SYMPOSIUM ON SCIENTIFIC PROBLEMS OF THE SUGAR INDUSTRY

OPENING ADDRESS

BY DR. K. S. G. DOSS, D.SC., F.R.I.C., F.INST.P., F.A.SC.
(Professor of Sugar Chemistry, Indian Institute of Sugar Technology, Kanpur)

I SHOULD at the outset thank Sir C. V. Raman for having given this opportunity for sugar technologists and sugarcane specialists to meet the scientists on a common platform for exchange of their ideas. It strikes me that this meeting has profound potentialities to me in particular, who is at present in entire charge of scientific research relating to sugar industry at the Indian Institute of Sugar Technology.

Scientific problems of sugar industry are those scientific problems, which are likely to solve many of the difficulties the sugar industry is facing. There are a number of ways in which the technologist can help at the symposium. He can in the first instance straightaway point out certain problems, which would be worthwhile being tackled by the scientists. Secondly, he can put forth before this learned gathering his most important difficulties, which are bottlenecks to the full realisation of his objectives so that the scientists can conclude for themselves how best they can take part in bringing about the solution of such problems. He could also bring to the notice of the scientists any phenomena noticed by him and which are likely to be of special significance. A similar contribution can be expected from sugarcane specialists as well.

In my short talk, I am going to put general aspects of the problems of sugar industry and give a short account of the problems that strike me at present and also an account of a few attempts that I have made for solving the same.

To put in a nut-shell, the objectives in organising the sugar industry would be:—

(1) to produce more sugar;

(2) to produce cheaper sugar;

(3) to produce better sugar;

(4) to find out new avenues for profitable utilisation of sugar as a raw material; and

(5) to make use profitably the waste products of the sugar industry.

While the problems of sugar industry can be stated generally as above, the solution depends on many factors. The solution is a function of time and circumstances. It is easy to illustrate this by taking one or two of the above objectives. For instance, to produce more sugar there are many possible ways. It may be by crushing more cane or it may be by crushing more efficiently the same amount of cane. One has to look through carefully and see what exactly would help the solution with regard to the enhancing of output of sugar. It may be stated generally that the main bottleneck from this point of view at present is not in the scientific or the technological aspect. It appears to be mainly economic, as was proved by the experiment tried by the Hon'ble Shri K. M. Munshi, when he was the Minister for Food and Agriculture. Just an announcement of allowing a fraction of the sugar produced into the free market under certain conditions, transformed a production deficit to a production excess within the course of a couple of years. This shows clearly that we can have the necessary amount of raw material as well as the equipment; it will be only necessary to attract the raw material into the factory by offering all necessary inducements to the cane-grower and to the sugar factory. As I have already pointed out, this is the position at the present moment, but the solution for this problem can as well be different under a different set of circumstances.

I may as well say a few words about the production of cheaper sugar. It is wrong at the present moment to find fault with the technologist for the high price of sugar. This becomes clear from the facts that roughly 60% of the price of sugar is due to cane, about 17% Government charges by way of excise duty and cane cess, about 12% towards labour, salaries and interest leaving hardly 8% in the hands of the technologists. It is clear from this that even if we can find out a miraculous process by which the sugar from the cane is all taken out without any expenditure on materials, the cost of sugar could have been lowered hardly by one anna per seer. Thus the main difficulty in the way of cheaper sugar is the high cost of raw material. I would not go into the question as to what is the cause of this high cost. One important factor appears to be that we are dealing with small holdings and consequently, cane development work becomes an extremely difficult affair. Small holdings, it appears, have to be accepted as facts in India. We cannot wipe them out perhaps as it will mean rooting out villagers and changing their mode of life. With the advent of the community projects and extension of co-operative organisations it may be possible to minimise the evils of these small holdings.

For the purpose of this symposium it appears desirable to keep the economic and human factors in mind, but only in the background and consider the problems facing the industry. Some of these problems arising may, when solved, act as palliatives and remove the incidental difficulties of the industry. Others may give solutions of interest from the long range point of view. The third type of problem may give results like the bolt from the blue and revolutionalise the whole industry.

Let me first consider the problems arising in the crushing of cane. One of the problems to which my attention was drawn was as to which basis is good for milling control—whether it is the *brix basis* or the *pol basis.* A careful examination of the existing literature indicated that there is a real difficulty in finding an absolutely reliable basis for judging the efficiency of milling. The milling consists in squeezing out the existing juice as efficiently as possible and bring about as good an admixture as possible of the added juice or water with the juice in the bagasse. It is the resultant effect of these two processes that we wish to judge by using the pol or the brix basis. Pol basis would have been universally adopted but for the fact that sucrose is not uniformally distributed in cane. Sucrose molecule being quite of a small size, it would be normally expected to pass through all or most of the cell walls and a uniform distribution of sucrose would normally take place if sufficient time was given. An exception to this, however, would be the portions of the juice rich in colloids which under even equilibrium conditions would contain less of sugar due to their having a high percentage of 'bound' or 'colloid' water. A more important cause of this non-uniformity appears to be due to the life-processes in the cells-processes whose nature and mechanism are yet baffling to the physicist and the chemist. The process of diffusion of solutes (the only mechanism by which homogenisation of the solute can take place) being an extremely slow process is easily upset by any life-process that may be occurring in the cells. What has been discussed with reference to sucrose also holds for any other solute present in the tissue fluid. It is thus seen that it is not possible to find any single constituent which would be uniformly distributed throughout the tissue fluid.

Research was, therefore, undertaken to find out as to which factor is homogeneously distributed throughout the cane. It occurred to me that osmotic pressure has the best chance of remaining constant all through the cane. Any difference in osmotic pressure would tend to bring about movement of water thereby tending to equalise the osmotic pressure. It is no doubt conceivable that such entry of water may be resisted by a counter-pressure in fully enclosed cells to some extent, but it appears that of all possible factors, this quantity has the best chance of remaining uniform all through the cane. With a view to make use of this idea for control purposes I have suggested a new basis which I have referred to as the " isotonic pol basis". " Isotonic pol " for any juice is defined as the pol of a sugar solution having the same osmotic pressure as the juice itself. This has been examined in a preliminary way in collaboration with R. N. Agarwal[1] and results are indicative of this basis yielding successful results. The difficulty, however, is to get at an easy and reliable method for measurement of isotonic pol. This is a matter for further investigation.

It should also be pointed out that when our Atomic Energy Commission Laboratories sets up its own nuclear reactor and produces radioactive isotopes, it may indeed be possible to make use of them for carrying out perfectly reliable milling tests for judging the efficiency of mills. There are many formulæ suggested for judging the efficiency of milling. The present author has critically examined some of them and suggested the lines for further development.[34, 35, 36]

Next we come to clarification. One of our immediate difficulties is the sulphur position. About a few months back the world sulphur position in general and the sulphur position in India in particular was very critical. In fact, the allotment of sulphur for the present season to the sugar factories in this country was brought down with a view to save sulphur. The sulphur position appears to be easing somewhat now, but it is indeed possible that at any time the trouble may repeat even in a more severe form. It is, therefore, of importance to evolve methods of clarification involving either no sulphur or those using less sulphur. From this point of view it is of interest to point out an attempt that has been made at the Indian Institute of Sugar Technology. The new process worked out by Prof. Saha (Director, Indian Institute of Sugar Technology) and Shri N. S. Jain[2] in which the present writer had some part to play, consists in carrying out alkaline filtration with addition of Sindri calcium carbonate sludge, which leads to a filtrate of very high clarity. This alkaline filtrate is treated with superphosphate extract which on filtering gives rise to juice of high purity, pale colour and great clarity. Experiments are on the programme for trying this process on pilot plant and large scales.

The filter aids prepared from carbonation press mud can replace the Sindri sludge. The technique for getting the filter aid has been developed by D. G. Walawalkar and R. S. Srivastava under a scheme of research at the Indian Institute of Sugar Technology, initiated by Dr. A. Nagaraja Rao, Industrial Advisor, Government of India, and completed under the guidance of the author.[3]

It was known that the use of bauxite in clarification would help not only e removal of colour but also would help in diminishing the ash content juices. Since bauxite is having a positively charged surface, it was sur-ising that it should be capable of removing cations such as Ca^{++} and K^{+}. n investigation was undertaken[4] which revealed that bauxite is incapable taking up cations normally. For instance, no measurable adsorption as observed from calcium chloride solutions. In presence of phosphate owever, there was a good adsorption of calcium ions even at a pH at which lcium phosphate is soluble. This result is of interest not only for its ndamental interest but also the important application that in cases wherein ices are deficient in phosphate, addition of superphosphate extract (or osphoric acid) would greatly enhance the de-ashing power of bauxite.

Another idea which strikes in clarification is the development of the imming process. Scum formation at the surface of cane juice can cause onsiderable degree of purification. Experiments by the present author as shown that the washed surface scums from the eliminators may contain ver 60% cane wax.[5] In carrying out skimming effectively, it would be neces-ry to use some colloidal materials. This is being done in the Gur industry, herein the extracts of *Deola* and *Suklai* are being used. It is to be noted owever, that it is worthwhile getting these addition agents in a concentrated rm absolutely ready for use. From this point of view the alginic acid eing produced from seeweeds in Travancore appears to have some potentiali-es. This needs investigation.

Cane juice contains in it a good percentage of surface-active substances. hese get removed to some extent through clarification. It is indeed of terest to find out how far these get removed. Surface-active substances fect evaporation and pan-boiling. They are also supposed to influence ystallisation. We have examined the different methods for estimating e surface-active substances by a multi-pronged attack. We worked out new method for determining rubin numbers.[6] We tried to spread cane ice on aqueous substrates by making use of the film balance of Langmuir.[7] e tried to study cane juice[6] by the method of surface accumulation—a enomenon discovered by the present writer[8] and independently by McBain d co-workers.[9] Finally we have been examining the influence of the rface-active substances on the electric double layer capacity of a dropping ercury electrode.[10] The last of these methods appears to have high otentialities and is under detailed investigation.

One of the lines of development in connection with clarification is the stematisation of the chromatographic technique for the purpose of examining the extent of destruction of reducing sugars. This is of great importance from the point of view of judging the exhaustability of molasses. Hitherto we have been considering anything that reduces the Fehling's solution as reducing sugar; by adopting quantitative paper or column chromatography, it would be possible not only to characterise the nature of the reducing sugar present, but also to quantitatively determine the same. It would be a great advance if the chromatographic determinations can be quickened by any modification so that it could be adopted for routine control purposes. This is again a problem having great potentialities.

In the various stages of clarification, the control of pH is very important. The indicators are very commonly used for the purpose. The nature of the errors caused by surface-active substances on indication by indicators has been studied by the present author.[11] This is of importance in that the raw juice contains a high percentage of such surface-active substances. From this work it appears that the most reliable method for pH determination is by using the glass electrode. It is necessary however to select a pH meter based on a good electrometer valve in order to obtain reliable results with robust glass electrodes.

Several factors have been suggested for judging the efficiency of clarification. A critical study has been made of these and it is shown that the so-called clarification factor is fundamentally defective and should not be used for assessing the efficiency of clarification.[12] The purity rise is shown to be a much better index.

Regarding settling, it has been suggested that high pressure settling would be helpful, as the ' Cartesian diver ' principle would operate in bringing about quick settling. The fallacy underlying this proposal has been shown by the present author.[13]

I would like to say a few words about ion exchange. It is not the purpose to consider in detail the full aspects of the potentialities of the ion-exchange process. In general it appears that if deionisation of cane juice can be effected, the recovery of sugar would be increased and the molasses would become edible. Whereas there is a likelihood of this being adopted by a few factories in time, it is matter for consideration whether this can be adopted in our country to convert what is now the cheapest raw material for power alcohol, a material of strategic importance, into edible sugar and syrup and even if so, at what cost. It would also be necessary to make sure if there is no deleterious effect of traces of resins that get dissolved out and enter into the molasses, on the edibility.

Regarding the process of evaporation, there are two main difficulties observed (*a*) Scale formation inside the tubes, and (*b*) Rust deposition outside the tubes. Many addition agents have been described for preventing scale formation, but the results reported have been conflicting. A few new devices have recently come up under different trade names, such as the superstat, the CEPI, etc., which are claimed to prevent scale formation. The theory underlying the performance of these new gadgets is far from clear. In fact, these claims remind us of the once popular " mitogenetic effect". In a way, I am inclined to think that one method of getting rid of scale is to produce the necessary conditions for helping their precipitation in the bulk solution instead of getting deposited on walls. This may be done by introducing high speed stirrers or sonic or supersonic vibrators in a proper place in the evaporator system. This is essentially a new idea and it requires experimentation as to the optimum conditions for getting best results. It has since come to my knowledge that an ultrasonic device has been put on the market by the Swiss firm under the name " Crustex".

Many addition compounds such as calgon, have been suggested for preventing scale. The possible effect of calgon on the colour of sugar produced has been investigated.[14] It is to be pointed out however that the results obtained by these compounds on scale formation are conflicting. Further work is needed to establish the conditions under which these may be useful.

In the sulphitation of syrup, use of packed columns would greatly help in reducing the loss of sulphur dioxide. Whereas the packed columns worked out in the author's laboratory for distillation[32] would not be suitable for this purpose, the use of Raschig ring packed columns would be most convenient. A column put up by Shri Awasthy at Burhwal Sugar Factory, at the instance of the author, is giving good results.

Regarding pan-boiling, it is indeed probable that the sonic and ultrasonic radiation, is likely to be useful for graining purposes. Already some work has been reported in this connection. This requires further investigation.

It is of interest to examine how far it is economical to use active carbon on C-Sugar and B-Sugar melts, with a view to get a single high grade sugar as the product. From this point of view, work in this laboratory has shown the possibilities of manufacturing good active carbons from bagasse,[15] press-mud[16] and molasses[17]. It has been further shown that the residues after extraction of wax from press-mud can be a raw material for cheap active carbon.[18] A reliable method has also been worked out for assessing the decolouring power of active carbons.[19]

In judging as to whether the pan-boiling and crystallisation have been conducted under the most optimum conditions, it would be necessary to examine the final molasses for its viscosity at the pan-boiling temperatures as well as the degree of super-saturation, by determining the saturation temperature. The existing methods for the determination of viscosity are defective in that they often employ large volumes of molasses. This makes it difficult to obtain temperature equilibrium, which is very important for getting reliable measure of viscosity. To remedy this defect, a rolling sphere method is being developed at this Institute, taking advantage of electrical methods for finding out the rate of rolling of the sphere. Similarly, it is proposed to examine the feasibility of the Toepler's schlieren effect and optical interference techniques for designing a sensitive saturascope. From the point of view of exhaustability of molasses, it is also of interest to examine the effect of individual salts as well as reducing sugars on the solubility of sucrose as well as the crystallization kinetics. Some work has been done in the present author's laboratory.[20]

It sometimes happens that sugar crystals develop in elongated forms. This leads to difficulties in curing. The cuase of this appears to be in certain impurities inhibiting growth over certain of the faces of the growing crystal. Work in this laboratory has shown that caramel tremendously lowers the growth rate on the 100 face of the sucrose crystal.[20]

From the point of view of developing a method for controlling the size distribution of crystals in strikes, the simplification in calculation introduced by the present authors would be of interest.[21]

The final quality of sugar depends amongst other things on the extent of colour development during processing. In this connection, a start has been made on the study of kinetics of colour development in sugar solutions.[33]

In drying and cooling there appears to be scope in combining the infrared heating with vacuum so as to eliminate the deleterious effect on the quality of sugar in the usual rotary driers. In the storage and transport of sugar it is of interest to try some of the new plastic lined bags, which appear to be proof against ingress of moisture. The use of plastic film for packing confectionery has been found to be advantageous as shown by work in the laboratory.[22]

In judging the quality of sugars, the determination of ash is important. A conductometric method was worked out by Zerban and co-workers. The theory of the method has been worked out in the present author's laboratory.[23-27] The regression formulæ connecting ash and conductivity have been derived for Indian molasses and gurs on the basis of data worked out in the author's laboratory.

A further property that has been suggested for judging the quality of sugar is based on the determination of gold numbers. This technique is very troublesome. An alternative method based on rubin numbers has been developed and applied to a few sugars.[28, 29, 30]

From the point of view of confectionery manufacture, even small traces of impurities affect the quality of sugar. This problem has been examined in detail in the author's laboratory.[31]

A scheme has been worked out for examining the quality of refined sugar cubes and data have been recorded on some samples of commercial refined sugars.[31] It has been found that electrical conductivity gives a good criterion for distinguishing a refined sugar from a white consumption sugar.

Storage of molasses is normally not a difficult problem. Occasionally, however, a very interesting phenomenon usually referred to as "Froth Fermentation" takes place completely spoiling the molasses. The phenomenon is very interesting. Almost suddenly the molasses starts frothing, rises in temperature up to 72° C. or higher, appears to boil and overflows out of the tanks. The remaining quantity of molasses gets highly caramelised and perhaps even carbonised to some extent. The cause of this extraordinary fundamental phenomenon is yet unknown. An examination of the literature is generally indicative that the first stage of the phenomenon is biochemical involving thermophilic organisms. The later stage may be a pure chemical reaction having a chain mechanism. Attempts have been made by us so far without success to reproduce this phenomenon in the laboratory by trying to initiate a chain reaction. This is a problem of great interest both from the fundamental and from the applied point of view.

Dielectric heating and capacity measurements at high frequencies have great potentialities in laboratory determination of moisture in bagasse (& molasses ?) for control purposes. This needs investigation.

The subject of by-products of sugar industry is too vast and so I have kept aloof from the subject for the purposes of this symposium.

I have given in this paper some of the ideas that have occurred to me and it would give me satisfaction if these take practical shape speedily by the co-operation of those present at the symposium and those who will read this report.

References

1. Doss and Agarwal .. *Proc. S.T.A.*, 15th Convention, Part I, 1946, pp. 18-23.
2. Saha and Jain .. *Ibid.*, 21st Convention, 1952, pp. 3–16.
3. Walawalkar and Srivastava .. *Ibid.*, 13th Convention, Part I, 1944, pp. 69-80.
4. Doss and Jain .. *J. Sc. and Ind. Res.*, 1945, **5B**, 4-5.
5. Doss and Kripashanker .. *Ibid.*, 1945, **3**, 462.
6. Doss and Kalyanasundaram .. *Proc. Ind. Acad. Sci.*, 1950, **32**, 402–8.
7. ——— .. Unpublished.
8. Doss .. *Curr. Sci.*, 1935, **4**, 405.
9. McBain and Wilson .. *J. Am. Chem. Soc.*, 1936, **58**, 380.
10. Doss and Co-workers .. *Curr. Sci.*, 1951, **20**, 199–200; *Proc. Ind. Acad. Sci.*, 1952, **35**, 27–33; 173–77, **36**, 493–500. *Indian Soap Journal*, 1952, **18**, 12–16. *Proc. S.T.A.*, 1952, **21**, 40–59; *J. Sc. and Ind. Res.*, 1953, **12B**, 84–85.
11. Krishnappa, Doss and Rao .. *Proc. Ind. Acad. Sci.*, 1946, **23**, 47–59.
12. Doss .. *Indian Sugar*, 1946, **9**, 94–95.
13. ——— .. *Ibid.*, 1947, **10**, 90–91.
14. Doss and Ray .. *Ibid.*, 1946, **9**, 277.
15. Doss and Jain .. *J. Sc. and Ind. Res.*, 1945, **3**, 393–6.
16. Rao and Jain .. *Proc. S.T.A.*, 1949, **9**, Part I, 293.
17. Doss and Singh .. *Ibid.*, 1950, **19**, 230–32.
18. Doss and Jain .. *Indian Sugar*, 1944, **7**, 149.
19. Doss and Singh .. *Proc. Int. Soc. Sugarcane Tech.*, 1950, **7**, **620–22**.
20. Doss and Ghosh .. *Proc. S.T.A.*, 1950, 19th Convention, 183–91.
21. Nayer and Doss .. *J. Univ. Bombay*, 1945, **13**, 11–12.
22. Kalyanasundaram and Rao .. Confectionery Production, May 1951, 318–19, 321.
23. Doss and Gupta .. *Proc. S.T.A.*, 1948, **17**, Part I, 58–66.
24. ——— .. *Ibid.*, 1949, **18**, Part I, 47–51.
25. ——— .. *Ibid.*, 1949, **18**, Part I, 42–46.
26. ——— .. *Ibid.*, 1950, **19**, 212–18.
27. Gupta .. *Ibid.*, 1951, **20**, 16–20.
28. Subrahmanya, Doss and Rao .. *Proc. Ind. Acad. Sci.*, 1947, **26**, 197–202.
29. Doss and Kalyanasundaram .. *Ibid.*, 1950, **32**, 402–8.
30. ——— .. *Proc. S.T.A.*, 1950, **19**, 200–8.
31. Kalyanasundaram and Rao .. *Proc. Ind. Acad. Sci.*, 1951, **34**, 49–53.
32. Doss, Jain and Husain .. *J. Sc. and Ind. Res.*, 1947, **6B**, 81; *Proc. S.T.A.*, 1948, **16**, Part II, 34–38.
33. Doss and Ghosh .. *Ibid.*, 1948, **17**, Part I, 51–57; 1949, **18**, Part I, 26–31.
34. Doss .. *Indian Sugar*, 1947, **10**, 91.
35. ——— .. *Proc. S. T. A.*, 1947, 15th Convention, Part II, 27–30.
36. ——— .. *Ibid.*, 1947, 16th Convention, Part I, pp. 1–9, 10–14, 15–18.
37. Doss and Jain .. *Ibid.*, 1947, 15th Convention, Part II, 41–46.