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PHYSICO-CHEMICAL STUDIES ON SUGARCANE JAGGERY *

(*A Preliminary Communication.*)

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Introduction: Jaggery is the most important of the products manufactured from sugarcane in India. The consumption of jaggery is about 2 to 2·5 times that of the total white sugar, the latter comprising of all that is (i) imported, (ii) manufactured in the local factories and (iii) produced by the indigenous '*bel*' method. This proves the still greater hold of the cottage industry of jaggery manufacture.

Jaggery is used for direct home consumption, and for the manufacture of refined sugar. On an average about 2·5 to 3 millions tons of jaggery are used for direct consumption and about 1 to 2 lakhs of tons for refining. But according to the Report of the Indian Tariff Board on Sugar Industry (1931), the return from 100 maunds of cane manufactured into *gur* (jaggery) and then refined is not more than 5·5 maunds as against 9 maunds obtained by direct manufacture from cane, while the amount of the molasses produced is approximately the same per unit of cane in each case. The process is wasteful, and is therefore not designed to make the best use of the country's resources. According to Srivatsava (1) the refinability of jaggeries varies from 42% to 65%, yielding but 4·2% to 6·5% of white sugar calculated on cane, Srivatsava adds that so long as the quality of *gur* (jaggery) does not improve, and the recovery of sugar remains at the present level of 5·5% on the basis of the original cane, the future of the refining industry must remain uncertain. Some measure of co-operation between the manufacturers of *gur* (jaggery) and the refiners, might lead to the improvement in the quality of the product which would not only give a better return to the cane grower, but would also make refining more profitable, thus giving a new lease of life to the industry. Again, even so long ago as 1909 the need for such a cooperation was emphasised by C. J. Mackay, when he said, "if the sugar industry in India is to hold its own against the foreign importer, development will have to be along the line of intense cultivation by the grower to increase the outturn of sucrose per acre and improvements in the making of raw gur (jaggery) by the villager preventing the heavy losses by inversion and adulteration entailed by the crude methods at present employed. If this can be done, the Indian refiner will have nothing to fear from foreign competition in India, and may in time be even able to export to other markets if not barred by prohibitive protective duties."

In spite of this insistent and the long-felt need for the production of uniform and superior quality jaggeries in respect of their colour,

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hardness, crystalline character, and keeping and refining qualities, the problem does not appear to have received the attention it deserves. The available literature on the subject is scanty, scattered and imperfect, and comprises only of a few casual references. In view of this, therefore, a more systematic study of the problem was started.

While the production of the jaggery is confined to a particular season of the year, its use whether for home consumption, or for marketing, or for refining, extends over the whole year. Some jaggeries keep well during all the seasons without softening or running into liquids, (the good), while others which are normally fairly hard, tend to soften during the damp weather, (the medium); besides these there are others which are damp, soft and sticky even to start with the bad. This therefore points to a necessity for investigating into the probable causes for these differential behaviours of the jaggeries, as a preliminary for a further investigation into the possibilities of producing jaggeries which may be of uniformly good quality or at least of jaggeries which may be as nearly so as possible. Therefore, in the present investigation an endeavour is made to understand the probable causes for these differential behaviours of the jaggeries, and its scope is limited to the study of the physico-chemical characters of the different types of jaggeries to elicit the probable factors that may be governing their keeping qualities.

In this preliminary communication a brief summary of the results of this study is presented while detailed papers will be published elsewhere.

Studies in the moisture relations of jaggeries: As the humidity or the dampness of the atmosphere is generally the main controlling factor, the responses of the jaggeries of different qualities to various humidities were studied. The results pointed to the following:

1. There appears to exist an optimum relative humidity lying between the limits 50 and 60% for all the types of jaggeries to keep well without changing their physical states.

2. The good jaggeries possess comparatively greater openness of texture and absorb smaller amounts of water at greater rates, while under the same conditions, the bad ones take up larger amounts at considerably slower rates.

3. The good jaggeries are capable of holding larger amounts of water in surface solution without themselves collapsing, while the bad ones collapse and change their form even with smaller moisture contents. This property accounts for the retention of the form and the hardness by the good jaggeries during the monsoon weather and for the softening and the running into liquid of the bad jaggeries.

4. Under drier conditions which favour loss of moisture, all the good jaggeries are characteristically capable of quickly parting with

larger proportions of water contained in them, retaining but only a very small fraction of it. All the bad jaggeries on the contrary, retain characteristically the larger part of the water giving up but a very minute fraction of it.

Thus these differential properties make it evident that the good jaggeries become quickly dry as the drier atmospheric conditions begin to prevail soon after the monsoon periods, while the bad ones sometimes become worse than what they had been even before the setting in of the monsoon. Once they collapse and begin to run into liquid during the highly humid weathers, even the medium jaggeries having an apparent hardness and solid form, not to speak of the bad ones, cannot regain their original shape, and as such, would continue thereafter to remain as thick pastes, if not exactly as liquids.

It is occasionally observed that some jaggeries develop an ashy appearance on standing for some time. Observations showed that this phenomenon is exclusively confined to the good jaggeries, and that this occurs during the fair weather that immediately follows a damp period. The ashy layer consists of minute but well developed crystals of sucrose formed as a consequence of the evaporation of the water which was taken up in damp weather and held in surface solution.

Studies in the Structures of Jaggeries. The different types of jaggeries also differ very markedly in another important respect, viz., their internal structures. All the good jaggeries characteristically possess an extensive internal core of crystalline sucrose covered on the outside by a thin envelope of a more deeply coloured material with more of the matrix. The core is highly crystalline and extremely hard, while the envelope is also hard, very compact and translucent. Some of the good jaggeries occasionally have very extensive and closely placed patches of crystalline sucrose, separated by very thin veins of the material with more of the matrix, in place of the distinct core and an envelope.

In the bad jaggeries the sucrose disposes itself in rhythmic bands or veins of varying widths and sometimes in widely separated patches of varying sizes bounded by thicker layers of the damp matrix material. While in the good jaggeries it is the material with more of the matrix that constitutes the veins, in the bad ones, on the other hand, it is the crystalline sucrose which exists as veins or bands. The differential structures, characteristic as they are, easily enable the appraising of the jaggeries. The type characters are so distinct.

Again, an examination of the microtome sections of jaggeries, the sections being obtained by a modified technique devised to suit the material, revealed marked differences to exist between the bad and the good jaggeries. In all the good jaggeries the sucrose crystals are big and well developed approaching the ideal candy type in form. The crystals in the core are closely packed and cemented together by very thin

films of the matrix. Even the crystals in the envelope are comparatively very big and fairly well formed.

In all the bad jaggeries the crystals are not well developed, either in form or in size. They are very minute. Again, compared with the good jaggeries, the number of the crystals in any given area in the section is enormously large in the bad jaggeries. While again in the good jaggeries most of the matrix is localised in the outer envelope, in the bad ones it is distributed over the whole mass of the jaggery. It forms thick films around individual crystals.

These observations serve to explain the openness of the texture in the good jaggeries. They also afford explanation for the absence of strength in the bad jaggeries to keep water in surface solution, as both the fluid matrix material and the minute sucrose crystals which are very minute in size tend to dissolve in water very readily. Their differential capacities to either absorb or retain water are also easily explainable based upon these observations. Thus it becomes clear that the properties of the jaggeries as revealed by their responses towards different humidities appear to be intimately associated with their internal structures. Again, from the results of the examination of the microtome sections of the bad and the medium types of jaggeries, it becomes obvious that they can be considered as consisting of mixtures of thick fluids with fine solid particles (minute sucrose crystals). Hence it can be expected that they behave as plastic bodies, wherein the relative proportions of the fluid matter and the solid particles, and consequently the fluid film pressures are the main operative forces in governing their physical states. Depending therefore upon the number and the size of the crystals on the one hand, and the relative proportion, the density, and the viscosity of the matrix material on the other, it can easily be realised that various types of jaggeries with different degrees of consistency, ranging from those with mechanical rigidity, mistaken for hardness, to jaggéries which are no more than thick pastes, could be had. It is within experience that jaggeries with different degrees of fluidity and yield values are met with.

In this connection it may be mentioned that while the moistures taken up by the jaggeries, no doubt, control their softening, yet it is not the only cause for affecting this change in the physical state. If external pressures are made to operate on the jaggeries in excess of the forces due to the fluid films, they tend, as do all the plastic bodies, to collapse and become pastes or fluids. This is what actually happens in practice. In the mode of preservation of the jaggeries which consists in piling them up in layers, one over the other, there are caused great stresses to continually operate on the jaggeries in the lower layers, which in consequence, collapse or change their form. The good jaggeries however do not yield so easily under these conditions.

Now these differences in the structures suggest that the conditions in the good are such that the formation of mulli and the growth of sucrose crystals proceeded well and unhampered, while this process must have met with high degrees of resistance in the bad jaggeries.

Studies in chemical composition: In order therefore to elicit information in regard to the probable factors which might be more directly responsible for causing these differential conditions, and therefore the differential properties, a large number of samples of jaggeries of different qualities was analysed for the several constituents and further the influences of these several constituents, were also studied by preparing synthetic jaggeries, adding them severally to pure sucrose solutions in graded proportions. The results showed that independently of the question of purity (high percentage of sucrose), the most potent of the constituents in the jaggery, affecting the crystallisation of sucrose, and so conditioning the physical structures of the jaggeries and their other related properties, comprise of what constitutes the *non-sugar organic matter* fraction.

The properties of this fraction in the good jaggeries differ markedly from those of the corresponding fraction in the bad ones.

These and other independent studies on the boiling of cane juice and the changes taking place during the process, and the experimental observations on the times and the temperatures of the setting of the jaggeries, indicate that the *non-sugar organic matter* in the bad jaggeries contain substances which cause high viscosities, retard the progress of boiling, cause the tenacious retention of moisture, and offer resistance to the formation of the nuclei and the growth of the sucrose crystals. The corresponding fraction in the good samples does not appear to be causing such adverse effects.

A preliminary examination of the juices and the jaggeries from canes raised under different manurial and cultural conditions suggests that the quality and the proportion of the nonsugar organic matter fraction are greatly modified and controlled by the particular conditions under which the cane is grown. For example, juices from canes grown by manuring them with castor cake contain these in least amounts, and in less harmful condition, while those from canes grown by manuring with ammonium sulphate alone are noted to have a larger percentage of these. Again when a cane is grown under absolutely dry conditions, or on saline soils, or when it is irrigated with brackish water, it is observed that this fraction is present in comparatively larger amounts, or in more harmful conditions, than when the same cane is grown under normal conditions.

Further work on this aspect is proceeding.

I take this opportunity to offer my grateful thanks to the Government Agricultural Chemist for the facilities afforded by him, and for his helpful guidance and the sympathetic criticism of the work during the course of the investigation.