

THE HISTORY OF VINEGAR PRODUCTION AND THE USE OF COCONUT TODDY AS A RAW MATERIAL

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PART II: COCONUT TODDY A RAW MATERIAL FOR VINEGAR PRODUCTION

NEARLY every writer who has dealt with the subject of the useful products of the coconut, alludes to the vinegar prepared from the juice. Coconut toddy vinegar when well made is reported to be of good strength and colour, of the highest keeping qualities, and very superior flavour. According to Dr. Gibbs quoting Lyon, "Its excellence is so pronounced that upon its merits it would readily find sale in the world's market."⁶

The Coconut toddy vinegar industry in Ceylon in its present form dates back from about 1924 when Government, as the writer has already pointed out, issued special licences for its manufacture. It will be evident from the figures quoted that since that time, the industry has not progressed much. The principal disabilities against encouraging the industry appear to have been the tendency for the common adulteration with imported acetic acid and the suspicion which attaches to toddy tapping for vinegar manufacture becoming a cloak for the illicit sale of fermented toddy. Perhaps another reason why it is not made on a large scale or become an article of commerce is probably due to the fact that toddy remains rather an expensive base as compared with other sources of vinegar, and that the coconut itself furnishes products, which are better adapted to taking a place in the world's markets. In any case it must be remembered that coconut toddy and its products are undoubtedly a useful adjunct to the industry and contribute several millions of rupees to the Island's revenue, and as there is plenty of scope for work in improving the vinegar industry, it is certainly worth encouraging.

The Tapping Process

"Tapping" is the term applied to the operations connected with the artificial extraction of the juice of palms. In the case of some palms such as the coconut (*Cocos nucifera*) it is the tender inflorescence which is tapped, while in the case of others such as Nipa palm (*Nipa fruticans*) it is the tender stem which is used for sap extraction. The sweet juice drawn this way, can be used as a fresh beverage or converted into various products such as alcoholic drinks, sugar, treacle, jaggery or vinegar. The most popular palm vinegars are usually derived from the saps of four genera only, viz., water palm (*Nipa fruticans*), sugar palm (*Arenga saccharifolia*), Buri palm (*Corypha elata*) and the coconut palm. The toddy from other varieties of palms is generally suited for the production of unrefined sugar and jaggery, and can also be fermented into mild liquors, or distilled into spirits.

Vigorous middle-aged coconut palms with close-set crowns and a large number of leaves with short and strong petioles are really best suited for tapping. In addition to these characters, the trees which produce the spadices regularly and which carry a large number of female flowers in each spadix should be given preference. It is also an advantage to select trees receiving a good supply of moisture because they are likely to yield comparatively larger quantities of sap over a longer period.

The correct stage when the unopened inflorescence is suitable for tapping can be learnt only by experience, but as a rule the right stage of development, is roughly judged by the state of the older spathe. When this is ready to burst open into flowers, then the younger one is approximately ready for tapping. The development of female flowers inside the spathe causes a swelling at the base of it, and the appearance of this swelling is a good indication of the appropriate stage. It is customary to tap only mature spadices in weak trees, but when they are vigorous immature spathes could also be utilised.

Though the methods of tapping differ in details in different places, the essential principles appear to remain the same throughout, and in fact are very similar to the system employed as early as the 17th century. The best description of the method used in Madras, Bombay, certain other parts of India, Philippines and Ceylon appears to be that given by Dr. Hugh Cleghorn.⁷ "When the spathe is a month old, the flower bud is considered sufficiently juicy to yield a fair return. When ready for tapping it (the spathe) is two feet long and three inches thick. It is tightly bound with strips of young leaves to prevent expansion and the point is cut off transversely to the extent of one inch. The toddy drawer then gently hammers the cut end of the spathe to crush the flowers thereby exposed and to determine the sap to the wounded part, that the juice may flow freely. The stump is then bound up with a broad strip of fibre. This process is repeated morning and evening for a number of days, a thin layer being shaved off on each occasion and the spathe at the same time trained to bend downwards. The time required for this initiatory process varies from five to fifteen days in different places. When the juice begins to flow the hammering is discontinued. A single spathe will continue to yield toddy for about a month during which time the collector mounts the tree twice a day and empties the receptacle. In this way one man can attend to thirty or forty trees."

The interval from the commencement of tapping to the dripping of juice depends on the skilfulness of the tapper, the method of tapping adopted, the seasonal conditions prevailing and the nature of the tree. This period varies from ten to twenty-five days or even more. Expertness in this work appears to consist very largely on the removal of the thinnest possible slice of the spathe by a single clean stroke of the knife. When this is properly done, a longer flow of toddy results from each spadix, and continues until only the stalk of the inflorescence remains. In Ceylon a single spathe flows as a rule for thirty or forty days, and there may be as many as three spathes being tapped at the same time on the same tree. As a rule the oldest spathe fails, soon after the third spathe, commences to give its regular supply of sap. Tapping twice daily, skilled tappers have been known to make a spathe to flow for three months, whereas the less efficient workers make them last on an average for only a month.

In the Philippines in order to facilitate the gathering of toddy, bamboo poles are often attached from tree top to tree top forming bridges upon which the toddy drawers can pass without descending to the ground, until such time as their collecting vessels are full. This method enables one collector to take care of as many as a hundred palms. In certain tapping groves in Ceylon a similar contrivance is adopted, whereby a system of ropeways interconnecting the trees is used, and though it resembles the Philippine device in many respects, it is rather hazardous for the tappers.

The fresh toddy which in India and Ceylon is collected in unglazed earthenware pots, is sweet and pleasant to the taste, and is one of the forms of the so-called "palm-wine" which was so



A CEYLON TAPPING GROVE
—with toddy-drawer passing on the rope-way.

toddy than the dwarf variety, yet there is found to be considerable variation in the yield of juice from day to day, season to season, spadix to spadix and tree to tree. As already pointed out the yield is also largely contingent on the expertness of the collector.

As a rule the sap flows more readily at night than during the day, and it is also an established fact that in periods of drought the yield is much less than when the tree is well supplied with water. During cloudy weather too the yield of sap is supposed to be poor. According to Marsden and Skilton,⁸ working in Malaya the maximum yield of juice is obtained about five weeks after the commencement of the flow of juice, which is about eight weeks after the commencement of tapping. This probably corresponds to the tapping of that part of the spathe where the female flower buds are situated.

Eaton⁹ records that in moist localities in Ceylon, with one tapping a day, the yield of juice per tree varies from 600 c.c. to 1,200 c.c. with two tappings from 600 c.c. to 3,000 c.c. and with three tappings from 1,100 c.c. to 4,738 c.c. He also mentions that the total yield of toddy per spadix ranges from three and a half to seven and a half gallons. (1 gallon=4,546 c.c.)

Child¹⁰ quotes the 1909 record of tapping in the province of La Laguna (Philippines) which gave 2,103,296 litres of toddy from 10,009 trees equivalent to an average of 209 litres per tree per annum. He also compares this with the figures for Ceylon supplied by the Excise Commis-

much extolled by the early European visitors to the Island. Like all other palm saps, coconut toddy rapidly ferments at tropical temperatures and becomes intoxicating and is extensively consumed both in India and Ceylon as an alcoholic beverage. On keeping for over twenty-four hours, this self-fermented toddy becomes sour and cloudy and therefore unfit for use as a drink. Once it has reached this stage, if properly acetified it can then be converted into an excellent vinegar (to be described below) which is commonly used for culinary purposes.

Yield of Toddy

Judging from the various figures available from Madras, Malaya, Java, Philippines and Ceylon, there appears to be a wide divergence in the yield of sap. Though the tall coconut palm yields more

sioner working out to 50 gallons per tree per year equivalent to 227 litres per tree per annum, which is not very different from the Philippine figure. (1 gallon=4.546 litres).

The period for which coconut palms can be tapped economically is also an important factor to be considered in estimating the potential yields of toddy. It is reported by some authorities that if a tree is used exclusively for toddy production it becomes weakened after a time and the flow of sap decreases resulting in permanent injury to the tree. To prevent this there is sometimes the practice of permitting about one spadix in every three to produce nuts. In the Philippines every inflorescence of the tree is tapped for some months but the tree is then given a rest, being allowed to produce nuts for a period. Whilst intelligent management will certainly increase the yield of sap per tree, unduly forcing a high rate of production would doubtlessly exhaust the trees rather rapidly. In Ceylon the practice has been to continuously tap palms for eight months and then give them a rest period of four months. This method appears to be satisfactory in not impairing the yielding capacity of the palms or producing deleterious reactions on their vigour and health. Some are of opinion, however, that a normal distribution of yield can be expected only when the trees are tapped for a period of six months. Beyond this time, large variations in sap production with frequent low yields could result, making continuous tapping for periods longer than this unprofitable.

Composition of the Sap

In considering the composition of the sap from the coconut, it is important to distinguish between the fresh unfermented juice usually referred to as "sweet-toddy" and the sap in various stages of fermentation called "toddy." Variations in the quality of the sweet-toddy (especially with regard to sugar content) have been observed by many workers and the weather perhaps is the principal factor affecting its composition, because it is well-known that during the rainy season the sap is always more dilute. Young palms are also supposed to give a weaker juice than the older ones, and the first juice which commences to flow on tapping is not reckoned to be so rich as that obtained from the lower part of the spathe.

The juice of the palm really compares very favourably with that of the sugarcane, not only regarding its sugar content but also in purity, and is superior to that of sugar beet, because the latter contains a large amount of foreign matter in proportion to the sugars. The following figures taken from Allen "Organic Analysis" (Vol. I, p. 450) will illustrate this point:—

	Density	Per cent. Sugar	Other organic constituents	Mineral salts as ash
Sweet-toddy	1.07	16.5	0.6	0.4
Sugarcane juice ..	1.07-1.09	18.2	0.45	0.35
Beet juice	1.06-1.07	16-17	1.45	0.67

Tapping coconut palms for raw sugar and jaggery is a very considerable industry throughout Southern India and is the source of the major portion of the sugar consumed there.

Based on a fair number of analyses Gibbs in the Philippines quotes the following figures representing the average composition of the fresh sap, which are compared below with those

quoted by Indian workers who give rather lower figures for the sugar content in the freshly drawn juice.¹¹

Philippine Figures				Indian Figures			
Density	..	..	1.07	Density	..	..	1.07
			Grams/100 c.c.				Grams/100 c.c.
Ash	..	..	0.40	Mineral matter	..	..	0.26
Cane sugar (sucrose)	..	..	16.5	Cane sugar (sucrose)	..	..	14.60
Proteins, etc.	..	..	0.60	Albumin	..	..	0.12
Acidity	..	..	trace	Gum	..	..	0.56
Invert sugar	..	..	trace	Oil	..	..	0.04
				Water	..	..	84.42
							100.00

According to Norris, Viswanath & Nair,¹² the fresh sap is supposed to contain fifteen per cent. of cane sugar and one per cent. of glucose. Other observers, including the Coconut Research Institute (Ceylon) have not reported the presence of glucose (or reducing sugars) in the perfectly fresh sap, but have recorded cane sugar concentrations averaging fifteen per cent. (actually ranging between 12% to 18%) and this could satisfactorily be adopted as a representative working average.

Minor Constituents

Besides the constituents shown in the above analyses, coconut toddy contains certain other minor components, of which, for example, the potash salts (two parts per thousand) remain unaltered throughout both processes of alcoholic and acetic fermentations of the sap. Certain other constituents, however, may disappear or become altered, whilst still others may be produced during the fermentations. One other very important minor constituent, which should receive mention in this connection is ascorbic acid or vitamin C. This occurs in sweet-toddy to as great an extent as three parts per thousand and does not appear to be affected by alcoholic fermentation. Besides this, fermented toddy is also stated to provide supplies of the complex of vitamins now grouped under the letter B, particularly B₂. Their presence has not been demonstrated in the unfermented sap, but probably they are derived from the growing yeasts which cause the fermentation. The distinctive characters of toddy and the palatability of its derivatives must certainly be associated with even another class of minor constituents which are not amenable to chemical analysis, and perhaps even of unknown chemical nature.

Preparation of Coconut Toddy Vinegar

The scientific principles underlying each stage in the process of converting a saccharine liquid of suitable strength into vinegar have already been carefully elucidated. Having now, a fairly exact knowledge of the composition of coconut sap, it will be abundantly clear what an excellent starting material it should be for vinegar preparation. Coconut toddy has an ideal composition for the preparation of the so-called alcoholic wash or "gyle" (the first step in vinegar manufacture) because it needs no fortification with adventitious sugar or salts, besides possessing the great overriding advantage of being a well-balanced medium containing sufficient nutriment for the growth and activity of yeasts and bacteria. Its composition being so favourable the process of alcoholization is spontaneous and quick, taking only about twenty-four hours. In fact, no sooner the sap

falls from the tree fermentation commences owing to the action of micro-organisms collected from its surroundings, unless special prior precautions are taken to arrest it.

In general, there are two well-known methods of vinegar manufacture, the slow "barrel process" and the quick "generator process." The latter is used almost exclusively in big scale commercial manufacture, and has not been adopted so far for the preparation of coconut toddy vinegar, and consequently will not be discussed here.

The slow process which is used in the household or small-scale production of coconut vinegar is really a modification of the so-called barrel process which was employed on the continent during the early years when vinegar was made as a home industry by simply providing an air supply and allowing barrels of cider wine or other alcoholic liquids to ferment spontaneously. This does not always produce a high-grade product.

The popular slow method of manufacture employed in Ceylon requires no elaborate equipment or plant, and is accomplished merely by the use of a system of vats (fermenting tuns) and barrels, using self-fermented toddy as starting material.

Alcoholization

The preliminary alcoholic fermentation of the collected toddy could conveniently be achieved by bulking the material in medium-sized open wooden vats and allowing it to stand for a maximum



ALCOHOLIZATION

View of fermentation vats in a factory.

of forty-eight hours. During this time, if conditions are satisfactory, the fifteen per cent. of sugar should be converted into about six per cent. of alcohol. It is quite important that the toddy should have undergone *complete* alcoholic fermentation before inducing proper acetification, because acetic acid in excess of about one per cent. concentration is deleterious to yeast growth. It is also important to avoid putrefactive fermentation which is commonly experienced during rainy seasons when water enters the collecting pots, and dilutes the toddy. If good, clean toddy, containing about fifteen per cent. of sugar is used, it should rapidly ferment giving the requisite six per cent. of alcohol at which strength the growth of harmful bacteria is prevented. At weaker strengths,

however, the toddy appears to be very liable to infection by organisms which cause putrefaction. How rapidly the process of alcoholic fermentation goes on can be illustrated by one of Gibbs'

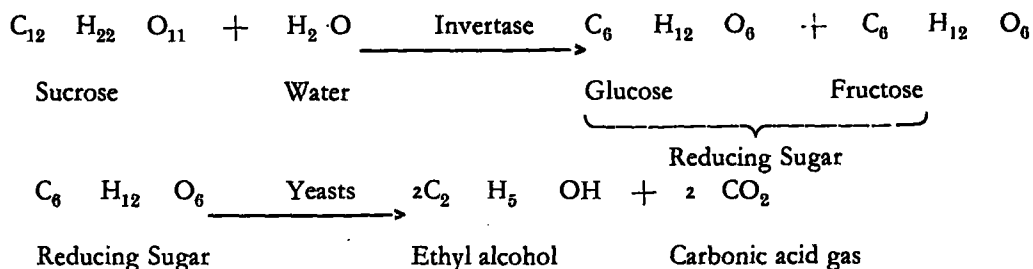
analyses of a sample examined by him at 10.00 a.m. of toddy which flowed during the preceding night :—

Fresh Juice (unfermented)					Partly Fermented Juice (10.00 a.m.)				
Density	..	..	..	1.07	Density	..	..	..	1.01
				Grams/100 c.c.					Grams/100 c.c.
Total solids	..	..	..	17.5	Total solids	..	..	..	3.72
Acidity as acetic	..	..	..	trace	Acidity as acetic	..	..	..	0.68
Alcohol	..	..	..	nil	Alcohol	..	..	..	6.00
Ash	..	..	..	0.40	Ash	..	..	..	0.41
Sucrose	..	..	..	16.5	Sucrose	..	..	..	0.29
Invert sugar	..	..	..	trace	Invert sugar	..	..	..	1.95
Proteins	..	..	..	0.60					

It will be observed from the above figures that a certain amount of acetic acid is produced whilst alcoholic fermentation is in progress, but as a rule, the acid concentration does not exceed 0.75 per cent. at the end of forty-eight hours, and thus cannot have any pronounced inhibitory influence on the yeasts. How far these fermentations should be allowed to proceed and what efforts should be taken to prevent them will, of course, depend upon the use which is to be made of the toddy. In the present case where complete acetification is the object, no anti-ferment of any kind is added to the toddy, nor is the fermentation process interfered with in any way till alcoholization is complete. The initial casual inoculation of the sweet-toddy with yeast spores (or germs) adhering to particles of dust in the air starts off a successful spontaneous fermentation which can naturally proceed to completion provided other conditions are favourable. The optimum temperature range for this change is usually reckoned as 75°-80°F (equivalent to 23.9° to 26.7°C).

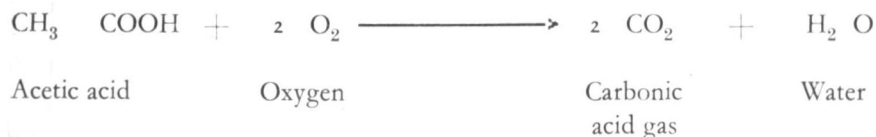
Chemical Changes

The chemical changes occurring in the toddy during this fermentation can be epitomised in two stages. Firstly, the enzyme invertase produced by the yeasts in the presence of oxygen and water converts the cane sugar into reducing sugars (glucose and fructose). Secondly, by further action of the yeasts the reducing sugars are quickly converted into alcohol and carbon dioxide. The reactions can be represented as follows :—



On ascertaining that fermentation is complete (Maximum of 48 hours), the yeast, pulp and other suspended matter should be removed from the toddy by a process of settling and sedimentation. The clear liquid can then be "racked" (drawn off) or transferred by decantation into acetifying vats of about 200-300 gallons capacity. At this stage, it is usual to make an adjustment for optimum alcohol concentration, when using raw materials yielding 14 per cent. or more of alcohol, because

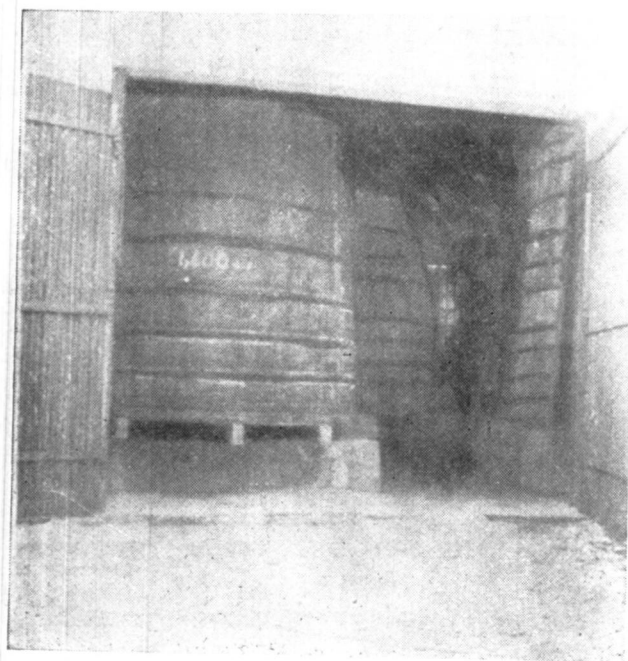
the zoogloea mat (mother of vinegar) forms only with difficulty owing to the toxicity of the alcohol. In the case of coconut toddy, however, which yields on an average about six per cent. of alcohol the need does not arise. On the other hand, the use of too low a concentration of alcohol can result in the loss of vinegar, because when the alcohol strength is less than two per cent. acetic acid is easily oxidised to carbonic acid gas and water with loss of aroma and flavour according to the equation :—



When it has been determined that the alcohol content of the fermented toddy is not less than six per cent., acetification could then to a certain extent be hastened by the addition of three per cent. of genuine coconut toddy vinegar as a starter to the alcoholic toddy. This initial acidification is carried out with two objects in view ; to inhibit the development of undesirable types of bacteria and to supply desirable acetic acid producing bacteria for seed purposes. Some vinegar makers add as much as 10-25% by volume of strong vinegar to the liquid.

Acetification

For acetous fermentation besides the alcohol a good supply of oxygen is essential, and also certain salts and nitrogenous compounds for mycoderma growth which, of course, the toddy already contains. In the typical Ceylon method the acetifying vats are filled almost to capacity and are then lightly covered with wooden boards and jute hessian or sometimes with coconut fronds.



ACETIFICATION

View of acetifying vats in a factory.

Doing it this way, aeration is not very satisfactory and consequently acetification usually takes about ten to fourteen weeks or even longer. If the relative surfaces of contact of the alcoholic toddy with the air is enlarged the formation of vinegar will be accelerated, but this is not feasible when using vats. Another slow process which is really a modification of the so-called "Orleans" method, is some times used where the acetification is carried out in barrel containers (holding about 25-40 gallons) which are filled only three-quarters, to give room for exposure to air. Bung holes, about an inch in diameter are bored to

permit the free circulation of air and they are screened with woven wire or cheese cloth to keep out insects. The barrels are then allowed to stand undisturbed until the vinegar has reached its

maximum strength when approximately three-fourths of the prepared vinegar are drawn off, and to the remaining one-fourth, newly fermented and settled toddy is added, thus starting a new acetic fermentation. This method, though applicable as a rule only to small scale production, becomes in a way a continuous process, whereby the slimy skin of *Mycoderma* once established inside the barrels remains undisturbed.

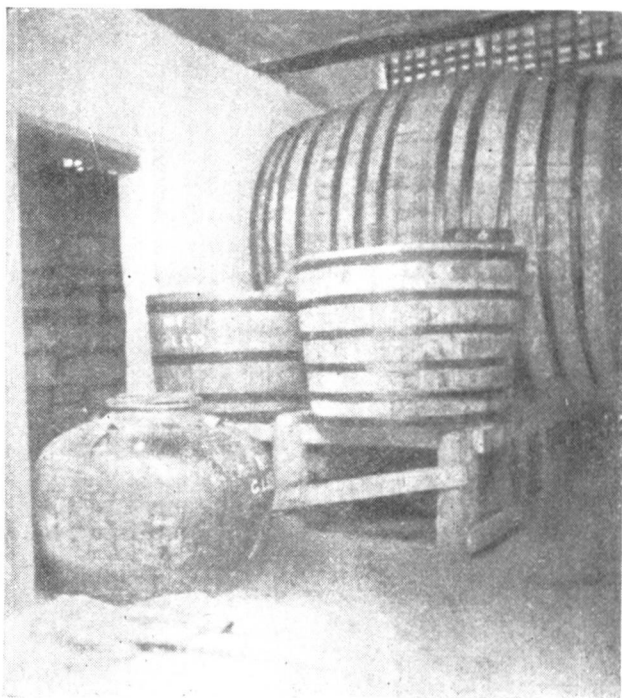
It should be interesting to note that on a small scale it is also possible to carry out the acetification of the alcoholic toddy in ordinary bottles. The toddy is strained through cloth into the bottles which are then left open or covered with muslin until acetification is complete.

Whichever method of acetification is employed, if it is satisfactorily carried out coconut toddy should yield on an average four to five per cent. of acetic acid from the fermented sap containing six per cent. of alcohol.

Precisely as described in the introductory part of this paper, the chemical changes involved in the process of acetification are firstly the oxidation of alcohol into acetaldehyde and then the subsequent formation of acetic acid from this product by the action of acetic bacteria.

Aging (Maturation)

Once acetification of the toddy is complete the next step in the manufacture is the maturation or aging of the "acetified" vinegar, under storage. When all the alcohol has been converted into acetic acid, the acetic bacteria (or their enzymes) will gradually destroy the vinegar by oxidation, unless they are inhibited through exclusion of oxygen or other means. The aging of the vinegar is usually done in barrels or maturation casks which are completely filled and sealed in order to prevent the access of air to the vinegar. This aging or maturation is a process that improves the flavour and clarity of the vinegar by removing the harshness in the odour and quality of the fresh product. This appears to be associated with the production of a class of chemical substances called esters, besides the fact that during storage unstable proteins, yeast, resin and other undesirable substances precipitate out of the liquid. The period of maturation allowed is variable, but as a rule the flavour steadily improves with time. To obtain the highest quality of vinegar some manufacturers, mature for as long as six months or even a year, during which period the harshness and biting taste completely disappear and the vinegar becomes mellow in



VINEGAR FACTORY

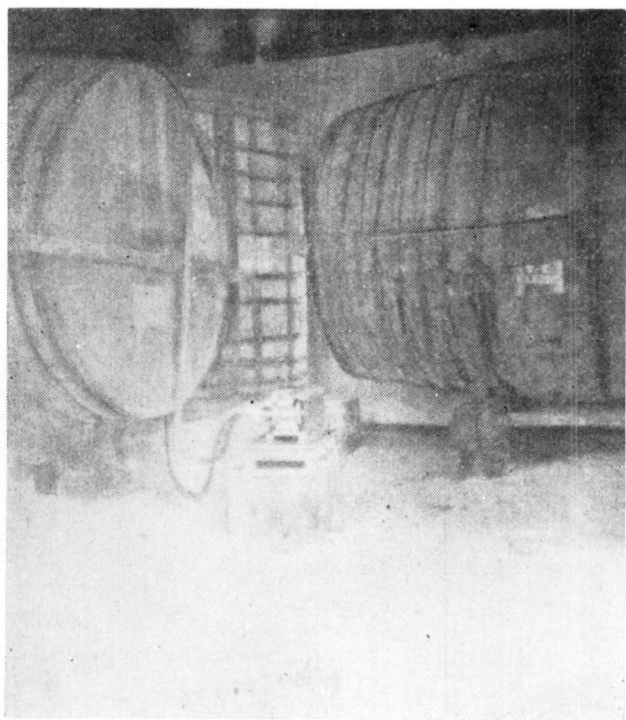
Inside view of a room, showing vats and maturation cask.

quality (*i.e.*, "matured"); the flavour and aroma of good vinegar becoming distinctly apparent. Sometimes with a view to enhancing the flavour there is also the current practice of adding spices like pepper, nutmeg or cinnamon, but this is always best done at the acetifying stage.

The matured vinegar in the casks or barrels is now carefully "racked off" into suitable containers, by the aid of a siphon without disturbing the sediment and with as little exposure to the air as possible. As a rule, the product will be clear and fit for home use, but when intended for sale it will have to be clarified, coloured and pasteurized before bottling. Clarification may be effected by filtration, using filter aids or by fining. The former method, however, is to be preferred.

Clarification

Filtration of vinegar is the most common method of obtaining a clear product. This is best done by folding a piece of flannel into two or three thicknesses, and passing the liquid through



VINEGAR CLARIFICATION

Matured Vinegar being siphoned and filtered.

it repeatedly till the filtrate appears clear. The efficacy of all filters, however, depends upon the gradual filling up of the pores of the filter cloth by the suspended material collecting on it. As a rule the product obtained, after direct filtration will be found suitable for bottling without further treatment, but in certain cases suitable filtering aids or even purifying agents may have to be employed. Based on experiments conducted at the Coconut Research Institute, it has been found that by treating the vinegar with about one per cent. of Hyflo-supercel (which is not a chemical agent but merely a filtering aid) at 160°F (71°C) and then rapidly cooling the mixture, settling and filtering, the resultant product remained clear for a long time. The heat treatment also produced a definite improvement of aroma. Other filter aids such as Kieselguhr (a compound of silica) or Spanish clay may also be used with equal advantage, but in extreme cases, refining agents like fish isinglass or bentonite may have to be used, none of which have been known to affect the physical or chemical characteristics of the vinegar.

Very occasionally a blue-black discolouration of the vinegar may result due to a combination of tannin compounds (especially from new casks) and iron which get introduced through contamination with water or the equipment used. Kreipe¹³ recommends a method of treatment with gelatine in the proportion of 2 to 4 grams per hundred litres of vinegar, which is supposed to remove the colour satisfactorily.

Colouring

Before bottling coconut vinegar is usually coloured with caramel (burnt sugar). In the usual method of preparing this, two pounds of sugar are heated in an earthenware flat-form "chatty" over a low open fire until it turns into a thick brown liquid. This is well stirred until the mass becomes black and sticky at which stage the chatty is taken off the fire and a bottle of good vinegar at once poured in. Any crust produced is thoroughly incorporated by mixing. The product is then stored away in a suitable container and used at the rate of about one table spoonful per bottle of vinegar at the time of bottling.

Pasteurizing and Bottling

When the vinegar has been aged, clarified and coloured it is then ready for pasteurization and bottling in suitable containers. For home use, however, it can be kept in carboys that have been steamed or sterilized, provided they are stored in a cool place. The process of pasteurization has for its object the preservation and maintenance of the strength of vinegar, the micro-organisms that are responsible for the deterioration of the product being killed at temperatures ranging from 60 to 71°C. This treatment is best carried out by first filling the bottles completely, and then tightly capping or corking them with treated corks, in order to prevent the access of air. Pasteurization is then carried out by submerging the bottles (or other suitable containers) in tanks of water heated to a temperature of 140-150°F (60-66°C) for about thirty minutes or until the temperature of the vinegar within the bottles has reached at least 140°F (60°C). The bottles are then removed from the water wiped dry and allowed to cool. On cooling the cork is cut flush with the mouth of the bottle, then waxed and capsuled. An alternative method appears to be the pasteurization of the vinegar in bulk, cooling to 70°F (21.1°C) and then bottling in the usual way.

Precautions Against Contamination

Since vinegar is corrosive, contact with certain metals should be avoided in its manufacture, storage and distribution. It readily attacks iron which is eventually dissolved, causing the vinegar to go cloudy and brown. Contamination with zinc produces an undesirable flavour in the product besides forming a poisonous zinc acetate. Galvanized iron equipment is therefore unsatisfactory on account of the zinc contained in it. Copper and brass are also equally unsatisfactory as they are easily attacked, with resulting adverse effects on the flavour of the vinegar. Wood, aluminium, glass, hard rubber, pressed paper and certain plastic products, however, can be used safely and satisfactorily in contact with vinegar.

Causes of Spoilage

Besides contamination with metals which affects the quality, direct spoilage of the vinegar is also sometimes caused by certain organisms, which need brief mention in this connection. These are vinegar eels, mites and flies. The eels are nematode worms (*Anguillula aceti*) about 1/8 inch long which are sometimes a source of considerable trouble in factories. They may gain access from dirt brought into the plant and from insects. They may attack the bacterial film and cause it to sink with resulting deterioration of the vinegar. Though harmless to human beings, from an aesthetic or quality standpoint they are objectionable, and their entrance can usually be prevented by keeping the plant in a high degree of cleanliness. Empty casks may be lightly sulphured to prevent their access, but if they have already entered the vinegar they are best destroyed by pasteurization and final elimination by filtration.

The vinegar mite is another enemy of the acetic bacteria. When once it obtains a footing within an acetifier, it multiplies rapidly, interfering with the oxidation, and is not easily exterminated. By placing a ring of turpentine or some other viscid or repellent substance around each air hole in the casks or barrels their access may be prevented. In order to eliminate mites the methods used against eels may sometimes be employed. Fumigating the room with burning sulphur is a help in some ways, and steam and hot water will also destroy the mites.

The vinegar fly (*Drosophila funebris*) usually breeds in decayed fruit, fruit juices and vinegar especially during the hotter months of the year. By keeping the factory scrupulously clean their presence can usually be avoided. It is about one-tenth of an inch in length, and is characterised by its large red eyes, red thorax and red legs. Vinegar makers do not pay much attention to the flies because they do not in any way affect the manufacture. The use of fine screens over the holes in barrels in which the fermentation is taking place, prevents their entry into the plant, and any trouble with flies in the factory itself could be minimised by not allowing any spilt vinegar to lie about upon the ground.

Yield of Vinegar

According to Cruess¹⁴ 50 to 55 parts of acetic acid may be obtained from 100 parts of sugar or approximately 1.26 grams of acetic acid from one gram of ethyl alcohol. It must be remembered, however, that a portion of the sugar is consumed in the production of substances other than alcohol and part of it also serves as food for the yeast. There is also a loss usually of some alcohol and acetic acid by evaporation during the two fermentations.

Under favourable conditions, on an average, it can be reckoned that eight gallons of coconut sap vinegar could be recovered from every 10 gallons of toddy fermented.

Characteristics of Coconut Toddy Vinegar

It will be evident from the above account that coconut toddy when used for vinegar making undergoes no sort of processing other than being simply allowed to ferment. This possibly explains the fact that the final coconut vinegar always retains an aroma reminiscent of toddy and some other toddy products, besides possessing certain characteristics which can be used chemically for purposes of identification or proving its origin from a toddy base.

The quality, reputation or price of a vinegar is not based entirely on its acetic acid content, but is largely controlled by the vagaries of human taste. The characteristics which give coconut vinegar its palatability and "body" and distinguish it from pure water solutions of acetic acid ("artificial vinegar") or even distilled vinegar ("Radical vinegar") are provided by those minor constituents which have already been mentioned. Unfortunately most of these components are of unknown chemical nature, and are not as a rule amenable to recognition by analytical methods and consequently they do not form the basis for defining standards of quality.

There is a "general standard for vinegar" acceptable to all concerned in its manufacture and examination, and well made, genuine coconut vinegar should easily conform to its requirements. It has been defined as follows :—

"Vinegar is a liquid derived wholly from alcoholic and acetous fermentations; it shall not contain less than 4 grams of acetic acid in 100 cubic centimetres of vinegar; it shall not contain arsenic in amounts exceeding 0.0143 milligramme per 100 cubic centimetres of vinegar, nor any sulphuric or other mineral acid, lead or copper, nor shall it contain any foreign substance or colouring matter except caramel."

Chemical Composition

Though there are no legal standards, coconut toddy vinegar has characteristics of its own, and good normal samples should have the following average chemical composition, and be clear with no signs of sedimentation or mycodermal growth :—

Density 30°C/30°C	1.010—1.015
Acidity (as acetic)	5.0%—6.0% (W/V)
Alcohol	below 0.5% (W/V)
Total solids	0.77—1.33% (W/V)
Ash	0.37—0.45% (W/V)
Potash (as K ₂ O)	0.15—0.22% (W/V)

Though the interpretation of the results of an analysis is not always an easy problem, yet the above analytical characteristics for coconut vinegar will serve as an “index” of its high standard in comparison with figures charted below for other reputed kinds of high grade vinegars.

	Cider Vinegar	Wine Vinegar	Malt Vinegar	Coconut Vinegar	Distilled Vinegar
Specific Gravity..	1.013-1.014	1.013-1.021	1.015-1.025	1.010-1.015	1.008-1.013
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
	(W/V)	(W/V)	(W/V)	(W/V)	(W/V)
Acetic acid ..	4.84	6.55	4.23	5.50	6.34
Total solids ..	2.49	1.93	2.70	1.05	0.35
Ash	0.34	0.32	0.34	0.41	0.04
Sugar	0.25	0.46	—	—	—

It is significant that coconut vinegar (in common with other palm vinegars), has very little or no sugar remaining in it, whilst those prepared from fruit juices or sugar cane juice contain a fair amount. Such vinegars are sweet, and a high percentage of residual sugar usually indicates improper fermentation. In order to establish the inter-relationships among the various constituents, in addition to the above analyses, it will be informative to estimate the percentage of sugar in the total solids, the percentage of ash in total solids, and the percentage of soluble ash in total ash. These determinations will indicate the character of the sample and are of great value in ascertaining adulteration and fixing standards of purity.

Analytical Characters

The percentage of sugar in total solids will give a measure of the completeness of the alcoholic fermentation, and coconut vinegar will in a large majority of cases be found to be completely fermented because the sugar present in the total solids will be negligible. The percentage of ash in the total solids should usually be constant for a given source of vinegar, but in the case of coconut vinegar they do fluctuate a little, especially when the collecting pots for the sap have been limed. The percentage of soluble ash in total ash is a far more constant factor than the per cent. ash in the total solids. This is a very useful analytical estimation because it can serve for the identification of a particular vinegar despite the addition of sugar, alcohol, acetic acid or starch to increase the acidity. This can be explained by the fact that sugar and starch leave no ash on incineration and though their addition would increase the total solids they would not alter the ash content. Thus the percentage of ash in total solids can change in value, but the percentage

of soluble ash in the total ash would still remain unchanged. Coconut vinegar is characterised by a high percentage of soluble ash in total ash primarily because it is rich in soluble potash salts.

Though analytical figures will usually reveal the differences between "natural" and "artificial" vinegars (the latter being always thin or deficient in "body," *i.e.*, they contain very little non-fermentable matter), yet it is not always possible to state with certainty the origin of certain vinegars. In the case of coconut vinegar, however, according to a method worked out at the Coconut Research Institute it is possible to detect any sophistication of genuine samples based on the presence or absence of two parts per 1,000 of potash salts. These, as already mentioned form a fairly constant proportion of coconut toddy and remain unaltered through both fermentation processes.

Though the flavour and characteristics of the final vinegar will depend in large part on the quality and type of raw material used (toddy in the case of coconut vinegar) yet it will be obvious from the foregoing discussion that other factors such as the selection of the micro-organism, the concentration of alcohol in the alcoholic liquid, the amount of oxygen supplied, the temperature of the fermentation, the conditions of aging, storage, clarification, the character of the tanks, containers and fixtures, coming into contact with the vinegar during the manufacturing process will all affect the quality of the finished product. There is also no need to emphasise the fact that the cleanliness of the plant, equipment and surroundings, are all likewise indispensable for the production of high grade vinegar.

Economic Considerations and Conclusion

Every country in the world has its own distinctive liquor industry, and in Ceylon, coconut toddy forms the base of an alcoholic beverage known as "arrack," a name which originated in Malaya. In considering the economics of vinegar production, it is important to note, that this industry will always be of subsidiary importance in comparison with the production of alcoholic toddy and arrack.

Besides the fact that toddy remains an expensive base for the production of vinegar (on account of the high costs involved in its tapping) the great snag about the manufacture of coconut vinegar is the fact that the toddy base is considerably more valuable than the manufactured product—vinegar. This is tantamount to saying, that vinegar is cheap and is in a way a debasement of the more valuable toddy. It will, therefore, be clear that if the vinegar manufacturer can sell an appreciable part of his toddy as toddy, there will be no economic urge for him to make vinegar out of it. This partly accounts for the fact that originally vinegar manufacture in Ceylon was primarily confined to the toddy dry districts of Kalutara and Matara, where there was considerable illicit trafficking in toddy. However, this being an excisable product, its conversion into vinegar has to be done under governmental supervision, and since 1939 there has been considerable amelioration in this matter as a result of the tightening up of excise regulations to avert such abuses. Unfortunately, after the acetification stage the excise authorities have no control, and consequently the present difficulties appear to be associated with the adulteration of coconut vinegar, with water and dilute acetic acid, with the result that it cannot cater for that class of consumers whose palate is sufficiently meticulous as to give preference to genuine coconut toddy vinegar over dilute acetic acid. The recent introduction in Ceylon of legislation in the form of a Pure Food and Drugs Act, as in England and other countries, does enable stringent action to be taken against offenders in this respect, but in any case the mutual honest co-operation of interested parties, including the manufacturer, wholesale and retailer is a *sine qua non*, in any efforts for the improvement and maintenance of high standards for coconut toddy vinegar.

Though the chances for increasing the production of coconut vinegar are remote, for reasons adduced above, yet there is ample scope for improving its quality and also the present methods of production. Numerous analyses of the crudely made product reveal potential possibilities of producing a very high grade vinegar from the sap of the coconut palm, and the writer's intention is merely to indicate some possible lines of development for the industry.

Though any big scale expansion of the vinegar industry in Ceylon seems likely only if for reasons of national temperance there is curtailment in the production of alcoholic beverages, yet there is no reason why there should not be a concerted effort on the part of all concerned, to effect an all-round improvement in the trade as it exists today. The Coconut Research Institute is always prepared to assist on the technical side with some recommendations for the advancement of the industry.

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