on average colour removal.

Table 2. Results for clarification using 250 ppm of the polyaluminium chloride products (low dosage).

Product No.	pH 7 colour removal (%)[a]			Cost per ton raw sugar (R)	Mud settling rate[b]	IV
	Repeat 1	Repeat 2	Average			
7	29	26	27	40	poor	8
13	19	28	24	35	no change	-
11	15	18	17	50	good	7
1	14	18	16	60	poor	7
10	5	16	11	40	poor	6
3	5	6	5	50	good	6
2	11	-1	5	50	no change	7
6	3	-3	0	55	good	6
12	17	-23	-3	unknown	good	6
8	-4	-7	-5	20	no change	6
9	-7	-5	-6	25	no change	6
4	-7	-10	-8	50	good	5
5	2	-22	-10	45	no change	5

[a]*Relative to a control and at pH 7*
[b]*Mud settling rate is designated 'poor' in cases where settling is unacceptable for clarification*
Highlighted rows indicate the best results overall
IV ≡ Indicator Value

Table 3. Results for clarification using 1000 ppm of the polyaluminium chloride products (high dosage).

Product No.	pH 7 colour removal (%)[a]			Cost per ton raw sugar (R)	Mud settling rate[b]	IV
	Repeat 1	Repeat 2	Average			
10	43	-	43	155	poor	10
1	44	43	43	230	poor	10
13	46	39	42	140	no change	-
7	42	38	40	160	poor	10
11	43	36	40	200	good	10
6	45	19	32	215	good	9
2	33	19	26	205	no change	7
3	23	14	19	195	good	7
4	17	17	17	195	no change	7
5	19	15	17	180	no change	7
8	16	3	10	85	no change	6
12	14	5	9	unknown	no change	6
9	3	-2	1	105	no change	6

[a]Relative to a control and at pH 7
[b]Mud settling rate is designated 'poor' in cases where settling is unacceptable for clarification
Highlighted rows indicate the best results overall
IV ≡ Indicator Value

A negative colour removal indicates an increase in colour at pH 7. Although the repeatability of the laboratory clarification method is generally not good, the poor repeatability that was observed on occasion (e.g. product 12 in Table 2) was unexpected.

The average colour results for the low dosage rates (Table 2) were poor overall; however, the best colour removal of 25% compared to the control was considered noteworthy. Results for the high dosage rates (Table 3) were excellent for at least half of the products, with the best average colour removal being 43% compared to the control.

An IV was calculated for all of the samples to assess whether the PAC products have a preference for removing any specific type of colour. Generally, higher colour removal also saw an increase in IV for the high dosage rate (from 6 for the controls to about 10 for at least the top five products in Table 3), indicating that the colourants generally considered to have been made in the factory appeared to be preferentially removed compared to the plant pigments. This is nevertheless a preliminary prediction.

Mud settling during clarification is extremely important. Carry-over of slow settling particles causes extreme difficulties later on in the process and in subsequent processes (e.g. refining). This is therefore one of the most important functions of colour removal products. Based on the average colour removal ability and mud settling rates, products 13 and 11 showed particular promise (highlighted in the tables). The costs at these high dosage rates will need some additional consideration.

Conclusions and Recommendations

A number of the PAC products were highly successful in removing additional colour during the clarification experiments. While the costs of some of these may render their use unsuitable on a routine basis, the use of shock dosages at the beginning and end of the season as well as in specific instances could be valuable, especially where the cost of handling or remelting of high coloured sugars becomes excessive.

It is also intended to assess the ability of the PAC products to remove polysaccharides and turbidity from the juice during clarification. Residual aluminium levels in the resulting clarified juice also need to be determined, especially when the sugar is to be used by bottlers. Some of the PAC products changed the mud settling rates and/or mud volumes. Products which negatively affect these factors are immediately deemed unsuitable for use in a sugar factory.

It is therefore recommended that the PAC products be further characterised in terms of their non-sucrose removal abilities and effects on clarification in the laboratory, and that further factory trials be undertaken based on these findings.

Acknowledgements

The authors would like to thank Buckman Laboratories and the CHC Group for supplying the PAC products that were tested.

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