

METHODS FOR DETERMINING SUITABILITY OF COCONUT SAP FOR PREPARATION OF JAGGERY, SUGAR AND GOLDEN SYRUP

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ABSTRACT

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It was found that sap containing more than 8% reducing sugars (as percent of the total sugars) is unsuitable for the preparation of jaggery. In preparation of crystalline sugar with such sap the yields dropped to 50%. However, the sap containing higher inverted sugar percentages could be used to advantage in the preparation of golden syrup.

A simple colour reaction based on the popular Fehling's test for sugars was adopted successfully in the field to test the sap for its suitability in preparing jaggery, sugar and golden syrup.

INTRODUCTION

Coconut inflorescence sap is one of the locally available sugar sources which is used commonly to obtain sugar concentrates in different forms such as treacle, jaggery and crystalline sugar for domestic consumption. The preparation of treacle is a simple process where the sweet toddy is concentrated by heating and it does not lead to any technical problems. The crystallization of sugar and solidification of jaggery depends on the composition of sap, which undergoes biochemical changes due to microbial activity during collection.

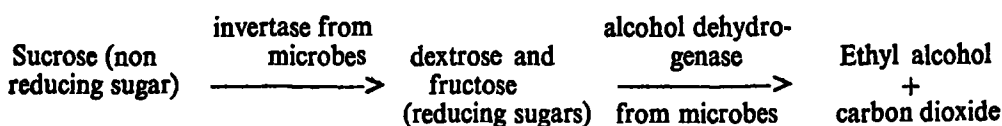
It is not difficult to prepare crystalline sugar from sap under laboratory conditions. However no success had been achieved in the preparation of sugar under commercial conditions. The inability of the sap concentrate to form solid blocks of jaggery too, is a common problem. In many instances the difficulties encountered in obtaining a quality product were due to paucity of scientific data on changes of the quality of raw material before it is processed and the effect of these changes on the end product.

Several methods were adopted by trial and error to overcome these difficulties in the past without much understanding of the scientific principles behind them.

Lime and bark of *Vateria acuminata* ("hal"-Sinhala) are the two substrates commonly placed in pots to check fermentation during collection of sap. The former acts as an antiferment due to high pH and the latter, delays fermentation due to the action of certain natural products in it. Recent work (Mohanadas, 1974) has improved the technique of keeping the

pH of sap high during collection using lime. The sap is next neutralized to pH 7 using a solution of Triple Superphosphate, just before concentrating. However, there are difficulties in obtaining the latter chemical in a pure form suitable for food use. Addition of crystalline cane sugar to sap during preparation of jaggery was another method adopted to increase the sucrose percentage in the sap. Even with these precautionary measures the crystallization of the above products was a matter of chance. An alternate approach that one could think of is the utilization of the property of inversion, to our advantage by enhancing inversion chemically or enzymologically. The inverted sap could then be concentrated to golden syrup.

Coconut sap as it oozes out of the tapped inflorescence is a 15–18% solution of sucrose. Enzyme activity converts (inversion) the sucrose to dextrose and fructose (reducing sugars). The reducing sugars are next converted to alcohol and carbon dioxide by microbes.



The first step in the above conversion plays a vital role in inhibiting the crystallization processes leading to the formation of sugar and jaggery.

Understanding the role of reducing sugar percentages and other parameters such as the pH of the sap is of significance in jaggery and sugar making. In this study the critical sugar levels were worked out and a simple test applicable directly in the field to check the suitability of coconut sap for successful sugar and jaggery production was established. If the sap was found to be unsuitable for preparation of jaggery and sugar by this test it is still possible to invert it further and to concentrate it into golden syrup.

MATERIALS AND METHODS

Fehling's solutions for testing sugars :

Fehling's solutions A and B were prepared as follows.

A — 34.64 g of copper sulphate pentahydrate with 0.5 ml of sulphuric acid (sp. gr. 1.84) was dissolved in 500 ml of water.

B — 173 g of potassium sodium tartarate quadrahydrate and 50g of sodium hydroxide were dissolved in 500 ml of water.

The solutions were allowed to stand for 2 days and filtered through asbestos wool. Equal volumes of these solutions were mixed just before the test or quantitative estimation. The Fehling's solution mixture was standardized using a sucrose solution. (Lane and Eynon, 1923).

Collection of sweet toddy

Sweet toddy was collected overnight (12–14 hr) in polythene bags containing about 7 g of "hal" (*Vateria acuminata*) bark by attaching the bags to the spathes. "Hal" bark helped in retarding microbial activity during the collection of sap. Samples of coconut sap, having spontaneously undergone different degrees of biochemical change (inversion) were used for experiments after separating the "hal" bark by filtration through cloth.

Estimation of sugars in sap

The percentage composition of the reducing and non reducing sugars in the sap were estimated by the procedure described by Lane and Eynon, (1923).

Test for the suitability of sap for jaggery and sugar preparation

Equal portions of the standard Fehling's A and B solutions (1.0 ml each) were mixed. The Fehling's mixture was boiled with 1.0 ml of sap. The colour was noted. A few samples of sap used in an industrial centre for sugar/treacle preparation were tested similarly.

Preparation of jaggery

The sap was used for experiments immediately after estimations and testing (Table 1 and 2).

The sap for preparation of jaggery was concentrated by heating over a flame up to 118–120°C, poured on to polythene (sheets) and left to harden.

Preparation of crystalline sugar

The sap for sugar preparations was concentrated similarly at 113–115°C. The solutions were seeded with a little sugar and left undisturbed for a week. Daily observations were made on the concentrate for the appearance of crystalline sugar. The crystallized sugar (known popularly as sugar crop) was centrifuged after 7 days. The residual molasses in the sugar were separated by rapid washing with a minimum quantity of water. The sugar yields were then estimated.

Preparation of golden syrup

Sweet toddy was boiled down at (100–112)° C with different values of 4 N hydrochloric acid. The effect of centrifugation of the sap, the effect of hydrochloric acid on caramelization and the effect of final neutralization of the acid were studied. The sample obtained by the best combination of the above procedures were compared against a sample of a commercial golden syrup.

Relationship between reducing sugar content and moisture absorption in jaggery on exposure to the atmosphere

The moisture content of jaggery samples containing different reducing sugar percentages was determined immediately after preparation. Replicate samples of these were kept exposed in the laboratory in open pans. Changes in weight due to moisture absorption/desorption were recorded.

RESULTS

Jaggery

The preparation of quality jaggery was not possible with sap containing more than 0.8g/100 ml of reducing sugar (Table 1). When sap containing more than 8% reducing sugar (as % of total sugars) was used, the jaggery formed was semi-solid and sticky resembling toffee. The critical reducing sugar percentage appeared to be between 6–8% of the total sugar content in sap. All acceptable jaggery samples tested for sugar ratio (reducing: total) contained less than 8% reducing sugar.

Table 1. *Critical sugar percentages for successful preparation of jaggery*

<i>reducing sugar g/100 ml sap</i>	<i>non reducing sugar g/100 ml</i>	<i>red sugar x100 total sugar</i>	<i>Appearance of jaggery</i>
0.16	17.7	0.9	light brown, hard
0.24	17.7	1.4	brown, hard
0.70	15.3	4.7	light brown, hard
0.80	15.9	5.0	dark brown, soft
0.97	17.3	5.6	dark brown, soft
1.30	15.7	8.3	dark brown, semi-solid, sticky
1.60	15.7	10.2	dark brown, paste, sticky
2.07	15.2	13.6	dark brown, paste sticky

With the increase in reducing sugar percentages the jaggery formed was darker in colour and soft (Table 1). When a sap concentrate at the critical reducing sugar level was poured on to a polythene paper to allow solidification, only the central portion of the mass hardened into jaggery. The periphery remained semi-solid and sticky (Table 2).

Table 2. *The relationship between colour reaction with Fehling's solution and nature of jaggery and sugar yields obtained from sap at different levels of inversion*

<i>red sugar x 100 total sugar</i>	<i>Colour reaction</i>	<i>appearance of jaggery</i>	<i>percentage sugar yields</i>	<i>number of days taken for appear- ance of sugar crystals</i>
0.9	blue	light brown, hard	99	1
1.3	green	brown, hard	76	1
5.6	brown	dark brown, soft	66	2
4.6*	brown	dark brown centre solidified periphery semisolid and sticky	49	5
13.6	brick red	dark brown paste, sticky	20	7

* The sap was concentrated about 1 hour after the sugar estimations. The figure does not indicate the actual composition of sap at the time of concentration.

The range of colours developed, using predetermined proportions of Fehling's mixture and sap could be successfully used for testing the sap for its suitability for jaggery making. The sap which retains the original blue colour of the mixture or turns green on heating was found to be suitable for making good jaggery (Table 2). Those giving a brown reaction also produced jaggery, but of a poor quality. A yellow or brick red reaction indicated that jaggery could not be prepared from such sap.

The absorption of moisture by jaggery appeared to depend on the percentage of reducing sugars and the relative humidity of the atmosphere. With lower reducing sugar percentages the moisture absorption was less (Fig. 1) and jaggery remained dry for longer periods of storage. The slight moisture desorption observed on the 12th and 27th days for all four samples was probably due to a drop in the relative humidity of the atmosphere. After about a month of exposure to the atmosphere, the jaggery turned sticky due to absorption of moisture and sometimes microbial growth too was observed. Those with higher reducing sugar content were susceptible to moisture absorption and microbial attack within 2-3 weeks of storage. The jaggery prepared from sap with minimum invert sugar content had the best keeping qualities.

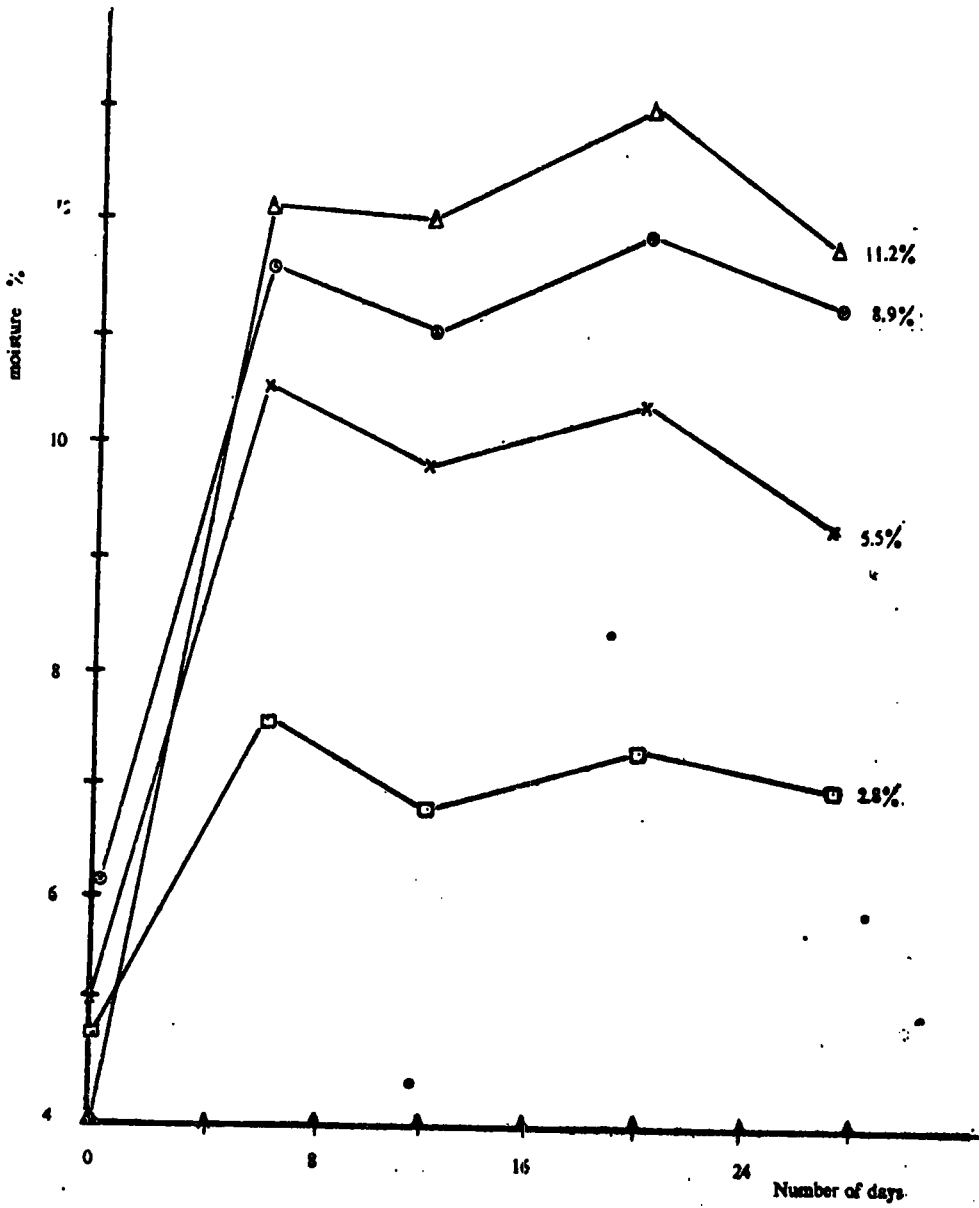


Fig. 1. Absorption of moisture by jaggery at different reducing sugar levels on exposure to atmosphere.

Sugar

In preparing sugar there is a greater chance of getting the end product than with jaggery. The sap containing even higher percentages of reducing sugar than the critical level for preparation of jaggery could be used to crystallize out sugar (Table 2). However the yields dropped with increase in reducing sugar content in sap (Fig. 2). The sap containing 7.5% reducing sugar yielded only 50% of the crystallizable sugar in the sap and the period taken for complete crystallization too increased to 4-5 days.

The same principle as for jaggery applies in the test for the suitability of sap for crystallization of sugar (Table 2). Samples giving brown or brick red reactions gave low yields leading to uneconomical production. The green reaction corresponded to about 75% efficiency in crystallizing out sugar in the sap. This is a reasonable yield from the industrial point of view. A yellow reaction is not a permanent colour and generally it disappears giving a brown colour. Yellow indicates a reaction between green and brown which corresponds to 65-70% of sugar crop (Fig. 2).

Several sap samples tested on the above basis at an industrial unit indicated brick red reaction. On estimation of sugars the sap showed reducing sugar levels of 5-10%. Following our observations it could be seen that this sap yields only about 60g of sugar per litre (10 oz of sugar per gallon) of sweet toddy under laboratory conditions. Under industrial conditions it would have been even less. Thus the process will not be economically feasible.

Golden syrup

Sap having pH as low as 4 could be used to prepare golden syrup. The centrifugation of sap did not alter the appearance of the end product significantly. Since filtration is much cheaper and less cumbersome, it is suggested that the sap be filtered through a cloth. Then the sap could be boiled down, preferably in a wide-mouthed earthenware pot. About 3 ml of 4 N hydrochloric acid per litre of sap should be added while it is boiling. When the boiling temperature is around 110°C the acidity should be neutralized using about 3.0 ml of 4 N sodium hydroxide (Fifal pH 5-6) and the sap boiled down further at a temperature of 113-114°C. Storing the concentrate for about a month in a glass container improved the appearance of the product.

A comparison of the properties of golden syrup prepared from coconut sap and those of imported cane sugar golden syrup is given in Table 3.

Table 3. Comparison of properties of coconut sap golden syrup with those of commercially available cane sugar golden syrup

<i>property</i>	<i>coconut sap golden syrup</i>	<i>cane sugar golden syrup</i>
Consistency in Brix	77-83	82
Invert sugar x 100 total sugar	69-72	60-62
pH	4.7	5.2
Colour	golden yellow (slightly turbid)	golden yellow (clear)
taste	sweet (not acidic) small crystals of sugar appear in the solution	sweet (not acidic) small crystals of sugar appear in the solution

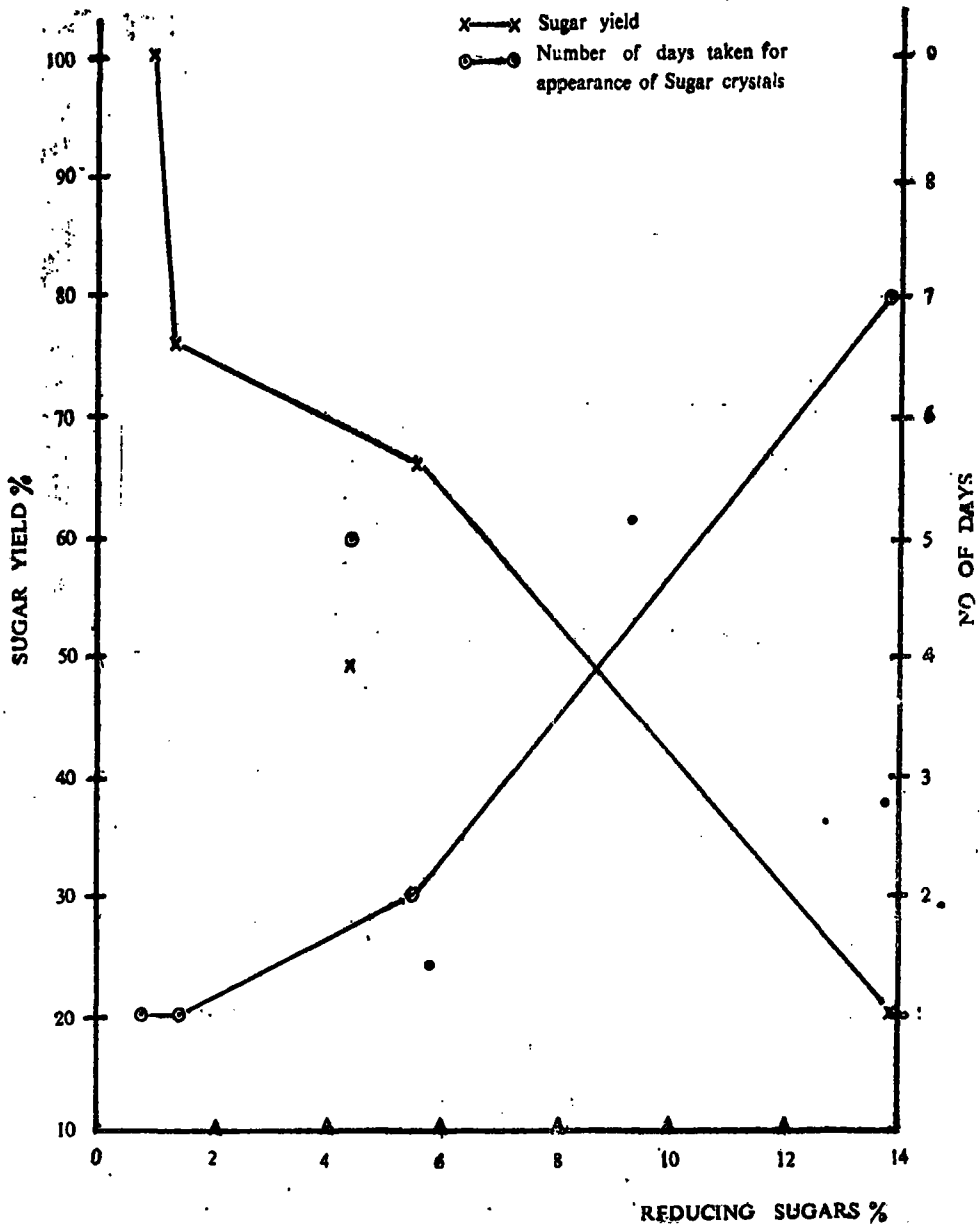


Fig. 2. Dependability of sugar crop yields and the time taken for crystallization on the reducing sugar content (as a percentage of total sugars in the sap).

DISCUSSION

The lack of a simple method to determine the suitability of coconut sap for jaggery and sugar preparation was one of the main setbacks in this cottage industry. The long duration between exudation and concentration of sap permits microbial activity, leading to biochemical changes in the sweet toddy. The experienced jaggery makers were able to use factors such as acidity (pH), turbidity of sap or frothing due to gas production, in selecting sap for jaggery preparation. Of these, pH, the more widely and scientifically used factor, gives a very rough idea on whether inversion has occurred in the sap.

Invertase activity is greatest in sap when the pH is around 6. During collection of sap, a succession of micro-organisms occurs in the pot (Atputharajah *et al.* 1977). They were found to bring about an initial drop in pH from 7 to 4. The inversion of sugar is generally associated with a drop in pH due to simultaneous activity of acid producing microbes. It is therefore reasonable to use the pH as an indirect indicator of inversion of sugars. A pH around 7, which is the pH of fresh sap, could be related to a low level or absence of reducing sugars in sap. However a lower pH does not necessarily mean that inversion of sugars has occurred or vice versa. On many occasions the sap at pH 6-7, sometimes even after careful control of the pH using lime, failed to produce jaggery and investigations showed the presence of high reducing sugar levels. On the other hand we were able to prepare good jaggery from sap of low pH (artificially decreased by adding acetic acid) if the reducing sugar levels were low. Testing the sap for reducing sugar content is the most reliable way of judging the suitability of sap for preparation of sugar and jaggery.

Once the semiquantitative estimation of reducing sugars in sap is done using the test described above, the preparation of jaggery or treacle becomes a straightforward concentration of sap with confidence for a good end product. There is no necessity to add cane sugar (sucrose) etc. This avoids the problem of ending up with a sticky product which is neither jaggery nor treacle. If the test indicates high reducing sugar percentages the sap could be boiled down to treacle. Such treacle will be much sweeter than those prepared from sap containing low reducing sugar levels. At this stage it will be more profitable to enhance inversion chemically to obtain golden syrup which has a better market value. It is difficult to get the exact correlation between sugar yields and reducing sugar content in sap due to the difficulty in obtaining pure sugar by centrifugal separation of molasses from crystallized sugar mixture. Sometimes it becomes necessary to add a few ml of water to wash away molasses adhering to sugar particles though it tends to lower the yields. The reproducibility of the results presented in Fig. 2 was low, but similar curves were obtained on repeating the experiment.

In obtaining coconut sap one has to depend to a very high extent on the experience and enthusiasm of the tappers. The techniques in tapping, preparing the pots, collecting sap, minimising microbial contaminations lie totally in the hands of the tapper. In an industry where a large number of tappers need to be employed, it is not possible to expect the same degree of competence. The chances are that only one or two well experienced people are in a position to deliver sap of the required quality. But this too, when mixed with sap of lower quality cannot be used for sugar and jaggery preparation. On an industrial scale, the safest product from coconut sap that one can think of with minimum technological problems, is treacle and that too with careful supervision.

It may be possible to prepare jaggery or sugar successfully on a small scale if a few members of a family get involved in a project. It needs much devotion, specially in the role played by the tapper in obtaining fresh sap and immediate boiling down to minimize inversion.

On the other hand, many precautions to avoid inversion need not be taken if the intention is to prepare golden syrup. However, it involves only the simple technique of adjusting the pH of sap with acid and alkali but yields a more valuable product.

CONCLUSIONS

A simple colour reaction based on Fehling's test could be used to distinguish between sap suitable for preparation of sugar, jaggery and golden syrup. In preparation of sugar, the yield depends to a very high extent on the degree of inversion of sap. The present high cost of sweet toddy together with the above factor makes sugar preparation uneconomical. It will not be easy to manufacture jaggery on a large scale unless chemical methods are employed to arrest microbial activity.

It is much more profitable to prepare golden syrup though it needs a little extra technical knowledge. There is no risk of financial loss as in the case of sugar or jaggery because even if one fails totally in attaining the quality standards expected in golden syrup, one at least ends up with a treacle of super quality.

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