Jaggery—Raw Sugar—or *Gul.*

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Introduction.

Jaggery making is one of the most ancient and important village industries of India, especially of N. India, providing employment for a very large number of people during the winter season when they would otherwise be out of work. India consumes on an average about 25 lakhs (2,500,000) of tons of jaggery, while the quantity of refined sugar consumed is only about 5 lakhs (500,000) of tons, so that this industry will continue to hold its position as the main source of sugar for Indians for many generations to come.

Jaggery is a wholesome food and is even preferred to sugar in many preparations. Orthodoxy is partial to it. Its agreeable flavour,—very much liked by many,—its distinct superiority over sugar in sweetness and its cheapness contribute greatly to its popularity.

The outlay needed for preparing jaggery is small as compared with the huge sums required in the case of a sugar factory, and from the same amount of canes the quantity of jaggery obtained is at least 30 per cent more than what is obtained as sugar. In short, jaggery making is the poor man's industry and it supplies him with a cheap sugar food.

It cannot however be argued from the above that sugar production is superfluous in India. On the other hand, it is realised that a preference for sugar is gaining ground among Indians as evidenced by the large amount of imports (nearly half a million tons) costing us something like 15 crores of rupees annually. Unlike jaggery, sugar is a world commodity and can be exported when produced in excess. Hence there will be a need for establishing large and up-to-date factories for sugar production; but it is desirable that these should find new cane areas, entirely for themselves, so that jaggery production may not be prejudicially affected for at least a few generations to come.

Composition of cane. The composition of cane is by no means of a constant character; it varies within wide limits. In a normal cane this variation generally lies within the following limits :—

Sucrose	8	16%	Acids free and combined	0·05	0·2%
Reducing sugars	0·1	1%	Fat, Wax and gums	0·2	0·6%
Nitrogenous bodies	0·2	0·6%	Ash	1·5	3%
			Water	90	80%

As is well known, this variation in composition is influenced by several factors such as the variety of the cane, the soil, the climate etc. To instance one factor—the influence of weather conditions on the composition of cane—a variety of cane, B208, giving 19 per cent of sucrose in its juice at Samalkota or Palur, analyses only about 17 per cent when grown at Taliparamba. This is due to the very heavy rainfall at the latter place. Again, the composition of cane differs not only from clump to clump, but also from cane to cane in the same clump and in different portions of one and the same stalk. Tops contain less of sucrose but more of glucose and other impurities than bottoms or the lower portions.

Percentages in juice.

	Brix.	Sucrose.	Glucose.	Purity.
Tops ...	16·0	12·5	1·5	78·1
Bottoms ...	18·0	15·2	0·7	84·4

Nodes and the rind contain more impurities and have been found to require greater pressure for extraction than internodes. *

	Brix.	Sucrose.	Glucose.	Purity.	Non sugar.	Glucose ratio.	Fibre in cane.
Nodes ...	15·7	12·8	0·15	81·5	2·75	1·17	18·28
Internodes. ...	17·7	16·4	0·61	92·6	0·69	3·78	8·00

	Fibre. %	Juice. %	Sucrose in juice. %
Rind ...	41·75	58·25	10·28
Centre (inside rind portion)	4·72	95·28	20·5

First mill juice extracted with less pressure is purer than the second mill juice.*

	Brix.	Sucrose.	Reducing sugars.	Ash.	Albuminoids.	Free & combined acid.	Gums.	Purity.	Glucose ratio.
I Mill.	15·36	12·93	1·54	0·37	0·18	·24	·10	84·07	11·91
II Mill.	14·60	11·41	1·39	0·58	0·50	·26	·56	78·15	11·30

* Cane Sugar and its Manufacture by H. C. Prinsen Geerligs P. 86 and P. 121.

It follows, therefore that in order to obtain a richer juice one must top the cane low, remove the rind and reject the nodes. The latter two propositions are impracticable. The only thing left to us is to top the canes low. This when accompanied with crushing at a low pressure ensures a good quality juice but is, as would be evident, attended with a decreased output, which is what happens when canes are crushed in a wooden mill.

Composition of juice. All the above mentioned ingredients of canes pass into cane juice and exist in it in different states. Sucrose, reducing sugars, free acids, organic and inorganic salts are in solution. Gums, proteins, portions of colouring matter and pectins are in colloidal solution, while cane wax, fine particles of bagasse and mechanical dirt are in suspension in the juice.

It is because of its containing gums etc., in colloidal solution that cane juice presents great difficulty in filtration. The aim of the sugar producer is to remove all impurities, whereas the jaggery boiler with his liming and skimming leaves in jaggery a good portion of the impurities. Heat coagulates the albuminoids which rise up carrying with them the insoluble colouring matter (viz) Chlorophyll and Saccharetin and other suspended matters. These form the scum and are removed. Portions of the precipitates formed on liming, such as the insoluble phosphates of calcium, pectins and gums are also partially removed during the process of skimming.

Colour. The colour of jaggery is mainly controlled by two agencies, viz., (1) the colouring matter existing in the cane and entering the juice on crushing and (2) the colouring matter developed during the process of boiling.

(1) The colouring matters that are present in the cane are (a) Chlorophyll, (b) Saccharetin (c) Anthocyans and (d) Polyphenols (the tannins).

Of these, chlorophyll is of minor importance since it is insoluble in cane juice and is easily removed with the scums.

Saccharetin is the colouring matter fixed in the fibre and passes into the juice along with the fibre. This is insoluble in cane juices which are acid, but dissolves imparting an yellow colour to the juice when the fibre comes into contact with lime or any other alkali.

Anthocyans are the colouring matters that impart varying shades of colour to the rind of the cane. These are soluble in cane juice and are completely precipitated by excessive amounts of lime but only partially by small amounts. The effect of this group of colouring matters on the colour of jaggery has however been found to be very slight from experiments conducted at the Sugarcane-Breeding Station, in which deeply coloured canes were often found to give lighter coloured jaggeries than light coloured ones.

Polyphenols or tannins are chiefly found in the buds, tops of canes and shoots and are soluble in cane juice, giving it a brown colour. Iron gives with tannin a bluish green reaction. From experiments conducted at the Sugarcane-Breeding Station it has been found in general that, other conditions being equal, juices containing more of tannin give deeper coloured jaggeries than those with less of it.

Jaggeries arranged in deepening order of colour.	Tannin % in juice.	Colour of cane.
Co. 210	0·043	Light pink.
Co. 227	0·053	Purple.
Co. 213	0·057	Pinkish.
Co. 241	0·081	Yellowish.
Co. 239	0·075	Yellowish green.
Co. 214	0·080	Yellowish green.

Other factors also probably interfere as there were a few cases of irregularity.

As has already been mentioned, the bad effects of these can be greatly minimised by removing tops of cane before milling.

2. (a) Solutions of sugars develop colour perceptibly when heated to high temperatures for long. Sucrose develops the least colour, glucose above 105°C a brown colouration and lævulose a still deeper one. In jaggery making, temperatures up to 120°C are common. Hence the greater the percentage of reducing sugars, the deeper is the colouration.

(b) Prolonged boiling intensifies the colour as this produces more reducing sugars.

(c) The presence of other impurities, like neutral salts and nitrogenous bodies induces pronounced darkening.

(d) In direct 'firing' it is not possible to avoid the effects of local heating.

(e) If overlimiting is done, the result is disastrous. A solution of sucrose boiled with lime develops only a light yellow colour; but when a solution of reducing sugars is boiled with a drop of lime cream, it darkens very much, the reducing sugars being decomposed into glucinic and saccharinic acids. This darkening is produced even by the salts of strong bases with weak acids like lime salts of weak organic acids, though only to a smaller degree.

To produce a good coloured jaggery, therefore, the canes should be topped low, the juices limed to slight acidity and boiled as quickly as possible.

Note. We may here note that decolourising agents like sodium bisulphite are being experimented upon for obtaining fine coloured jaggeries.

Keeping quality. It has been recognised that even sugars do absorb a certain amount of moisture when exposed to an atmosphere saturated with moisture. It is no surprise, then, that jaggery which is a much more impure stuff than sugar, absorbs a good deal of moisture when exposed to a saturated atmosphere. Now, jaggeries are known to differ in the rate of absorption of moisture and it was thought worthwhile to study what factors contributed to this. To this end, a juice was divided into six portions and treated differently as detailed below. These were made into jaggeries and their moisture absorbing capacities determined.

Treatment.	% Moisture absorbed in 9 days.	Character of jaggery soon after boiling.
1. Juice boiled as such ...	3·8	Colour good, slightly soft.
2. Juice limed ...	2·1	Slightly ash coloured and hard.
3. Juice plus 2 grms glucose plus lime ...	6·7	Colour same as No. 2, but not so hard.
4. Juice plus 2 grms glucose only ...	8·5	Colour same as No. 1, but slightly softer.
5. Juice plus 1·0 grm sodium chloride plus lime ...	17·3	Not friable.
6. Juice plus 1 grm Pot. sulphate ...	2·5	Same as No. 2.

From the above, it will be seen that sodium chloride and reducing sugars favour absorption of moisture, sodium chloride doing this much more than reducing sugars. Potassium sulphate has practically no effect.

Table A, showing jaggeries with about the same glucose ratio, but with varying chlorine contents.

Jaggery from.	*Glucose ratio.*	*Chlorine.*	*Total moisture.*
Co. 204 limed.	7·3	0·9	23·7
Co. 210 ,,	7·7	1·3	27·2
Co. 206 ,,	7·1	1·4	30·9
Co. 221 ,,	9·2	0 6	21·9
Co. 208 ,,	9·4	1·2	28·0
Co. 202 ,,	9·6	1·2	28·0
Co. 221 Unlimed.	36·9	0·5	32·8
Co. 201 ,,	36·0	1·2	38·5
Co. 208 ,,	38·9	1·2	38·6

Table B, showing jaggeries with about the same chlorine content but with varying glucose ratios.

Jaggery from.	*Chlorine.*	*Glucose ratio.*	*Total moisture.**
Katha.	0·1	5·3	5·6
Dhaulu.	0·1	17·9	9·2
Co. 214 limed.	0·6	2·3	20·6
Co. 221 ,,	0·6	9·2	21·9
Co. 214 Unlimed.	0·6	16·6	27·8
Co. 221 ,,	0·5	36·9	32·8
Co. 204 limed.	1·0	7·3	23·7
Co. 204 Unlimed.	0·9	15·8	27·5
Co. 201 limed.	1·3	7·7	27·2
Co. 208 ,,	1·2	9·4	28·0
Co. 202 ,,	1·2	9·6	28·0
Co. 202 Unlimed.	1·2	31·2	36·4
Co. 201 ,,	1·2	36·0	38·5
Co. 208 ,,	1·2	38·9	38·9
Co. 206 limed.	1·4	7·1	30·9
Co. 206 Unlimed.	1·4	21·6	33·1

*Original moisture in jaggery + moisture absorbed in 26 days.

It will be seen from above that with jaggeries of about the same glucose ratio the total moisture varies with the chlorine content and with jaggeries of about the same chlorine content the total moisture varies with the glucose ratio. It is thus evident that chlorine and glucose easily affect keeping quality.

Cane gum is another factor that induces moisture absorption as a quantity of it prepared from cane juice was found to have absorbed 7·4% moisture when exposed to saturated atmosphere. It is interesting to note that action of lime on gums is beneficial in that it reduces the quantity of moisture absorbed as seen from below :—

Moisture absorbed in one month.	Gums.	Gums and 5 drops of lime cream.
19-11-21 to 15-12-21.	7·4%	5·7%

Preservation.

To preserve jaggeries, it seems therefore necessary to keep off moist atmosphere from coming into contact with them. One of the methods found successful at the Sugarcane-breeding Station is as follows. The jaggery samples are arranged on raised bamboo platforms, and are loosely covered over with trash and smoked. After about 2 hours' smoking, the loosely covering trash is wrapped round the moulds and an outer lighter covering of paddy twists completes the operation and secures greater immunity from absorption of moisture.

Liming and period of boiling.

Object of liming. Cane juice is acid in reaction and on boiling undergoes inversion, this being chiefly dependent on the period of boiling and the amount of acidity as may be seen from below:—

(a) Effect of the duration of boiling on inversion.

Variety unlimed juices.	Sucrose in juice.	Glucose in juice.	Purity of juice.	Period of boiling.	Amount of sucrose inverted in 100 grms of juice.
Co. 204	14·16	0·51	82·0	2¼ hours.	1·5 grms.
Co. 206	12·24	0·19	79·0	2½ ,,	2·0 ,,
Co. 214	16·37	below 0·15	86·4	2¾ ,,	2·1 ,,
Co. 202	14·0	0·54	81·1	3 ,,	2·8 ,,
Co. 201	12·58	0·60	78·2	3¼ ,,	2·9 ,,
Co. 221	15·89	0·67	87·6	4½ ,,	3·5 ,,

(b) Effect of acidity on amount of inversion.

Acidity in juice. (decinormal potash required for 100 c. c. of juice)	Glucose ratio in juice.	Glucose ratio in jaggery.	Duration of boiling.
13·0	3·6	10·3	1½ hours.
17·0	2·9	11·7	1½ ,,
25.0	0·8	23·2	1½ ,,

As shown before, a high proportion of invert sugar in jaggery favours absorption of moisture. Liming reduces this inversion to a great extent as illustrated below:—

Variety—Co. 204.

	Sucrose.	*Glucose.*	*Glucose ratio.*
Composition of juice ...	14·16	0·51	3·0
Composition of jaggery prepared without lime ...	70·3	11·1	15·8
Composition of jaggery prepared with lime ...	77·4	5·6	7·2

Variety—Co. 206.

Composition of juice ...	12·24	0·19	1·6
Composition of jaggery prepared without lime ...	65·1	14·1	21·7
Composition of juice prepared with lime ...	74·3	5·3	7·1

In juice limed to exact neutrality, differences in the duration of boiling do not seem to produce so marked an effect on the amount of inversion, which in this case seems to depend to a certain extent on the glucose contents of the juice.

Variety.	Sucrose in juice.	Purity in juice	Period of boiling	Glucose in juice	Amount of sucrose inverted in 100 grms of juice.
Co 205	12·51	79·2	2½ hours.	0·82	0·25
Co. 202	14·00	81·1	3 „	0·54	0·7
Co. 208	12·85	81·7	2½ „	0·45	0·7

Lime assists in coagulating albuminoids and precipitates a portion of pectin and gums and the whole of acid calcium phosphate in the juice. These precipitates are partly removed in the scum. Lime thus lessens the quantity of soluble impurities in the juice and thereby assists in bringing about a quicker crystallisation of sucrose.

When to add lime:—Since lime is found to act upon the scum of the juice, producing a dark stuff, it would be better to add the lime just after the removal of the first scum. This further avoids

the discolouration due to local action of lime on saccharetin of the minute fibre particles of the juice as these are mostly removed in the first scum.

Quality and quantity of lime to be added :—Shell lime has been found to give a purer and brighter product than stone lime, as the former is much purer than the latter.

Over-liming should never be done as this produces lime glucosates which at high temperatures decompose into dark and viscous substances. It is safer to have the juices slightly under-limed as this gives better coloured jaggeries than when the juices are made neutral or alkaline. Even under-liming does have a slight adverse effect on the colour of the product obtained for reasons mentioned elsewhere.

There is more inversion in the later stages of boiling than in the earlier. The duration of boiling roughly falls into two stages, the earlier one occupying the period before the so-called "Mutthukothi" of the local jaggery-boilers sets in and the later one representing the stage beyond that up to the removal of the pan from the fire. The earlier stage indicates a temperature of up to about 103°C and takes up about three quarters of the total time of boiling and the later one, indicates a temperature rising from 103°C to 120°C and takes only a quarter of the total time. Nevertheless, it has been found that inversion is greater in the later stage than in the earlier, thus bringing out the importance of temperature on inversion.

Date of boiling.	Glucose ratio in juice.	Glucose ratio after one hour.	Glucose ratio in jaggery in another half an hour.
22-5-'23.	3·7	4·8	10·3
23-5-'23.	3·6	4·3	8·3
25-5-'23.	4·0	5·1	10·8

It follows therefore that considerable care should be taken to see that the minimum of time is taken in the later stage. Feeding must be uniform and the temperature should not generally be allowed to rise higher than 120°C. In the preparation of cubes however, the temperature may exceed this limit by 2°C to 3°C.

As far as is known, the practice of liming is not in vogue in North India. The secret of success there seems to lie in the fact that only as much quantity of juice is taken as can be boiled down in 1½ hours. Moreover, the Upper Indian canes contain glucose in such small quantities that the amount of invert sugar formed is not enough to prevent the jaggery from setting. It must be admitted, however, that North Indian jaggeries though bright in colour are slightly acid in taste and comparatively soft; but this quality of stuff is preferred to hard but comparatively deeper coloured jaggeries.

Points to be remembered in jaggery making:—

1. Canes to be cut only when fully ripe:—As is well known, sucrose is at its maximum in the cane when it is fully ripe and to determine this judgment with the naked eye is unreliable, as during the ripening period the sucrose is subject to a sudden rise of 2 to 3% without any marked changes being noticed externally. On account of considerable variations in the composition of canes from clump to clump and cane to cane as mentioned elsewhere, a periodic analysis of several representative canes from different parts of a field is the only satisfactory method of determining the maturity of a whole field of canes.

Sudden rise during ripening.

Variety.	Date of Analysis.					
	21-1-1921.		21-2-1921.		19-3-1921.	
	Brix%	Sucrose%	Brix%	Sucrose%	Brix%	Sucrose%
Seedling No. 8664	14·32	9·99	16·58	13·16	16·87	13·37
,, 13451	14·59	10·49	17·40	13·81	17·34	14·00
,, 18131	16·33	12·75	17·87	14·71	17·91	14·51

2. Canes to be crushed soon after cutting:—Canes deteriorate very rapidly when the temperature during the harvesting season is high as in these parts. It is better, therefore, to keep them always in shade and sprinkle a small quantity of water over them occasionally. If this is done, the loss by inversion is much reduced (vide Year Book, Madras Agricultural Department, 1920).

3. The juice from the mill may with advantage be passed through a strainer before it enters the boiling pan.

4. The juice to be stored in clean vessels kept in shade:—In jaggery making as there is little risk of the machinery breaking down, there is no need to preserve the juice with formaline. Juice was found to undergo only a very slight change when kept for about 8 hours in shade in clean vessels.

Average of three juices.

Time of analysis.	Brix%	Sucrose %	Glucose%	Glucose ratio.	Purity.
9 A. M.	16·07	12·39	0·61	4·9	77·1
10-30 A. M.	16·14	12·40	0 64	5·1	76·9
1-45 P. M.	16·29	12·41	0 65	5·2	76·0
4 P. M.	16·41	12·49	0·67	5·3	76·1
5 P. M.	16·41	12·49	0·69	5·5	76·1

5. Apart from the influence of the other impurities such as gums etc., reducing sugars and chlorine play an important part in affecting the keeping quality of jaggery as has been pointed out already. The greater the amount of these substances the worse is the keeping quality.

6. In sugar factories, the juices are limed, any excess of lime removed by sulphurous, phosphoric or carbonic acids and the lime precipitates removed by filtration. As filtration is not practicable under the existing conditions, of jaggery making, the safest course would be to under-lime the juice to avoid deepening of colour.

7. Prolonged boiling increases inversion and colouration and there is more inversion in the later stages than in the earlier. Therefore boiling must be finished within the minimum amount of time consistent with an economy of fuel. With pure juices, the boiling pans may be big and the time may extend up to three hours without much harm as it is not quite economical to have small pans. With juices of low purity (say below 80) to get a comparatively good product, the pans must be much smaller so that boiling may be finished within two hours.

8. Quick crystallisation and the formation of a large number of crystals means hard jaggery. With pure juices, these conditions are satisfied and moulds or cubes are readily obtained With impure juices the crystallisation may be hastened as follows. Just after removal of the pan from the fire, a small quantity of powdered sugar or good jaggery may be added and the whole mass stirred, quickly transferred to a shallow trough and then stirred slowly. This is afterwards transferred into pits or zinc moulds. This procedure enables another charge to be started immediately with the same pan without much loss of heat.

It is not claimed here that any exhaustive study has been made on the subject of jaggery boiling. This is only some preliminary work recorded to show that there is a vast scope for systematic and elaborate work in the science of Jaggery-making.

In this connection our thanks are due to the Government Sugarcane Expert for facilities afforded.

Discussion.

Mr. Govinda Kidavu—Deputy Director of Agriculture—observed that the main question as far as Malabar was concerned was the keeping of jaggery. In Malabar jaggery often ran liquid during the rains, that of Red Mauritus being particularly liable. If the latter could be improved, he declared the extension of sugarcane cultivation in Malabar was quite assured.

Mr. G. Rajagopal Nayudu said that it was possible to effect improvements in the methods of the ryot. Firstly *cleanliness* was a point on the importance of which stress should be laid. Secondly, attempts might be made to clarify the juice whether by the use of animal charcoal or of sulphur. He mentioned that in certain cases he had seen fine clay being used to clarify the cane juice before boiling. In conclusion he remarked that the colour and the keeping quality were usually diametrically opposed characters.

Reporter Mr. K. N. Ramasami Ayyar wished to know from the Government whether any steps had been taken to improve cane

cultivation in the Madras Presidency and whether any efforts had been made to send students to Java for studying the cane problem.

Sir K. Venkata Reddi Nayudu—Minister—said that he was proud to be able to say that, far from being inactive, Madras was the first Province in India to take steps to carry out the recommendations of the Sugar Committee. The Cane Breeding Station, it must be remembered, was—though situated in Madras—really a Government of India concern. He added that at Anakapalle, steps were being taken to establish a cane station, and moreover an officer had been specially deputed to study conditions of Cane growing in Tanjore, Godavari and the Agencies.

Rao Sahib M. R. Ramaswami Sivan remarked that inversion of sucrose into glucose was the chief point to be guarded against in jaggery making.

Mr. Vellingiri Gounder, M. L. C., was of opinion that so far as the Coimbatore ryot was concerned keeping quality was infinitely more important than its sucrose content.

Mr. K. Raghavachari—Assistant Director of Agriculture—stated that at Wallajahpet where large quantities of Jaggery are manufactured, ryots store it in large earthern pots in which it keeps well for a year or more. Large balls, he said, were also sometimes prepared and lasted much longer than the small cubes.

Mr. B. Viswanath—Govt. Agricultural Chemist—stated that from his experience with regard to Coconut Jaggery, he could endorse the statement that keeping quality and colour were mutually exclusive. Addition of lime was necessary for ensuring its keeping quality but it resulted in blackening the jaggery. Addition of alum was useful in deliming the preparation, but it made it soft. The greater the quantity of lime, the harder he declared would be the jaggery; and the smaller the cubes, the greater the chances of jaggery turning soft.

Mr. Unnikrishna Menon—Assistant Superintendent—said that cubes when bundled in straw and kept under straw lasted long.

Mr. T. V. Rajagopalacharya—Assistant Professor of Agriculture—observed that the Coimbatore ryot was a very shrewd person. He did not care in any way for colour; what he did care for was its keeping quality. He added lime at the very latest stage which resulted in a hard jaggery. He further added that *Samakkulam* was noted for producing the best quality in Coimbatore, and this jaggery was one of the darkest in colour.

Mr. Noyce—Development Secretary (once President of the Indian Sugar Committee)—declared that conditions in Java were entirely different from those prevalent in India. As might be seen from a perusal of the Sugar Committee's report, the central factor of the Javan system was the Sugar Factory. Moreover all research work was carried on financed not by the Government but by private corporations. There was little need therefore for sending anybody to Java for sugarcane work. As regards the breeding of new canes Rao Sahib T. S. Venkataraman probably knew as much as anybody in Java.

Rao Sahib T. S. Venkataraman—Govt. Sugarcane Expert—observed that the jaggery maker was often not anxious to get rid of the impurities of the juice because of the consequent loss of weight in the finished product. Widely divergent qualities were needed in the various jaggery markets of India. As for the Coimbatore ryot he had to cater to the demands of a market which favoured keeping quality rather than colour. As these two qualities were antagonistic to each other, the problem required thorough investigation, but could not be taken up for want of staff. The conditions in India were very different from those in other countries. Jaggery was actually preferred to Sugar in most parts of India and in his opinion it was a delicacy and almost a sweetmeat. The speaker thought that more work ought to be done in India before thinking of sending anybody to Java.

Mr. K. Krishnamurti Rao in replying to criticisms stated that the subject of the present paper was worked up as a sideline in the midst of more legitimate work and thought that more work was needed before making any definite pronouncement on the subject.