SOME SCIENTIFIC PROBLEMS OF THE SUGAR INDUSTRY

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No other single industry can offer as many problems for solution to the numerous branches of Science and Engineering. Of immediate interest would be those, the solution of which will directly or indirectly help the Indian Sugar Industry in reducing the cost of production. The growing of sugarcane presents all the problems connected with the creation and bringing up of a eugenically perfect child, its feeding, protection against the onslaught of pests and diseases, maturity problems, etc.,—problems more complicated at each stage due to the medium of its growth, *viz.*, soil and the air and the inanimity and immobile nature. Satisfactory solutions to these problems become more difficult when they come to be examined by economic standards.

The recovery of crystal sugar from the mature cane involves several steps, each such step presenting numerous problems aimed at the perfection of the several unit processes and equipment individually and in relation to each other. The history of the development of the sugar industry in the field and in the factory all over the world represents the outstanding achievements of men of science in this field. Even so judged by the present day standards and the needs of the future we are still far away from our goal. The sugarcane, which is the most efficient fixer of solar energy of all plants, is still a highly inefficient machine, the percentage fixed by it being very small compared to the total quantity that reaches it. The sugarcane is still a very uneconomic baby in respect of its food, water and labour requirements. The recovery of crystal sugar from the sugarcane is also a highly inefficient process involving huge amounts of power, fuel and labour, all of which should be very much smaller. The various by-products of the sugar industry both in the field and in the factory still await proper utilisation.

In so far as the cost of sugarcane forms 60% of the ex-factory price of sugar or 72% of the total cost excluding taxes, the greatest effort should be directed to increase the yield and sugar content in cane at minimum cost. The Tariff Board, 1950 reported yields of 11·7 tons cane/acre in U.P., 9·8 tons in Bihar, 32·9 tons in Bombay and 14·0 tons in the whole of India. This roughly corresponds to production of 350 lb. of sugar per acre per month in India and 750 lb./acre/month in Bombay. Compare this with possibilities. Wilcox's studies based on plant-biological facts and ideal cultural conditions place 190 tons sugarcane per acre as the maximum. Twenty years ago the Bureau of Experiment Stations, Queensland recorded at South Johnston 144 tons sugarcane per acre and 22·9 tons of sugar per acre on a 16-month crop. In the 1950 Hawaiian Crop Ewa Plantation recorded an average of 14·05 tons/sugar per acre on the entire plantation of over 4,700 acres corresponding to 1,307 lb. sugar/acre per month. In India, Walchandnagar recorded an yield of 122·4 tons of sugarcane per acre (on 3 acres) and 14·13 tons sugar per acre corresponding to 1,900 lb./acre/month. There is thus scope for increasing the production of sugar per acre per month at least by 100%.

Varietal Problems.—While a number of varieties are showing improved results in North India, CO-419 is still the best cane in the Deccan. This variety has recently given considerable room for anxiety due to its inexplicable inferior performance in some cases. This has been ascribed to a degeneration resulting from different causes such as senile degeneration of the variety, soil exhaustion and deterioration and loss of certain essential fertility factors. Whatever future investigations may reveal, there is a very urgent necessity to intensify our breeding programme to enable the creation of eugenically and economically better varieties tailor-made to suit widely differing cane-growing regions in India.

Soils.—Systematic investigations on a uniform basis into the soils of the cane-growing regions in India both for fixing manurial schedules and for guarding the maintenance of the fertility status of the soil are urgently called for. Considering that the farmer's methods of 40 centuries are being replaced by the necessary evil of modern mechanical cultivation and intensive fertilisation most unbalanced, the importance of conserving all sources of organic matter and suitably composting and returning the same to the soil has to be realised. Methods to turn sugarcane trash and other residues rapidly and economically to compost have to be perfected. The increasing importance of maintaining a proper ratio of cattle population to cultivable land in the interest of maintenance of soil fertility and quality of crop is still to be appreciated. The " grow-more food " campaign and the pressure on land resulting from food scarcity have taken off the much needed rest and a healthy rotation. This is not safe for the soil.

Climate.—Under present state of knowledge and resources, the existing climate has to be accepted and the growing of cane adjusted to suit it. It is obvious that the Deccan and South India present more favourable conditions for sugar production and this fact is behind the proposals of shifting the industry to the extent possible from the North, where factors other than climatic suitability were responsible for the early development of the industry.

Manuring.—The poor condition of the cane-growers in most cases is responsible for inadequate manuring of the cane crop. Such improvement as has been possible is in the factory areas, where the factories take interest in cane development. Intensive manuring is practised in most of the factory farms in the Bombay Presidency. More than 50% of the cost of cane is for manures. On the efficient use of manures, therefore, lies great scope for reducing cost of production and preventing waste of manure and spoilage of land. A proper combination of plant foods, applied according to the needs of the plant depending on age, soil and season, is the greatest need in the field of sugarcane nutrition. The following figures in respect of utilisation of nitrogenous manures reveals the need for urgent action. The nitrogen applied in lb., per ton of cane produced in different areas, is as follows:—

Punjab	3·4 lb.
U.P.	3·5 lb.
Bihar	4·0 lb.
Madras	3·7 lb.
Bombay	7·5 lb.
Walchandnagar Prize Plot	8·2 lb.
Average of prize plots in different factories	12·6 lb.
Hawaii	4·0 lb.
Java	1·6 lb.

Similar figures in respect of other manures may reveal more startling variations and wastes. The above figures indicate that while heavy manuring results in increased yields, the efficiency of utilisation of the applied manure decreases. Intensive work is called for to increase the efficiency of manure utilisation. The mechanism of nutrient uptake, needs detailed study in view of the findings that more than the concentration of nutrients it is the physico-chemical properties of the ions, at the surface of the soil colloids that determine nutrient uptake and distribution. Manuring schedules based on soil analysis, plot experiment, available plant nutrients in the soil, etc., have all been unreliable, laborious, time-consuming and what is more important, of the nature of "*Post-mortems.*" Recent studies of "Foliar diagnosis," which utilise the plant itself to analyse its nutritional requirements, excesses and deficiencies have proved of greater value. Ask the plant what it wants and at what stage of its growth and feed it accordingly.

The Clement's crop-log system which is based on the analysis of the leaves and sheaths of the sugarcane plant at different periods of growth has been a successful attempt in this direction and more than 30% of the cane grown in Hawaii are manured on this system. It is high time that the manuring schedules on the sugarcane plantations in India are placed on a more scientific basis.

Another important problem is the fixation of added nutrients by the soil especially of phosphorus which nutrient plays such an important role in plant metabolism. Placement of phosphates at the active root zone, thus increasing local concentration, beyond the fixing capacity of the soil and aerial spraying, have been so far suggested.

Another aspect which is gaining importance in recent years in the nutrition of sugarcane is the role of trace elements. Small amounts of elements like boron, copper, zinc, manganese, molybdenum, etc., appear to play key roles directly or indirectly in the nutrition of sugarcane. Promising results have already been obtained at Ravalgaon by the use of boron, zinc and copper.

Water.—Sugarcane is a water-loving plant and needs large quantities of water. Both the yield and quality of sugarcane under intensive manuring depend on the judicious control of soil moisture. The present plot-layouts and irrigation techniques, as also irrigation intervals have to be examined and revised with a view to improving the economy of water, conservation of nutrients, prevention of erosion and maintenance of vigorous growth. The water requirement of the cane crop in the Bombay-Deccan is 150″ to 170″ acre inches per year inclusive of rainfall and depending on the soil. Of the 140 to 150 acre inches given through irrigation in some of the lighter soils the quantity of water lost through seepage alone is between 60% to 70%. This excess water washes away the nutrients and by collecting in the lower areas spoils the land due to water-logging. Where there is enough depth of sub-soil the level of water table rises and causes salt accumulation at the surface.

Insects, Pests and Diseases—Insecticide and Weedicides.—Pyrilla, Top-Shoot borer and Stem borer are threatening the industry in many parts. In spite of D.D.T. and Gammaxene, the only successful method for controlling Top-Shoot borer and Stem borer has been the method of picking and destroying the cane infested. With Pyrilla however, Gammaxene and D.D.T. have proved useful in many parts. A recent finding by Wagle which shows promise for the control of Pyrilla is the fungus "Green Muscaradine". 2-4-Dichlorophenoxy acetic acid (Fernoxone I.C.I.) and other weedicides are proving helpful in the control of weeds. One important aspect that needs further work is the effect of these chemical insecticides and weedicides on the soil micro-flora. Are they doing unknown harm upsetting the normal biological balance?

Maturity and Quality.—The technique of bringing the cane to maturity by control of growth factors, timing of manurial applications and the maintenance of the plant in the state of maturity for a long period have to be perfected. The technique of controlling the irrigation towards the end of the growth period and the ultimate "drying off" as it is called has reached a high standard in Hawaii. The degree of drying off is controlled by the moisture index which at the harvest is as low as 72.

Controlling of tasselling or arrowing of cane by exposing to strong light in the night for 10 days has given 1½ tons or more sugar per acre in the experiments in Hawaii.

Fundamental investigations into the mechanism of photosynthesis, formation, translocation and accumulation of sucrose in the sugarcane plant and the controllable factors influening these mechanisms are called for. The radioactive isotopes of carbon and phosphorus are new tools available for probing deeper into these complicated processes. The Hawaiian Sugar Experiment Station has for the last two years been working with radioactive carbon dioxide and radioactive phosphorus.

Field Mechanisation.—Great scope exists in the sphere of field mechanisation in the growing of sugarcane. This aspect has already well progressed on the farms of the Bombay factories. In other places the small size of holdings and lack of financial resources are obstructions to any progress in this direction. Increasing the size of the units on a collective or co-operative basis to at least about 50 acres would help mechanisation on the lines of Australia, where one farmer with two assistants (sometimes members of his family) manages with the help of mechanised units one 50-acre block, requiring external help only at the time of harvest. Small units for preparing the land, for planting and for interculturing have been in use. Even small harvesters are under trial in Australia.

Sugar Manufacturing

Clarification.—The sulphitation process using lime and sulphur has for a long time been the cheapest and simplest method of cane juice clarification for direct consumption white sugar. The only other process in use in few factories in India is the double carbonatation process which though superior is costlier and limited by the availability of good quality lime stone. Sulphur being an imported product and a strategic material, efforts of scientists are called for to evolve a superior and cheaper method of clarification and without using sulphur. The electrical method of clarification worked by D. N. Ghosh is a commendable attempt in this direction. The process consists in passing a D.C. through cane juice using iron electrodes and controlling the current density voltage and temperature of the electrolysis, separation of the waxy foam, precipitating the iron as iron phosphate and filtering. The report of large-scale trials made at the Experimental Sugar Factory on this process are awaited with interest. Trials conducted on a small scale at Ravalgaon showed that the method as at present involves considerable quantities of current, iron in the form of electrodes, difficulties in the filtration of the iron phosphate precipitate, etc. It is gathered that the sugar produced from this process at the Institute at Kanpur was greyish in colour and contained appreciable quantities of iron.

Treatment of midsap, *i.e.*, the syrup of about 45° Bx., from the penultimate body of the evaporator and subsequent return to the last body has been receiving increasing attention in recent years and needs to be followed up for establishing merits.

A few papers have appeared on new techniques in clarification by Prof. Saha of the Indian Institute of Sugar Technology. One of them relates to the treatment of juice at high alkalinities and high temperatures and filtration at such temperatures. The results in the laboratory have given very good rises in purity and brilliant juices. Large-scale trials at Ravalgaon have however shown that it is dangerous to adopt the process on the large scale, unless suitable equipment are designed to overcome the time factor, which is the essential requisite for success of the process. Obviously the high temperatures and alkalinities set up undesirable decomposition reactions which rapidly increase with time. Moreover this process involves more cost due to increased sulphur, labour, equipment, etc. The same objections apply to the technique of treating midsap at high temperatures and high alkalinities.

Another clarification procedure evolved by Prof. Saha is "clarification without sulphur". This process involves a preliminary treatment with Sindhri Sludge (precipitated calcium carbonate) liming to high alkalinity (10·5) filtering, treatment with phosphate and again filtering. Walawalkar has raised objections to the above claim and states that the Sindhri Sludge is highly impure for the purpose and involves very high transport costs, etc. Further that the superphosphate used requires sulphuric acid for its production, which means sulphur. These views have to be carefully examined against the claims of Prof. Saha. A few trials of the process in the laboratory at Ravalgaon indicated likely difficulties in the filtration stages.

With the developments in Chromatography, it should now be possible to study in greater detail the variations in the composition of cane juice and the changes during the different conditions of treatment. Such a knowledge would be very useful in designing suitable clarification techniques and to understand more clearly the exhaustibility of molasses, *i.e.*, the influence of the various non-sucrose constituents in the molasses, which set a limit to the separation of sugar from it in crystal form.

Another subject of very great interest and importance is the deionisation of cane juices. Considerable progress has already been made in the manufacture of suitable resins and in the technique of deionisation. The N.C.L. is working on this. The difficulties are of an economic nature and primarily relate to the cost of regenerants. This field has large possibilities.

Process Control and Equipment.—Most of the operations at present are batch processes involving the human element, bulky equipment and non-uniformity of the results. Future trends are for continuous processing with automatic controls involving electronic and remote control devices. Such is possible with sulphitation, settling, filtration and evaporation. A considerable portion of the operation of the vacuum pans can now be automatically controlled. Continuous crystallisers and continuous centrifugals have also now been working. It will not be long before the entire sugar manufacturing is done by continuous operation with automatic electronic controls involving great reduction in labour, a major item in the manufacturing expenses. The labour per shift in an Indian factory would be of the order of 200 per shift and 500 and more including every one, as against 40 per shift and 150 for the entire factory in Queensland and Hawaii.

Steam and Fuel Problems.—The cane sugar industry is in the happy position of being potentially independent of extra fuel. Even so as against the requirement of about 25% bagasse % cane, the industry is using 35%. Though in some factories the bagasse production is much higher than 25%, the increasing value of bagasse as a raw material for various other industries, urges the utmost economy in the use of this fuel, which would mean efficient generation and use of steam. Semi or complete electrification of factories, efficient prime movers, high pressure boilers equipped with furnaces designed for efficient combustion and heat recovery are called for. Closed condensate system for boiler feed is important. Improvements in technique and equipment should also be designed to reduce the power required, when increasing quantities of by-product power become available.

The moisture % bagasse needs to be reduced from the existing level of 48%-50% to about 20% or lower and the necessary changes in furnace design made.

On the steam utilisation side, maximum economy is called for by adoption of continuous settlers and filters multiple effect evaporation with pre-evaporators and vapour heating from the 1st and 2nd bodies improved pans with mechanical circulators, cooling and reheating of massecuites and continuous centrifugals.

Chemical Control.—Considerable scope for scientific work lies in the field of chemical process control, accounting and auditing. The first essential is to introduce uniformity in the methods of sampling and analysis. Accurate, simple and rapid methods to determine sucrose in sugar house products are required to enable the more accurate sucrose basis of chemical control to be adopted. Similarly rapid and reliable methods for the determination of true solids, in sugar house materials are an urgent need. The refractometer is at present the simplest and nearest approach to the solids by drying. Methods of juice preservation also need study.

Utilisation of By-products and Wastes.—The wastes of the sugar industry include those on the farm and in the factory. On the farm the wastes are cane tops, roots and stubbles and cane trash, together forming 20% to 30% of the millable cane. The wastes from the sugar factory are bagasse (32% to 38% on cane), press cake (1·5% to 3·5% on cane) and molasses (3% to 4% on cane).

The cane tops can support a large dairy herd and farm animals. In Brazil 1·96 gallons of alcohol are recovered from cane top from one ton cane. The roots and stubbles (2% to 3%) remain in the soil and add to the organic matter.

Cane trash is being burnt and represents enormous waste. Work at Ravalgaon and Walchandnagar have shown its possible uses in making cardboard and packing material. Cane trash properly composted and returned will be of very great help to the maintenance of soil fertility.

With improvements in steam and fuel economy the bagasse can form a valuable source of cardboards, insulation boards, paper and α-cellulose.

Press cake contains valuable cane wax to the extent of 8% to 15%. This wax is being recovered at Ravalgaon on the large scale. Cane wax valued at several crores are being thrown away every year, while waxes are being imported into India. Considerable work has been done on the recovery, fractionation and bleaching of sugarcane wax. Further work is necessary to improve the hardness of the wax and its solvent retention properties. This requires modifications in the composition of wax on the lines of the German I.G. Waxes, from Montan Wax. The N.C.L. has made some progress in this direction.

Molasses is the main by-product of the sugar industry, which awaits proper utilisation. Innumerable products can be made from molasses by fermentation, the most important so far being alcohol. From the 4 lakh tons of molasses turned out by factories in India about 24 million gallons of power alcohol can be produced. The present consumption of petrol in India is 240 million gallons per year. It is established that power alcohol can be safely mixed with advantage with petrol for use as motor fuel to the extent of 15% to 20%. It is, therefore, obvious that the entire production of molasses can be absorbed for the manufacture of power alcohol for motor fuel purposes. The recommendations of several committees and panels have so far not produced visible progress. Let us hope that the recommendations and findings at the seminar on power alcohol recently held at Lucknow under the auspicies of the E.C.A.F.E., will result in some progress in this direction.

CONCLUSION

Obviously the problems of the sugar industry are numerous and call for intensified efforts and team work for solution.

There are immense possibilities of such efforts resulting in increased yield and quality of sugarcane, decrease in manure, labour and manufacturing costs and in the end the overall costs of sugar production. Crores of rupees have been collected from the industry for research and development, but very little actually used for this purpose. It is in the realisation of the very great importance of intensive research and in the proper utilisation of the funds that the future of the industry rests for its survival.