# COLOUR BEHAVIOUR IN CANE JUICE CLARIFICATION BY DEFECATION, SULFITATION AND CARBONATION

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## Abstract

COLOUR is sugar's most important commercial attribute but, in juice clarification, its removal is usually not considered among primary objectives. However, based on results presented, all standard clarification procedures have the potential for significantly higher removal of colour than is realised in the industrial practice. Four principal juice clarification procedures, viz. defecation by hot liming, sulfitation, carbonation and double-carbonation were tested and various aspects of colour behaviour investigated. Carbonation is not widely used in the cane sugar industry, but periodic spikes in sulfur prices, sugar quality issues and environmental concerns have stimulated efforts to consider replacing or supplementing sulfur dioxide with carbon dioxide that may be available cost-free from the fermentation plant. The colour removal, viz. the relative difference between colour of raw and clarified juice, obtained in our tests was on average 35, 47, 44 and 74% for defecation, sulfitation, single-carbonation and modified double-carbonation, respectively. Several factors affecting clarified juice colour in hot liming were tested, viz. the time and temperature during settling; bagacillo and soil content, and phosphate and protein addition. At low lime dose, below about 1 kg CaO/tonne cane (defecation, sulfitation and carbonation), most colour removal results from adsorption on the heat-coagulated cane protein, rather than on the nascent calcium precipitate. However, the adsorptive capacity of the precipitate for cane colorants appears only partially exhausted in the normal procedure. Lowering the clarifier temperature by 11°C was found to limit the juice colour increase in the clarifiers to nearly zero. Although the decolourisation effects of sulfitation and carbonation were found to be about equal, the apparently lower thermal stability of clarified juice and syrup produced by carbonation may require further study.

## Introduction

The colour of sugar, be it raw, direct mill white or refined is its most important commercial attribute, and much resource is spent by the millers and refiners to comply with the market requirements on the colour of their product. Crystallisation itself, apart from producing a stable, marketable product is also 95–99% effective in partitioning colour and is, in the production of low colour sugar, supplemented by a number of carbon and ion-exchange resin-based adsorption processes and, to a lesser degree, by methods based on chemical reactions that render colourless the colorant molecules.

The main objectives of juice clarification are to raise its pH and eliminate suspended solids. Colour removal is at best considered a secondary objective, rarely monitored by the mill laboratory and to our knowledge never used as a criterion to assess, let alone control, the process. The use of

$SO_2$ is widespread in clarifying juice in production of plantation white sugar, however periodic spikes in sulfur prices and sugar quality issues have stimulated efforts to reduce or even eliminate its use. With that in mind, a carbonation process has been tested and compared with standard sulfitation and defecation. Besides eliminating the use of sulfur, carbonation would also provide a means to utilise and sequester some of the excess $CO_2$ that may be available cost-free in some sugar factories from molasses or juice fermentation. The traditional double-carbonation process was used initially in cane juice clarification in Java (Honig, 1959), later practised for many years in South Africa (Rault, 1960), and is still used nowadays in some cane factories in China, Taiwan (Sheen *et al*., 2003) and elsewhere. Although it is reported to provide excellent, low colour clarified juice, the very high lime consumption of 11–15 kg CaO per tonne cane is making the economics increasingly un-sustainable. In this program, some modifications were tested to reduce lime consumption and replace the filtration of all first carbonation juice by settling and filtration of the concentrated mud.

**Materials and methods**

In most cases, raw juice was prepared by milling samples of cane brought to Audubon from the Sugar Research Station. Usually, 0.6 to 0.8 L of pressed juice was diluted to 1 L volume to bring the brix closer to that of factory mixed juice, and clarified by four methods: defecation by hot liming, sulfitation, single carbonation or double carbonation.

For defecation, the diluted juice was brought to and kept boiling for about one minute in a microwave oven, then quickly limed while stirring with $Ca(OH)_2$ slurry to a pH between 7 and 8.2. Then 2.5 ppm of Ciba Magnafloc LT340 flocculant was added while stirring, the whole volume of limed juice transferred to a covered 1 L glass beaker and allowed to settle in a 96°C water bath, usually for 60 minutes, before sampling the supernatant for analysis.

Sulfitation was done in a 6 L stirred jacketed glass reactor provided with lime slurry and gas inlets, and pH and temperature readouts; usually by first liming 1 L of diluted juice at about 50°C to a pH of 8–9 and then gassing with $SO_2$ to a pH of about 7. Alternatively, gassing was done first to pH 3–4 followed by liming to pH 7. The clarification performance was about equal, but the former was preferred as it was considered to be more closely comparable with the carbonation tests where gassing with $CO_2$ must be done at alkaline pH (Figure 1) because of the negligible rate of absorption of carbon dioxide below pH 6. In either case, the sulfited and limed juice was heated and kept boiling for one minute, flocculant added and settling done as in defecation.

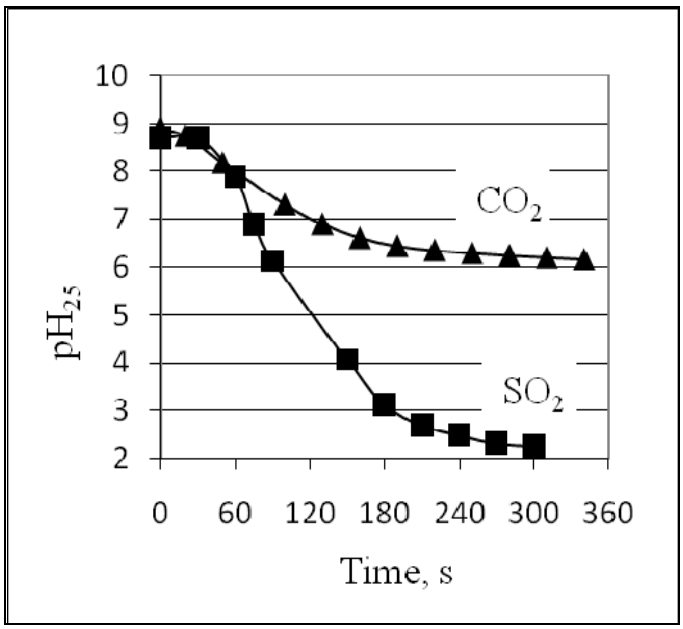


Fig. 1—Absorption rate of carbon dioxide and sulfur dioxide in limed juice.

Carbonation was done by liming the diluted juice in the 6 L stirred reactor kept at 50 to 60°C, to pH 8–9, kept at the high pH for 2 to 5 minutes and then gassed with $CO_2$ to pH 7–8, over about 5 minutes. The heating, flocculating and settling followed as before. The quantity of lime was maintained about the same in both sulfitation and carbonation to allow direct comparison between the two methods, and at levels comparable with those used in plantation mill white factories throughout South and Central America. In the following text, the pH measured at room temperature (about 25°C) is denoted as $pH_{25}$.

Double carbonation was done by preheating 1 L of diluted raw juice in the 6 L reactor to 50°C and liming with 3–5 g CaO to a pH 10.5–11. The pH was then reduced with $CO_2$ to about 10, temperature raised to 60°C, flocculent applied, and the mud settled for about 60 minutes to 25–30% of the initial volume. No precautions were taken to remove dissolved air from the juice. The supernatant from settling and filtrate from vacuum filtration of the thickened mud were combined and pH of the combined clear juice then reduced with $CO_2$ to pH 6.5–7. The carbonated juice was brought to boil and the small amount of the second carbonation precipitate removed by filtration under vacuum. The filterability of the first carbonation mud was measured with the same apparatus and mostly following the same procedure as before (Saska, 2005) in measuring filterability of clarifier mud. A temperature of 60°C was chosen, at 0.7, 1.4 and 2.1 x $10^5$ Pa pressure, a filtration area of 3.1 $cm^2$ with the support formed by a 20 µm stainless steel mesh and pre-coated with HyfloSuper Cel filter aid.

It is sometimes recommended that lime suspension be 'aged' before its use in juice clarification but, in these tests, the analytical grade $Ca(OH)_2$ that was used was mixed with water at about 1:10 ratio and used immediately. No adverse effects on settling or turbidity removal were noted.

All tests reported in this paper were done during the 2008–2009 season at ASI with juice extracted from the main varieties of cane nowadays grown in Louisiana (i.e. L 97-128, HoCP 96-540, LCP 85-384, etc.). However, other tests at EEAOC in Argentina (Zossi and Cardenas, 2009) have confirmed the validity of the present conclusions regarding the colour behaviour in clarification of juice produced from the two main cane varieties grown in Tucuman.

## Results

### Colour removal in clarification

The colour of raw juice ranged from 10 000 to 20 000 IU (Table A1 in the Appendix) with the variations reflecting effects of different cane varieties, cane conditions and the varied quantities of tops and green leaves crushed with the clean billets. The relative decolourisation, defined as 100 × (Colour of raw juice – Colour of clarified juice) / Colour of raw juice for defecation by hot liming, averaged 32%; sulfitation and carbonation were nearly equally efficient in terms of colour removal, with decolourisation of 45% and 42%, respectively (Table A2) with lime (CaO) consumption of about 0.7 and 0.9 g/L respectively versus the 0.5 g/L used in normal defecation (Table A1).

Although the colours of clarified and in particular of mixed juice are rarely measured in the factories, the limited available data (Eggleston, 2002; Sahadeo *et al*, 2002) indicate that the factory performance in terms of colour removal is substantially lower than the laboratory test results reported in Table 1 and in the Appendix Table A2.

Among the reasons for the difference between factory performance and laboratory decolourisation may be localised overheating or overliming in the industrial process, excessive residence times of juice or mud in the industrial heaters, clarifiers or filters, or other factors.

No systematic measurements were done of the mud settling characteristics. However, all three procedures produced well-settling mud with no apparent differences in settling rates among the three methods. Clarified juice turbidity varied mostly within the 50–150 NTU range, similar to

the range of industrial clarified juice and, as with mud settling rates, no systematic differences among the three clarification methods were observed. The large standard deviation of the CaO dose comes from the intentional variations introduced in the procedure to test the robustness and response of the process.

**Table 1—**Average colour before and after juice clarification, the lime dose used and relative decolourisation achieved.

| | Colour, IU | | CaO, g/L | | Decolourisation* |
|---|---|---|---|---|---|
| | Avg | SD | Avg | SD | % |
| Raw juice (N=26) | 14 367 | 4113 | | | |
| Defecation (N=18) | 9766 | 3668 | 0.5 | 0.3 | 35[a] |
| Sulfitation (N=20) | 7858 | 2821 | 0.7 | 0.5 | 47[b] |
| Carbonation (N=17) | 8351 | 3127 | 0.9 | 0.7 | 44[b] |

* different superscript letters (a or b) indicate a significant difference ($p \leq 0.05$) between two data sets; while same letters indicate a statistically insignificant difference

## Changes of juice pH and colour during settling

The composition of clarified juice and consequently the clarification method may have an impact on the rate of colour increase later in settling, during evaporation and in the vacuum pans. Thus thermal stability of the juice needs to be considered when evaluating clarification. To that effect, the residence time was varied from ½ to 4 hours for the three types of clarified juices (Table 2), at 96°C i.e. close to the average temperature in the industrial clarifiers, and at 85°C for clarified juice from hot liming, and its effect on juice colour and pH.

**Table 2—**Colour increase and pH drop during settling at 96°C and 85°C, for different clarification conditions.

| | Colour, IU | | CaO, g/L | | Decolourisation* |
|---|---|---|---|---|---|
| | Avg | SD | Avg | SD | % |
| Raw juice (N=26) | 14 367 | 4113 | | | |
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* Different superscript letters (a or b) indicate a significant difference ($p \leq 0.05$) between two data sets; while same letters indicate a statistically insignificant difference

At 95°C, the colour increase in defecation and carbonation juices was found to be about equal, approximately 600 IU/h, but lower for juice produced by sulfitation. The pH drop during settling of defecation juices was found significantly higher than in sulfitation and carbonation.

Reducing the temperature from 96°C to 85°C during settling of defecation juice had a dramatic effect on colour formation rate and pH drop. Colour increase was reduced six-fold to less than 100 IU/h and the pH drop about two-fold.

Although not studied here, it is probable that comparable improvements would ensue in sulfitation and carbonation. It was suggested (Zossi *et al.*, 2009) that this could be accomplished in the industrial process at a low cost by re-routing the vacuum filtrate that is now usually sent back to the mixed juice tank.

The limed juice would be heated and flashed as usual, but its temperature would then be reduced downstream of the flash tank by the cooler filtrate. This would be expected to reduce juice

colour and reduce the sucrose inversion loss, similar to the benefits derived from the short residence time clarifiers. Additional benefits are expected from avoiding recycling through the juice heaters the considerable amount of mud and flocculant contained in the generally poor quality filtrate.

**Thermal stability of syrup**

The rates of Maillard and other mechanisms responsible for colour formation are known to increase at lower water concentrations. Therefore, a series of 'thermal storage' tests at 70°C were also done with syrup following the same methodology as in the recent raw sugar storage tests (Saska and Kochergin, 2009). Syrup from each clarified juice was prepared in a glass laboratory 'rotovap' evaporator, under vacuum at 50–55°C. Colour increased in storage in each case (Figure 2); with the approximate slopes of 15, 9, 29 and 13 IU/h for defecation, sulfitation, carbonation and double carbonation, respectively.

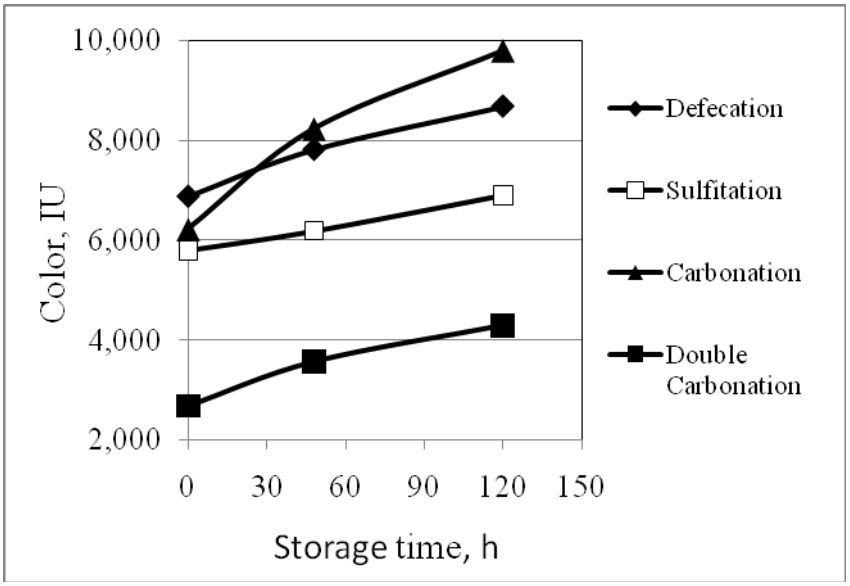


Fig. 2—Colour increase of 60 – 70 brix syrup produced from the four different clarification procedures and stored at 70°C.

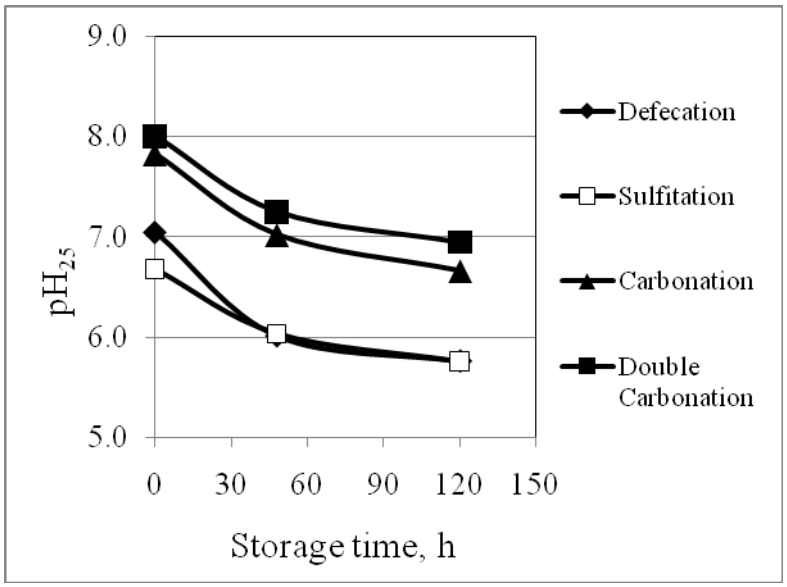


Fig. 3—pH drop during storage of syrup produced by the four different clarification procedures.

Because of the lower temperature, the rate of colour formation is much slower than in settling (Table 2), but the sulfitation syrup again exhibits the slowest colour increase of all. The pH drop (Figure 3) is about equal in all four cases, and apparently independent of the initial pH.

**Mechanism of colour removal**

It is usually assumed that, in juice clarification, any colour removal is due to adsorption of colorants on the nascent crystals of calcium phosphates and other sparingly soluble anions, in analogy to the more frequently studied colorant behaviour in sugar refining by phosphatation or carbonation. However, the few experiments that are summarised in Figures 4 and 5 indicate that adsorption on heat-coagulated cane protein may be the prevalent mechanism for colour removal in juice clarification. In the experiments in Figure 4, bringing the raw juice to boiling without any lime addition removed nearly 7000 IU or 39% of the initial colour. The full hot-liming and clarification done on the same juice only added another 6% to the total 45% decolourisation. When 100 mg/L aliquots of phosphoric acid were added to the mixed juice prior to liming, the colour removal by hot-liming increased by about 600 IU per aliquot.

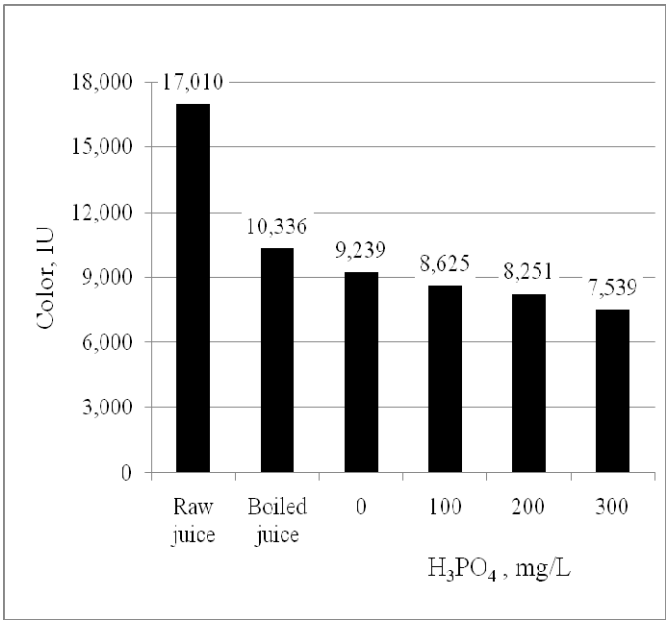


Fig. 4—Colour of raw juice, raw juice after boiling and clarified juice by hot liming after addition of phosphoric acid.

In the experiment in Figure 5, cane protein was supplemented by sequential additions of bovine serum albumin (BSA), a structurally similar protein.

An addition to diluted raw juice of 1.5 g/L of protein increased the colour removal by hot liming by an additional 1500 IU. Another 3 g/L of BSA was added (for a total of 4.5 g/L) to the clear juice from this experiment, and the spiked juice was briefly boiled again; however, no additional lime was added.

The colour decreased by another 1300 IU. This was repeated one more time, for a total of 7.5 g/L of protein, with an additional 600 IU removed. It is therefore clear that both BSA and cane protein when heat-coagulated or during heat-coagulation have strong affinity for cane colorants.

The decolourisation effect, however, decreases with increasing dose of the protein; perhaps because the affinity of the protein is specific for only certain fractions among the wide variety of cane juice colorants. Unlike BSA, egg-white albumin was found ineffective in juice colour removal. Bagacillo or soil particles in only coarsely screened industrial cane juice have a substantial effect on the mud behaviour in clarifiers, most notably the former providing the bulk of the mud volume.

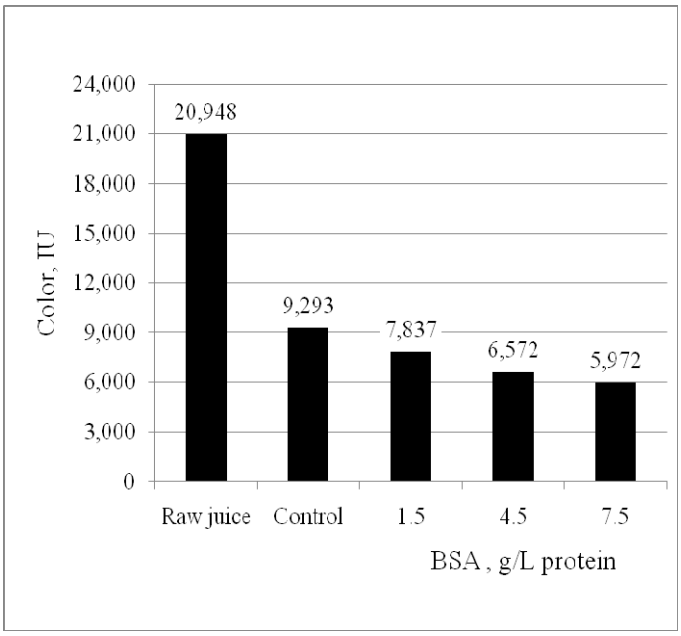


Fig. 5—Colour of raw juice, clarified juice by hot liming (control), and clarified juice after sequential additions of bovine serum albumin.

Whether they affect colour of clarified juice as has been sometimes alleged is less certain. The experiments summarised in Figure 6 indicate that neither has any detectable influence above the normal experimental variations. The added amounts indicated in Figure 6 are given in g dry matter/100 mL raw juice.

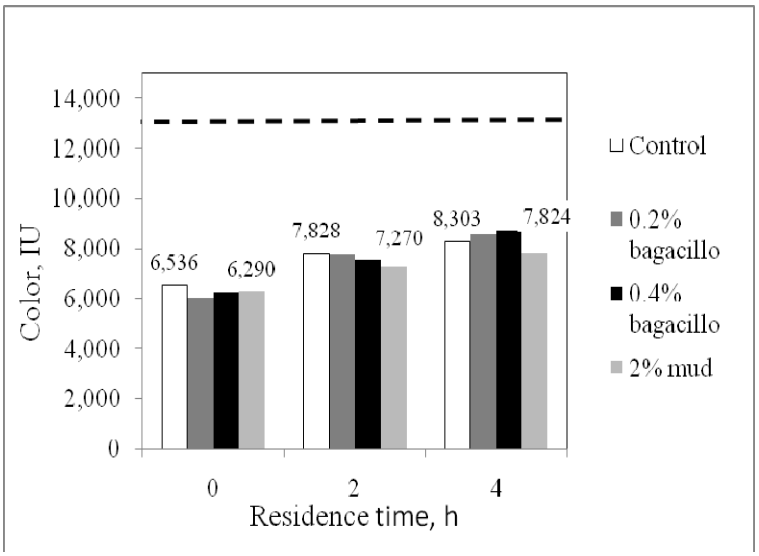


Fig. 6—Colour of raw juice (13 200 IU), juice clarified by hot liming (control), and juice clarified by hot liming after additions of bagacillo or dry mud to the raw juice.

The clarifier underflow is made up of 90–95% clarified juice with colour that one could assume identical to that of the clarifier overflow provided the residence times were comparable. However, some previous observations in factory tests (Saska, pers. comm., 2009) indicated that the colour of the 'mud juice', that is the juice entrained in, and recovered from the mud in vacuum filters, was on occasions actually lower than that of the overflow from the clarifiers. This prompted tests to determine the state of saturation of the adsorptive capacity of mud particles for colorants. In

the experiments reported in Table 4, cane juice was clarified by hot liming and its colour determined as usual (CJ colour and Decolourisation 1 in Table 4). The settled mud was then blended for a few seconds in a standard kitchen blender, solids separated by centrifugation, and the colour of the supernatant juice again determined by the standard method. In all, twenty experiments were done and are reported in Table 4; the colour of the supernatant from the blended mud (Mud colour and Decolourisation 2 of Table 4) always decreased, sometimes by up to 2700 IU. This is evidence that the adsorptive power of the hot-liming precipitate is not exhausted in the standard process.

**Table 4—**Colour of raw juice, juice after hot liming and of the 'mud juice' after blending the mud.

| RJ colour IU | CJ colour IU | Mud colour IU | Decolourisation 1* % | Decolourisation 2* % | Difference % |
|---|---|---|---|---|---|
| 15 957 | 9986 | 7764 | 37 | 51 | 14 |
| | 10 429 | 7742 | 35 | 51 | 17 |
| | 9811 | 7575 | 39 | 53 | 14 |
| | 10 000 | 7701 | 37 | 52 | 14 |
| 17 390 | 8689 | 7473 | 50 | 57 | 7 |
| | 8838 | 7331 | 49 | 58 | 9 |
| | 8919 | 7519 | 49 | 57 | 8 |
| 17 390 | 8013 | 6132 | 54 | 65 | 11 |
| | 7993 | 6176 | 54 | 64 | 10 |
| | 8189 | 6287 | 53 | 64 | 11 |
| | 8356 | 5936 | 52 | 66 | 14 |
| 12 712 | 6772 | 6467 | 47 | 49 | 2 |
| | 7010 | 6691 | 45 | 47 | 3 |
| | 7241 | 6492 | 43 | 49 | 6 |
| | 7165 | 6655 | 44 | 48 | 4 |
| | | | Avg 46[a] | Avg 55[b] | |

*Different superscript letters (a or b) indicate a significant difference ($p \leq 0.05$) between two data sets; while same letters indicate a statistically insignificant difference

Blending the mud may expose internal surfaces of the precipitate, rendering them available to adsorb more colorant. It would seem, therefore, that potential exists for further improvements in decolourisation above the levels reported in Table 1.

**Double-carbonation**

In the modified double-carbonation procedure, the CaO dose was reduced on average to 3.1 g/L (Table 5), or about four-times greater than the present industrial process. Decolourisation at these conditions was 74% on average, with some values exceeding 80%. Clarified juice turbidity was less than 10 NTU, and Ca and Mg ions determined by ion-chromatography were about 500 and 200 mg/L, respectively.

**Table 5—**Average performance of the double carbonation clarification of cane juice.

| | Ca0 added g/L | $pH_{25}$ of CJ | Colour, IU | | Decolourisation | |
|---|---|---|---|---|---|---|
| | | | RJ | CJ | % | IU |
| Avg (N=43) | 3.1 | 7.4 | 12 302 | 2877 | 74 | 9432 |
| SD | 0.9 | 1.2 | 3917 | 660 | 12 | 3489 |

The filterability of the thickened first carbonated mud may be the critical parameter for the scale-up of the modified process. Therefore, the effects of various parameters, e.g. the quantity of lime used were measured. The filterability of the juice, thickened by settling to about 30% of the original volume, was found unaffected (Figure 7), and comparable with filterability of the standard hot liming defecation mud determined under identical conditions (Saska, 2005). The volume to be

handled by the filter station is greatly reduced, and its capacity in terms of tonnes of cane per day increased.

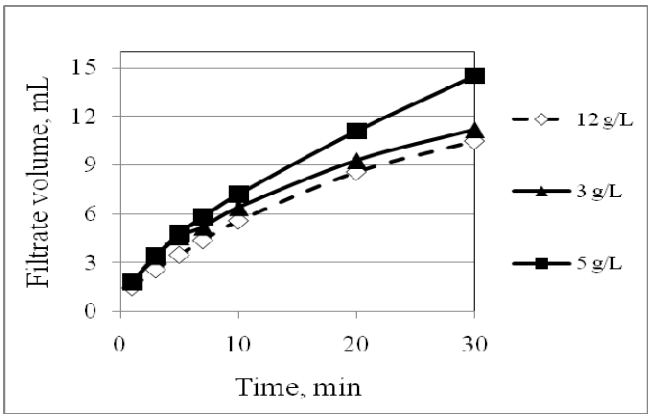


Fig. 7—Filterability of thickened mud from the modified process (solid lines) with 3 and 5 g/L of CaO, and that of the industrial double carbonation process with 12 g/L CaO (dotted line).

## Conclusions

The average decolourisation that was achieved in juice clarification by defecation, sulfitation, single carbonation and modified double carbonation was 35, 47, 44 and 74%, respectively. However, available data indicate that decolourisation that is routinely achieved in defecation (Eggleston, 2002; Sahadeo *et al.*, 2002) and sulfitation factories (Zossi and Cardenas, 2008) is considerably less.

Replacement of $SO_2$ by $CO_2$ (carbonation) is feasible, achieving comparable decolourisation and mud settling characteristics, but the apparently lower thermal stability of clarified juice and syrup from carbonation requires more study.

The colour increase at conditions typical in industrial clarifiers was found to be about 600 IU/h for defecation and carbonation, and about 350 IU/h for sulfitation clarified juice. By reducing the settling temperature by 11°C, the colour increase could be reduced to less than 100 IU/h.

An indication was obtained that, in juice clarification, most decolourisation comes from adsorption of cane colorants onto heat-coagulated cane protein rather than onto the nascent calcium precipitate, and that some of the adsorption capacity remains unused in the standard process.

No significant effect was observed from either bagacillo or soil on colour removal in clarification.

Significant reductions of CaO consumption in the commercial double carbonation process to about 3 kg CaO/tonne cane are possible, in conjunction with thickening of the first carbonation mud by settling and polishing filtration after the second carbonation.

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# APPENDIX

**Table A1—**Colour of raw and clarified juice obtained in different clarification procedures, and the lime dose used.

| | RJ colour IU | CJ colour, IU | | | CaO, g/L | | |
|---|---|---|---|---|---|---|---|
| Test # | | def | sulf | carb | def | sulf | carb |
| 1 | 14 006 | 9845 | | 9659 | 1.1 | | 1.8 |
| | 11 793 | 8882 | 7651 | | 0.8 | | |
| 2 | 19 642 | 13 549 | 10 755 | 11 312 | 0.7 | 1.7 | 2.0 |
| 3 | 16 618 | 12 794 | 9245 | 9225 | 0.8 | 1.5 | 1.8 |
| 4 | 17 853 | 14 409 | 10 834 | 10 791 | 0.8 | 1.5 | 2.6 |
| 5 | 13 016 | 11 685 | 8786 | 9044 | 0.6 | 1.4 | 1.1 |
| 6 | 15 629 | 8509 | 7671 | | 0.4 | 0.7 | |
| 7 | 16 598 | 9762 | 7513 | | 0.4 | 1.2 | |
| 8 | 19 565 | | 8505 | 9172 | | 0.5 | 0.5 |
| 9 | 22 373 | | 8143 | 8070 | | 0.5 | 0.5 |
| 10 | 13 000 | 8571 | 8318 | 8612 | 0.2 | 0.3 | 0.3 |
| 11 | 12 972 | 6853 | 6258 | 6288 | 0.2 | 0.3 | 0.3 |
| 12 | 11 915 | 6661 | 6487 | 6733 | 0.2 | 0.3 | 0.3 |
| 13 | 25 880 | 20 202 | 17 400 | 18 000 | 0.4 | 0.7 | 0.7 |
| 14 | 11 556 | 6518 | 5709 | 6068 | 0.2 | 0.3 | 0.3 |
| 15 | 17 606 | 9186 | | | | | |
| | 15 544 | 9768 | | | | | |
| 16 | 11 114 | | 6087 | 5699 | | 0.5 | 0.5 |
| 17 | 11 114 | | 6014 | 5998 | | 0.5 | 0.5 |
| 18 | 10 910 | 5980 | 5422 | | 0.2 | 0.5 | |
| 19 | 10 910 | | 5426 | | | 0.7 | |
| 20 | 10 910 | | | 5935 | | | 0.7 |
| 21 | 10 910 | | 5861 | | | 0.8 | |
| 22 | 10 910 | | 5071 | 5483 | | 0.8 | 0.7 |
| 23 | 10 910 | 6500 | | 5873 | 0.2 | | 0.7 |
| 24 | 10 300 | 6122 | | | 0.2 | | |
| Avg | 14 367 | 9766 | 7858 | 8351 | 0.5 | 0.8 | 0.9 |
| SD | 4113 | 3668 | 2821 | 3127 | 0.3 | 0.5 | 0.7 |

**Table A2**—Absolute and relative colour removal in different clarification procedures (other conditions are given in Table A1).

| | colour removal, IU | | | colour removal, % | | |
|---|---|---|---|---|---|---|
| Test # | def | sulf | carb | def | sulf | carb |
| 1 | 4161 | | 4347 | 30 | | 31 |
| | 2911 | 4142 | | 25 | 35 | |
| 2 | 6093 | 8887 | 8330 | 31 | 45 | 42 |
| 3 | 3824 | 7373 | 7393 | 23 | 44 | 44 |
| 4 | 3444 | 7019 | 7062 | 19 | 39 | 40 |
| 5 | 1331 | 4230 | 3972 | 10 | 32 | 31 |
| 6 | 7120 | 7958 | | 46 | 51 | |
| 7 | 6836 | 9085 | | 41 | 55 | |
| 8 | | 11 060 | 10 393 | | 57 | 53 |
| 9 | | 14 230 | 14 303 | | 64 | 64 |
| 10 | 4429 | 4682 | 4388 | 34 | 36 | 34 |
| 11 | 6119 | 6714 | 6684 | 47 | 52 | 52 |
| 12 | 5254 | 5428 | 5182 | 44 | 46 | 43 |
| 13 | 5678 | 8480 | 7880 | 22 | 33 | 30 |
| 14 | 5038 | 5847 | 5488 | 44 | 51 | 47 |
| 15 | 8420 | | | 48 | | |
| | 5776 | | | 37 | | |
| 16 | | 5027 | 5415 | | 45 | 49 |
| 17 | | 5100 | 5116 | | 46 | 46 |
| 18 | 4930 | 5488 | | 45 | 50 | |
| 19 | | 5484 | | | 50 | |
| 20 | | | 4975 | | | 46 |
| 21 | | 5049 | | | 46 | |
| 22 | | 5839 | 5427 | | 54 | 50 |
| 23 | 4410 | | 5037 | 40 | | 46 |
| 24 | 4178 | | | 41 | | |
| Avg | 4997 | 6856 | 6552 | 35 | 47 | 44 |
| SD | 1660 | 2532 | 2614 | 11 | 8 | 9 |

# EVOLUTION DE LA COULEUR PENDANT LA CLARIFICATION DU JUS DE CANNE PAR DEFECATION, SULFITATION ET CARBONATATION

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**MOTS CLEFS: Canne a Sucre, Couleur, Clarification, Sulfitage, Carbonatation.**

**Résume**

LA COULEUR est le plus important attribut commercial du sucre mais, à la clarification, sa réduction n'est pas considérée parmi les principaux objectifs. Cependant, toutes les procédures de clarification ont le potentiel pour une diminution plus élevée de la couleur que celle réalisée dans la pratique industrielle. Quatre procédures de clarification, notamment la défécation par chaulage à chaud, le sulfitage, la carbonatation et la double carbonatation ont été testés pour étudier le comportement de la couleur. La carbonatation n'est pas beaucoup utilisée dans l'industrie du sucre de canne, mais des augmentations périodiques du prix du souffre, des problèmes de qualité de sucre et les préoccupations environnementales ont stimulés les efforts pour remplacer ou compléter le dioxyde de soufre par le dioxyde de carbone qui peut être disponible gratuitement a partir de l'usine de fermentation. La réduction de couleur entre le jus mélange et le jus clarifie, obtenu au cours de nos tests était en moyenne 35, 47, 44% et 74% pour la défécation, le sulfitage, la carbonatation simple et la double carbonatation, respectivement. La durée et la température au cours de la décantation, la présence de bagasse folle et du sol, l'ajout de phosphate et de protéines, tous des facteurs affectant la couleur de jus clarifié durant le chaulage chaud, ont été testés. À de faibles doses de chaux, en dessous d'un kg de CaO/tonne de canne (défécation, sulfitage et carbonatation), la réduction de couleur se fait par l'adsorption sur les protéines de la canne coagulées par la chaleur, plutôt que sur le précipité de calcium. Toutefois, la capacité d'adsorption des colorants par le précipite n'est pas bien utilisée pendant la procédure normale. Abaisser la température du décanteur par 11°C limite l'augmentation de couleur du jus dans les décanteurs à presque zéro. Quoique que la décoloration du sulfitage et celle de la carbonatation soient plus ou moins comparables, la stabilité thermique apparemment inférieure du jus clarifie et du sirop produits par la carbonatation peut exiger une étude plus approfondie.

# COMPORTAMIENTO DEL COLOR EN CLARIFICACIÓN DE JUGO DE CAÑA POR DEFECACIÓN, SULFITACIÓN Y CARBONATACIÓN

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**PALABRAS CLAVE: Caña de Azúcar, Color, Clarificación, Sulfitación, Carbonatación.**

**Resumen**

EL COLOR es el atributo comercial más importante del azúcar pero, en clarificación de jugo, su remoción usualmente no es considerada entre los objetivos primarios. Sin embargo, con base en los resultados presentados todos los procedimientos estándar para clarificación tienen el potencial par la remoción significativa de color que lo considerado en la práctica industrial. Se probaron cuatro procedimientos de clarificación de jugo, defecación por encalado en caliente, sulfitación, carbonatación y doble carbonatación, y se investigaron varios aspectos del comportamiento del color. La carbonatación no se usa ampliamente en la industria del azúcar de caña pero los incrementos periódicos en el precio del azufre, aspectos de calidad del azúcar y preocupaciones ambientales han estimulado los esfuerzos para considerar el reemplazo o suplemento del dióxido de azufre con el dióxido de carbono, que puede estar disponible gratis de la planta de fermentación. La remoción de color, es decir la diferencia relativa entre color de jugos, crudo y clarificado, obtenida en las pruebas, fue en promedio 35, 47, 44 y 74% para defecación, sulfitación, carbonatación sencilla y doble carbonatación modificada, respectivamente. Se probaron varios factores que afectan el color del jugo claro en el encalado en caliente, como tiempo y temperatura durante la sedimentación, contenido de suelo y bagacillo y adición de fosfato y proteína. Con dosis bajas en el encalado, por debajo de 1 kg CaO/tonelada de caña (defecación, sulfitación y carbonatación) la mayor remoción de color resultó de la adsorción en la proteína de caña coagulada por calor en lugar que en el precipitado de calcio. Sin embargo la capacidad de adsorción del precipitado para los colorantes de la caña aparece sólo parcialmente agotada en el procedimiento normal. Se encontró que el descenso de 11°C en el clarificador limitó el incremento de color del jugo en los clarificadores a cerca de cero. Aunque los efectos decolorantes de sulfitación y carbonatación fueron prácticamente iguales, las aparentemente más bajas estabilidades térmicas del jugo clarificado y la meladura, producidas por la carbonatación, pueden requerir estudios posteriores.