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Method for the Accurate Determination of Carbonic Acid present as Carbonate in Soils

BY

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A Method for the Accurate Determination of Carbonic Acid present as Carbonate in Soils

(*Received for publication on 22nd March 1922.*)

The amount of organic carbon in a soil is usually determined by deducting the amount of carbon dioxide (CO_2) present as mineral carbonate from the total carbon dioxide (CO_2) obtained by its complete combustion and that obtained by the decomposition of the residue of combustion with acid. The amount of organic carbon in Pusa soil is very small compared to the amount present as carbonate, and consequently in order to obtain reliable values for the former it is necessary to determine the latter with great accuracy.

The main difficulty in the determination of CO_2 of mineral carbonate in soil, as pointed out by F. S. Marr[1] and J. C. Schollenberger[2] and verified by a series of determinations carried out at Pusa [Expts. I, II & V], lies in the fact that, on boiling a soil with acid, the organic substances present in it are decomposed and give out CO_2. Marr also observed that CO_2 is liberated when some soils are boiled with water under atmospheric pressure. Our experience of the decomposition of Pusa soil with dilute boiling acid shows that, in spite of the soil containing only a small amount of organic matter, the results obtained with about one gram of soil are not sufficiently accurate. [Expt. I (1), (2) and (3).] The error, however, is considerably minimised by taking a larger quantity of soil for decomposition, but the results thus obtained, in triplicate determinations, still do not agree very well one with the other [Expt. I (4) and (5)].

Because of these difficulties, Marr adopted the method of decomposing the soil carbonates by boiling with dilute acid under reduced pressure at 50°C. and absorbing the liberated gas (CO_2) in standard alkali. This involves double titration which is somewhat objectionable.

Gravimetric estimation of CO_2 by decomposing soil by Marr's method has been found to be impracticable, as under above conditions soda-lime tubes lose moisture, and sulphuric acid tubes give out spray owing to the rapid passage of gas through them on evacuation. By properly pre-

[1] *Jour. Agri. Sci.*, III (1908—1910).
[2] *Jour. Ind. Eng. Chem.*, VIII (1916), No. 5, pp. 427-428.

paring the sulphuric acid tubes (described later on) formation of spray in the tubes may be prevented if the gas is aspirated under slightly reduced pressure. It is doubtful, however, whether this will be the case, and whether the CO_2 will be completely absorbed, when the gas is drawn through the tubes in a rapid stream under the reduced pressure required to boil the dilute acid at 50°C. Moreover, a very complicated arrangement, such as a bath for constant temperature (50°C.), an efficient Geryk or Töppler pump, and a reaction flask and tubes sufficiently strong to bear the pressure, is necessary for such an operation, and these generally are not available in ordinary laboratories.

Consequently an attempt was made to devise some method for the gravimetric determination of CO_2 under atmospheric pressure and *without the employment of heat*. This is only possible if the soil carbonates could be completely decomposed by dilute acid in the cold and if by any means the dissolved CO_2 could be completely liberated from the solution.

In Pusa soils the carbonates are present mostly as calcium carbonate and to a slight extent as magnesium carbonate. So, finely ground calcium carbonate and dolomite were qualitatively tested with dilute hydrochloric acid in the cold. The former was found to be completely dissolved and the latter left a slight residue of sand which was not further dissolved even on boiling with stronger acid. It was, therefore, assumed that the carbonates present in the soil would be completely decomposed by dilute hydrochloric acid *in the cold*.

Some experiments were next carried out to see whether the dissolved CO_2 could be completely washed out by the evolution of hydrogen in the reaction mixture with aluminium and hydrochloric acid.

For this purpose sodium carbonate was decomposed in the cold with excess of hydrochloric acid and then hydrogen was generated by dropping in a piece of aluminium foil. The hydrogen was finally driven off from the tubes by aspirating CO_2-free air. In all cases it was found that if the hydrogen be generated at a proper rate it was possible to estimate all the CO_2 liberated during the reaction either in the cold or when heat was employed [Expt. III A (1), (2) and III B (1), (2)].

The next question which arose was whether the presence of clay would occlude or adsorb any CO_2 in the cold. To decide this point a quantity of kaolin, which had been previously treated with strong HCl and washed free of acid and dried, was mixed with some sodium carbonate. The mixture was decomposed with hydrochloric acid and then hydrogen was generated as before and CO_2-free air finally aspirated through the tubes to replace the hydrogen. The results obtained show that no occlusion or adsorption of CO_2 took place [Expt. III A (3)].

sample of soil was next taken for the purpose of experiment, and here difficulty was experienced owing to the caking of the soil at the bottom of the flask leading to incomplete decomposition. This trouble was overcome by the use of a specially designed apparatus which contained a mercury-sealed stirring arrangement. Arrangements were also provided to allow of a piece of aluminium foil being introduced when necessary, *i.e.*, after the decomposition of the carbonates. The apparatus was so arranged that the acid could be introduced without coming in contact with the aluminium foil. A full description of the apparatus and the method of employment is given later.

A further difficulty was met owing to the adherence of the fine clay to the surface of the aluminium foil, diminishing the rate of the generation of hydrogen and so preventing the dissolved CO_2 being driven off. This was overcome by the introduction, after the decomposition of the soil, of a few drops of copper-sulphate solution, thus forming an aluminium-copper couple and accelerating the generation of hydrogen. If mercury is substituted for copper-sulphate, the aluminium amalgum in presence of the acid generates hydrogen too rapidly to be controlled. The method of using copper-sulphate possesses the advantage that the evolution of hydrogen can be reduced by dilution, or, on the other hand, the reaction can be rendered more active by introducing further amounts of copper-sulphate as desired.

An apparatus and method were finally evolved by which the carbonates of the soil could be completely decomposed at the ordinary temperature with excess of dilute hydrochloric acid and the mixture stirred all the while. The CO_2 which remains dissolved in the menstrum is driven out by a stream of hydrogen generated by the action of aluminium and hydrochloric acid and a few drops of copper-sulphate solution. At the end, CO_2-free air is drawn through the flask and the tubes by aspiration, to sweep away all the CO_2 and finally to drive away all the hydrogen in the tubes.

Very good results (*i.e.*, triplicate determinations agreeing very well) have been obtained by the above method [Expt. IV (1), (2) (3)].

The results obtained by boiling the mixture of soil and acid for ten minutes after it is completely decomposed in the cold and then generating hydrogen for a longer time were only very slightly higher than those obtained in the cold [Expt. V (1), (2), (3)], showing that the decomposition of the mineral carbonates under the latter condition was complete. The small variations in the triplicate determinations made by boiling the soil with acid are probably due to the decomposition of the organic substances present.

Description of the apparatus.

The apparatus (Fig. 1) consists of a reaction flask (M) to which the stirring arrangements for the introduction of acid are attached (also shown separately in Fig. 2). The delivery tube of the flask is connected to a double condenser (P) which is attached to a "T"-piece provided with a three-way stopper (Q) at the junction of three arms. The other end of the "T"-piece is attached to the bulbed tube (S) containing a little H_2SO_4, which in turn is attached to three H_2SO_4 tubes (T) of which the third one is weighed and regarded as the guard tube. Two soda-lime tubes (T') are employed to absorb the CO_2 and two H_2SO_4 tubes (T") to retain the moisture given off by the soda-lime tubes. Finally there is a second bulbed tube (S') containing little sulphuric acid to show the rate of passage of the gas through the tubes. An aspirator is employed to draw the gases through the tubes.

The mercury-sealed stirrer and the acid introducing arrangements are shown in Figs. 2 and 3.

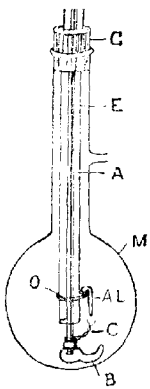
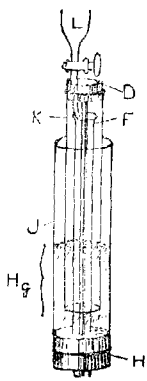


Fig. 2.



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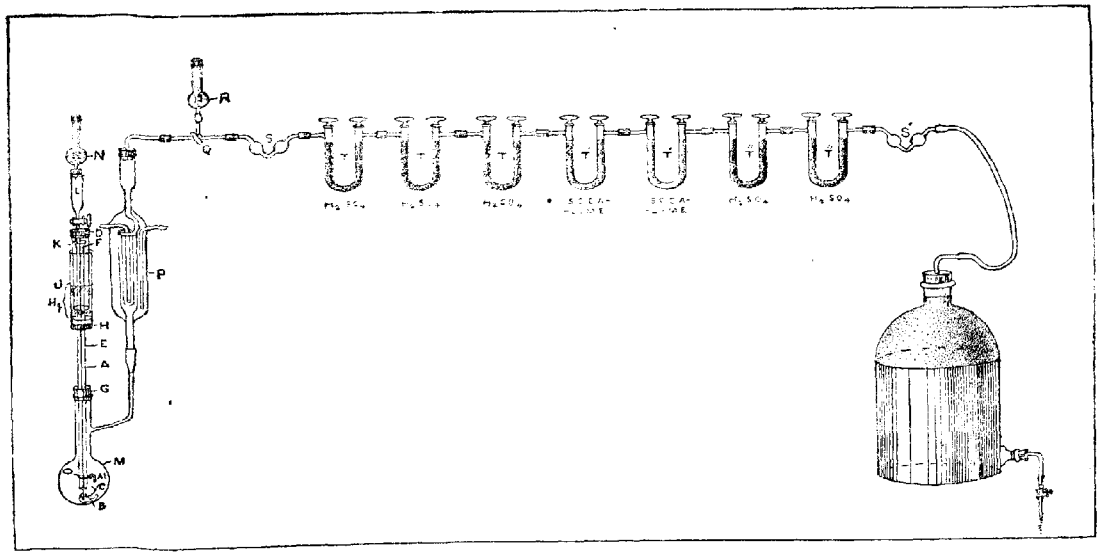

Fig. 1. Sketch of the apparatus used for the determination of CO_2 present as mineral carbonates in soil.

These consist of a glass rod (A) having a movable glass blade (B) attached to the flattened end of the rod. A bent copper wire (C) is fastened to the rod a little above B to detach the aluminium foil (AL) when required. The rod (A) is fixed into the bung (D) at the top and is surrounded by the tube (E), which passes through the bungs (G) and (H) and is widened somewhat at (F) to receive acid from the stoppered vessel (L). The outer jacket of the mercury-seal (J) is fitted to the bung (H) and the inner tube (K) fixed to the bung (D) and dips into the mercury in the outer jacket (J) of the mercury-seal. The stem of the stoppered funnel (L) passes through the bung (D) and is bent inward over the top end of the tube (F).

A soda-lime-tube (N) is attached to the top of the funnel (L) (Fig. 1), whenever required, for drawing CO_2-free air into the apparatus.

Method of procedure.

Five to six grams of finely ground soil are weighed and washed into the reaction vessel M with two lots of 5 c.c. each of CO_2-free water each time, and the apparatus fitted together.

A mixture of 10 c.c. of strong HCl and 5 c.c. water (CO_2-free) is introduced little by little from the stoppered funnel (L) and the soil stirred continuously by turning the bung (D), so that the evolution of gas may be regular and at a moderate rate, the rate being indicated in the first bulbed tube (S). When the whole of the acid is run in and no further quantities of gas are evolved on stirring, it is assumed that the decomposition of the soil carbonates is completed. The stirrer is now raised so that the piece of aluminium foil is displaced and falls into the acid and hydrogen begins to be evolved. [It will be seen from the sketch (Fig.1) that the stirrer can be raised so much as to displace the aluminium foil without allowing any gas to escape through the mercury seal.)

As stated previously, the evolution of hydrogen in mixture of soil and dilute acid is slow and this is accelerated by introducing a few drops of $CuSO_4$ solution, thus forming an aluminium-copper couple. Hydrogen is allowed to evolve at a moderate rate at first for 15 minutes and then, when the rate is slowing down, a further quantity of 10 c.c. of strong HCl is added and hydrogen is evolved for another 10 minutes.

At this stage the outer jacket (J) (Fig. 3) is filled with mercury, so that most of the gas (CO_2, if any) is driven out of the inner space of the mercury-seal arrangement; the acid funnel is next washed with a little CO_2-free distilled water to get rid of HCl fumes (which may afterwards come into the soda-lime tube). The soda-lime tube N is now attached and

a slow current of CO_2-free air is drawn in through the whole apparatus, by means of the aspirator, to sweep away any CO_2 remaining. When this is completed, the connection of the reaction flask with the tubes is broken by turning the three-way tap (Q) and CO_2-free air aspirated through the absorption tubes for half-an-hour so as to displace any hydrogen from the U-tubes. Half an hour's aspiration was found to be amply sufficient to displace all the hydrogen. The weight of CO_2 evolved is found by weighing the absorption tubes and the final drying tubes.

The rate of evolution of CO_2 and hydrogen, and the passage of air into the tubes, should not exceed 1 litre per half-an-hour.

Some difficulty was experienced owing to the formation of spray in the H_2SO_4 tubes but this can be prevented by preparing pumicee saturated with sulphuric acid in a special way* and placing glass wool in the upper portions of the U-tubes.

The results obtained by this apparatus and procedure have proved to be very satisfactory. For Pusa soil, containing only a small amount of organic substance, the method of determining CO_2 by decomposing the soil carbonates with boiling dilute hydrochloric acid gives fairly good results if a large amount of soil (5—7 grams) is taken for decomposition [Expt. 1 (4) and (5)]. But in the case of soil rich in organic matter, boiling under atmospheric pressure involves the danger of decomposing the unstable organic substances, and the new method is recommended in such cases.

Summary and conclusions.

1. Carbonates in the calcareous Pusa soil can be completely decomposed with hydrochloric acid, without boiling, if the soil be efficiently stirred.

2. The soil occludes no carbonic acid under the conditions in which the experiments are carried out.

3. The dissolved CO_2 in the acid liquid can be completely driven out by the generation of hydrogen in it.

4. The rate of evolution of hydrogen in the menstruum can be regulated by the introduction of copper-sulphate solution.

5. The CO_2 of mineral carbonate in soil can be gravimetrically determined with great accuracy by the use of the special apparatus according to the method recommended.

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* Ignited pumice is boiled with water for half-an-hour. The water is next replaced with strong sulphuric acid and kept overnight. The sulphuric acid is changed three times. Prepared in this way the pumice will not float in strong H_2SO_4. It is then thoroughly drained and introduced into the tubes through the stem of a funnel.

EXPERIMENTS.

	Quantity of soil taken	% C (Mineral)
I. Boiled for 5 minutes	(1) 1 gram	3·855
	(2) ,,	3·922
	(3) ,,	3·905
	(4) 5—7 grams	3·860
	(5) ,,	3·873
II. Boiled for 1 minute—		
(*a*) H generated, not stirred internally	(1) 1—2 grams	3·794
	(2) ,,	3·816
	(3) ,,	3·861
	(4) ,,	3·741
	(5) ,,	3·825
	(6) ,,	3·794
	(7) ,,	3·809
	(8) ,,	3·846
	(9) ,,	3·806
(*b*) H generated, stirred internally	(1) About 6 grams	3·731
	(2) ,,	3·855
	(3) ,,	3·736
III. Decomposition of—		
(A) Na_2CO_3 *in the cold* and generation of H *in the cold.*	(1) 2—2·5 grams Na_2CO_3	11·243
	(2) 2—2·5 grams Na_2CO_3	11·154
	(3) 2—2·5 grams Na_2CO_3+3 grams Kaolin	11·120
(B) Na_2CO_3 boiled and H generated in hot solution.	(1) 0·559 grams Na_2CO_3	11·310
	(2) 0·5403 grams Na_2CO_3	11·200
IV. Decomposition of soil in the cold by acid and liberation of CO_2 from the cold solution with H & $CuSO_4$ (few drops).	(1) 5—7 grams of soil	3·861
	(2) ,,	3·859
	(3) ,,	3·863
V. Decomposition of soil in the cold mixture, boiled afterwards for ten minutes and H generated for a long time.	(1) 5—7 grams of soil	3·889
	(2) ,,	3·865
	(3) ,,	3·875

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Tamarind as a Source of Alcohol and Tartaric Acid

BY

H. N. BATHAM, M.A.,
Offg. Agricultural Chemist, United Provinces

AND

L. S. NIGAM, L.Ag.,
Assistant to Agricultural Chemist, United Provinces

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Tamarind as a Source of Alcohol and Tartaric Acid.

(*Received for publication on 7th January, 1924.*)

India is full of resources, vegetable and mineral, and there are many raw products which are capable of being used for industrial purposes. The tamarind (*Tamarindus indica*), which is so widely found in India, has yet been only partially investigated, although every part of the tree is utilized for some purpose or other, the most important being the fruit. According to the varieties of fruit, the tree is divided into three classes :—(1) The sour fruited, (2) the sweet fruited and (3) the red fruited. The pulp of the fruit of the last variety is of a rose colour and commands the highest price and is preferred for preserving.

Of the three parts of the fruit, *viz.*, shell, seed and pulp, the last is the most useful. It is for the sake of the pulp that the fruits form a regular article of commerce. Besides their consumption for edible purposes in India, they are largely exported to Europe. According to "Tropical Agriculture,"[1] a new market has sprung up for tamarind in Italy, where it is in demand for the manufacture of syrups and sweetmeats. According to the same authority, the average annual yield of an adult tree is 350 lb. of pods or fruits, which represent 200 lb. of prepared pulp. The pulp is thus about 75 per cent. in the fruit. The average percentage of the seed and the pulp, as determined in the decorticated fruits available in the Cawnpore market, is 32 and 68 respectively. Therefore, the greatest part of the fruit is the pulp, which principally consists of sugars and tartaric acid. The sugar content ranges from about 30 to 40 per cent. and tartaric acid from about 9 to 15 per cent. as can be seen from the analyses of different samples of tamarind procured from the Cawnpore market as well as from the analyses by other workers. The tartaric acid was determined by the revised form of Goldenburg method (1907),[2] and the reducing sugars by Soldiani method modified by Ost, which was described in a Pusa Bulletin.[3] The results are given in Table I.

---

[1] *Tropical Agriculture*, Nov. 1905.

[2] Lunge and Keane. *Technical Methods of Analysis.*

[3] *Bull. 13 of Agri. Res. Inst. Pusa.*

TABLE I.

Showing the percentage of reducing sugars and tartaric acid in different samples of tamarind.

Sample No.	Reducing sugars	Tartaric acid
1 .	39·56	9·65
2 .	41·80	9·52
3 .	33·96	11·16
4 .	30·21	12·76
5 .	38·88	10·65
6 .	29·16	8·69
7 .	Traces	2·25
8 .	Appreciable quantity	5·51

There appears to be some relation between the contents of sugar and tartaric acid: the higher the sugar content the less the quantity of tartaric acid and *vice versâ*. Sample No. 6 was one year old and seems to have deteriorated in its two contents as is the case with *mahua* (*Bassia latifolia*) flower when kept for a year or so, as mentioned later on. Samples Nos. 7 and 8 were unripe tamarinds in different stages, and it appears that probably both sugar and tartaric acid were in their formative stage.

It is due to the presence of these two constituents that the pulp is consumed by Indians in the form of congies, syrups, *chatni*, beverages, etc., but no industrial use has yet been made of it.

Some time ago, efforts were made in New Caledonia to distil alcohol and wine from banana and tamarind.[1] The latter produced an excellent brandy manufactured in the following way :— The fruit picked a little before it was ripe was crushed in water and the whole allowed to ferment. From 13·5 kilos of fruit 8 litres of brandy of good quality were produced. A very remarkable fact is the absence in the tamarind of the essential oils, which pollute almost all fruit or grain alcohols below a certain degree. Besides alcohol, there can be extracted from the fruit of the tamarind a certain quantity of tartaric acid.

Recently a process has been worked out by Dr. Sudborough and Mr. P. N. Vridhachalam[2] to manufacture tartaric acid from the tamarind pulp. In this manufacture three difficulties had to be

[1] *Jour. Soc. Chem. Ind.*, May 1889.

[2] *Jour. Ind. Inst. Sci.*, III, 5.

encountered. The first, *viz.*, that about the filtration of the aqueous extract of the pulp, was removed by the use of an autoclave. The second difficulty about the refining and bleaching the solution was solved by the use of different bleaching agents. The disposal of the bye-products was the third important point left for others to solve.

From the analytical data available at present it seems that the predominant constituent of the pulp is sugar, which, if first converted into alcohol, would place the manufacture of tartaric acid from tamarind on a sound commercial basis, as is done with grapes, first fermenting the juice for the production of alcohol and then utilizing the residue for the manufacture of tartaric acid.

Dr. Sudborough and Mr. P. N. Vridhachalam say in their paper that although heating in an autoclave is necessary to facilitate the separation of the aqueous extract from the residue, it destroys appreciable amounts of reducing sugars present and the fermentation of the mother liquors from the calcium tartrate precipitate would not be likely to pay.

In order to avoid this loss of sugar, which is a valuable asset in the tamarind pulp, by autoclaving, some preliminary experiments were made in the year 1921 to ferment the pulp extract first, so that the whole of the sugar is made available for the formation of alcohol without undergoing any loss by autoclaving, and then to prepare tartaric acid from the mother liquor after fermentation and also to see the effect of fermentation on the tartaric acid content of the pulp.

Fermented by the organisms, naturally present, the pulp yielded 10·79 per cent. by weight of absolute alcohol, which was determined by ascertaining the specific gravity of the distillates from the fermented must.[1] The same work was simultaneously carried out by Dr. Marsden of Madras, and his findings[2] confirm our results. He reports that 1,000 grm. tamarind were lexiviated, the extract fermented and distilled - giving an yield of alcohol—10·75 per cent. In one of his experiments a yield of 14 per cent. alcohol equivalent to a sugar content of 28 per cent. was also obtained.

Two sets of experiments were started, each in duplicate, to mark the progress of the conversion of sugar into alcohol. The first set was with a pulp containing 33·96 per cent. sugar and the second with a pulp containing 41·00 per cent. sugar. These experiments were carried out in open vats, as is done in distilleries, and the results are given in Tables II and III.

[1] Leffmann and Davis. *Allen's Commercial Organic Analysis*, Vol. I.

[2] *Madras Dept. Ind. Bull.* 4 (N.S.)

TABLE II.

Showing the progress of the conversion of the sugar content of the tamarind pulp into alcohol.

Days	REDUCING SUGAR PER CENT.		ACTUAL ALCOHOL FORMED PER CENT.		Average actual alcohol formed per cent.	Average theoretical alcohol per cent.	Average loss of alcohol per cent.	Average loss of sugar per cent.
	Vat I	Vat II	Vat I	Vat II				
1	33·96	33·96	..	..	..	..	..	..
2	31·98	31·21	1·05	1·15	1·10	1·21	0·11	0·22
3	25·83	26·83	2·15	3·74	2·94	3·90	0·96	1·88
4	16·18	16·26	7·43	6·93	7·18	9·07	1·89	3·69
5	8·55	9·01	8·09	8·56	8·33	12·87	4·54	8·88
6	5·55	5·73	10·25	9·60	9·93	14·47	4·54	8·88
7	4·85	4·85	10·71	10·79	10·75	14·88	4·13	8·08
8	3·08	3·05	10·17	9·85	10·01	15·79	5·78	11·31

TABLE III.

Showing the progress of the conversion of the sugar content of the tamarind pulp into alcohol.

Days	Reducing sugar per cent.		Actual alcohol formed per cent.		Average actual alcohol formed per cent.	Average theoretical alcohol per cent.	Average loss of alcohol per cent.	Average loss of sugar per cent.
	Vat I	Vat II	Vat I	Vat II				
1	41·00	41·00	..	..	..	..	..	..
2	39·23	39·23	0·78	0·89	0·83	0·90	0·07	0·14
3	37·44	38·23	1·59	1·59	1·59	1·62	0·03	0·06
4	37·44	37·44	1·68	1·70	1·69	1·82	0·13	0·25
5	32·10	32·10	4·19	3·89	3·99	4·55	0·56	1·09
6	16·05	19·61	11·52	10·48	11·00	11·84	0·84	1·64
7	6·67	7·13	12·42	11·52	11·97	17·43	5·46	10·68
8	3·57	3·57	8·47	10·18	9·33	19·13	9·80	19·17

During fermentation there is a wastage of sugar, which is not a small amount and may be due to the growth of different kinds of bacteria, mucor, etc., in the fermenting liquor. It is also worthy to note here that there is a certain percentage of sugar, though small, which escapes fermentation.

Another experiment was performed in duplicate to see the effect of fermentation on the tartaric acid content of the tamarind pulp. Estimation of tartaric acid was carried out on alternate days and not daily as was the case with sugar in the former experiments. The results are expressed in Table IV.

TABLE IV.

Showing changes in the tartaric acid content of the tamarind pulp during fermentation.

Days	Tartaric acid per cent.		Average tartaric acid per cent.	Average loss of tartaric acid per cent.
	Vat I	Vat II		
1	9·52	9·52	9·52	..
3	9·23	9·20	9·21	0·31
5	9·23	9·23	9·23	0·29
7	8·75	8·99	8·87	0·65
9	8·99	8·87	8·93	0·59

Although there appears to be a little decrease in the quantity of tartaric acid during fermentation, still the outcome of alcohol will considerably outvalue this loss.

The tamarind pulps fermented in the above experiments contained 33·96 and 41·00 per cent. reducing sugars; therefore, the yield of alcohol was even less than $\frac{1}{3}$rd the weight of the sugar contents. According to the equation—

$$C_6H_{12}O_6 = 2C_2H_5OH + 2CO_2$$

the theoretical yield of alcohol is little more than half the quantity of the sugar. In the distilleries of the United Provinces, the parent substances used for the production of alcohol are mostly *mahua* (*Bassia latifolia*) flowers and molasses and the yield of alcohol from each is given in Table V.

TABLE V.

Showing the yield of alcohol from mahua flowers and molasses.

Parent substance	Sugar content	Liquor produced	Weight of alcohol per 100 sugar
New *mahua* flowers . .	52 55	4½ gall. L.P.	50
Old *mahua* flowers . . .	42 45	3·8 4 ,,	50
Molasses	60 62	4½ 4 ,,	40

The *mahua* flowers give the theoretical yield of alcohol, while molasses gives less, due to the presence of a certain amount of sugar, which escapes fermentation, technically called by distillers as unfermentable sugar.

Thus the amount of alcohol produced from the tamarind is not in proportion to that of the sugar content, as it ought to be. The pulp during fermentation was every now and then examined under a microscope, and it was found that, along with the growth of healthy adventitious yeast cells in strongly acid medium, there was also a growth of different kinds of bacteria, moulds, etc., which may be one of the chief causes of the decreased production of alcohol. Hence it was thought desirable to ferment the pulp with pure cultures of yeasts, which may increase the yield of alcohol. Comparative experiments in duplicate were then carried out on the fermentation of sterilized tamarind must in Erlenmeyer flasks tightly corked with sterilized cotton wool by means of Saccharomyces Ellipsoideus, Saccharomyces Exiguus, Saccharomyces Capsularis, beer yeast from Solan Brewery, Simla, yeast from Cawnpore Sugar Works, and adventitious yeasts in tamarind. The results are shown in Table VI.

To make the results easily intelligible the highest figures calculated as percentage of alcohol produced per 100 of tamarind pulp are shown in Plate I. The vertical column represents the percentage of alcohol yielded.

It will thus be seen that Saccharomyces Ellipsoideus gives a yield of alcohol which nearly approaches the theoretical amount and far exceeds the quantity obtained with other yeasts. The spontaneous fermentation of the must of the tamarind pulp is thus not quite adapted for the production of alcohol.

Besides, during the alcoholic fermentation with adventitious yeast, it was marked in several experiments that the yield of alcohol was

spasmodic and slow, but with pure cultures it was not so. To elucidate this the results of two experiments are shown graphically in Plate II.

TABLE VI.

Showing the fermentative efficiency of different species of yeast.

Name of yeast	Sugar in pulp	Alcohol found per cent.		Average alcohol found per cent.	Alcohol calculated	Fermentative efficiency of yeast per cent.
		Flask I	Flask II			
S. Ellipsoideus . .	38·87	19·26	19·26	19·26	19·87	96·93
S. Exiguus . . .	38·87	15·93	15·87	15·90	19·87	80·02
S. Capsularis . . .	38·87	13·84	13·76	13·80	19·87	69·45
Beer yeast . . .	38·87	13·86	13·86	13·86	19·87	69·74
Cawnpore yeast . .	38·87	13·80	13·92	13·86	19·87	69·74
Adventitious yeast . .	38·87	12·98	12·82	12·90	19·87	64·92

Thus it can be seen that, with Saccharomyces Ellipsoideus, there is every day a rise in the yield of alcohol, which was greatest on the 7th day, while with adventitious organisms there was rise and fall, reaching the maximum yield on the 8th day.

In order to find out the influence of the concentration of the must on the production of alcohol, several trials were made in the very beginning to ferment the pulp with varying quantities of water. The fermentation was found to be at its best when the ratio of the pulp to water was between 1 : 3·5 and 1 : 5. Therefore, the above experiments were carried out with one of pulp to five of water at room temperatures which varied from 25° to 39° C. and it was marked that the higher the temperature nearing 40° C. the better and quicker the alcoholic fermentation.

In conclusion, we would, therefore, point out that if the fermentation of the tamarind pulp is to be carried on commercially with pure cultures of yeast in place of adventitious organisms, the yield of alcohol is sure to increase, consequently enhancing the profit calculated by Dr. Marsden for the manufacturers of tartaric acid and alcohol from tamarind.

Finally, we take this opportunity to express our thanks to Dr. and Mrs. Norris of Madras, and Mr. Lissenborough of Cawnpore Sugar Works, for their kindness in supplying us with samples of pure cultures of different varieties of yeasts, and also to B. Manna Lal Khare, Lecturing Assistant, for his help during the investigation.

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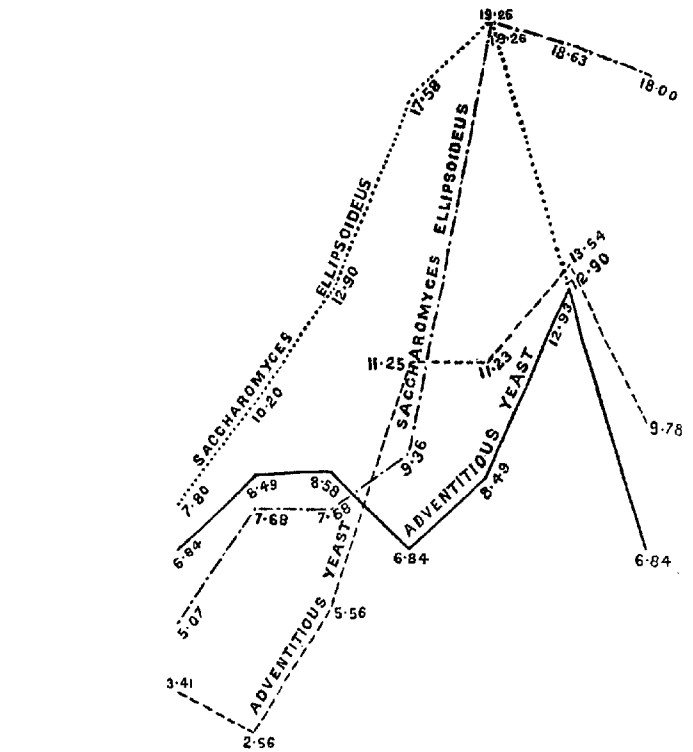
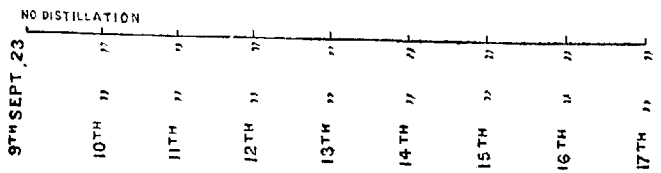
PLATE I.

S. ELLIPSOIDEUS 19·26
S. EXIGUUS 15·90
S. CAPSULARIS 13·80
BEER YEAST 13·86
CAWNPUR YEAST 13·86
ADVENTITIOUS YEAST 12·90
64·92 ADVENTITIOUS YEAST
69·74 CAWNPUR YEAST
69·74 BEER YEAST
69·45 S. CAPSULARIS
80·02 S. EXIGUUS
96·93 S. ELLIPSOIDEUS
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
FERMENTATIVE EFFICIENCY OF DIFFERENT SPECIES OF YEAST %

PLATE





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