THE BY-PRODUCTS OF THE SUGAR INDUSTRY—A NEGLECTED SOURCE OF REVENUE

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The Sugar Industry gives rise, as is well known, to two by-products, namely, bagasse and molasses, which are considered in South Africa as almost worthless. True, bagasse supplied the fuel for working the mills, but where it is not all used for this purpose and collects in a dump outside the mill, it is treated as valueless. Molasses, the very word to-day causes a fit of depression to the mill authorities, not because it ever was very valuable, but even its penny per gallon has gone. To-day, on all sides can be heard such remarks as "You can have the stuff if you will guarantee to take it away," "What on earth are we going to do with our molasses next crop?" etc.

So are treated these two valuable products upon which nature spent such cunning in forming. Valuable, you say! Yes, very valuable, and worthy of much close examination. Wherever there is found in nature certain atoms strung together into chains, as is the case in the cellulose of bagasse and the sugars in molasses, man has had presented to him products already in an advanced state of manufacture. This fact every organic chemist will appreciate, and it is a most wasteful thing to burn these compounds. Nevertheless, when they have to be burnt each presents peculiar problems. I spent a whole year in designing a furnace which would burn molasses satisfactorily, and five different designs were tried before success was attained.

These two by-products, viz., molasses and bagasse, can be made to yield other products, the value of which would surpass the revenue earned by the main product. Such a position has befallen many industries before, and in others the by-products have been elevated from liabilities on the industry to considerable earners of revenue. Examples of such cases are provided by the recovery of glycerine from the splitting of fats in the soap industry. At one time the glycerine as "sweetwaters" was run into the factory drain. On its recovery and concentration such value was obtained from it that the main product, soap, became the by-product and the demand for glycerine became enormous. In the cotton industry once only the cotton was valued and the seeds neglected. In 1926 (the latest figures I can get) the value of the cotton harvested in the United States was $982,736,000 dollars, and the by-product prepared from the seeds returned revenue amounting to $256,627,431 dollars, i.e., more than 25 per cent. of that resulting from the main product. Again the tomato ketchup industry in Italy rejected for years enormous weights of pips until it was shown that a very valuable oil could be expressed from them. Now the annual return from the oil is in the neighbourhood of $20 per cent. of that earned by the main product, and once more the Quaker Oats factory in America used their boilers with the hulls resulting from the decortication of the oats. To-day furfural is prepared from the hulls and is finding ever increasing use in the preparation of electric fittings. Instances of this kind could be multiplied indefinitely.

The Sugar Industry as already stated holds exactly the same potentialities. Indeed actual demonstration has been provided in the preparation of Celotex in Louisiana. In 1928, 300,000,000 square feet of this board has been manufactured. This is sufficient to floor the road from Johannesburg to Durban—409 miles and 30 feet wide—four times. The value of the board was $9,000,000 dollars, while that realised for the refined sugar did not reach $7,000,000 dollars. Thus it will be seen that the value of the by-product exceeds that obtained for the main product, and this without taking into consideration what could be won from the molasses.

Whether the Sugar Industry got this $9,000,000 dollars or not for the purpose of this argument does not matter, that value lay in the by-product.

There are several other outlets for the profitable utilisation of bagasse by processes which are being exploited commercially, one of the most important being paper and cardboard. This consists of extracting the cellulose from the bagasse. A complete analysis of dry bagasse gives in addition to sugar—

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\begin{align*}
35-40\% & \text{ Cellulose.} \\
20-25\% & \text{ Pentosans.} \\
12-16\% & \text{ Lignin.} \\
2-3\% & \text{ Ash.}
\end{align*}
\]

At least 30 per cent. of the weight as cellulose can be extracted, and the demand for derivatives of cellulose for the production of lacquers, artificial silk and the enamel industry is rapidly increasing.

Another constituent worthy of extraction are the pentosans from which furfural, referred to above, is prepared. The pentose sugars can also be fermented by bacteria found in saurkraut and silage into acetic and lactic acids.

In molasses we have an exceedingly cheap and abundant source of raw material from which many very valuable chemicals can be prepared. There is no reason why we should not prepare these products here and so benefit by our own raw material.

The products of South Africa in other fields are meeting and conquering the competition from other countries on the English market. One has only to call to mind the wine trade, the citrus and egg industries. The latter is a particularly good example for competition from such agricultural
countries as Denmark and Ireland had to be met and overcome. To-day the South African egg has a ready sale on the London Market at paying prices, and this in spite of the 7,000 mile journey it has to undergo. Such being the case, it should be possible to put on the Home market successfully the much more valuable products resulting from our exceedingly cheap raw material—molasses.

As an example of one series of products consider the following:

Starting with Molasses at 85 Brix we can get: Molasses, Alcohol, Acetic Acid, Calcium Acetate, Sodium Acetate, and from the Calcium Acetate, Acetone.

The molasses is first fermented to alcohol, and this can be done either in closed or open vats. The former are preferable as they produce a higher yield owing to the exclusion of wild bacteria which cause the fermentation to produce side products, the loss of alcohol by evaporation—especially in our hot country—is very great when using open top fermenters. One hundred litres of alcohol (175 lbs. specific gravity being taken at .7946) result from the fermentation of 300 kilograms of molasses of 85 Brix. This weight of alcohol is a conservative figure; better results can be obtained by strict control of the pH of the vat and careful breeding of the yeast used to ferment the mass. The alcohol is not obtained from the vat at the weight used in the calculation of the yield but in a much diluted state. Should the alcohol be the final object of the fermentation, it would have to be concentrated and this would involve a concentration process which would be omitted in the preparation of the next chemical in the above series, i.e., acetic acid. Acetic acid can be prepared from the diluted alcohol by a further type of fermentation. Here again the type of plant used plays an important part in the yield. In some places it is usual to carry out the acetic fermentation in wooden vessels, but the evaporating losses are considerable, so that more modern plants are using acid-proof stoneware, which, due to their non-porous nature, reduce these losses to a minimum. For the calculation of the yield 80 per cent. as a conservative conversion can be reckoned on, consequently from 175 lbs. of alcohol 182.6 lbs. of dilute acetic acid will result. This acetic acid may now be treated in several ways according to the object sought. It may either be concentrated and sold as such, or neutralised by sodium carbonate yielding 414 lbs. of crystallised sodium acetate, or neutralised by lime whereby 256.6 lbs. of calcium acetate would result.

In carrying out both the above fermentations it cannot be emphasised too strongly that only a pure, wholesome, potable water must be used for dilution of the mass to be fermented. The rivers of Zululand and Natal, which are polluted by the sugar mills, are very unsuitable for such a purpose.

The calcium acetate may be carried a stage further and by distillation acetone will result. The yield in this case from 256 lbs. of calcium acetate is 80 lbs. of acetone, which is a 70 per cent. yield on the raw material.

Acetone, however, may be obtained in a better yield by other processes starting from acetic acid. In Squibb's process, using barium carbonate as a catalyst, a 90 per cent. yield can be obtained, and from the Shawwinigan process with lime as a catalyst, a 95 per cent. yield results.

The acetone itself may in turn be used for the production of isopropyl alcohol. This alcohol has come into great favour of late years as a substitute for ethyl alcohol, and it can be made from acetone at a price which compares favourably with that of ethyl alcohol. It is therefore clear that the cost of this series of process is not excessive.

Schematically then we have the following:

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Molasses.
300 Kg. (660 lbs.).

Ethyl Alcohol.
175 lbs.
80% yield.

Acetone.
83.6 lbs.
95% yield.

Acetic Acid.
182.6 lbs.
100% yield.

Sodium Acetate.
414 lbs.
70% yield.

Calcium Acetate.
256.6 lbs.
100% yield.

Acetone.
56 lbs.

Isopropyl Alcohol.
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There is no doubt that this scheme of producing these compounds is the cheapest. Fermentation processes beat others in first cost and consequently in that of the final product. A few remarks about these products may be of interest.

Alcohol is too well known to need any comment, but one wonders why don't the mills use alcohol engines for their cane transport as is done in other countries and save their coal bills?

Acetic Acid is a valuable chemical finding very considerable demand on the Home market. It is used in many ways, some of which have been indicated above, but many other valuable salts are prepared from it. It is the starting point for many syntheses in organic chemistry. Its market during 1929 was: For Glacial Acid, 99/100%; £64—£68 in glass per ton; Glacial Acid, 98/100%, £53—£55 in barrels per ton; Glacial Acid, 90%, £42/10/- per ton; 80%, £37—£39 per ton.
The salts of acetic acid referred to above have been in steady demand at the following prices:—

Sodium Acetate, £22 per ton.
Lime Acetate, Grey, 80%, £16/10/- to £17 per ton.

Butyric Acid has an enormous and ever-increasing demand as a solvent in the trade and in many other directions, artificial silk trade, the explosives, etc. In 1917 a factory was put down in Australia to manufacture it from molasses by the distillation of lime acetate. It is only lately that it has been found possible to prepare it direct from acetic acid. This latter method is the cheapest of all the known ways. At the end of 1928 butyric acid was fetching about £60 a ton. Early in 1929 it rose to £70, and then remained all the year between £76/10/-—£85, according to quality.

Isopropyl Alcohol has also a growing demand as a substitute for ethyl alcohol owing to the duty imposed on the latter for industrial purposes. It can be produced at a price which compares favourably with that of ethyl alcohol, and it is being produced by several manufacturers of fine chemicals in America, on the Continent of Europe and in England.

In the scheme outlined above we have two products which can be easily combined to produce a third for which there is a huge demand. By esterifying alcohol and acetic acid there results ethylacetate. This ester was made in the United States for home consumption to the value of £1,000,000 during 1928. The size of this figure gives better than pages of explanation the extent of the trade. Its market value lies between £70 and £74 a ton.

Again starting from molasses three other acids can be prepared by direct fermentation. They are lactic, butyric and citric acids. The two former acids are prepared almost exclusively by fermentation; the latter is a new competitor of the old Italian industry where citric acid is prepared from lemon juice.

Lactic Acid is important industrially, and in 1928 it was enacted that it should be admitted duty free into England on the Key Industries Act. Quite recently certain esters of lactic acid have come into demand as solvents in the modern lacquer industry and as fixatives for perfumes. The acid itself is in large demand in the leather industries. It is prepared with a 90 per cent. yield by the direct fermentation of the cane sugar and glucose in molasses. It is then clarified and concentrated in vacuo and put on the market as 80 per cent. lactic acid and is quoted at about £50 a ton.

Butyric Acid is prepared similarly to lactic acid. Its manufacture from another source has been the subject of an important French patent, i.e., Le Franc process for ketones.

Citric Acid has only within the last four or five years entered the field as a competitor to the lemon juice industry. It is being prepared by fermentation already in Germany, in England and in America. The natural product has now to meet severe competition from the fermentation product, the total Italian export for 1929 being worth £400,000. This figure gives some idea of the value of this trade. The fermentation method of preparation is bound in the near future to increase owing to the ease of manufacture and cheapness of the raw material. The market value of citric is about 1/2 to 1/3 a pound, and it can undoubtedly be produced much cheaper by fermentation.

Summing all these processes together we get a bird's-eye view of them in the scheme represented below:

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  Molasses.
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      /  \     
     /    \    
    /     \   
   /       \  
  Lactic Acid.    Acetic Acid
     /\         
    /  \        
   /    \       
  Lactic Esters.
       /\    
      /  \   
     /    \  
    /     \ 
   /       \ 
  Acetone.
       /\    
      /  \   
     /    \  
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   /       \ 
  Sodium Acetate.
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      /  \   
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   /       \ 
  Isopropyl Alcohol.
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All these processes in the above series of changes are well established and in practical commercial production. This paper was not intended as a treatise on the methods of manufacture—that can be provided if necessary—but to call the attention of the South African Sugar Industry to the opportunities at its door if it will investigate the position. Such investigation cannot be undertaken solely by the business side of the industry, the technical side is just as important and intricate. It is impossible to convey in such a short paper the vast background to the statement made. The fermentation industry is a rapidly growing one, largely brought about by the post-war demand for solvents, etc., for the artificial silk, lacquer and films industries. During my five years' study of these potentialities I have noted patent after patent taken out, new solvents called for, and old methods of manufacture superseded. Perhaps some examples may assist in giving a slight idea of the size of the undertaking. In one factory in which the fermentation of starch is carried out, 40,000 gallon fermentation vats are used, and between 40 and 50 of these are started daily. In another two tons of citric acid are produced daily. In 1927 25,000,000 gallons of lacquers were used in the United States alone, the constituents of which
are the higher alcohols, etc. They have largely replaced varnishes and paint for finishing automobiles and are rapidly invading other fields. They bear different trade names, but consist essentially of dissolved cellulose from cotton and woody fibre which is then dissolved in various alcoholic and ethereal liquids. The preparation of the necessary solvents by the distillation of wood and the fermentation of maize has promoted these new industries. Molasses surely is a cheaper raw material than maize; the latter costs say 13/- a bag and the same weight of molasses say 1/-.

This whole question is worthy, as I have said, of thorough investigation. I have heard it said that we are sugar makers and not chemical manufacturers, but to-day, in the face of fierce world competition, such an attitude is wrong and hurtful to the industry. Other industries have found salvation in exploiting their whole resources in every economic way possible. It is absolutely necessary to cease to look upon the laboratory as a mere control station, it should be looked upon as the source of advance. Pasteur has said: "Les laboratoires sont les temples de l'avenir, de la richesse et du bien

The laboratories are the temples of the future, of wealth and well-being. The truth of this dictum has been proved by the great European companies, such as The Imperial Chemical Industries, British Dyestuffs, Ltd., etc., in England, the Interessen Gemlinschaft, etc., in Germany, and hosts of other concerns all over Europe and America. Particularly in hard times these people turn to their laboratories for help, and this lesson South Africa has got to learn or go under.

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Note.—This paper was read at a joint meeting of the S.A. Chemical Institute and the S.A. Technologists' Association in the evening of March 25th.

No copy was made of the discussion.