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## ON THE MANUFACTURE OF SUGAR FROM THE SUGAR CANE.

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THE art of manufacturing and refining sugar has now attained to the rank of the second industry in the world. The two sources from which the supply of sugar is derived are the beet root and sugar cane—the one growing in Europe, the other requiring the heat of a tropical climate to bring it to maturity. Many other plants also have the property of producing crystallizable sugar, identical in chemical composition with that prepared from the beet or cane; notably the sugar maple (*Acer. saccharum*), from which a large quantity of sugar is manufactured in Canada, the United States, and Borneo, but the supply is now gradually falling off on account of the destruction of the maple forests.

The sugar obtained by the natives of Bengal and Siam from the various species of palm is, on account of the crude way in which it is manufactured, of very inferior quality, and is mainly consumed in the countries where it is grown. The juice of the Nipah palm (*Nipa fruticans*) is almost equal in saccharine richness to that extracted from the cane, with the advantage that it is much cleaner, and contains no coloring matter or chlorophyll the vegetable matter being easily precipitated, giving a liquor as clear as spring water. This species of palm flourishes near the sea, or on the edges of brackish pools, and takes up a large quantity of salt, which makes its appearance in the juice in varying quantities; sufficient, in some cases, to give the liquor a decidedly saline taste. Were it not for this drawback, I have no doubt that a large quantity of excellent sugar would be obtained from this source.

Since the time when the beet root was first experimentally cultivated for sugar, it has, by careful cultivation become the source of nearly half the total quantity of sugar which is produced at the present day. It is not, however, entirely due to the agriculturalist that beetroot sugar is able to compete so successfully with cane, but a great deal of the success attending its production is due to the fact that the manufacturer called in the assistance of chemistry and chemists, to enable him to decide on the most scientific and profitable method of working; and although the average quantity of crystallizable sugar contained in the beetroot juice is only half that which is contained in the juice of the sugar cane, and other impurities are likewise present which have to be removed previous to the evaporation of the liquor to form the best crystals, yet the quality of the product is superior to and commands a much higher price than the raw cane sugars which are imported to this country from the colonies, and which require to be refined previous to consumption. Of course, Demerara sugars, and also sugars from other countries where the vacuum pan is in use, compete favorably with the refined article, either on account of their peculiar color or some other distinguishing mark which renders them pleasing to the eye, and even, perhaps, from the fact of their containing a proportion of uncrystallizable sugar (molasses), they are more palatable to the public, who, for some purposes, prefer the impure article to the pure loaf sugar.

The reason for the difference in quality between the colonial cane sugar and continental beet sugars is easily found when we take into consideration the difference in the mode of manufacture, and also the fact that the extraction of sugar from the beet has been investigated scientifically by some of the leading continental chemists, and chemistry and proper chemical supervision rule all the operations from the manuring of the root to the time when the sugar is turned out of the factory in an almost chemically pure condition. That this is so, is proved by the fact that almost every chemical journal issued contains the results of some research or enquiry into one or other of the important operations connected with its manufacture or the products produced therefrom; and, further, every manufacturer knows so well the great importance of chemical analysis, that hardly one beetroot sugar factory is without a chemist. Now, in the case of the sugar-cane planter: he begins by manuring his land with some compound which is very likely to be quite unsuitable for the variety of cane which he wishes to grow; perhaps he does not consider it necessary to trash his canes or clean them so as to allow the rays of the sun to exert their action on the cane, and assist in producing the saccharine matter; but leaves them to grow as best they may until the time comes for cutting and extracting the sugar; in many cases the boiling-house is unable to keep pace with the cutting, from bad weather or other causes, and a stock of canes are standing at the mill, and perhaps remain exposed to the atmosphere for some days, but this is not of so much importance, as I shall afterwards show (except in the case of canes that have been grown on land that is poor in lime salts: in this instance the juice is generally very acid, and rapidly undergoes fermentation even before it is expressed from the canes), as a practice which I have frequently seen followed of leaving a portion of the juice to stand all night, or cleaning and evaporating the juice to a density of  $18^{\circ}$  to  $20^{\circ}$  B., and allowing it to stand—say for 8 to 12 hours—to settle, thus causing fermentation to set up, and consequent loss of crystallizable sugar and formation of molasses; in fact, in many boiling-houses the operations are conducted entirely by rule of thumb, and the overseer in charge knows little or nothing about the composition or properties of the substance which he is manufacturing.

Of course these remarks do not apply with the same force to estates which work with the triple-effect and vacuum pan, but even in many of these cases mistakes are made, and losses of sugar occur which would be prevented and remedied if a system of analysis were carried out. Occasionally, syrups are allowed to stand too long a time before re-boiling, under the supposition that on account of the density they will keep any length of time, but in hot climates the temperature is so favorable to fermentation, that in syrups of a density of  $38^{\circ}$  to  $40^{\circ}$  B. crystallizable sugar is converted into glucose, although the appearance of the surface of the liquor would not seem to indicate that any chemical change was taking place; indeed, it is not even necessary that the sugar should be in the form of syrup to allow of this change taking place, for low sugars will form molasses and drain rapidly when heaped in bulk or stowed in a ship's hold, owing to rapid conversion of crystallized sugar into glucose by the action of fermentation. This is a well known fact, and the loss of weight in cargoes of raw sugar is constantly being determined; but the actual loss of crystallizable sugar caused by drainage and deterioration, and formation of probably not less than from 2 to 4 per cent. more glucose in the raw sugar than it contained when shipped, is a fact that, up to the present time, has been lost sight of. In one instance, where a dry sugar, containing 88 per cent. crystallizable sugar, 3 per cent. uncrystallizable, and .92 ash,

was stored for six months in a warehouse in Manila: at the end of that time the bags were quite wet and sticky, and molasses was draining away in considerable quantities; the sugar then showed a loss of 6 per cent. in crystallized sugar, and formation of nearly 5 per cent. of glucose, besides being very acid to litmus paper. A sample of Taal sugar, kept in a well stoppered bottle in the laboratory for one year, showed a decrease of  $1\frac{1}{2}$  per cent. in the crystallizable sugar, and a corresponding increase in the amount of glucose. Another very common mistake in sugar houses abroad consists in sending molasses to the distillery before the whole of the sugar has been obtained; these molasses should be re-boiled to a jelly, and allowed to crystallize slowly in tanks, by which means a further supply of sugar is obtained which would otherwise have been converted into alcohol.

It will be seen from what has already been said, and it is also a well-known fact, that a great waste of sugar goes on in the process of open-air boiling, and many mechanical contrivances have been invented in order to obtain the sugar in a solid form at as low a temperature as possible; the best of these, and the one which is now adopted in all countries that send to England and elsewhere sugar suitable for direct consumption, is the vacuum pan; but in many sugar-producing countries the vacuum pan has not been adopted, either from want of capital, or from a conservative tendency on the part of the planter, who prefers to go on spoiling his sugar by open-air boiling to adopting machinery which would in a very short time pay for itself in the quality and increased price of the article produced.

In the colony of Queensland, which in point of time is one of the youngest of the sugar-producing countries but which has gone far ahead of older settlements, a high-class vacuum pan sugar is produced polarizing 97 to 98 per cent., from juice of which the following analyses are specimens:—

CANE JUICE EXPRESSED FROM CANES GROWN IN THE MARY DISTRICT,  
QUEENSLAND, AUSTRALIA.

	Gingham Cane.	China Cane.	Mixed Samples from various species of Cane.	
Baumé at 15.5° C .....	11.5° ..	10.5° ..	11.6° ..	11.6° ..
Crystallizable Sugar .....	19.50 % ..	16.40 % ..	18.30 % ..	18.30 % ..
Glucose .....	.25 ..	.41 ..	.45 ..	.45 ..
Ash (Soluble Salts) .....	.70 ..	1.11 ..	.37 ..	.37 ..
Other organic matters .....	1.17 ..	2.51 ..	3.14 ..	3.14 ..
Total solid matter .....	21.62	20.43	22.26	22.26

These juices all yield very good sugar, giving on the average of one season's work 1.25 lbs. of sugar per gallon of juice at 10° B., of which 65 to 70 per cent. is nearly white crystals, and compares very favorably with colonial refined sugar; the remaining quantity is sugar of a lower grade, and obtains a ready sale as "pieces." This result is obtained without the use of bone-black, and the only method of purification adopted is the plan of precipitating the vegetable "feculences" with milk of lime, and removing them by skimming as they rise to the surface of the liquor when heat is applied.

The manner in which these juices behaved in the boiling-house was very different, great difficulty being experienced in the treatment of the China cane juice, the sugar produced being worse in quality and deficient in quantity when reduced to the standard of 10° B. as compared with the juice from the Gingham cane which was easily converted into sugar of excellent quality; the reason of this is apparent from the analyses, the China cane containing a larger quantity of ash or soluble salts which have the property of converting crystallizable sugar into glucose during the operation of boiling. It is curious to note the

difference in quality between these two samples of juice, especially as the two species of cane were grown on one plantation under similar conditions, it is evident that the China cane has the property of abstracting from the soil a larger proportion of mineral salts, and these salts, when soluble, go greatly towards explaining low yield of sugar and large quantity of molasses; these analyses show the necessity of studying the composition of the juice from the various species of cane so as to determine the most suitable class of cane to grow, and also the kind and proportion of manure to employ so as not to increase more than is absolutely necessary the quantity of those salts which are so detrimental in the process of manufacture to the quality and quantity of the sugar produced.

The Philippine Islands export large quantities of raw sugar. The production is said to amount to nearly 200,000 tons per annum, but none of the sugar exported is of good quality, as the following analyses of dry sugars will show :—

	Yloilo Sugars, No. I.		No. II.		No. III.		Zambales Imitation Yloilo.
Crystallizable Sugar ....	85·30	..	81·60	..	78·60	..	82·10
Glucose.....	5·80	..	8·30	..	9·10	..	7·70
Ash .....	·94	..	1·02	..	1·90	..	2·00
Moisture .....	5·06	..	6·06	..	5·56	..	4·20
Unknown organic matter.	2·90	..	3·02	..	4·84	..	4·00
	100·00		100·00		100·00		100·00
	Cebu Sugar, superior.	Cebu Sugar, current.	Pampanga (new Sugar), unelayed.		Laguna Sugar.	Taal Sugar.	
Crystallizable Sugar..	81·20	..	71·00	..	78·40	..	70·6
Glucose .....	7·80	..	10·90	..	10·60	..	12·0
Ash .....	2·15	..	2·56	..	1·80	..	3·5

The Zambales sugar is the same number by Dutch Standard as No. 1 Yloilo. The proportion in which these sugars are produced is  $\frac{1}{3}$  of No. 1, to  $\frac{2}{3}$  of No. 2, to  $\frac{5}{8}$  of No. 3. The insoluble organic matter in these sugars is generally less than ·2 per cent., and is of a very slimy nature; the remaining soluble unknown organic matter is the amount which it is necessary for the bone-black to absorb. Of course all these sugars are produced by a similar arrangement to the copper-wall, and in some districts the destruction of sugar by burning in the process of evaporation, is exceedingly large. The cane juice expressed from the ripe canes is of fair quality, and will compare favorably with the Queensland samples. A sample from the Taal district, which is extremely fertile and well suited for sugar plantations, showed to analysis :—

Crystallizable Sugar .....	18·30
Glucose .....	·10
Ash.....	·30
Other organic matter .....	3·25
	21·95

With a vacuum pan and proper machinery a juice of this quality should yield excellent grocery sugar. It would hardly be of such good color as the Queensland sugar on account of the large proportion of green coloring matter (chlorophyll), a portion of which was not precipitated by neutralization with milk of lime, but the sugar would compare very favorably with crystallized Demerara. At the present time the quality of the sugar produced from this juice corresponds to the analysis of Taal sugar given above, the article being fit for nothing but brewing black beer.

In one district in Luzon, where the cane grows luxuriantly often to a height of 12 feet, and one stool produces four or five canes, the crushing season lasts considerably longer than in other districts, and the sugar produced is of superior quality. The soil being

extremely fertile, a sample was analysed, and showed the following results on the dried sample :—

CANE SOIL FROM CAMARINE SIN, LUZON.		
Silicious matter.....	53.39	°/o
Alumina.....	13.16	
Oxide of Iron .....	4.80	
Oxide of Manganese .....	.10	
Oxide of Magnesia.....	.42	
Potash and Soda, as Chlorides .....	1.14	
Carbonate of Lime .....	1.60	
Sulphuric Acid .....	.09	
Phosphoric Acid .....	.25	
Carbonic Acid .....	Traces.	
Organic and Volatile Matters .....	25.05	
	100.00	
Moisture in Sample before drying .....	6.79	°/o

Unripe canes invariably contain a large quantity of glucose, which is probably converted in the process of ripening into crystallizable sugar.

The following analyses are of canes known to be in an unripe condition and juice from them:—

UNRIPE CANES.		JUICE FROM UNRIPE CANES.			
Crystallizable Sugar..	10.00	Crystallizable Sugar .....	8.60 °/o	7.76 °/o	7.24
Glucose .....	2.80	Glucose .....	3.10	2.30	2.50
Ash .....	.74	Ash .....	.21	.25	.34
Soluble Ash ....	.32	Unknown Organic Matter..	1.27	1.74	2.89
Woody Fibre .....	12.26				
Water .....	74.20	Total Solid Matter.....	13.18	12.05	12.97
	100.00				

In order to ascertain whether the juice of the cane underwent any decomposition when the canes were kept for some time previous to crushing, the following experiments on unripe canes were made. These canes were selected, as it was thought probable that they would deteriorate more rapidly on account of their acidity, and the fact of their containing less saccharine matter.

Two plants were selected, each having two healthy canes growing from the one stool ; the juice from one of these was expressed and analysed immediately, the other was put aside in the laboratory for eight days, at the expiration of which time the juice was expressed and submitted to analysis.

FIRST EXPERIMENT.			
Weight of Cane.....	1 lb. 10½ oz.	..	2 lbs. 8½ oz.
Loss of Weight in 8 days.....	..	..	4.75 oz.
Equals per cent. ....	..	..	11.8 per cent.
Baumé of Juice .....	5½°	..	5½°
Crystallizable Sugar.....	5.99 per cent.	..	7.33 per cent.
Glucose .....	1.70	..	1.50
Ash .....	.30	..	.32
Unknown Organic Matter .....	2.27	..	1.99
Total Solid Matter .....	10.26	..	11.14
Reaction.....	Slightly acid.	..	Slightly acid.
SECOND EXPERIMENT.			
Weight of Cane .....	2 lbs. 1½ oz.	..	2 lbs. 6½ oz.
Loss of Weight in 8 days .....	..	..	4.7 oz.
Equals .....	..	..	12 per cent.
Baumé.....	5½°	..	5½°
Crystallizable Sugar .....	8.17 per cent.	..	6.54 per cent.
Glucose .....	1.90	..	1.40
Ash .....	.26	..	.24
Unknown Organic Matter .....	.87	..	2.34
	11.20	..	10.52
Reaction .....	Slightly acid.	..	Slightly acid.

These results show that no fermentation of the juice had taken place during the time the canes had been exposed after cutting ; in fact, the singular result of the glucose being less in the exposed samples, would seem to indicate that a ripening action had been going on ; these results must be taken for what they are worth, but they would certainly seem to indicate that canes could be kept and transported long distances without undergoing loss of crystallizable sugar ; but this, of course, only applies to sound canes, and the result might be quite different in cases where the rind of the cane was cracked or eaten into by rats.

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