

STUDIES IN SUGARCANE JAGGERY

III. The Empirical Test for the End-point of Boiling in

Jaggery Manufacture.

By T. Varahalu, B. A., M. Sc.,

Agricultural Research Institute, Coimbatore.

The test usually applied to mark the end-point of boiling in the manufacture of jaggery consists in subjecting, from time to time towards the last stages in the process, small portions of the boiling mass to sudden cooling by pouring them into large bulk of cold water. At the stage when this supercooled portion assumes a sufficient degree of hardness as judged by the sound produced when struck against the sides of the pan, the boiling is stopped, the pan removed from the furnace and the mass allowed to cool until signs of the crystallisation of sucrose, or in other words, of the setting of jaggery, become visible. It is then gathered into a heap and transferred into moulds.

The cane juice contains a large bulk of water with sucrose, reducing sugars, non-sugar-organic matter and minerals, free and in organic combination, dissolved, or suspended in it in various states of aggregation. As the boiling progresses, the syrup formed thickens in consistency. When the 'rab' stage, familiar in sugar manufacture, is attained, the mass consists of a supersaturated solution of sucrose. If in this condition, it is slowly cooled, sucrose crystals separate out from the mother liquor and the latter becomes to that extent less supersaturated.

But instead of cooling at this stage, in jaggery manufacture it is subjected to further continuous heating. Due to this cause, the solvent action of the mother liquor tends to increase, while at the same time, its quantity gets diminished, due to the rapid evaporation of water from the open pan. Thus, the two processes taking place simultaneously operate in a manner mutually antagonistic with respect to quantities of sucrose held in solution.

As however the liquor gets diminished more rapidly under the open pan conditions, it would be expected that more sucrose would be thrown out than is held in solution.

Now, every external influence upon a mobile system produces a change in such a direction that the resistance of the system towards the external influence is increased as a result of this change. As such, it should be that the sucrose theoretically thrown out of solution is continually changing its phase into a fused or molten form, consequent on the absorption of heat. Thus, it can be easily visualised that a stage would be reached in the boiling of the juice to jaggery, when the

whole mass would consist of molten or fused sucrose with the impurities embedded in it, taking even the residual water only as an impurity. Therefore the answering of the empirical test seems only to mark the stage when this phase transformation is accomplished.

From this it follows that the conditions for the setting of jaggery, or the crystallisation of sucrose from the final mass, in the normal method of manufacture of jaggery, can be taken to be similar to those governing the crystallisation of any substance from its melt, i. e. to the conditions of the transformation of liquid (melt) to solid (crystal) when the liquid phase alone is present to start with.

It is well known that the following are among the most important of the factors for the good crystallisation of any substance from its melt :—

- (i) The specific crystalline capacity of the substance.
- (ii) The molecules of the substance should possess high specific velocities for free and rapid movement.
- (iii) The resistance to the velocity of the spontaneous nuclei formation should be a minimum.
- (iv) The system should allow of free translational movements of the molecules of the crystallising substance.
- (v) The distances over which the molecules have to travel, before finding nuclei to deposit themselves on, should be short, or in other words, the thickness of the adsorbing layers should be as small as possible.

These conditions may now be applied to the crystallisation of sucrose in the setting of jaggery. The conditions (i) and (ii) are constant for purposes of the present study as the substance concerned is a chemical unit, sucrose, but the only factor on which these depend is that of temperature. But so far as the factor (ii) is concerned, it is also a function of the molecular weight of the substance, and in the case of sucrose, this is as high as 342, and is inherently comparatively sluggish in its movements. Any system in which it is present in high concentration presents conditions of viscosities of high magnitudes. Further, sucrose has very high solvating capacities. Factors (iii) and (iv) are mainly concerned with the proportion and the properties of impurities accompanying sucrose, and with the temperature of the system, and factor (v) is almost exclusively determined by the proportions of the non-sucrose materials or the impurities.

The rate at which nuclei form is a fundamental factor on which the rate of crystallisation depends. But the mere existence of the nuclei need not necessarily lead to the formation of crystals. The crystal formation and their growth is considerably influenced by the stage in the period of cooling at which the nuclei form. If the nuclei form at a high speed immediately below the melting point, they grow

uri-
ity.
the

ery,
mal
ose
the
hen

ant
om

ific

or-

s of

ore
her
as

of
are
ned
end
t is
the
ely
igh
les.
and
s of
the
or-

ich
the
he
the
lei
ow

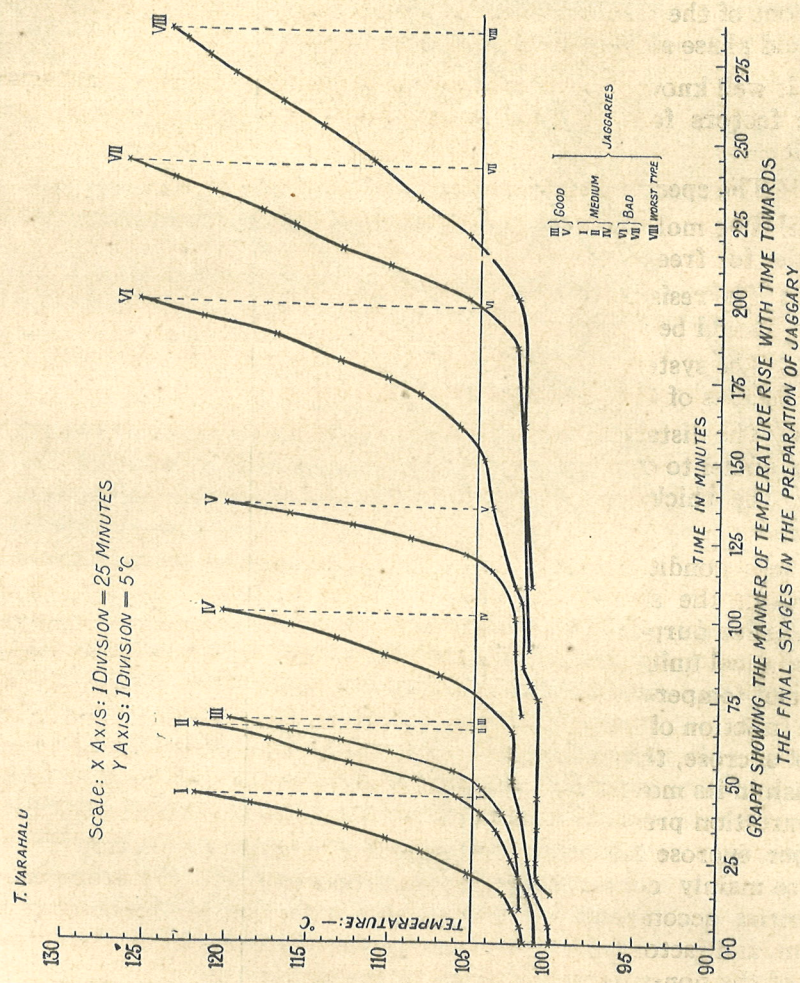
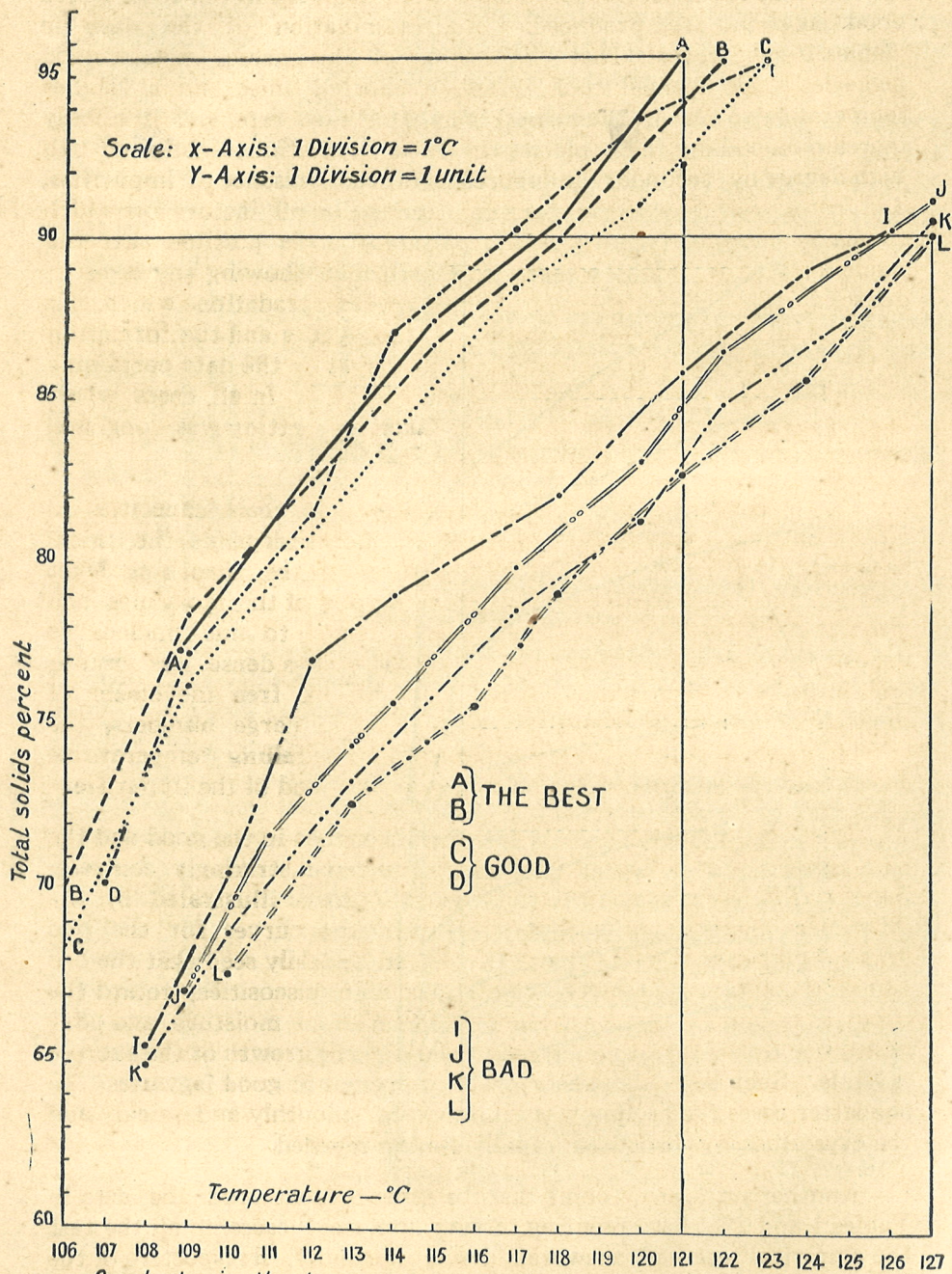


PLATE I



Graph showing the changes in concentration & the corresponding temperatures during the boiling down of the cane juice to Jaggary.

quickly into visible crystals. This is what happens in the cases where good jaggeries are produced. An examination of the data in Tables 1 and 2 reveals that the setting of the masses where good jaggeries were formed took place in shorter times and at higher temperatures. But if the nuclei form at a slow rate and gradually increase on cooling, the velocity of their formation is affected to a high degree by secondary influences as (a) the presence of impurities, and (b) the viscosity of the medium, and so, on all factors on which the latter depends. Under such conditions, it is possible that the nuclei may only tend to remain latent without showing any signs of growing into visible dimensions. The several gradations which this suggests in the matter of the setting of the jaggery and the formation of the crystals and their growth, are illustrated by the data pertaining to the bad jaggeries presented in Tables 1 and 2. In all cases where bad jaggeries are produced, the time taken for setting was long, and temperature at which it took place was low.

On the concentration of the impurities and their capacities to adsorb on the already heavy molecules of sucrose depends the thickness of the adsorbing layer. This thickness of the adsorbing layer controls both the rate of the translatory motion of the molecules and also the distances over which they have to travel to find nucleus to deposit themselves on. The medium should be less dense, less viscous and be at a higher temperature to admit of free movement of molecules. Otherwise even if the nuclei form in large numbers, the crystal growth will be greatly impeded. The falling temperatures accentuate the adverse effects both of viscosity, and of the impurities.

That the impurities which accompany sucrose in the good and the bad jaggeries are so distinctly different, and cause strikingly contrasting effects in the process of jaggery manufacture is illustrated by the differences in the slopes and the forms of the curves for the two types of jaggeries in Plates I and II. It can be easily seen that the bad jaggeries contain substances which cause high viscosities, retard the progress of boiling, cause a tenacious retention of moisture, and offer resistance to the formation of the nuclei and the growth of the sucrose crystals. Such adverse effects are not present in good jaggeries. In the latter cases the boiling was taking place smoothly and quickly and the crystallisation proceeded rapidly and unimpeded.

Another interesting point that becomes evident from the data in Tables 1 and 2 is that excepting in very abnormal cases, in all the rest the empirical test was answered almost normally, irrespective of the fact whether there were produced good or bad jaggeries eventually from these masses. This invariable tendency to answer the empirical test on the part of the final masses in all cases at once suggests that they all tend to approach one common physical condition, namely that

of molten or fused sucrose with all the impurities, including the residual water, embedded in it, and that the answering of the test only marks the completion of this approach.

Thus, the answering of the empirical test does not seem to convey, as such, any more meaning beyond indicating the completion of the transformation. The test does not by itself ordinarily throw any light on the probable behaviour of the final mass after answering the test, whether it would eventually yield a good or a bad jaggery. This test also does not appear to have any relationship to the quality of the juice started with. The final strikes obtained from rich good juices, as also those resulting from the use of juices which are poor, usually answer the test almost alike.

But it must be here noted that as the degree of abnormality of the juice increases, due to whatever cause, the approach to the common physical condition is either imperfect, or delayed or not approached at all, depending upon the particular conditions.

In the light of these considerations, it will be seen that so far as the physical conditions of the jaggeries are concerned, they may be considered in three distinct stages:

- (i) The condition when the final concentrate answered the empirical test.
- (ii) The condition when the setting of the jaggery or the crystallisation of sucrose takes place, and
- (iii) The condition of the jaggery in the final form.

In stage (i) it may be considered as a mass of molten or fused sucrose with the impurities embedded in it, the molten sucrose forming the continuous phase.

In stage (ii) when crystallisation takes place during cooling, there will result a contraction of the mass in the mould, and a discontinuity in the outer phase of the fused sucrose due to crystal formation. The consequence of this would be that a sort of syneresis occurs and the previously protected syrupy fluid exudes out.

Now, if the crystallisation takes place in shorter time and at higher temperature, the crystals would grow well and the largest portion of the enclosed fluid would exude out. Due to the high temperatures prevailing, the liquid will be thin and highly mobile. In this state, and assisted by the high stresses which also prevail concomitantly, it is easily driven from the centre to the periphery in the mould, and gets compressed into thin envelope on the outside, the sucrose crystals forming a hard highly crystalline inner core. This is what happens in all good jaggeries, as will be seen in a subsequent communication.

But if the fluid is viscous and slow drying, and further, if its proportion is also high, the portions of it that first leak out, when the

discontinuity in the sucrose phase occurs consequent on nuclei formation, quickly surround and enmesh each particle, and prevent the rapid diffusion of the sucrose molecules towards the nuclei. This diffusion is further retarded with fall in temperature. Thus the crystals do not grow well and the fluid remains distributed over the entire bulk of the jaggery, without being driven far towards the periphery. These conditions obtain in varying degrees in bad jaggeries.

In stage (iii) when jaggeries have set and cooled down and as they are available for direct consumption, they may be considered as consisting of the matrix material mixed with solid crystals of sucrose of different sizes. The differences in the hardness, strength, consistency and in structures noticeable so commonly among jaggeries, are evidently intimately associated with the drying capacity of the matrix, and the number of crystals of different sizes, and the proportions which they bear to each other and to the total matrix.

Again, with lapse of time, diffusion through the matrix takes place extremely slowly, such that with ageing, crystal growth and fresh crystal formation are frequently observed to take place.

The author takes this opportunity to express his grateful thanks to Rao Bahadur B. Viswanath, Director, Imperial Agricultural Research Institute, New Delhi and to Mr. P. V. Ramiah, the Government Agricultural Chemist, Coimbatore, for the facilities and encouragement they afforded.

Table 1.

Showing the Times and the Temperatures of the Setting of Jaggery.

Variety.	Temp. at the end of boiling. - °C.	Time taken for the setting of jaggery minutes.	The temp. at which the setting took place. - °C.
<i>Good Jaggeries.</i>			
P. O. J. 2878	123	9	109
Co. 213	122	9	104
"	120	7	110
Co. 313	123	8	109
B. 208	119	6	108
Co. 281	121	11	105
Co. 281	121	13	106
M. A. 21	122	10	105
Co. 243	119	10	104
<i>Bad Jaggeries.</i>			
Co. 313	123	18	95
D. 131	124	18	93
Co. 213	123	24	95
Co. 213	121	22	93
J. 247	120	27	89
Co. 313	121	20	91
E. K. 2.	122	25	86
Purpure Mauritius	123	18	92
P. O. J. 2878	120	17	95
Co. 243	122	80	64
Co. 213	123	60	70

Table 1 (continued).

These two were not fully ripe and they were grown in dry lands. There was profuse frothing and fuming. The empirical test was not answered satisfactorily. The mass did not actually set; it only congealed on cooling. It was tough, stringy and glassy.

J. 247	124	95	60
The mass did not set but only congealed into a glassy material. The canes consisted of superfluous sets which remained over for some days during hot weather. The final mass in this case did not answer the empirical test at all. The chilled mass always remained soft. It could not be even gathered well into the hand. The mass did not show signs of crystallising even after one year as judged by the naked eye.			

Table 2.

Statement Showing the Manner of Temperature Rise Towards the Final Stages in the Boiling Down of the Cane Juice to Jaggery.

Sample Number.							
I.		II.		III.		IV.	
Time in Min.	Temp. - °C.	Time in Min.	Temp. - °C.	Time in Min.	Temp. - °C.	Time in Min.	Temp. - °C.
5	102	15	101	10	102	5	100.1
10	102.5	20	101.5	27	102.2	15	100.1
15	103	25	102.5	40	103.2	25	101.5
21	105.2	35	103.5	48	104.5	40	102
28	108			53	106.2	50	102.5
32	110.2	40	104.5	58	110	65	102.5
35	112.5	45	106	62	113	76	104.8
39	115.5	50	108.5	64	116.2	82	107
42	118.5	55	112.5	68	120	88	110.5
45	122	58	115			93	113.5
		62	117.5			97	116.3
		66	122			101	120.6
						103	124.5

Sample Number.							
V.		VI.		VII.		VIII.	
70	102		100	110	101.5	90	101.5
90	102.5	20	101	180	102.5	110	101.5
100	102.5	75	101	200	105.6	160	102.1
110	104	80	101.5	210	110.5	200	102.5
120	105.5	85	102	215	113.5	220	105.6
125	109	105	102	222	116.5	231	108.8
129	112.6	110	102.5	227	118.5	243	111.6
132	116.5	135	104	232	121.5	254	114.8
135	120.5	150	104.5	236	124.0	262	117.4
				242	127.0	270	120.4
		160	106			276	122.0
		170	108.5	Fuming and Frothing The test is however answered.		281	123.4
		175	110.5			284	124.4
		180	113.5			Fuming and Frothing. The test is not answered well. The chilled mass was always soft.	
		188	117.5				
		193	122				
		197	126				

Approximate Time (Min.) taken for the Completion of the Boiling from the Time when about 105°C is Reached.

Sample No.	I.	II.	III.	IV.	V.	VI.	VII.	VIII.
*Time in Min.	25	24	18	27	17	43	45	67

* These times are as measured from the graph. (Plate II).