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Research Article

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Analytical and chemical aspects of sugar processing

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ABSTRACT

This presentation deals with the chemical balancing of the clarification zone for cane sugar manufacturing on the basis of molar ratio of reactant. The essentiality of the said balancing along with control by conductometric means have been discussed in detail. Moreover due to ever increasing cost factor of basic chemicals as required in sugar industry i.e. mainly sulphur and phosphoric acid an option has been indicated for fruitful adoption.

Keywords; Sugar Colour, quality control, non sugar, cane juices

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INTRODUCTION

Colour in terms of reflectance value in Indian market and SO_2 content at lowest ebb is the basic thrust of today's need. However, in India any make shift arrangement from conventional way is an apprehension of affecting the final product. This paper is an extract of practical experience drawn from several trials conducted by authors in a few sugar factories on full scale basis. The implementation of proposed process does not concern with any equip mental change in the existing system. The basic approach of the proposed process is the chemical balancing and conductometric control of the process parameters.

In the present context it is imperative to discuss the sugar colour value in Indian market versus global market. Since both the parameters i.e. SO_2 reduction and colour value befits for better quality sugar, it is important to know the interrelevancy of these parameters under reference. The world over view for colour value has been deemed in a dual system. In India it is measured in solid phase, whereas mostly in foreign countries it is evaluated in liquid phase.

Logically in any chemical evaluation the determining parameter should have linear relationship with its relevant parameters to establish, the determining parameter. As database observations are available elsewhere[1], the conclusion drawn thereof reveals that colour value in liquid phase is not having any linear relationship with any individual non sugar constituents. These non sugar constituents are having relevance with determining parameter. Such basic study finds a way to redress the ICUMSA colour value to establish its theoretical explanation.

In contrary the reflectance value is having better reproducibility with ±2% error margin as reported [2], whereas the ICUMSA colour value has permitted ±10 units which enlarges at lower ICUMSA colour value of sugar i.e. $\geq$50 and gets negligible at higher range i.e. $\leq$150 on percentile basis.

Further to this, plantation white sugar manufacture also aims for So_2 reduction. The reduction in So_2 consumption is directly proportional to less So_2 content in sugar crystal. This is for obvious reason prevents the color deterioration and enhances the storage condition/life.

On these aspects, it has become a point of concern to critically analyze the conventional process and to find a remedial approach on its theoretical values.

Approach:
Conventionally and as per available literature[3] if we consider the clarification zone, it reveals that the phosphate content of juice should be around 300 ppm. Such quantity of phosphate content has been experienced as optimum dose for helping the tricalciumphosphate precipitation and thereby enhances the settling phenomena. Of course this chemical reaction to take place needs addition of milk of lime (MOL). The addition of milk of lime helps for multipurpose i.e. in clarifying the juice. Initially it enhances the juice pH to combat the enzymatic inversion. Secondly for tricalcium phosphate precipitation to entrap the suspended impurities which settles out leaving the juice more clear and of higher purity. Simultaneously milk of lime reacts with sulphur dioxide for known benefits. For these reactions in a reactive system condign conditions are required to be provided for desired results. These conditions are relevant to pH value, time of reaction, temperature and finally the molar ratio of reactants.

The detailed discussions on the above points are needed for better understanding and control thereof. The relevant points are taken up as under for complete reactive system.

EXPERIMENTAL SECTION

ICUMSA colour was determined by the GS2/3-10 method (ICUMSA 2005) - 50 gm cane juice was dissolved in 50 ml of double distilled water (50% w/w); the solution was filtered through a membrane filter (pore size 0.45 µm). The first few ml portion of the filtrate was discarded and the pH was adjusted to 7.0+0.2. The absorbancy was determined at 420 nm in a 50 mm cell with double beam UV-VIS spectrophotometer. The calculations are shown below

$$as = As/bc = -\log Ts/bc$$

Where Ts = Transmittancy
As = Absorbancy
b = Cell length (cm)
c = Concentration of total solids (g/cm^3).

It was calculated with the help of refractometric Brix and specific gravity table for pure sucrose solutions. In ICUMSA 'a_s' is multiplied by 1000.

These values reflect a higher colour contamination as compared to an average commercial sample.

RESULTS AND DISCUSSION

Bulk pH:
During sugar processing it is evident that sugar house product in the streamline remains in bulk quantity. The mixing of milk of lime is to be @ 1.0-1.4% v/v of 6-8. Be may definitely hold good to change the PH of bulk medium. Whereas mixing of any process chemical @ ppm dose can only effect negligible change in pH. The crux of the point reveals the fact that care is imperative in case of substantial addition of any chemical to control the pH. At the same time addition of any process chemical may be extreme acidic or alkaline @ ppm dose is not much of concern. This point is needed to be discussed for the reason that any process chemical of wide range of pH can be used. It is in view of the fact available in Table 1, which clearly indicates in the entire sugar processing zone, the complete pH range of colour formation[4].

The close observation of the table clearly suggests that mostly the alkaline medium is responsible to keep the colour intact whereas in the acidic zone the colour disappears and does not reflect on final product.

Table -1pH range in sugar processing/colour formation

Particular	Temp.^{0}C	pH range	Reaction
Juice extraction	65-75^{0}C	5.0-6.4	Melonin formation
Juice purification	60-95^{0}C	7.0-12.5	Degradation of reducing sugar
Juice evaporation	80-130^{0}C	8.5-9.5	Non enzymatic colour formation
Crystallization	40-100^{0}C	7.0-9.0	Non enzymatic colour formation

It gives a clear concept that any process chemical of acidic nature is definitely most appropriate pH range for the purpose of colour removal. As above the apprehension of acidic range in the bulk material for any inversion is not theoretically sound.

Looking at the other aspect the processing system requires concentrating on operational temperature and time of reaction in comparison to bulk pH change, if any, within negligible range. Bourzutschky [4], Gillett [5] have studied these parameters with respect to formation of colour during sugar processing. The study reveals on specific conditions i.e. rate of colour formation/increase with temperature, residence time during evaporation.

To be more specific, a few important, colouring conditions is worth mentioning in the present context. Saceharetin dissolves in alkaline medium and changes from colourless to yellowish. On acidification it turns colourless again. One of the most significant colour making reaction is Maillard reaction which undergoes in case of reducing sugars and amines or amino acids are present. The reaction initiates and accelerates with enhancing temperature and increasing alkalinity. Extraction at low concentrations and natural to slight acidic conditions parctically no Maillard reaction occurs.

Further to this degradation of the Amadon compounds occurs with increasing pH value at higher rates, they are stable under acidic conditions. Similarly with increasing pH values colour formation is more marked than with higher temperature colour formation is 10 times higher at 8.0 pH compared to 5-9 pH.

Data Analysis:
In the present context a few experiments were carried out to gather the effect of time and temperature against ICUMSA colour value of clear juice as obtained from factory operation. The colour formation is distinct from fig. 1 and 2 for time & temperature respectively as delineated from table 2 & 3. The fig. 1 & 2 shows a steeprise of the parameters in question. These results are in line of findings reported elsewhere [4]. The fact finding readings are clearly vouching for temperature and time factors to be responsible of colour formation during the process and pH may not be a point of consideration for negligible change in the bulk medium. The control and regular monitoring of pH and effect in the bulk medium can be made out by applying conductivity means[6]and more work is in progress[7-9].

Table – 2
Time vs ICUMSA for factory clear juice

S.no.	Time	ICUMSA
1	0	480
2	5	510
3	10	700
4	15	1000
5	20	1280
6	25	1690
7	30	1970

Table – 3
Colourvs Temp. for factory clear juice

S.no.	Temp°C	ICUMSA
1	80	500
2	85	550
3	90	980
4	100	1890

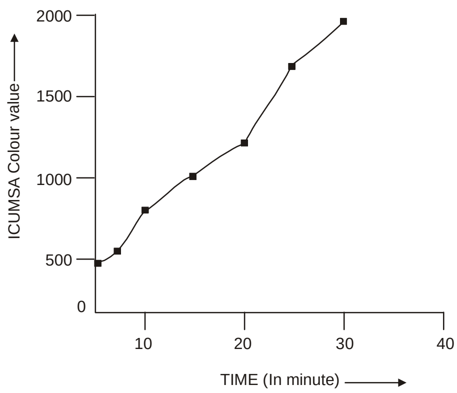

Fig. 1

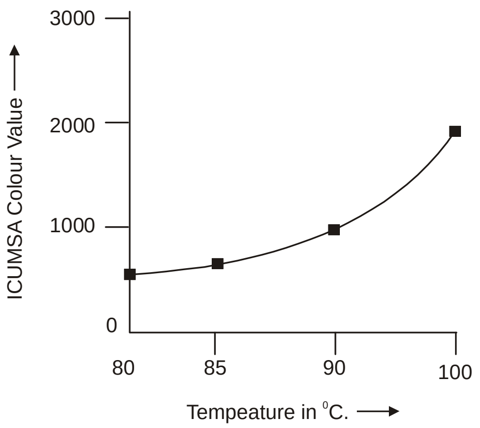

Fig. 2

Molar Ratio:
Any chemical reaction is subject to its molar ratio among the reactants and products thereof. Molar ratio depicts the actual requirement of reactants to follow any chemical reaction. In sugar industry the basic reaction of lime and juice

followed by sulphur dioxide undergoes conventionally on percentile basis of lime and sulphur consumption. In general the range of dose for lime and sulphur are around 0.20% and 0.06% on cane respectively. This is irrespective of various reactive contents of juice. The basic need of lime and cane juice reaction is to raise the pH to check enzymatic inversion and simultaneously tricalcium phosphate precipitation. Conventionally the enhancement of pH is not the basic but to make up of phosphate level around 300 ppm in juice by addition of phosphoric acid indicates the tricalcium phosphate precipitation is equally essential. Instead, the settling aid can help out the basic need of making the sulphited juice clear by way of separating the mud. Of course the mud content shall be primarily the precipitate of tricalcium phosphate formation. This precipitate is definitely limit to already available phosphate content in the juice. Hence, if extra addition of phosphoric acid is eliminated at mixed/clear juice stage then also it is possible that by use of settling aid juice clarity can be achieved. This is not only a cost effective but unnecessary addition of extra phosphate can be avoided.

The above proposition is based on the calculation of chemical reaction on molar ratio.

$$3Ca + 2PO_4 \rightleftharpoons Ca_3 (PO_4)_2$$

From above the phosphate to calcium molar ratio stands for 1.58. Further to this in terms of P_2O_5&CaO the factor becomes 0.7 & 1.4 respectively. Now in case of only 150 ppm phosphate content the CaO requirement stands for only 93 ppm. Similarly the CaO requirement towards So_2 reaction if considered the total CaO content required, can be found out. In addition to this another 20% CaO can also be added and accordingly lime dose can be balanced.

In the above process of lime dose fixation, the CaO content of milk of lime is more important then available CaO in the lime. The available CaO in lime reflects the purity of lime and not the actual needed dose.
On the above lines the authors have experienced through conductometric control, the overall performance falls under satisfactory range in terms of mud control at clarifier and clarity of clear juice. The ultimate effect on molasses being calcium as molassegnic matter, a substantial reduction in CaO content was observed i.e. in the range of 15-20%.

The option:
On the above discussed parameters, and the ever increasing cost factor of chemicals in particular sulphur and phosphoric acid the need of chemical balancing is essential and imperative and simultaneously steps required to adopt polymer based chemicals available in Indian market to omit the use of sulphur& phosphoric acid, such alternatives were well triedand can produce sulphur free sugar.

Another important factor of the present day sugar quality concerns to ICUMSA colour value only. In fact the sale of sugar through Indian production is majority open to Indian market only. Relating to this our scale of whiteness is on reflection basis in solid phase. This is purely based on the luster of sugar crystals and hardness with sharp edges. Whereas in the race of making more white sugar the sugar crystals does loose the hardness and luster. It may be seen that whiter sugar becomes soft to powder like with mild attrition only and looses its reflection value. Secondly the crystal clarity is also missing so far crystal morphology is concerned. However the ICUMSA colour value remains under 100. So far the Indian market is the avenue; sugar crystal production should be emphasized for hard, sharp edge and full of luster instead of having tendency of brittleness. Alternatively the sugar crystal should have higher modulated reflectance than lower ICUMSA colour value only.

CONCLUSION

On the basis of observed data it is imperative to consider the chemical balancing of sugar manufacturing process on molar ratio basis. Further to this keeping in view the ever increasing rates of basic chemicals, conventional process system needs to be modified with cost effective by using alternative chemicals for clarification and relevant purpose.

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