

4227

NA-109-1

SCIENCE EDUCATION SERIES

No. 16

INDUSTRIES BASED ON  
ALCOHOLIC FERMENTATION IN SRI LANKA

by

U. SAMARAJEWA

NA-109

NATURAL RESOURCES, ENERGY AND SCIENCE AUTHORITY  
47/5 Maitland Place  
Colombo 7  
1986

4227

INDUSTRIES BASED ON  
ALCOHOLIC FERMENTATION  
IN SRI LANKA

**UPALI SAMARAJEWA**

B.Sc. (Sri Lanka); Ph.D. (Sri Lanka)

F.I. Chem. C.; C. Chem.; M.I. Biol. (Sri Lanka)

Senior Lecturer in Agricultural Chemistry  
(Food Science)

## FOREWORD TO THE SERIES

The dissemination of scientific information is one of the main functions of the Natural Resources, Energy and Science Authority. The Journal of the National Science Council published by this Authority provides a medium for the publication of scientific research papers, and "Vidurava", the quarterly science bulletin contains scientific articles of a general nature which are of interest to the public.

There is still a wide gap in the availability of reading material on scientific subjects of local interest. One result of this is that science students confine their reading only to their school notes and to the few available text books which are mostly published abroad. In an attempt to improve this situation, the Working Committee on Science Education Research of the Natural Resources, Energy and Science Authority decided to publish a series of booklets on scientific topics of local interest as supplementary reading material for students and the general public. The authors who have been selected by the Committee to prepare these booklets are experts in their respective fields. The manuscripts that were submitted by the authors were examined by referees before being accepted for publication. The views expressed in these publications are those of the authors and are not necessarily those of the Natural Resources, Energy and Science Authority.

I must thank the Working Committee on Science Education Research of the Natural Resources, Energy and Science Authority, and in particular Prof. V. Basnayake who is the Hon. Director of the Working Committee for the work they have done to make this project a success.

**R. P. Jayewardene**  
*Director General*

## CONTENTS

	Page
List of Figures	
List of Tables	
1. Introduction	1
History	
Present status	
2. Biochemistry and Microbiology	7
Theory	
Congeners	
Microbiology	
Controlled alcoholic fermentation	
3. Palm sap fermentation	12
Introduction	
Tapping	
Physiology of flow of sap	
Composition	
Preservation	
Microbiology	
Controlled fermentation	
4. Other fermentations	36
Cane sugar and molasses	
Beer	
Cashew apple juice	
Nipa	
Fruit waste	
Rice	
Coconut water	
Manioc	
Cereals	

5. Production of spirits	47
Introduction	
Distillation	
Stills	
Estimation of alcoholic strength	
Maturation	
Blending	
Colouring	
Clarification	
Processed arracks	
Other attractive features	
6. Quality and standards	67
Toddy	
Beer	
Palm sap distillates	
Origin of congeners	
Nomenclature	
Hygienic practices	
Excise regulations	
7. Related Industries	83
Sugar	
Vinegar	
Animal feeds	
Polysaccharides	
Production of yeasts	
Bottled sweet sap	
8. References	87

## LIST OF FIGURES

1. Physical and chemical changes in fermenting coconut palm sap.
2. Flow diagram for the production of beer.
3. Liquid-vapour equilibrium curve for the distillation of ethanol-water mixtures.
4. Pot still.
5. Separation of congeners during laboratory distillation into different fractions of the distillate.
6. Still for low wine distillation.
7. Illicit distilling units used for coconut palm sap.
8. Patent still.
9. Comparison of the ratio of isoamyl alcohol : isobutyl alcohol in arrack and whiskeys.
10. Distribution of congeners in the synthetic palm sap distillates fermented using yeasts isolated from the coconut sap.

## LIST OF TABLES

- I Production figures for alcoholic beverages in Sri Lanka -1982
- II Aroma compounds reported in alcoholic beverages.
- III Proximate composition of coconut palm sap.
- IV Macro and micro-nutrients on coconut palm sap.
- V The distribution of bacteria in fermenting coconut sap.
- VI The distribution of yeasts in fermenting coconut sap.
- VII The distribution of the Genera of yeast isolates from fermenting coconut sap.
- VIII A comparison of alcoholic strengths in the different scales.
- IX Changes in major volatiles during maturation of coconut sap distillates.
- X Requirements for beer and stout in Sri Lankan standards.
- XI The analytical requirements in arrack.
- XII Congeners in Sri Lankan arracks.
- XIII Congener production by coconut palm sap yeasts.
- XIV Common alcoholic beverages and the raw materials used for their production.
- XV Revenue from the alcoholic beverage industries to the State in 1982.

## Chapter I

### INTRODUCTION

#### History

The yeasts have been exploited for their ability to convert sugars to potable alcohols in Sri Lanka, since ancient times. Historical documents indicate the consumption of the intoxicant "sura" around the first century A. D. In the ancient Sri Lankan system of grouping people into castes, depending on their means of livelihood, a separate caste existed consisting of those tapping palms for sap. This indicates the recognition attributed to the production of alcoholic beverages in the ancient Sri Lankan society. However, the production of alcoholic beverages remained a cottage industry for centuries. Later it developed into an export oriented industry for a short period, in the 19th century.

In 1834, the Excise Ordinance of Ceylon was introduced. This created a system of taxes and licences for the tapping of coconut palms. The Excise Department was established in 1912 for the control of the production of alcoholic beverages and a new Government policy was evolved in 1924 for regularising the quality of arrack. With these changes the alcoholic beverage production in Sri Lanka shifted from a small scale cottage industry to a privately owned large industry

having eight coconut toddy distilleries established in the North-West coast of Sri Lanka. The distilleries were functioning under the supervision of the Excise Department and the produce was supplied to the Government for sale. The State set up a distillery for cocouut toddy at Seeduwa in 1949. This was expanded as State Distilleries Corporation in 1974 to include the supervision of the functioning of the private distilleries, thus taking away part of the responsibilities of the Excise Department.

### **Present status**

The largest alcoholic beverage industry in Sri Lanka today is the coconut sap fermentation industry which produces the fermented beverage "toddy" and the distilled beverage "Arrack" (Table I). These beverages are popular due to their characteristic flavour preferred by the local tongue and the low cost of production.

On a volume basis the toddy accounts for 75 percent of the fermented alcoholic beverages in Sri Lanka. It is consumed as a fresh drink in the areas where the palms are tapped. The toddy is bottled and pasteurized for improved keeping qualities. The bottled toddy is popular in the hill country of Sri Lanka, where fresh toddy is not available. The bottled toddy industry caters largely to those of the low income groups in the Estate sector. Presently there are eight toddy bottling factories situated in the Western coastal belt North of Colombo and in Jaffna.

TABLE I

## PRODUCTION OF ALCOHOLIC BEVERAGES IN SRI LANKA IN 1982

<i>Type and manufacturer</i>	<i>litres produced</i>	<i>Total</i>
<b>Toddy</b> ... ..	19 298 611	19 298 611
<b>Beers</b>		
Ceylon Brewery ... ..	4 221 190	
MacCullum Brewery ... ..	2 094 870	6 316 060
<b>Wines -</b>		
3 private cottage industries: (Fruit wines)	4 392	4 392
<b>Arracks - State Distilleries Corporation</b>		
Blended arrack ... ..	17 583 304	
Arrack(Coconut) ... ..	9 564 307	
Arrack (Palmyrah) ... ..	14 270	27 161 881
<b>Processed Arracks</b>		
W. N. Mendis & Co. Ltd ... ..	75 867	
Rockland Distilleries Ltd. ... ..	75 867	151 734
<b>Foreign Liquors (locally produced )</b>		
Sri Lanka Sugar Corporation		
Gin, Brandy & Rum ... ..	43 109	
Arak ... ..	29 703	
<b>Rockland Distilleries Ltd.</b>		
Gin ... ..	6 325	
Whiskey ... ..	2 140	
Brandy ... ..	3 273	
Lemon (Gin) ... ..	3 227	
<b>Gilbeys Ltd.</b>		
Captain Cheers ... ..	298 982	
V & A ... ..	21 298	
Dominics Military... ..	8 057	416 124

They produce the brands "Ambassador", "Apollo", "Empire", "Leo", "Palmyrah", "Regal" and "Singha". All the brands except "Palmyrah" contain coconut toddy.

Next to toddy, the main fermented beverage in Sri Lanka is the beer. Beer accounts for 25 percent of the local consumption of the brewed products. The beers and stouts are produced in two breweries situated at Nuwara Eliya and Meegoda (off Colombo). Almost all the raw material needs of the breweries are imported. Their beverages appear under several trade names. The beer and stout industries maintain the same standards and similar processing conditions as in the Western breweries and their brand names are associated with the methods of processing in the brewery, the type of yeasts used and the alcoholic strength, in keeping with the established norms in the beer industries elsewhere.

Although the demand for wines is high in Sri Lanka, specially during Christmas, no attempts had been done to establish a Wine Industry in Sri Lanka. This may probably be due to the limited production of grapes and the high competition from the cheaper fermented beverages toddy and beer. There exists a large potential for the production of fruit wines in Sri Lanka using the exotic varieties of tropical fruits. However, the amount of wines produced today (Table I) is negligible and operate as a home industry.

In the area of the distilled beverages the demand for the coconut based alcoholic beverages cannot be met by the present production capacity. The

coconut sap distillates are therefore blended with spirits from molasses to bridge the gap between production and the demand. These blends are referred to as "Special" brands and sometimes contain only three percent of the coconut sap distillates. The State Distilleries Corporation purchase the rectified spirits or silent spirits for blending, locally, from the sugar cane industry at Hingurana and Kantalai, and coconut spirits from 'Rockland' and 'Mestiya' Distilleries. The local production of the silent spirits is far below the requirements and spirits are imported from countries such as Brazil. The imports are sometimes as high as 30% of the local needs.

The brands of arrack produced by the State Distilleries Corporation belong to three broad groups. The blends of spirits from coconut and sugar cane, defined as blended arracks are marketed under two trade names the "Special Arrack" and "Extra Special Arrack".

The second group consisting of distillates from coconut, matured for different durations are branded as "Coconut Arrack", "Sri Lanka Arrack", "Old Arrack", "Very Special Old Arrack (VSOA)", "Old Seeduwa", "Seven Year Old Coconut Arrack", "Ten Year Old Coconut Arrack" and "Double Distilled Arrack".

The distillates from palmyrah sap is branded as "Palmyrah Arrack". Of the total volume of distilled beverages produced in Sri Lanka 98 percent is manufactured at the State Distilleries Corporation

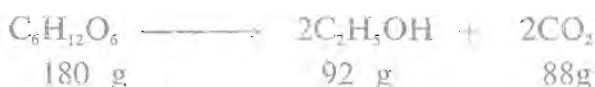
Another category of arracks produced in Sri Lanka are referred to as the processed arracks. They are manufactured by processing blends of coconut and neutral spirits at two private distilleries, the Rockland Distillery and W. N. Mendis and Co. All other spirits produced in Sri Lanka uses sugar cane molasses as the raw material. They are collectively referred to as "foreign liquors". The "foreign liquors" are produced at the Sri Lanka Sugar Corporation, Rockland Distilleries and Gilbeys Ltd. The products from the former two distilleries are named to simulate the more popular brands of spirits from the Western Countries (Table I) and the local product arrack. Gilbeys use their own brand names which do not indicate any association with the spirits distilled from raw materials other than cane sugar or coconut. The silent spirits are imported for some of these industries.

## Chapter II

### BIOCHEMISTRY AND MICROBIOLOGY

#### Theory

In alcoholic fermentation, a sugar such as glucose or fructose, in solution, is converted to ethyl alcohol and carbon dioxide. The energy released during the conversion is utilized by the micro-organisms. The total process can be approximated for a hexose by the equation :



This represents a theoretical yield of 51% (w/w) for ethanol, based on the sugar used. The loss due to production of carbon dioxide is 49% (w/w). The equation is, however, only an approximation. In addition to the production of ethanol and carbon dioxide, sugar is consumed by the yeasts for growth and in the production of small amounts of other compounds. Studies on detailed mass balances of alcoholic fermentation using selected yeasts in pure culture (Oura 1977) suggest that an ethanol yield of 90-95% as predicted in the above equation is obtainable. The yields for other products fall in the ranges given below.

Glucose (100g) →	Ethyl alcohol	(43.8-48.4)	g
	Carbon dioxide	(43.5-46.6)	g
	Succinic acid	(0.6-1.4)	g
	Glycerol	(3.0-5.2)	g
	Yeast	(0.4-1.7)	g
	Fused oils and others	(0.1-1.6)	g

## Congeners

Ethanol in its pure form has little flavour and none of the characters of the popular self flavoured beverages such as toddy, wine, brandy, rum, whiskey and arrack. It is the one percent, or thereabouts, of the other compounds (Table II) that give a liquor its character. These compounds are present individually in the order of parts per million. Some of them are produced during fermentation while others originate from the raw materials used as the source of sugar. A few hundreds of these congeners are present in alcoholic beverages. Among them, two groups of compounds the "fused oils" consisting of three to five member carbon alcohols, and the ethyl esters of a variety of fatty acids, make a major contribution to the flavour (Suomalainen and Lehtonen 1979).

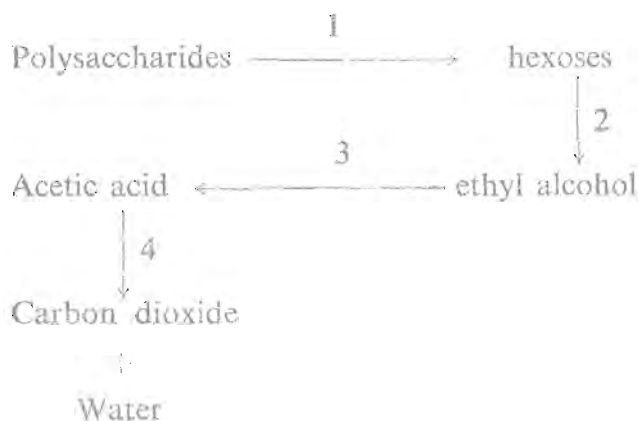
## Microbiology

The alcoholic fermentation represents a single step in a more elaborate series of biochemical changes brought about by micro-organisms to obtain their energy requirements. The total process referred to as spoilage consist of the following steps.

TABLE II

AROMA COMPOUNDS REPORTED IN ALCOHOLIC BEVERAGE  
(KAHN, 1969).

Type	Number	Description
Alcohols	38	C <sub>1</sub> to C <sub>16</sub> , matsutakeol, menthol, octen-3-ol
Acids	80	formic to hexacosanoic (C <sub>26</sub> ) lauric palmitic, stearic
Esters	118	many combinations of above acids and alcohols
Carbonyl compounds	41	formaldehyde to many substituted compounds
Acetals	17	Diethoxymethane to triethoxypropane
Phenols	41	vanillin, syringaldehyde, contributed mostly from wood
Hydrocarbons	11	benzene, naphthalene etc.
Nitrogen compounds	18	amines, pyrazines
Sulphur compounds	11	methyl, ethyl and pentyl sulphides
Lactones	17	butyrolactone to dodecalactones
Sugars	4	fructose etc.
Unclassified compounds	11	lignins etc.
Total	407	



In nature, the first step, conversion of polysaccharides to simple hexose sugars is brought about by

either the mold enzymes, as in solid phase fermentations of raw materials such as soybean to produce "tempeh", or by the inherent enzymes, in case of malting of barley for the production of ethyl alcohol.

The micro-organisms responsible for the second step, the conversion of sugars to ethanol consist of a variety of yeasts, dominated by those belonging to the Genera *Saccharomyces*, *Schizosaccharomyces*, and *Pichia*. Among them the species of *Saccharomyces cerevisiae*, *Saccharomyces ellipsoideus*, *Saccharomyces bayanus*, *Saccharomyces chevalieri* and *Saccharomyces exiguus* are observed to be dominant or used in different alcoholic fermentation industries. Sometimes certain subspecies of the above organisms such as *Saccharomyces cerevisiae Calsbergensis* are used for specific flavour characteristics in the beer industry. Recently the bacteria *Zymomonas* sp. has gained popularity as an efficient ethanol producing organism especially in the production of alcohol as a motor fuel.

Under natural conditions the above micro-organisms together with many other non-ethanol producing organisms are associated with the second step in the process. Such collections of micro-organisms are reported often on spontaneously fermented alcoholic beverages such as toddy (Apatharajah 1983) and several African beverages such as Nubian Gin (Noor 1979) and Palm Wines (Okafor 1978). In alcoholic fermentation industries where specific alcohol concentrations and flavour requirements are considered important, such as in beer industries in Sri Lanka, only certain species of *Saccharomyces* capable of producing the required characteristics are used for fermentation.

In uncontrolled fermentations the ethanol produced by above organisms are further converted to acetic acid by bacteria, mainly the *Acetobacter suboxydans* species. This forms the basis for the production of vinegar which is a four percent solution of acetic acid (step 3). If the reactions are not checked at this stage further oxidation (step 4) may occur due to the activity of *Acetobacter oeroxidans*. The alcoholic fermentation thus forms one of the steps in a sequence of biochemical changes leading to spoilage.

### **Controlled alcoholic fermentation**

In the modern alcoholic fermentation industries, the ethanol producing step of the above sequence is isolated and controlled for increased efficiency and regulation of the flavour and aroma. To achieve this sugars are extracted from the raw material under aseptic conditions. The action of spoilage organisms is prevented by the introduction of suitable antiferments or by heat treatments. The sugar is next fermented using selected yeast cultures of known ethanol producing capacity. The ability of yeasts to produce desirable congeners, resulting in acceptable flavour and aroma is given high consideration in the selection of the micro-organisms.

After fermentation, the brew is either processed and bottled or distilled to obtain the potable spirits. The spirits are matured for durations upto twelve years or more. They are blended, coloured and flavoured prior to bottling for sale.

## Chapter III

### PALM SAP FERMENTATION

#### Introduction

In Sri Lanka, the major raw material for the alcoholic fermentation industry is obtained by tapping the tender inflorescence of three palms the Coconut (*Cocos nucifera* Linn.) (Pol- Sinhala; Tennai - Tamil), the Palmyrah (*Borassus flabellifer* L.) (Tal- Sinhala; Panai-Tamil) and the Fish-Tail or Toddy Palm (*Caryota urens* L.) (Kitul- Sinhala; Tippilipana- Tamil). Of the three the coconut is tapped industrially in large scale in the areas of the Western coastal belt of Sri Lanka extending to 75 km North and 50 km South of Colombo. The inflorescence of the palmyrah palm is tapped in the Jaffna peninsula and to a small extent in the Eastern coast of Sri Lanka. The "kitul" palms are not grown in large scale in any particular area of the country, but is tapped wherever it is available. It exists as a cottage industry for the production of toddy and as a source of sugars, treacle and jaggery.

In contrast to those fermentation industries where the sugar is extracted from the raw material either by crushing or dissolving in water, the extraction of the sugary juice from the palms itself is a skilled technique, referred to as tapping.

## Tapping of the Palms

The method of tapping the coconut palm is ancient and remains much the same even today (Nathanael 1970). The tender unopened spadix just prior to splitting of the spaths is suitable for tapping. By this time the spadix is about 60 cm long, 7-10 cm in thickness and show a slightly bulging base due to development of the female flowers inside it.

Prior to commencement of tapping the preselected spadix is tightly bound with fibre all along its length at intervals of one to four centimeters. This prevent it opening out prematurely. The outer surface of the spadix is then bruised by beating with a wooden mallet. The pointed apex of the spadix is pounded with the end of the mallet to crush the tip. The operation is repeated on the second and the third days and a thin slice of apical tissue is pared off on the third day. The cut end of the spadix is carefully pounded with the handle of the mallet to pack the crushed floral tissues tightly at the apex. This prevents the exuding sap collecting within the body of the spadix.

The tapping and pounding operations are continued on the fourth and fifth day. From sixth day onwards a thin slice of tissue is pared off from the free end of the spadix in addition to tapping and pounding. The slicing is continued twice a day and tapping once a day till the sap begins to drip.

As the sap commences to flow the tapping and pounding operations are discontinued, but the spadix is sliced off twice a day. At this stage the spadix is bend downwards to an angle of  $30^{\circ}$  to the horizontal and tied to a coconut frond. A fluted spout made of green coconut leaf is pinned to the cut end of the spadix to direct the sap into the earthenware collection pot slipped over the free end of the spadix to collect the sap.

The preparation of the spadix may take up to a month and depends on the expertise of the tapper, method of tapping, seasonal conditions and the nature of the palm.

As tapping continues the spathe covering the inflorescence get dried and falls off. The spikelets of the inflorescence are then firmly tied with fibre and tapping is continued, sometimes slicing even the stalk of the inflorescence till the flow of sap stops. The pounding and tapping operations are not practised in the Philippines and Java (Copeland 1931); only slicing is done to obtain the sap.

In addition to slicing off of the spadix to create a wound certain mixtures of plant material are applied to the cut end of the spathe by some tappers. This prevents the rapid healing of the wound (Browning and Symons 1916). The substances used are lime (mineral), lime fruit (citrus) leaves of cinnamon (*Cinnamomum zeylanicum*) (Kurundu- Sinhala; Karuwa-Tamil) wild cinnamon (*Neolitsea cassia*: Devul kurundu- Sinhala) shoe-flower (*Hibiscus furcatus*; Naabritta- Sinhala)

and other species of *Hibiscus*, *Aporosa* and *Eriodendron anfructuosum* (Imbul- Sinhala).

The flow of sap is variable, but reaches the maximum when the inflorescence is tapped near the female flower buds. A single spadix could be tapped for nearly one month and during this period a second spadix is brought to production.

The yield of sap varies from spadix to spadix, palm to palm, day to day and season to season. In Sri Lanka it had been found to be more economical to tap for a period of eight months and give a period of rest for four months annually. The palms are allowed to rest during the droughts of January to April.

Among the varieties of coconuts the dwarfs (*Nana*) are uneconomical for tapping. The tall varieties (*Typica*) give better sap yields averaging to 1582 ml per day when tapped throughout the year (Nathanael 1955a). The corresponding yield for the tall  $\times$  dwarf hybrid palms is 2177 ml (Jeganathan 1974).

In the "kitu!" palm the inflorescence is first stimulated by depositing a mixture of ingredients into a cavity made near the axil of the inflorescence. The spadix is washed with lemon juice and leaves of certain jungle wines are coiled round the spadix to prevent it opening. Thin slices of tissue are cut off from the apical region daily and the exuding sap is collected (Molegoda 1945).

The palmyrah palm is dioecious and both male and female flowers could be tapped. The male is found to yield more than the female (Corner 1966). Here too the unopened spadix is tied with fibrous strands and thin slices of tissue are cut off from the end of the spadix. The exuding sap is collected in earthenware pots.

### **Physiology of flow of sap**

The flow of sap from the sliced inflorescence is suggested to be an active process in view of its similarity to flow of liquid from a wound in the skin (Copeland 1931) and also based on the observation that flow of sap occurs in defoliated and felled trunks of palms (Bose 1923). The exudation also show a polar nature, as a stem of a tree with inflorescence tapped cannot yield sap (Tammes 1931). There is evidence to suggest that the flow of sap is associated with respiratory activity (Pethiyagoda 1978), the root pressure and the the active secretion by cells near the tapped area (Corner 1966).

### **Composition of palm saps**

The fresh coconut sap as it drips from the spadix is a faintly brownish liquid containing 15-18 percent sugars almost totally in the forms of sucrose. Apart from the sugars the sap also contains 2.5 percent non-fermentable matter of which 0.5 percent is ash and two percent is organic solids (Table III) including proteins, fats, gummy substances and minor constituents (Nathanael 1960). Variable macronutrient concentrations

TABLE III  
ANALYTICAL FIGURES OF CONSTITUENTS IN THE COCONUT  
PALM SAP

<i>Analytical characteristics</i>	<i>Sri Lanka</i> <sup>1</sup>		<i>Philippines</i> <sup>2</sup>	
	<i>unfermented</i>	<i>fermented</i>	<i>unfermented</i>	<i>fermented</i>
Total solids (g/100 ml)	15.2-19.7 (17.04)	2.43-3.36 (2.39)	17.5	3.72
Sucrose (g/100 ml)	12.3-17.4 (14.3)	—	16.5	0.29
Ash (g/100 ml)	0.11-0.40 (0.26)	0.23-0.38 (0.30)	0.40	0.41
Invert sugar (g/100 ml)	—	—	trace	1.95
Acidity (as acetic) (g/100 ml)	0.00-0.21 (0.10)	0.32-0.35 (0.33)	trace	0.68
Alcohol percentage (v/v)	—	4.9-5.8 (5.3)	—	6.0
Gum (g/100 ml)	—	—	—	—
Albumin (g/100 ml)	—	—	—	—
Oil (g/100ml)	—	—	—	—
Proteins (g/100 ml)	0.26-0.32 (0.29)	—	0.60 <sup>3</sup>	—
Density (g/ml)	1.058-1.068 (1.063)	1.001-1.005 (1.003)	1.07	1.01 <sup>1</sup>

<sup>1</sup> Browning and Symons (1916)

<sup>2</sup> Gibbs (1921)

<sup>3</sup> Undetermined Nitrogenous compounds

Figures within brackets are average values.

(Table IV) and the micronutrients Iron, Manganese, Boron and Zinc had been observed (Silva 1974). The fresh sap contains 160-300 mg of ascorbic acid per 100 ml (Benerjee 1935).

TABLE IV  
MACRO AND MICRO NUTRIENT CONTENT OF COCONUT PALM SAP

Nutrients	Unfermented sap <sup>1</sup> (g/100 ml)		Fermented sap <sup>2</sup> (g/100 ml)	
	Range	Average	Range	Average
Nitrogen	0.033-0.038	0.036	0.030-0.037	0.033
Phosphorus (as P <sub>2</sub> O <sub>5</sub> )	0.015-0.023	0.019	0.023-0.030	0.026
Potassium (as K <sub>2</sub> O)	0.144-0.203	0.173	0.128-0.0200	0.163
Calcium (as CaO)	0.0017-0.0021	10.0019	0.0017-0.1121	0.002
Magnesium (as MgO)	0.0060-0.0085	0.0072	0.0035-0.0045	0.004
Manganese (as Mn)	44-66 mg	51 mg	—	—

<sup>1</sup> Nathanael (1955)

<sup>2</sup> Jeganathan (1974)

Apart from sucrose the other sugars observed in unfermented coconut sap were glucose and fructose in traces (Atputharajah 1983) and raffinose and inositol (Gopinathan 1962). The organic acids lactic acid and succinic acid also had been detected (Atputharajah 1983). Van Pee Swings (1971) reported the presence of tartaric acid, malic acid, pyruvic acid, cis-aconitic acid and citric acid in addition to the above in fermenting coconut sap.

Seasonally, sediments of white gelatinous masses could be observed in coconut sap. This material could sometimes be seen even on the spadix and is referred as "Rabath" due to its resemblance to cooked rice. They are polysaccharide encapsulations produced by the micro-organisms of the *Leuconostoc sp.* They convert the sucrose in the sap to dextrans (Samarajeewa *et al.* 1977). The acid hydrolysis of the "rabath" produced fructose, glucose and seven unidentified sugars as detected by paper chromatography. This indicates the presence of many breakdown products from complex molecules such as polysaccharides. The "rabath" also contain the amino acids alanine, aminobutyric acid, arginine, aspartic acid, glutamic acid, glycine, leucine, ornithine, proline, serine, threonine, tyrosine, and valine. These may probably be the sugars present in coconut sap itself that has got trapped into the gelatinous encapsulations.

The palmyrah sap contains less sugar than the coconut. The observed mean values vary between 12 to 12.5 percent in the form of sucrose (Ratnasingham 1967) and up to 0.14 % of reducing sugars. The reducing sugars were identified as glucose and fructose. Paper chromatographic studies had indicated the presence of another sugar suspected to be raffinose (Savarimuthu *et al.* 1980). The palmyrah sap contain the amino acids aspartic acid, glutamic acid, serine, glycine, threonine, alanine, valine, leucine, isoleucine, tyrosine, phenyl alanine, methionine, cystine and aminobutyric acid together with the two amides

asparagine and glutamine. However these amino acids are reported to vary and disappear in the sap during fermentation.

The sap of the kitul palm is found to contain 15-16 percent of total sugars, 0.34 percent reducing sugars, traces of acids and a pH of 6.5 as it trickles down from the spadix (Theivendirarajah *et al.* 1977).

### Preservation of the sap

Preservation of palm sap is one of the major problems encountered, both prior to fermentation and after fermentation, in improving the quality of the beverages.

Traditionally the microbial activity in the sap was checked by the flame sterilization of the pots prior to the collection of sap and also by the introduction of milk of lime (Cowap and Geake 1932). Liming is done to increase the pH to 9-10 (Ratnasingham 1967) and the optimum results could be obtained with 0.55 g of calcium oxide per 100 g of fresh juice (Murthi and Dasa Rao 1955).

The introduction of plant material to retard alcoholic fermentation had been a popular practice since ages. The bark of 'Hal' (*Vateria copallifera*) had been observed to be efficient in retarding fermentation in both kitul (Theivendirarajah and Jeyaseelan 1977) and coconut palm saps (Browning and Symons 1961; Nathanael 1959). The extracts of *Vateria copallifera* contain at least three polyphenolic fractions having

inhibitory activity on micro-organisms (Abeygunawardene 1981). Aqueous extracts (containing 5-10 percent) from dried bark of *Vateria copallifera* inhibited the growth of *Staphylococcus* and *Micrococcus* species isolated from coconut sap. However *Enterobacter* and *Bacillus* species were not suppressed by these aqueous extracts. The polyphenols from *Vateria copallifera* bark appear to possess a selective effect in suppressing certain micro-organisms in fermenting sap. The leaves of 'Ankenda' (*Achronychia pedunculata*) and bark of 'Kahata' (*Careya arborea*) and fruits of 'Goraka' (*Garcinia cambogia*) had been observed to be less effective in retarding fermentation of palm saps but more effective in clarification of the saps (Joachim and Kandiah 1939). In the Philippines the ground tanbark of 'tungog' (*Ceriops tagal* (Perr) C. B. Robinson) is added to sap collecting bamboo tubes for the same reason (Fernandez *et al.* 1978). In Java a mixture of jak wood (*Artocarpus heterophyllus*), juice from leaves of *Piper betel* and lime is used to inhibit fermentation (Anon. 1978). The extracts of the bark of *Saccoglottis gabonensis* is used successfully in arresting fermentation of Nigerian Palm Wines (Faparusi and Bassir 1972). However Okafor (1975a) was not able to separate the effective inhibitory components from the bark extracts of *Saccoglottis gabonensis*.

The use of chemicals is a more efficient and convenient means of arresting fermentation as their effects could be quantified and pre-decided. The chemicals tested as antiferments in palm saps include addition

of 7 ml toluene per pot (Wells and Perkin 1922), one percent alcoholic solution of cupric acetate (Dennet 1929), saturated solutions of copper sulphate (Cowap and Geake 1932) 10-60 ppm of sulphanilamide (Walwalker 1950), mixtures of potassium bisulphite and sodium benzoate (Oruche and Levi 1957) methyl, propyl and butyl derivatives of para hydroxy benzoate (Unson 1966), sodium metabisulphite (Jeyaraj 1961; Faparusi 1969), 0.2 percent benzoic acid (Child 1974), potassium sorbate (Okafor 1977) and mixtures of them. Some of these chemicals are not permitted as food additives today.

Of the various chemicals it is worth considering the sodium metabisulphite in view of its successful application in the wine industry today (Amerine and Kunkee 1968). The sulphur dioxide (70 ppm) from sodium metabisulphite was partially effective in arresting alcoholic fermentation of coconut sap. However, acetic fermentation was found to occur later (JeyaRaj 1961). In *Elaeis guineensis* palm sap the amounts of sodium metabisulphite needed to arrest alcoholic fermentation at pH 4-5 was found to be too high for human consumption (Faparusi 1969).

Detailed studies on the application of sodium metabisulphite in arresting fermentation in the coconut sap at pH 4 have shown that it is effective in checking the bacterial activity. It stops the action of wild yeasts in coconut sap completely at concentrations of 150-200 mg L<sup>-1</sup>. Experiments on the commercial exploitation

of this method in the coconut industry by introducing sodium metabisulphite to sap collecting pots resulted in 29 percent increase of ethanol production at  $188 \text{ mgL}^{-1}$  concentration of metabisulphite and duration of 3.6 days of fermentation (Samarajeewa *et al.* 1985). The maximum tolerance limit of sodium metabisulphite in beverages is  $200 \text{ mg L}^{-1}$ . The above method shows high potential as an industrially applicable technique for the controlled fermentation of coconut sap.

Apart from the use of plant materials and chemicals, heat treatments had been attempted for the preservation of unfermented and fermented palm saps. Heat treatment is more acceptable than chemicals and is easily applicable to the bottled sweet sap or bottled fermented toddy. Heat sterilization of the coconut sap at  $80^{\circ}\text{C}$  for 20-25 min. (Mohanadas 1974) is practised widely in the coconut industry today in the bottling of coconut toddy. However, the bottled toddy does not appear to be biochemically inactive, perhaps because the treatment is insufficient for complete inactivation of the bacterial spores and the heat resistant co-enzymes.

Although the flash pasteurization of coconut sap of specific gravity 1.002 to 1.020 at  $68-82^{\circ}\text{C}$  and for durations of 3 to 5 sec. was found to be satisfactory, it cannot be practised in the industry efficiently unless rigid aseptic conditions are adopted (JeyaRaj 1961). The shelf life of toddy could, however, be increased by heat treatments such as coil pasteurization, bottle

pasteurization and Seitz filtration (Anon. 1972a). The coconut toddy when subjected to centrifugation followed by flash heating at 85°C and leaving at 75°C for 15 min, it could be stored satisfactorily up to one month (Paranavitana *et al.* 1975).

Combination of heat treatment together with the use of chemicals is more effective as a preservative technique. Combination of 70 ppm of sodium metabisulphite with heat treatment of oil palm wine at 68°C for 30 min. preserved the wine without loss of flavour (Chinarasa 1968). Mixtures of other chemicals such as sorbic acid, diethyl pyrocarbonate and sodium metabisulphite together with heat treatments provide satisfactory preservative effects (Okafor 1975a), but the doses of metaspulphite added was too high even in combination with heat to be accepted as a preservative (Mossel 1971) in oil palm wines. The vacuum concentration of unfermented coconut sap in a thin film line concentrator at 25 lbs per sq. inch vacuum and steam pressure of 5 lbs per sq. inch followed by pasteurization at 60°C for 10 min. retained the original flavour of sap and preserved it (Patric and Rama Rao 1964). However, the cost of such operations limit its application in the industry.

The need to develop methods to arrest spontaneous fermentation in palm saps during collection has led to a considerable amount of laboratory research on this problem. But very little success had been achieved in applying them in the field except in the use of sodium metabisulphite which was tested extensively in the field.

## Microbiology of the sap

The major problem in the palm sap fermentation industries in the world is the microbial metabolism of the palm sap before it is brought down the palm for any treatment. This limits the efficient processing of the sap. Microbiological investigations of the palm saps by many workers have shown the presence of a variety of micro-organisms during collection.

The earliest reports on micro-organisms in the coconut sap describes the presence of *Saccharomyces cerevisiae* together with other yeasts resembling *Saccharomyces ellipsoideus*, *Schizosaccharomyces mellacei*, *Zygosaccharomyces bakeri*, *Saccharomycodes ludwigii* and bacteria and molds resembling *Monilia* and *Oidium* (Browning and Symons 1916). Damodaran (1928) reported two types of yeasts and one bacteria. In a comparative study of the yeast from coconut, kital and palmyrah saps all yeasts isolated were identified as *Torulopsis* (Liyanage and Senthc Shanmuganathan 1970).

In a more elaborate study on the identification of yeasts from fermenting coconut sap (Jayatissa *et al.* 1978) seventeen isolates of yeasts belonging to five genera were observed. They included four isolates of *Saccharomyces exiguus*, four isolates of *Saccharomyces cerevisiae*, two isolates of *Pichia fermentans* and one isolate each of the following: *Saccharomyces rosei*, *Saccharomyces fructuum*, *Torulopsis holmii*, *Torulopsis*

*versatilis*, *Wingea robertsii*, *Candida robusta* and *Candida lambica*. Later the same authors reported yeasts of the genera, *Saccharomyces* (21 strains) *Schizosaccharomyces* (one strain), and *Candida* (one strain) from coconut and palmyrah palm wines (Liyanage *et al.* 1981).

Similar variable microbial populations were reported in the fermenting coconut sap from Philippines (Yamagata *et al.* 1980). They observed *Saccharomyces chevalieri* to be the dominant yeast in coconut sap fermentation. Of the micro-organisms isolated from the kitual palm, yeasts belonging to the genera *Brettanomyces* and *Saccharomyces* had been identified (Theivendirajah *et al.* 1977). Of fifteen cultures of yeasts isolated from the palmyrah sap (Ahmad *et al.* 1954) eight isolates of *Schizosaccharomyces pombe*, six of *Saccharomyces chevalieri* *Guilliermondii* and one of *Saccharomyces ludwigii* Hansen had been identified.

Many similar diverse microbial populations have been identified from palm saps of different origin in different parts of the world (Roelofsen 1941; Saito and Otani 1935; Simmonart and Laudelout 1951; Bassir 1962; Bassir 1968; Okafar 1972a; Pee and Swings 1971; Faparusi 1969; Okafar 1975b; Faparusi and Bassir 1971; Okafar 1972b; Faparusi 1973; Faparusi 1974 and Fernandez *et al.* 1979). Almost all these studies concentrated on identification of micro-organisms either in a given sample at a single

stage of fermentation or contributions from a given source of contamination such as tapping equipment, tapping holes, visiting insects *etc.*, *etc.*

In a more detailed study on the micro-organisms present at different stages of fermentation of oil palm wine, a sequence of organisms starting from lactic acid producers which are replaced later by ethanol producers, have been reported (Faparusi and Bassir 1971).

In the fermentation of coconut sap a succession of micro-organisms initially consisting of a dominant flora of lactic acid bacteria is (Table V) followed by a dominant flora of yeasts (Table VI). The yeast flora is later replaced by a flora of acetic acid bacteria (Atputharajah 1983). Even within the yeast flora dominance by *Saccharomyces chevalieri* was observed (Table VII). Of the total yeast population observed in this study fifty percent consisted of the alcoholic fermenting yeasts *Saccharomyces* and *Pichia* whereas the others appeared to be merely present at some stage or other and get eliminated without contributing to alcoholic fermentation. In the coconut sap *Saccharomyces chevlteri* is the main alcohol producing organism in contrast to *Saccharomyces cerevisiae* observed in many other alcoholic fermentation industries. The role of the initial dominant flora of lactic acid bacteria is reflected in the biochemical changes observed in the coconut sap (Fig. 1). An initial drop of pH from 7 to 4, a drop in the total sugar content and drop

TABLE V  
THE DISTRIBUTION OF THE BACTERIAL SPECIES ISOLATED FROM  
THE COCONUT SAP AT DIFFERENT DURATIONS OF FERMENTATION

Bacterial species	Duration of fermentation in hours													
	4	7	10	13	18	28	39	55	61	79	103	127	157	
<i>Bacillus firmus</i>	1	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Enterobacter</i> spp.	0	1	0	1	0	1	0	1	1	0	0	0	0	0
<i>Staphylococcus</i> spp.	0	1	0	0	0	0	0	0	0	1	1	0	0	0
<i>Lactobacillus</i> spp.	0	1	0	2	0	0	0	0	0	0	0	0	0	0
<i>Micrococcus</i> spp.	0	0	1	0	0	0	0	0	0	0	0	0	0	0
<i>Leuconostoc</i> spp.	0	0	1	1	0	0	0	0	0	0	0	0	0	0
<i>Bacillus cereus</i>	0	0	0	0	2	2	1	0	0	0	1	0	0	0
<i>Bacillus larvae</i>	0	0	0	0	1	0	0	0	0	0	0	1	2	0
<i>Bacillus circulans</i>	0	0	0	0	2	1	0	1	0	0	3	0	0	0
<i>Acetobacter aceti</i>	0	0	0	0	0	0	0	0	0	0	3	1	1	1

TABLE VI

THE DISTRIBUTION OF YEAST SPECIES ISOLATED FROM THE COCONUT SAP AT DIFFERENT DURATIONS OF FERMENTATION

Yeast species	Duration of fermentation in hours														
	4	7	10	13	18	28	39	55	61	79	103	127	157		
<i>Candida guilliermondii</i>	0	0	0	0	0	0	0	0	0	1	3	2	2		
<i>Candida Parapsilosis</i>	1	1	2	3	1	0	0	1	0	1	0	0	0		
<i>Candida tropicalis</i>	0	0	0	0	0	4	1	0	0	1	0	0	0		
<i>Candida valida</i>	0	2	0	0	1	1	1	0	2	4	0	0	1		
<i>Kloeckera javanica</i>	2	1	0	0	0	0	2	2	0	0	0	0	0		
<i>P. chie. etchelsii</i>	0	0	0	0	1	0	0	0	0	0	0	0	0		
<i>P. chie. furinosa</i>	0	0	0	0	0	0	1	0	0	0	0	0	0		
<i>Pichia guilliermondii</i>	0	0	0	0	0	0	0	0	0	0	0	1	0		
<i>Pichia membranaefaciens</i>	0	0	0	2	1	2	1	2	2	2	0	0	0		
<i>Pichia ohmeri</i>	0	0	0	2	3	1	3	3	0	0	0	0	0		
<i>Rhodotorula glutinis</i>	0	0	0	0	0	0	0	1	0	1	0	0	0		
<i>Saccharomyces bailii</i>	1	0	0	0	0	0	0	0	0	0	0	0	0		
<i>Saccharomyces chevalieri</i>	3	2	2	3	1	0	1	9	1	8	20	7	1		
<i>Saccharomyces ludwigii</i>	0	0	0	0	1	0	2	0	0	0	1	2	0		
<i>Schizosaccharomyces pombe</i>	0	0	1	1	0	0	0	0	0	1	1	1	0		
<i>Sporobolomyces salmonicolor</i>	0	0	0	0	0	0	1	0	0	0	0	0	0		
<i>Torulopsis candida</i>	0	0	0	0	0	0	0	0	0	0	1	2	1		
Group A	0	0	0	1	2	3	1	0	0	0	0	0	0		
Group B	0	0	0	2	2	0	0	0	0	0	0	0	0		
Yeastlike organism	0	0	0	3	5	2	0	0	0	0	0	0	0		
TOTAL	7	6	5	13	19	15	14	17	5	19	26	15	5		

TABLE VII

THE DISTRIBUTION OF THE GENERA OF YEAST ISOLATES IN FERMENTING COCONUT SAK DURING SUCCESSION OF MICROORGANISMS

<i>Genus</i>	<i>No. of isolates</i>	<i>Percentage</i>
<i>Candida</i>	36	22
<i>Pichia</i>	25	15*
<i>Saccharomyces</i>	59	35*
<i>Others</i>	46	28
Total	166	100

\*Efficient Ethanol producing yeasts

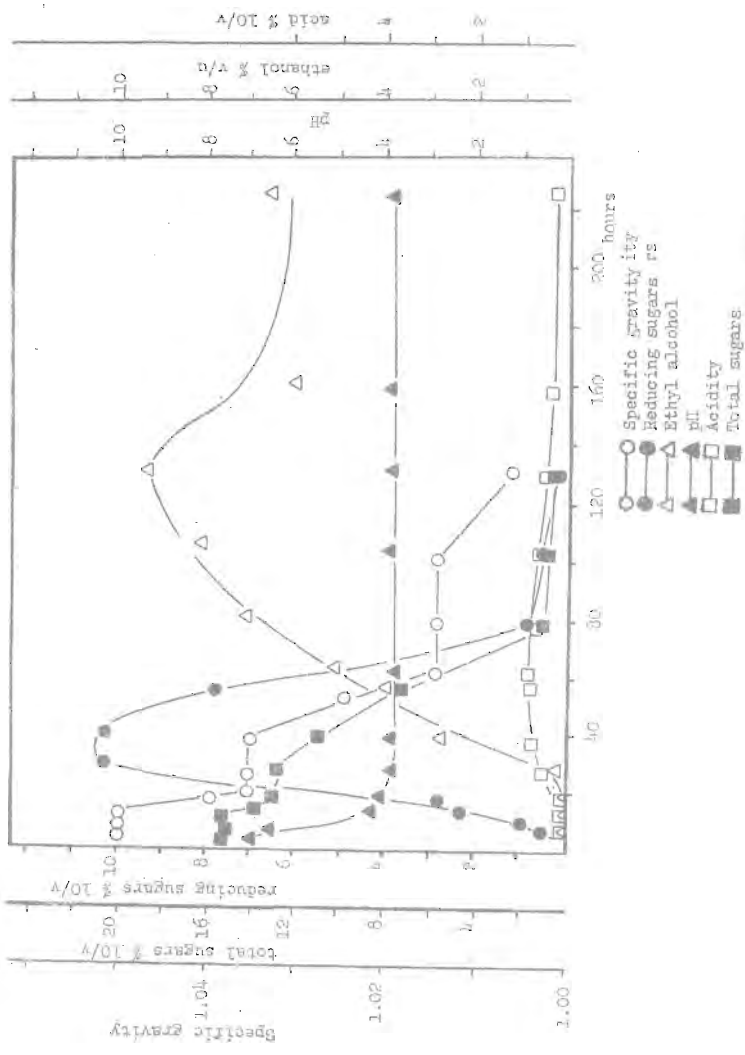


Fig. 1. Physical and chemical changes in coconut-infused wine during fermentation.

in the specific gravity starts very much before the commencement of the alcoholic fermentation. These changes are due to the activity of lactic acid bacteria. They produce up to 2.5 g of lactic acid per litre of sap (Samarajeewa *et al.* 1981) prior to alcoholic fermentation. The spontaneous fermentation of coconut sap by a natural microbial population could therefore be more appropriately called a lactic-alcoholic fermentation (Atputharajah *et al.* 1980). The alcoholic fermentation however is followed by an acetic fermentation if the process is left unchecked (Nathanael 1955b).

The total process of fermentation in the coconut sap is by a succession of micro-organisms whose activities are checked by the changes in the chemical constituents in the sap during fermentation. The steps occurring in coconut sap parallels the lactic-alcoholic fermentation observed in Nubian gin (Nout 1966) and the succession of micro-organisms suggested in palm wines (Faparusi and Bassir 1971) both of which are products of spontaneous fermentations. Perhaps the same mechanism may be operating in other palm saps, such as palmyrah and kitul.

For the fermentation to be efficient yeast cultures of high potency should be maintained in fermentors. Wooden or metal barrels could be used as fermentors. The fermentation takes three to four days. These quality control measures add to the cost of production for the manufacturer. The additional burdens are not preferred by the manufacturers specially when a beverage such as coconut arrack has a ready market.

The production of high ethyl alcohol yields in coconut sap fermentation is reported in pilot scale. The microbial activity during the collection of sap is arrested by using flame sterilized pots containing 'Hal' bark and lime. The collected sap is sterilized by heating to 90°C in 45 gallon capacity barrels and allowed to cool. Introduction of selected yeasts to the treated sap produced the ethyl alcohol yields of 9-9.5 percent. These alcohol yields amount to almost fifty percent increase in production compared with the ethyl alcohol yields of 6-7 percent obtained by natural fermentation (Samarajeewa *et al.* 1976). Yet the method did not gain popularity in the industry due to additional work and the cost involved.

### **Controlled fermentation**

Most of the popular alcoholic beverages in the Western countries are produced today by the controlled fermentation. These techniques cannot be applied directly in the fermentation of palm saps due to inherent problems associated with the collection of the sap.

In the collection of sap from the palms they are exposed in the pots to the micro-organisms from the environment for a period of up to 24 hours. The activity of micro-organisms during collection of sap could only be prevented by the introduction of acceptable preservatives to the cleaned sap collecting pots. This involves more work for the tapper and higher

expenditure to the producer. The additional work reduces the number of palms that could be tapped by a person per day. The associated higher costs deter the manufacturer although increased revenue is ensured at the end by higher ethanol yields. Development of such processes need strong incentives in the form of higher wages, additional support of capital expenditure for equipment and continuous operation of a demonstration with free technical assistance. The establishment of "Generator" vinegar process in Sri Lanka is one such successful example.

Examination of the microbial population in the spontaneously fermenting sap indicates that conditions could be manipulated for increased ethyl alcohol yields without introduction of selected yeasts. Of the 144 yeast isolates from the microbial succession in coconut sap tested for their ability to produce ethanol, 52 percent of the isolates showed 95 percent efficiency in conversion of sucrose to ethyl alcohol (Aputharajah *et al.* 1984). The average ethyl alcohol production for all yeast isolates tested works out to 4.4 percent whereas for the high ethyl alcohol producers the value was 9 percent. This indicates the possibility of increasing yields from the present 6-7 percent in the industry to 9 percent. It could be achieved by suppressing the non alcohol producing organisms (wild yeasts) by introduction of 150-200 mg of sodium metabisulphite per litre of sap (Samarajeewa *et al.* 1985).

Another major problem in the spontaneous fermentation of coconut sap is the production of hydrogen sulphide by the micro-organisms. This produces a strong repulsive sulphurous smell which is common in bottled toddy. The hydrogen sulphide is produced during the active alcoholic fermentation of the sap by the yeasts utilizing the amino acids methionine and cysteine in the sap (Jansz *et al.* 1974). The formation of hydrogen sulphide could be reduced by promoting the conversion of cysteine to cystine, inhibiting protein hydrolysing activity or by the introduction of 0.06 percent ammonium ions to the sap (Jansz *et al.* 1975; Kalyananda *et al.* 1976). The introduction of ammonium ions provide an additional advantage of increasing the ethanol production.

This is probably due to increased yeast activity associated with high nitrogen levels. In the industrial scale the introduction of ammonium chloride resulted in variable increases in ethyl alcohol yields upto 32 percent on the average, sometimes showing increases as high as 46 percent (Liyanage 1983).

## Chapter IV

### OTHER FERMENTATIONS

Apart from the palm saps there are several other raw materials available in plenty in Sri Lanka, that could be used as the base for the production of ethyl alcohol. Most of them possess an advantage over the palm saps because their juice is trapped in solid cellular material and hence could be extracted under required controlled conditions to be fermented.

On the other hand it is not possible to expand the palm sap fermentation industry further by increasing the number of coconut palms tapped. The tapping of coconut palms deny the production of the coconuts which form a major dietary and export commodity in Sri Lanka. Coconuts are presently in short supply. Therefore the alcoholic beverage industry in Sri Lanka need be expanded to increase the use of other raw materials for fermentation. Some of the raw materials with considerable potential are discussed below.

#### **Cane sugar and molasses**

Cane sugar is used as the raw material for the production of Rum and Gin in many parts of the world. It also has gained a recognition as a relatively cheap

raw material in the "Gasohol" industry where alcohol is produced to be mixed with petrol as a motor car fuel.

The technology for the fermentation of cane sugar juice is not complex as that of beer. The extract need not be clarified chemically to remove interfering substances. The main sugar in the extract is sucrose which could be fermented directly by the introduced yeasts under controlled conditions. However the molasses tend to get contaminated easily by yeasts from the environment (Liyanage *et al.* 1982).

In Sri Lanka, the molasses are used today for the production of ethyl alcohol under controlled conditions. The ferment is distilled mainly for silent spirits or rectified spirits. Little attention is paid for the flavour characteristics of the product. The yeasts used are not of high brewing quality as is being done in the foreign Rum industries, where careful selection of micro-organisms is done to develop the required flavour characteristics (Lehtonen and Suomalainen 1977). The potential of molasses as a raw material for the production of quality alcoholic beverages is not utilized most efficiently. It only serves as a source of spirits that need be processed and flavoured in converting to an acceptable alcoholic beverage. The recent attempts to establish private sector alcoholic fermentation industries based on sugar cane have not reached expected success, apparently due to the high cost of production of the spirits locally. The spirits

are cheaper in the world market today. The beverages produced from sugar cane in Sri Lanka are of low popularity, perhaps due to absence of sufficient flavour constituents to mask the raw taste of ethyl alcohol.

In Sri Lanka, it would be difficult to establish a Rum or Gin industry that could compete successfully with the arrack industry. The reasons are many. Such an industry needs fairly acceptable technology to obtain improved flavour.

Flavour is one of the most important characters on which the consumer would decide on an alcoholic beverage. The flavour of coconut arrack is well established today and is preferred by many Sri Lankans. Secondly the cost of production of such alcoholic beverages may be more than that of arrack.

A more feasible approach would be the development of molasses fermentation industry to supplement the palm sap fermentation industry with silent spirits for more acceptable blends containing at least fifty percent of coconut spirits.

With the increased emphasis on expansion of sugar cane cultivation in Sri Lanka the potential in the use of molasses for the alcoholic fermentation industries will be high in the future.

## **Beer**

Production of beers is one of the well established alcoholic fermentation industries in Sri Lanka. The technology for the production is the same as in the

Western countries. The old fashioned wooden fermentors are replaced by modern stainless steel fermentors in the Sri Lankan breweries today. The steps involved in the production of beer are presented in Fig. 2.

In this process the barley grains are moistened and allowed to germinate to activate the inherent enzymes for the conversion of the stored polysaccharides into more simpler sugars such as maltose (malting) and glucose. During mashing the germinated grains are crushed releasing soluble sugars and amino acids into the water. The extract is sweet and is referred to as wort. If necessary, sugars may be added at this stage. After separation of the wort the sediment is used as a cattle feed and is referred to as spent grains.

The separated wort is next boiled with either added sugar or added extracts from other grains together with "hops", the extracts from the flowers of hop (*Humulus lupulus*). The "hops" contribute the resins containing the compounds humulones and lupulones which are responsible for the bitterness in beer. The boiling inactivate the enzymes which had already completed their role of converting polysaccharides to simpler sugars. The boiling or the cooking also helps in further separation of the proteinaceous matter together with spent hops which is filtered and disposed as a fertilizer.

Prior to mashing and cooking operations the germinated barley is kilned to inactivate the enzymes. The kilning also contribute to the colour of the final

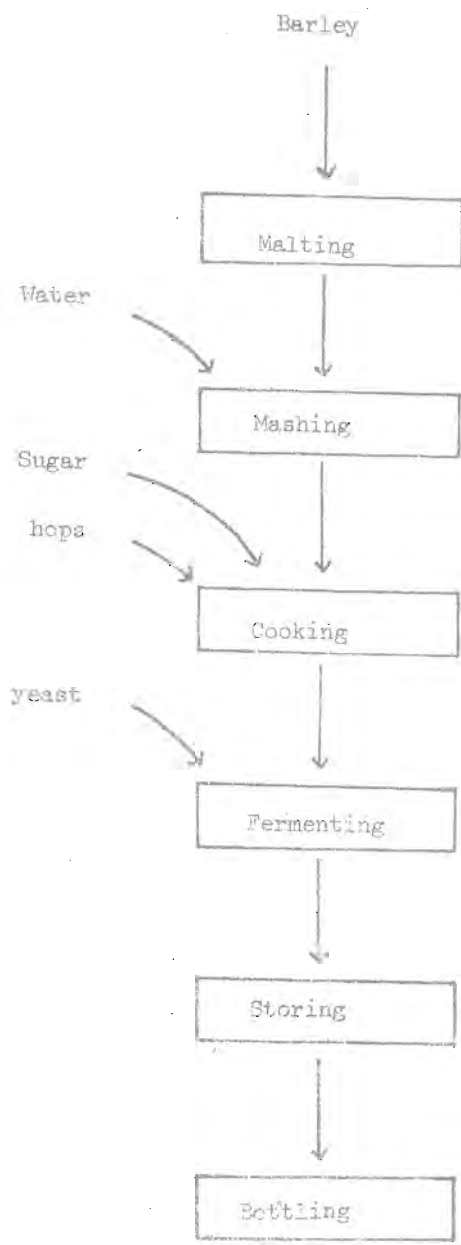


Fig. 2 Flow chart for the preparation of beer

product, beer. Kilning at higher temperatures produce the stouts which resemble dark coloured "English beers". Lower kilning temperatures produce a lighter colours as in "German beers".

After cooking and allowing the wort to cool its specific gravity is adjusted by dilution or addition of sugars such that the wort contains the required concentration of sugars for fermentation. It is next fermented using specific strains of the yeasts of the genus *Saccharomyces*. The yeasts are selected for various characteristics such as alcoholic strength, their ability to ferment at the bottom or top of the wort solution and flavour/aroma.

After fermentation beers are stored for maturation, sedimentation and clarification. They are next filtered, pasteurized and bottled with carbon dioxide under pressure.

In each stage of fermentation the quality of raw materials play a vital role in the flavour of beer. For instance the purity and quality of water is one important criterion.

A few hundred brands of beer are produced in the world today. They all involve modifications in the above basic steps of the process.

Barley, the raw material used for beer production, is expensive. It is replaced partially today by the extracts from various other grains. In Sri Lanka,

attempts have been made to use Sorghum (*Sorghum vulgare*) for partial substitution of barley in the beer production. The optimum conditions for the malting of sorghum have been worked out (Pathirana *et al.* 1983). In a comparative study of malting qualities in Sri Lankan varieties of sorghum (Jayatissa *et al.* 1980) their malting losses were observed to be somewhat higher than that of barley. Among the varieties tested yellow and pink varieties were found to possess the best malting qualities.

Rice is also substituted for barley in the beer production. With the achievement of self sufficiency in rice in Sri Lanka it may be possible to use rice as a cheap substituent for barley.

However, the use of these raw materials lead to other problems such as production of haze in beer due to the altered molecular sizes of the proteins resulting in incomplete separation. Technological improvements to rectify these deficiencies need be developed.

### **Cashew apple juice**

Cashew is planted in large scale in Sri Lanka for the export of the cashew nuts and the extraction of oils from the shells. The cashew apple is a total waste today. The annual production of cashew nuts is around 150 metric tonnes. The weight of cashew apple is 7-8 times that of nuts. This amounts to 1000-1200 metric tonnes of cashew apple containing 8 percent of

contains 10-12 percent of sugar and ferments naturally to give an acceptable "toddy". Its potential as a source of alcoholic beverage need be explored.

### **Fruit waste**

Many tropical fruits are rich sources of sugar. In the fruit canning industries the cuttings, core, pomace and peels from the fruits are discarded as waste. Sometimes 40-50 percent of fruits are wasted this way. This contain 60 percent of extractable juice containing 7-10 percent sugar. The extracts from these fruits could be used as a raw material for alcoholic fermentation to produce wines and brandies (Jeya Raj 1981). However, they would pose limitations due to other strong chemical constituents that may interfere with the fermentation.

### **Rice**

In many South East Asian countries rice is used as a raw material for the production of alcoholic beverages referred to as rice wines and rice beer (Steinkraus 1983). In Japan it is done in large scale in the production of "Sake". In several other countries rice wines are produced in small scale either as cottage industries or as illicit brews. They are referred to by different local names.

Basically the production of these beverages involve the use of a mixture of molds (*Mucor/Rhizopus* sp.) and yeasts (*Saccharomyces* sp.) together with

lactic acid bacteria. The molds breakdown the starches, the lactic acid bacteria reduces the pH and the yeasts ferment the sugars. Fermentation of rice for alcohol in the industrial scale would be one of the profitable means of utilizing rice in the future.

### **Coconut water**

Coconut water contains 2-4 percent sugar. It is totally wasted in the coconut industry today. The annual waste of sugar as coconut water was estimated to be approximately six thousand metric tonnes (Samarajeewa 1983). Coconut water is however, not considered as an important raw material in the fermentation industry today due to its low sugar content. Fermentation with added sugar or by mixing with other sugar sources is one of the possible means of utilizing it (Jayatissa *et al.* 1972).

### **Manioc**

Manioc (*Manihot esculenta*) is a rich source of starch that could be hydrolysed to sugars for alcoholic fermentation. It is used in several countries for the production of alcohol. It is one of the popular crops in Sri Lanka and could be used as a raw material for production of alcoholic beverages.

### **Cereals**

In many countries in the world cereals are used as cheap raw materials for the production of alcoholic beverages, specially when there is over production. They form important sources of ethyl alcohol

for the production of the spirits, Vodka and Gin and also for the production of blends of Scotch-Whiskeys. Present agricultural diversification schemes may produce excess of cereals that may be diverted for the production of alcoholic beverages in Sri Lanka.

On the whole, the available raw materials are not fully utilized in Sri Lanka today for the production of alcoholic beverages. Many raw materials are unutilized and totally wasted. The dependance on imported spirits for production of alcoholic beverages in Sri Lanka could be avoided if the available raw materials are used efficiently.

## Chapter V

### PRODUCTION OF SPIRITS

The ethyl alcohol concentrations normally present in the fermented beverages are too low to impose a self preserving effect on the beverages. The common ethyl alcohol concentration are three to six percent in the beers, six to seven percent in coconut toddy and ten to eighteen percent in the wines. At these alcohol concentrations the fermented beverages are spoiled by micro-organisms unless precautionary measures are adopted. On the other hand the ethyl alcohol producing yeasts, themselves cannot tolerate more than fifteen to eighteen percent ethyl alcohol. Therefore their activity is reduced at ethyl alcohol concentrations above twelve percent and stops at higher concentrations.

In the fermented alcoholic beverages preservative methods such as heat treatment, addition of chemicals, saturation with carbon dioxide or fortification with ethyl alcohol are practised to prevent the spoilage.

Another means of preservation is the concentration of ethyl alcohol in the fermented beverage by distillation. The distillation separates the more volatile organic compounds together with a certain percentage of water from the fermented brew leaving

behind the less volatile components including unutilized carbohydrates, proteins and the yeast cells. This process leaves behind a considerable portion of the compounds that would otherwise indicate the characters of the raw materials used for the fermentation. The separation by distillation is a useful means of masking the origin of ethyl alcohol. The method could also be used to introduce new flavours as is being done in the preparation of gin by redistilling the ethyl alcohol with added "botanicals" such as coriander seeds, juniper berries and angelica roots. The conversion of fermented beverages to spirits also helps in reduction of the bulk, lowering the transport costs and the handling costs. As different concentrates of the constituents in the ferment distil off at different temperatures the method could also be used to eliminate unwanted constituent as well as to concentrate more acceptable constituents.

### **Distillation**

The principle involved in the distillation of alcoholic beverages is that at the boiling point of the alcohol-water mixture the composition of the vapour above the liquid surface contains a higher concentration of ethyl alcohol than the liquid immediately below the vapour. The vapour once condensed therefore contains a higher concentration of ethyl alcohol. The same principle applies to other volatile components in the fermented beverage. During distillation the components from the beverage do not separate individually depending on their boiling points, but as

constant boiling mixtures which depends on the composition of the liquid subjected to distillation. The boiling point of the mixture would be lower than that of the individual components and continue to vary with the changes in the composition of the components in the boiling beverage.

Well fermented coconut sap would contain about eight percent of ethyl alcohol. The pattern of distillation in this beverage could be understood by studying the liquid vapour equilibrium curve for a model system of ethanol water (Fig. 3). The figure is a plot of ethanol percentage in the distillate (vapour) against the ethanol percentage in the liquid phase in side the distillation pot. The line A-B represents the vapour-liquid equilibrium curve and C-B the the operating line for the model.

In distilling the eight percent ethanol solution its composition in the liquid phase is given by the point D (8%). The composition of the vapour phase is given by the point E (47.5% ethanol). When this vapour is condensed it would contain 47.5% ethanol in the liquid (F). If this liquid is distilled now it could produce a vapour of composition given by G (76.5%). The process could continue on redistillation giving a third distillate of composition I (84.2%) a fourth of composition K (88.5%) and so on. With each successive distillation the ethyl alcohol concentration increases in the distillate, but the degree of enrichment decreases at each step. However, the composition

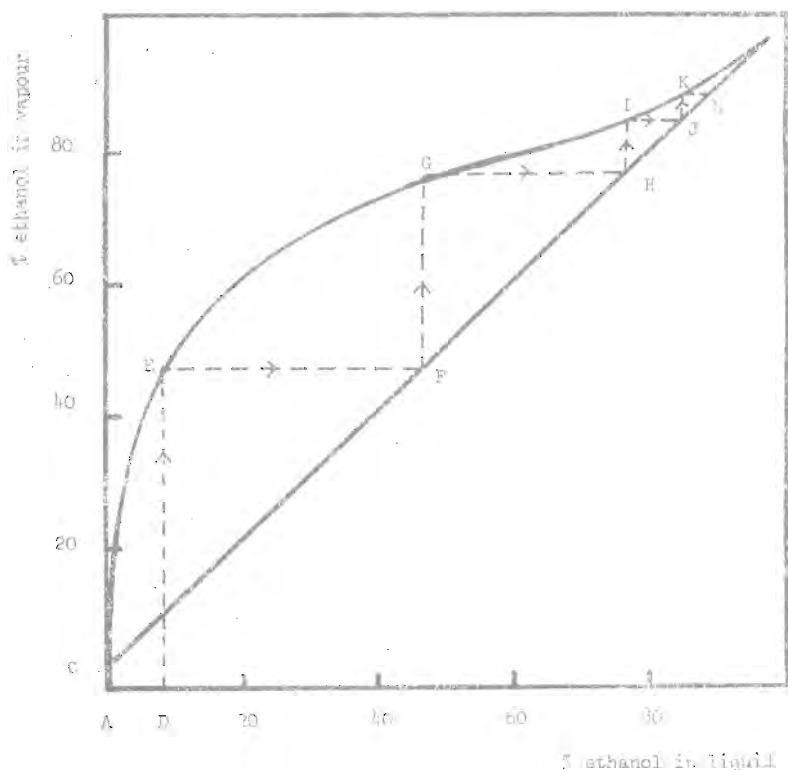


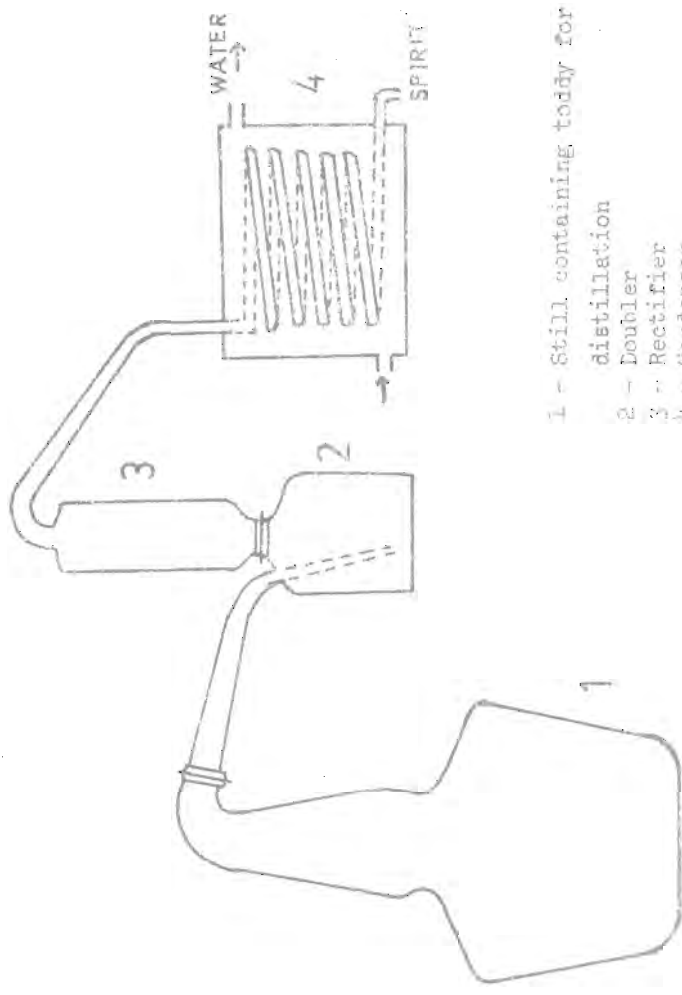
Fig. 3. liquid - vapour equilibrium curve for the distillation of ethanol - water mixtures (reflux ratio=4; number of column plates=5)

of the distillate would not approach that of pure ethanol, as ethanol-water forms a minimum boiling point mixture (azeotrope) at 78.2°C at a composition of 95.6 percent by weight of ethanol and 4.4 percent by weight of water.

In a simple, single distillation of this nature one could theoretically expect to separate vapour of a certain composition from the liquid at a given boiling temperature. However, in practice the rising vapour condenses as it cools on touching the walls of the unheated parts of the distilling apparatus before it passes to the condenser. When this happens the vapour rising in the tube comes across the condensed vapour containing higher amount of ethanol than the liquid from which the vapour separated. This results in a reflux effect and the steps of several successive distillation described in Fig. 3 occurs simultaneously. This effect is theoretically quantified by describing an equivalent of a number of plates in the reflux condenser. In the model system described here the reflux effect is equivalent to 5 such plates. This principle is utilized in the industrial distilling plants (stills) to obtain pre-determined ethyl alcohol concentrations by designing to possess the equivalent of a desired number of plates.

## Stills

In the alcoholic beverage industries in Sri Lanka two types of stills are used. The stills used for batch distillations are referred to as pot stills (Fig. 4). A pot



- 1 - Still containing today for distillation
- 2 - Doubler
- 3 - Rectifier
- 4 - Condenser

Fig. 4 Pot still.

still is equivalent to a simple laboratory distillation apparatus where the fermented solution is added to the pot and heated with steam, electricity or firewood. The still should be allowed to cool and refilled after each distillation. This still is a larger version of the alchemist's alembic. It also contains a short reflux column, referred to as rectifier. The rectifier helps in increasing the ethyl alcohol concentration in the distillate. However the ethyl alcohol content continues to vary during distillation in a pot still, the initial fractions containing higher concentrations of ethyl alcohol.

In Sri Lanka pot stills are used in all the commercial distilleries. In the distillation of toddy the pattern of emergence of different compounds vary depending on their association with other molecules and the boiling points. The separation pattern of congeners from coconut toddy (Fig. 5) indicate that compounds such as butyl alcohol and amyl alcohol separates in higher concentrations in early fractions of the distillates whereas methyl alcohol separates in the later fractions of the distillate. Those separating early are referred to as "foreshots" in the industry and are added back to the toddy to be redistilled to recover the ethyl alcohol. The next fraction that distils off is referred to as "middle runnings" and consist of 65-85% ethyl alcohol (v/v). The last stages of the distillate contains large proportions of heavy components. They are referred to as "tailings." The separation of these three fractions at the correct stage of dis-

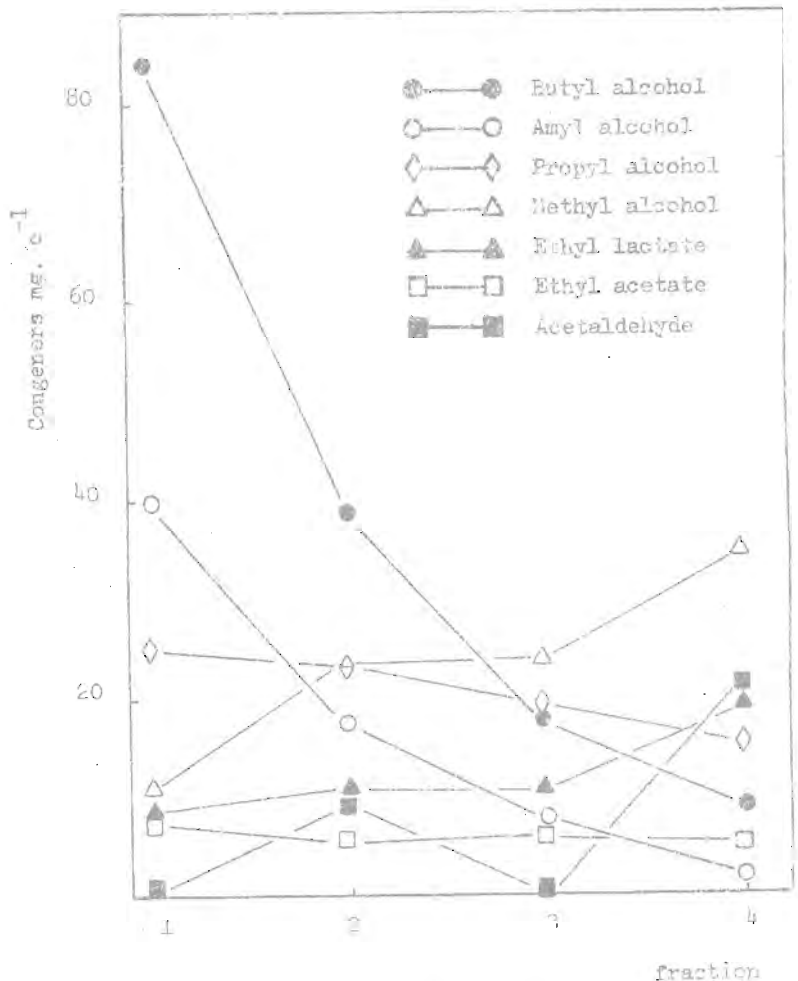
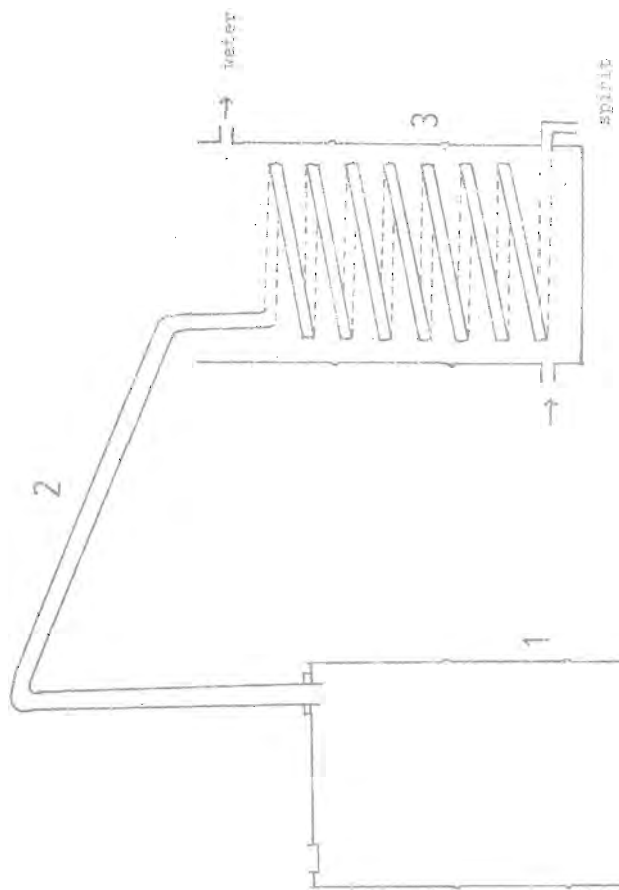


Fig. 5. Separation of congeners from coconut toddy into different fractions of the distillate in a laboratory distilling apparatus

tillations could yield a "middle running" fraction of optimum flavour due to the best combination of the congeners.

In Sri Lanka, the pot stills are also used solely for the purpose of concentrating the ethyl alcohol to 40-43 percent paying no attention to the separation of congeners. Such distillates are referred to as "low wines". They cannot be consumed directly without further processing, as they contain a large proportion of acids and esters. This distillation serves the purpose of concentrating ethyl alcohol for its self-preserving action from toddy which would otherwise get converted to acids, and ester. The stills used for low wine distillation at the co-operative distillery at Dankotuwa in 1970's were made of used oil drums of 45 gal. capacity (Fig. 6). They are replaced now by a pot still. The apparatus used for the illicit distillation of ethyl alcohol from toddy in the backyards (Fig. 7) also fall into the category of pot stills.

Another use of the pot stills is the second distillation of the low wines. The concentration of ethyl alcohol in the low wines is diluted to 28 percent by volume and is distilled. The fractions are collected at pre-determined stages depending on the quality and the quantity of low wines used. Here too the "foreshots" and the "tailings" are separated. The "middle runnings" are further separated into two fractions, the "double distilled middle runnings" and the "second fraction". During the double distillation the rate of the distillation and the alcohol content of the distillate is carefully monitored to obtain



- 1 - Barrel containing toddy to be distilled
- 2 - Copper tube
- 3 - Condenser

Fig. 6. Still for the 'low wine' distillations

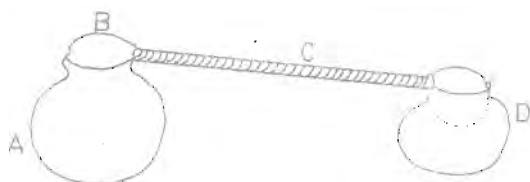
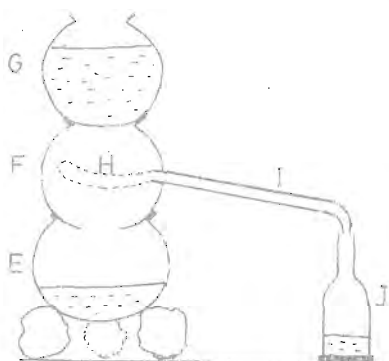


Fig. 7. Two illicit distillation units consisting of,

- A - Domestic clay pot for boiling toddy (wadi beliyu; Sinhala)
- B - Still head which is a smaller pot, inverted (veimudiya; Sinhala)
- C - Bamboo reinforced with coils of wet rope (bambaru; Sinhala)
- D - A combined condenser and receiver (daru kalay; Sinhala)



- E - Clay pot for boiling toddy
- F - Middle clay pot with an open bottom for the vapour to rise
- G - Upper aluminium pot containing water for cooling the vapour
- H - Wooden spoon to collect the condensing vapour dropping from the bottom of the upper pot.
- I - Copper tube to take the distillate out
- J - Bottle for collecting the distillate

(In this apparatus all joints are sealed with clay).

a product having desired concentrations of congeners (Ekmon 1983). In certain spirit industries in the West a triple distillation is performed for further regulation of quality in the distillates.

The distillation by patent stills is a continuous process where the toddy is fed at the top of a boiling column (stripper), which is heated by steam (Fig. 8). Here, the rising vapour comes across the downward moving toddy and the concentration of the ethyl alcohol in the vapour increases as it bubbles through the toddy. The ethyl alcohol gets concentrated further in the rectifier columns. The still could be operated to obtain ethyl alcohol concentrations as high as 95 percent by proper adjustments of the temperature and the flow of sap. In contrast to the pot stills, the distillate from the continuous stills cannot be separated into "foreshots" and "tailings". No control could be exercised on the concentrations of congeners. The distillate therefore does not contain the required levels of flavour components. It is the most efficient type of still for concentrating ethyl alcohol.

A continuous still referred to as the "French patent still" is used in the distillation of coconut toddy in the distillery at Seeduwa. The patent still adjusted to obtain a distillate at this concentration contains the optimum bouquet and taste for arrack.

### **Estimation of alcoholic strength**

The need to measure the strength of the spirits arose before the days of exact scientific measurements. A scale was therefore established on the basis of the

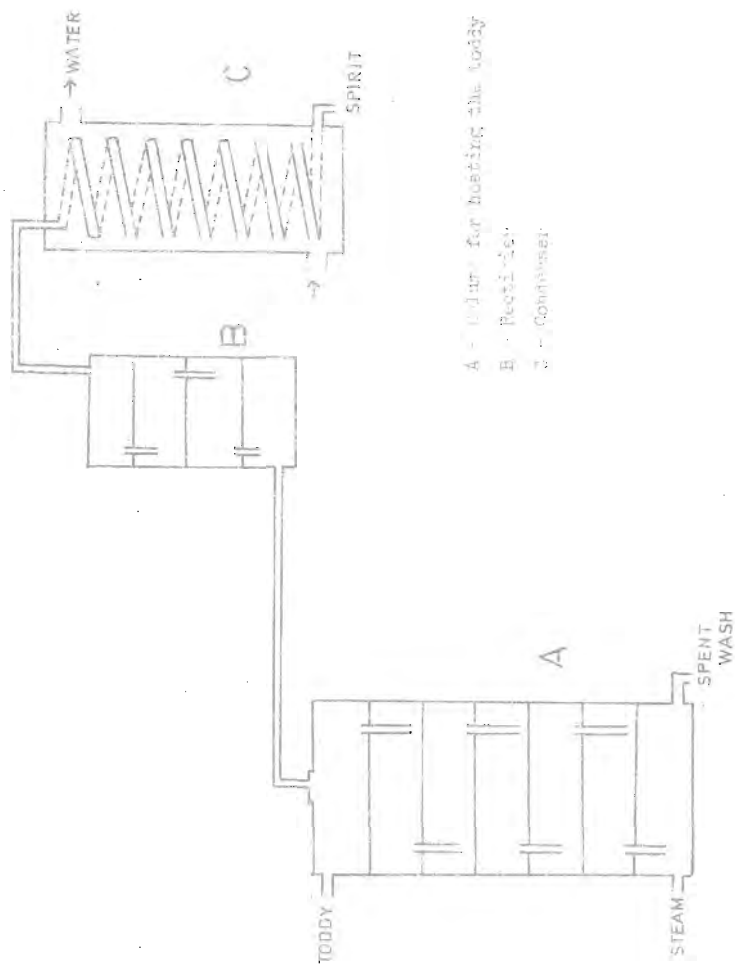


Fig. 8. Patent still

ability of the spirit to ignite when mixed with gun powder. The spirit that catches fire when ignited this way was called "over proof" (OP) and that does not catch fire "under proof" (UP). The critical point being referred to as "proof". It is now defined as "that which at the temperature 51°F weighs exactly 12/13 th's of an equal measure of distilled water". As the definition implies it is measured in practice in terms of specific gravity by means of a hydrometer invented by Sikes, a customs officer, (Jeffs 1973).

Today, this scale is used at a different temperature. In the United Kingdom it is measured at 60°F at which temperature the proof spirit contains 49.3 percent by weight or 57.1 percent by volume of alcohol. The United States of America uses a somewhat different scale. Other scales based on percentages of volume and weight are used in the European countries. A comparison of the commonly used scales are given in Table VIII.

In the scale used in the British Isles the concentrations below 100 proof (Table VIII) are referred to as under proof. Thus 90, 80, 70 would read respectively as 10, 20 and 30 under proof (UP). The values above 100 proof would be read as 10 over proof (OP) and so on. Sri Lanka too uses this system.

The illicit spirit producers in Sri Lanka test the alcoholic strength by dipping their fingers in spirit and holding it to the flame. If the spirit catches fire it is diluted till it does not catch fire.

TABLE VIII

A COMPARISON OF ALCOHOLIC STRENGTHS EXPRESSED IN  
DIFFERENT SCALES (JEFFS 1973)

1	2	3	4	5	6
90 U.P.	10	5.6	5.7	11.4	4.6
80 U.P.	20	11.3	11.4	22.8	9.2
70 U.P.	30	17.1	17.2	34.4	14.0
60 U.P.	40	22.7	22.9	45.8	18.7
50 U.P.	50	28.4	28.6	57.3	23.5
40 U.P.	60	34.2	34.4	68.8	28.4
30 U.P.	70	39.9	40.1	80.2	33.4
20 U.P.	80	45.6	45.8	91.4	38.5
10 U.P.	90	51.2	51.4	O.P.2.8	43.8
Proof	100	56.9	57.1	14.2	49.3
10 O.P.	10	62.7	62.9	25.7	55.0
20 O.P.	20	68.5	68.6	37.0	60.9
30 O.P.	30	74.1	74.2	48.4	67.0
40 O.P.	40	79.8	79.9	59.9	73.4
50 O.P.	50	85.5	85.6	71.3	80.1
60 O.P.	60	91.2	91.3	82.7	87.2
70 O.P.	70	97.0	97.2	94.3	95.6

1. Sri Lanka (British Isles)
2. Sikes proof spirit percentage or degrees at 60°F
3. Volume percentage at 59°F or Gay Lussac (France, Belgium)
4. Volume percentage at 60°F or Traalles (Austria, Italy, Russia)
5. Proof spirit percentage (USA)
6. Weight percentage (Germany)

## Maturation

In spite of many precautions in the distillation the fresh spirits are harsh in their taste and disagreeable in odour, probably due to the presence of unwanted congeners. The spirits are generally stored in wooden casks for years for them to mature and become mellow. The chemistry of maturation is not properly understood yet. It is known that certain oxidation and exchange reactions occur at the wooden surface. Some constituents in the spirits are probably absorbed by the wood or are oxidized. Certain compounds such as syringaldehydes from the wood passes into the spirits. The maturation of spirits are done generally up to periods of seven years and occasionally up to twelve years.

In the coconut spirit industry the distillates from the pot and patent stills are matured in seasoned "Halmilla" (*Berrya ammonilla*) and Teak (*Tectona grandis*) vats of capacity 1000 to 3000 gallons. They are stored for durations between six months to seven years. Normally, the distillates from different distilleries as well as from different stills are matured separately. In the case of "Old Arrack" a blend of patent and pot stills are matured for 2 years.

The changes observed in some of the congeners in coconut sap distillates from pot and patent stills on maturation in "Halmilla" vats up to five years are presented in Table IX. The significant changes observed here are the increase in methanol and the

TABLE IX  
CHANGES IN MAJOR VOLATILES DURING MATURATION OF FERMENTED COCONUT SAP DISTILLATES

Type of distillate	age months	Congeners mg kg <sup>-1</sup> of Ethanol																
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
Double di-tilled in pot still	1	17	135	428	1480	119	2673	53	tr.	N.D.	N.D.	N.D.	tr.	N.D.	N.D.	N.D.	N.D.	tr.
	8	20	133	414	152	14	2311	69	tr.	N.D.	N.D.	N.D.	tr.	N.D.	N.D.	N.D.	N.D.	tr.
	38	25	128	447	1656	48	2183	54	tr.	N.D.	N.D.	N.D.	tr.	N.D.	N.D.	N.D.	N.D.	tr.
	60	26	145	454	1682	95	1370	63	tr.	N.D.	N.D.	N.D.	tr.	N.D.	N.D.	N.D.	N.D.	tr.
French patent still	1	13	93	244	1007	79	3189	744	tr.	N.D.	N.D.	N.D.	tr.	N.D.	tr.	N.D.	N.D.	N.D.
	8	18	102	262	1115	86	3226	829	+	N.D.	N.D.	N.D.	tr.	N.D.	tr.	N.D.	tr.	N.D.
	43	20	96	303	1132	40	719	545	tr.	N.D.	N.D.	N.D.	tr.	N.D.	N.D.	tr.	N.D.	N.D.

1. Methanol; 2. Propan-1-ol; 3. 2-Methyl Propanol; 4. Amyl Alcohol; 5. Acetaldehyde;  
6. Ethyl Acetate; 7. Ethyl Lactate; 8. Butan-1-ol; 9. Butan-2-ol; 10. 3-Ethoxy Propanol  
11. 3-Ethoxy Propanol; 12. Ethyl Formate; 13. Isobutyl Acetate; 14. Isoamyl Acetate;  
15. Acetic Acid; 16. 1,1 Diethoxy Propane.

acetic acid contents and the reduction in acetaldehyde content. The increase in methanol content may be a contribution from the wood due to breakdown of the pectic components releasing methanol. The drop in acetaldehyde may be due to the oxidation or evaporation. The increase in acetic acid perhaps indicate a slow oxidation of ethanol. There may be other changes occurring in the components which are in the order of parts per billion.

It is reported (Ekmon 1983) that the maturation process could be enhanced by increasing the area of contact between the wood and the spirit. This is achieved by lowering into the spirit a stainless steel basket containing carefully roasted "Halmilla" and Teak wood shavings. The spirits in the vats are stirred at fortnight intervals for better aeration.

The maturation treatments increase the total solid content in arrack and makes it mellow and pleasant. The illicit arracks are not subjected to any form of maturation.

### **Blending**

Blending is practised in most spirit industries to reduce the cost of the product by mixing low cost distillates from the patent stills with the more expensive distillates from the pot stills. It is also practised in the whiskey industry where distillates from barley fermentations are mixed with distillates from other grain fermentations purely for economic reasons. The blending

of pot and patent distillates help in balancing the levels of congeners which are in higher concentrations in the distillates from pot stills and absent or low in those from patent stills.

In the coconut arrack industries pot and patent distillates as well as distillates of different maturity are blended and marketed under different brand names.

### **Colouring**

Synthetic colours are not used in the spirit industries. The spirits are either marketed as colourless liquids in case of Vodka and Gin, or receive their colour by the extraction of colouring substances from the wood during maturation and from the added caramel. Caramel is prepared for this purpose by heating the crystalline cane sugar and dissolving it in ethanol. There is no established standard or limitation to the use of colour. Different amounts of caramel are added in the arrack industry in Sri Lanka to obtain varying shades of brown colours for different brands. However, excess caramel could impart bitterness to the spirits.

### **Clarification**

Sometimes the matured distillates appear hazy due to presence of proteinaceous or pectinaceous material. The haze is removed by addition of white

of raw eggs, gelatine or isinglass. The proteinaceous or pectinaceous substances are sedimented by these additives leaving a clear spirit.

### **Processed Arracks**

The processed arracks are blends of coconut arrack and neutral spirits which are flavoured by adding essences. In the production of processed arrack the distillates could also be exposed to carbon (charcoal) particles for the removal of some of the harsh constituents.

### **Other attractive features**

Many attractive features such as the use of bottles of different capacity and of fancy shapes together with introduction of a whole fruit into the bottle by introducing a bud still growing in a branch to a bottle, or having a separate bottom compartment to the bottle containing juices to be used as shandy are used in the spirit industries in the world. In Sri Lanka a bottle of smaller capacity (185 ml) that could be carried in the pocket was introduced in the arrack industry a few years back. Another development is the introduction of a bottle of more attractive shape in a cardboard carton produced for the International Conference of Pacific and Asian Travel Agents.

## Chapter VI

### QUALITY AND STANDARDS

The quality of alcoholic beverages is attributable to the effects produced by a combination of ethanol and a large number of secondary compounds (Table II) referred to as congeners or congenics. They are derived from the raw materials, the micro-organisms involved in the fermentation and the reactions occurring during the distillation and the maturation of alcoholic beverages. The presence of these compounds in concentrations above their flavour threshold values contribute distinctly to the flavour and aroma and thereby the quality.

#### Toddy

In the spontaneously fermented palm saps (toddies) the contribution of congeners by the micro-organisms are innumerable and hence it is not possible to lay down any regular standards for quality. Consumers prefer toddy at different levels of fermentation ranging from sweet, slightly fermented sap containing about two percent ethyl alcohol to fully fermented acidic sap containing six to seven percent ethanol together with about one percent acid, sometimes with a strong sulphurous smell. The only estimations done to check the quality are the ethyl

alcohol content by ebulliometry (Samarajewa and Tissera 1975) and the total acidity by titrating with standard sodium hydroxide using phenolphthalein as the indicator.

In bottled toddy, in spite of the heat treatment at 90°C for 20 minutes the biochemical reactions continue in the bottles resulting in variable quality.

## Beer

In the beer industries in Sri Lanka the raw material, the micro-organisms and the processing conditions are carefully controlled. The fermented brew therefore is of regular quality. In the industry, regular testing is done to maintain the quality within the limits (Table X) stipulated in the Sri Lankan standards for beer (Anonymous 1973).

TABLE X  
REQUIREMENTS IN THE SRI LANKAN STANDARDS FOR BEER  
AND STOUT

<i>Characteristic</i>	<i>Requirement</i>
Ethyl alcohol percentage (v/v)	2.0 - 10.0
pH	3 - 4.8
Carbon dioxide in bottled beer, minimum percentage (m/v)	0.3
Arsenic mg L <sup>-1</sup> (maximum)	0.5
Lead mg L <sup>-1</sup> (maximum)	0.2
Copper mg L <sup>-1</sup> (maximum)	2
Tin mg L <sup>-1</sup> (maximum)	250

Apart from the bottled form the beer is also sold as draft beer, off a storage vat. The same standards as for bottled beer apply for the draft beer except for the carbon dioxide concentration.

### **Palm sap distillates**

The quality of palm sap distillates, commonly referred to as 'arrack' is much more regular than the fermented sap from which they originate. This is due to the separation of many compounds during distillation followed by condensation of certain compounds volatile at a selected temperature range.

In the palm sap distilleries in Sri Lanka the quality is checked regularly by the estimation of the alcoholic strength, the extract, esters, total acids, fixed acids, volatile acids, furfural, aldehydes, higher alcohols, copper, iron, lead, tin and also by an assessment of bouquet and taste.

There are no specifications laid by the standardization authorities for the spirits distilled in Sri Lanka. The proposed specifications for the distillates from the the sap of the coconut, palmyrah and the kitul palm group the distillates into three categories. The first group contains arrack distilled from the palm saps. The second group defined as "blended arracks" are mixtures containing at least ten percent of arrack together with potable alcohol from other sources. The third group consists of processed arracks. The expected

limits for the constituents in arrack are given in Table XI. These limits are made use of in the detection of illicit spirits by the public analysts.

TABLE XI  
THE CHEMICAL REQUIREMENTS IN ARRACKS

<i>Characteristics (Maximum)</i>	<i>Requirements</i>
Total solids	1000*
Total acids as acetic acid	100*
Fixed acids as acetic acid	5*
Esters as ethyl acetate	300*
Higher alcohols as amyl alcohol	300*
Aldehydes as acetaldehyde	15*
Furfural	1*
Methyl alcohol	not detectable
Copper	3**
Lead	1**
Tin	1**
Iron	1**

\*parts per 100 L. of absolute alcohol

\*\*mg kg<sup>-1</sup>

## Congeners

The tests adopted in the industries only provide an indication as to whether the products confirm to the acceptable limits. Detailed studies on quality would include the estimation of trace amounts of congeners. Of the several hundreds of congeners present in distilled beverages two groups of compounds the

higher alcohols, and the esters of several C<sub>15</sub> - C<sub>18</sub> fatty acids are important. They are responsible to a greater extent for quality characteristics (Suomalainen and Lehtonen 1979) in the spirits.

The concentrations of the higher alcohols and several other congeners observed in a few brands of arrack in Sri Lanka are presented in Table XII (Samara-jeeva *et al.* 1982).

TABLE XII  
CONGENERS IN SRI LANKAN ARRACKS  
(mg L<sup>-1</sup>Absoluta Alcohol)

congeners/brand	coconut	double distilled	old seeduwa	special	Jaffna	illicit
Ethanol %	31	32	40	29	35	18
Methanol	9	16	14	26	22	8
Propanol	90	120	105	2	623	43
2-methyl propanol	260	397	336	20	331	282
Amyl alcohol	1080	1472	1351	60	1314	1350
Acetaldehyde	28	10	79	38	95	194
Ethyl acetate	208	70	570	105	1482	568
Ethyl lactate	706	49	108	43	320	1066
1-butanol	tr < 30	tr < 30	tr < 30	tr < 30	tr < 30	tr < 30
2-butanol	ND < 5	ND < 5	ND < 5	ND < 5	500	ND < 5
3-ethoxy propanol	ND < 5	ND < 5	tr < 10	ND < 5	ND < 5	ND < 5
3-ethoxy propanol	ND < 5	ND < 5	ND < 5	tr < 10	700	tr < 10
Ethyl formate	tr < 25	tr < 25	tr < 25	tr < 25	tr < 25	tr < 25
Isobutyl acetate	ND < 4	ND < 4	tr < 10	ND < 4	ND < 4	ND < 4
Isoamyl acetate	ND < 4	ND < 4	ND < 4	ND < 4	40	ND < 4
Acetic acid	ND < 12	ND < 12	tr < 15	ND < 12	tr < 15	ND < 12
1,1 diethoxypropane	ND < 2	ND < 2	ND < 2	ND < 2	30	tr < 5

tr — traces

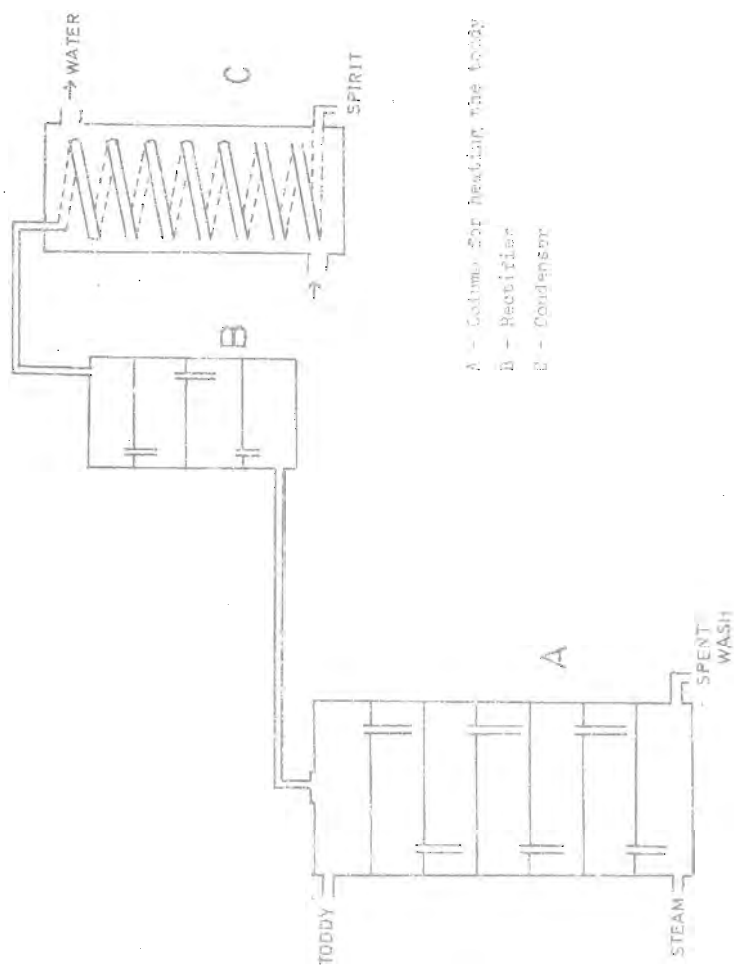
ND — not detected

The arracks "Coconut arrack", "Double distilled arrack" and "Old Seeduwa" are similar in the congener concentrations estimated. The "Jaffna arrack" which

is a mixture of distillates from coconut and palmyrah showed a higher propanol content. One of the striking features is the low congener content observed in "Special arrack" which is a blend containing very low percentage of the distillates from coconuts. This probably explains the poor quality associated with the "Special arrack". In this respect, the illicit arrack, distilled from pure coconut toddy in an acceptable home scale distilling unit (Fig. 7), is as good as the more reputed brands prepared in the large distilleries.

Another striking feature in the Sri Lankan arracks is the high ethyl lactate content, which is generally not observed in spirits such as whiskey and brandy, fermented under controlled conditions, but in naturally fermented products such as Nubian gin (Nout 1979). The high ethyl lactate contents in palm sap beverages are produced from the lactic acid observed at the lactic fermentation phase in the palm saps. The possibility of formation of esters of different organic acids due to competitive esterification by coenzyme A from brewers' yeasts is an already observed phenomenon (Nordstram 1962). The same process may be occurring in the fermentation of palm saps where lactic acid concentrations are high.

In the industry, the total ester content is estimated chemically as a quality parameter. This estimation probably reflects both the ethyl acetate and ethyl lactate concentrations together. The ethyl lactate could be present in even higher concentrations than ethyl acetate. Thus a comparison of total ester values from coconut



- A - Column for heating the toddy
- B - Rectifier
- C - Condenser

Fig. 3. Patent Still

## Origin of the congeners

Yeasts play an important role in the production of the congeners found in alcoholic beverages (Suomala and Nykanen 1966). The total concentration of congeners produced vary widely depending on the species of yeasts (Table XIII) and is not related to the amount of ethyl alcohol produced by them. The ratio of the congeners produced too vary from species to species (Fig. 10). This feature could be made use of in the selection of the micro-organisms to improve the quality of a beverage. For instance the ratio of isoamyl alcohol to isobutyl alcohol production by three species of coconut sap yeasts are as follows.

<i>Saccharomyces cerevisiae</i>	5 : 1
<i>Saccharomyces exiguus</i>	1 : 1
<i>Candida sake</i>	3 : 1
Mixed yeasts	4 : 1

TABLE XIII

TOTAL CONGENER PRODUCTION BY THE COCONUT PALM SAP YEASTS WHEN INCUBATED IN A TEN PERCENT SUCROSE SOLUTION CONTAINING OTHER NUTRIENTS AND A DISTILLATE OF 1/4 ORIGINAL VOLUME COLLECTED.

Species	Ethyl alcohol percentage	Congeners mgL <sup>-1</sup> distillate
<i>Candida sake</i> ... ..	8	870
<i>Saccharomyces cerevisiae</i> ... ..	11	838
<i>Saccharomyces exiguus</i> ... ..	22	711
<i>Pichia farinosa</i> ... ..	3	255
<i>Candida guilliermondii</i> ... ..	4	222
<i>Schizosaccharomyces pombe</i> ... ..	23	141
<i>Candida valida</i> ... ..	0.2	25
<i>Pichia etchellsii</i> ... ..	0.2	21
<i>Pichia membranaefaciens</i> ... ..	0.2	15
<i>Rhodospodium glutinis</i> ... ..	0.2	11
<i>Pichia humboldtii</i> ... ..	0.2	7
Mixed culture of above ... ..	2.3	1068

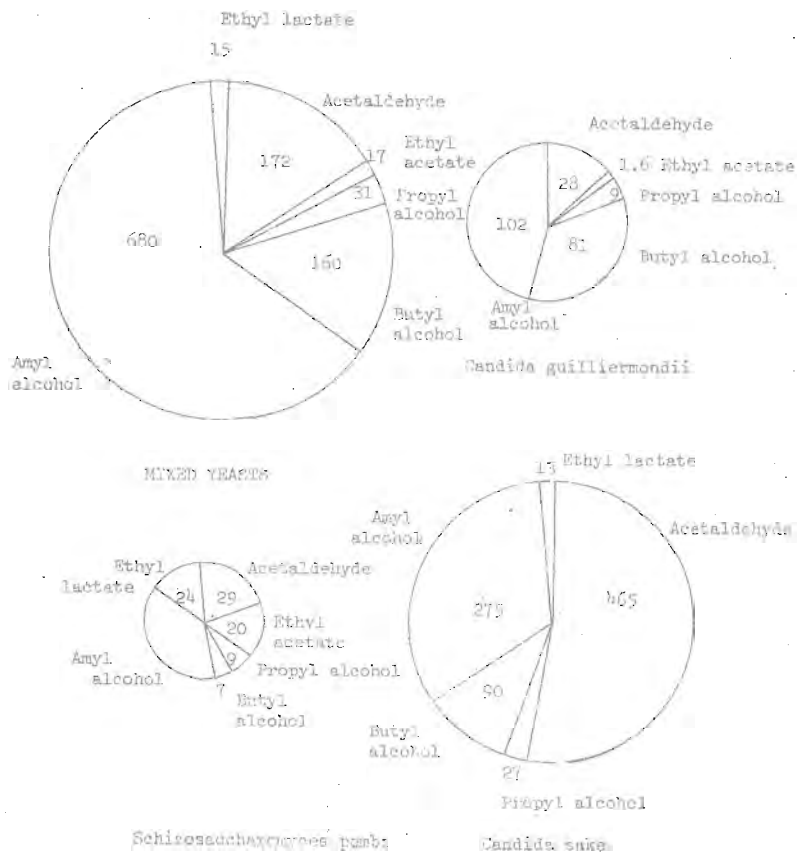


Fig. 10. Distribution of congeners in a synthetic palm sap distillate fermented using yeasts isolated from the coconut sap. Area of the circles represent the total amount of congeners present.

In arrack the observed ratio is 4:1 as would be expected from a mixed culture. If pure yeast culture of *Saccharomyces cerevisiae* is used the ratio would increase to 5:1 and the curve for coconut arrack (Fig. 9) would be closer to that of Bourbon. The possibility of manipulating the congeners through the selection of fermenting micro-organisms provides the mechanism to change the quality of arrack.

## Nomenclature

Although no rules are established governing the naming of the alcoholic beverages anywhere in the world, there are certain accepted principles practised in the industry. The beverages are usually named based on the raw material (Table XIV). At times prominence is given to the location of the production of the raw materials or the beverage.

TABLE XIV

COMMON ALCOHOLIC BEVERAGES AND THE RAW MATERIALS USED FOR THEIR PRODUCTION

<i>Raw material</i>	<i>Fermented product</i>	<i>Spirit</i>
Barley	beer	whiskey
Grapes	wine	brandy
Apple	cider	—
Molasses	—	rum
Grain/Potatoes	—	vodka
Cashew	feni	—
Palm saps	toddy	arrack

For instance there are many grape wines named by the locality in which grapes are produced. The names are used as indicators of flavour characteristics imparted by the soil conditions, yet they all fall within the broad category wines. Similarly Scotch whiskey could be produced only in Scotland where the peaty soils and quality of water imparts certain character to the beverages.

On account of the popularity of whiskey anywhere in the world today, grains other than barley are used in the production of whiskeys. The American whiskey known as Bourbon (named from the Bourbon county in Kentucky) is produced from maize. There is a legal requirement that Bourbon should contain at least 51 percent spirit from maize. Similarly Rye whiskey should come from a mash containing at least 51 percent rye. The Canadian whiskey is produced from a mixture of maize, rye and barley.

Although the word arrack is defined in Sri Lanka today as the spirits prepared from sap of coconut, palmyrah or toddy palm it has gained a different meaning in the Western countries. In the West, the word AR(R)ACK is used to indicate a spirit originally distilled from rice in the Dutch Indies and India or any sort of fiery native spirit. The spirits of various less popular origins are therefore referred to as arracks. Establishing the word arrack in the liquor terminology in the world as a product originating from palm saps would itself be a considerable problem as the term is already used to indicate the spirits of suspicious origin.

In Sri Lanka, within the alcoholic beverage industry itself the word arrack had gained different meanings. The higher popularity of the distilled beverages produced from palm sap has resulted in the use of the name arrack to indicate spirits produced from sources other than palm saps. Sometimes such spirits are given brand names similar to arrack with minor changes in the way they are spelt. Apart from this the spirits containing palm sap distillates, in concentrations as low as two to three percent, are referred to as arracks in the industry. These practices leave a gap between the acceptable definitions and the practices in the industry which could be narrowed down only with proper legislation.

### **Hygienic practices**

There are no strict regulations or a code of good practices to maintain hygienic conditions in the fermentation of palm saps in Sri Lanka. An inoculum of organisms, in fermenting sap, is allowed to remain in the sap collecting pots throughout the year. Many insects fall into these pots and pots are also visited by birds and rodents. In the booths where the fresh toddy is sold the storage barrels contain diverse microflora. Diseases like amoebiasis is not uncommon among the regular consumers of fresh toddy.

The conditions are not so bad in the distillation industries as regular cleaning is practised and the distilled spirits do not permit the growth of any organisms in them.

## Excise regulations

The production of alcoholic beverages is a highly profitable venture anywhere in the world and is controlled by the excise regulations for the purpose of taxation, prevention of adulteration and maintenance of regular quality.

The Excise Ordinance of Sri Lanka controls the tapping of coconut trees for the sap to be fermented, the distillation of alcoholic beverages and the sales at taverns, hotels and other outlets. The revenue for the state is collected through licensing systems for the tapping of coconut trees and sales outlets. This revenue is collected by the Government Agents of the district and excise officers are appointed under section 7 of the Ordinance to enforce laws.

The licensing systems for tapping vary depending on the scale and purpose of tapping. Tapping of palms for the distillation of arrack is restricted to the Western coast belt of Sri Lanka up to 75 km North and 50 km South of Colombo. Here the tax is collected for each tree tapped and the trees permitted to be tapped are marked by the excise officers.

The licences are also issued by "Grama Sevakas" for tapping up to 10 palms without a tax to draw unfermented sap exclusively for the preparation of treacle and jaggery. These licences are referred to as cottage licences and any householder is issued only one such

licence (Rupasinghe 1983). The conditions of the licence forces the use of slaked lime in the pots for the collection of sap so that the sap does not get fermented.

In Jaffna the tapping of toddy operate under a co-operative system where supervision is mainly by the co-operative officers and occasionally by excise officers. The taxation is by the Inland Revenue Department.

The major contribution to the excise income on alcoholic beverages arises from the duty for the distillation of beverages. This comprises of 97 percent of the total income (Table XV). In Sri Lanka the palm sap distillation industry is controlled totally by the State Distilleries Corporation. They supervise the production, purchase and sale of spirits even in the private distilleries.

TABLE XV  
REVENUE TO THE STATE FROM THE ALCOHOLIC BEVERAGE INDUSTRIES IN  
SRI LANKA 1982

<i>Source</i>	<i>Income Rs.</i>	<i>% Distribution</i>
Duty on locally distilled (foreign type) liquor	53 683 144	6.5
Duty on other locally distilled liquor	753 990 453	91.2
Arrack Tavern rents	4 977	0.006
Toddy Tavern rents	9 764 756	1.2
Toddy tapping licence fees	104 787	.013
Local liquor licence fees	3 362 332	.407
Foreign liquor tavern rents	1 196 675	.145
Foreign liquor licence fees	4 758 910	.575
Composition fees & late fees	129 180	.016
	<u>826 995 214</u>	

Other minor sources of income include the fines imposed on those involved in illicit production, transport and sale of alcoholic beverages.

Under the excise regulations no person is expected to keep in his possession more than 1500 ml of alcoholic beverages. The sale of alcoholic beverages to women and those below 21 years is not permitted. The Excise Manual of Sri Lanka (Part I) describes all the legal aspects and the functioning of officers under Excise Ordinance.

Another important aspect handled under the Excise Ordinance is the technology of production of toddy and arrack. The Excise Manual of Sri Lanka (Part II) developed following the Indian Excise Manual describes in detail the technological steps involved in the collection of sap, storage, transport, distillation, maturation, blending, checking the quality, bottling and labelling. It provides the necessary guidelines for the producers and also detailed information on the functioning of the warehouses, distilleries and the measurements involved in the industry (Anonymous 1954). The practices described in it help in the maintenance of hygienic conditions and the quality of the produce. The enforcement of regulations to maintain the quality are looked after by the Excise Department by implementing the Excise Ordinance of Sri Lanka.

## Chapter VII

### RELATED INDUSTRIES

Alcoholic fermentation represents a single step in a sequence of reactions occurring spontaneously. The other biochemical conversions in this sequence are also made use of in the production of foods. These food industries are linked to each other and sometimes operate side by side within the same premises manufacturing an array of food items.

#### Sugar

Apart from the conversion of the sugary juices obtained from plants to ethyl alcohol the juice is concentrated to obtain the syrups and the crystalline sugars which sometimes is the more important industry compared to the production of alcoholic beverages. The crystallizing out of solid sugar from these juices containing sucrose need certain pre-conditions for the crystallization to be a success. For the preparation of jaggery the sugars in the sap should be almost totally in the form of sucrose and the sap should not contain more than eight percent of inverted sugars (Samara-jeewa and Wijeratne, 1979). In crystallizing out sugar the yields drop with the increased percentage of inverted

sugars in the juice. The sugary juices where the inversion has occurred could be concentrated to treacle, or further inverted to concentrate it to golden syrup or could be fermented for ethyl alcohol.

After crystallizing out sugar from the juices of saps, the liquid fraction contains sufficient sugars to be fermented. They could be used as the raw material for alcoholic fermentation. An alcoholic fermentation industry, therefore, develops side by side with a sugar industry. This linkage could be seen at the sugar factories at Hingurana and Kantalai in Sri Lanka.

### Vinegar

The vinegar is produced by the acetic fermentation of the ethyl alcohol. The conversion is brought about by a group of bacteria collectively referred to as acetic acid bacteria. In the alcoholic fermentation industries, the precautionary measures adapted to prevent the microbial contamination fails at times and the ethyl alcohol get oxidized further to acetic acid. When this happens, the next best solution is to allow acetic fermentation to continue and enhance it by aeration. In some of the wine and beer industries vinegar generators are installed to make use of any spoiled ethyl alcohol from the alcoholic fermentation industry. In Sri Lanka, the vinegar industry functions separately and is not catered directly by the alcoholic fermentation industry (Nathanael 1958). This is perhaps because the quality regulations on the total acidity of fermented

alcoholic beverages are not implemented strictly and the beverages of low quality due to high acidity could still be sold for consumption.

### **Animal feeds**

In the alcoholic fermentation industries the main concern is on the carbohydrates of the raw material for the fermentation. The nitrogen compounds are required only in minor quantities. The sediments after the extraction of the carbohydrates from the raw materials or after fermentation are rich sources of nitrogen that could be utilized as animal feed. In the beer industries the spent wash, after extracting the sugar is diverted as a cattle feed. In the palm sap industries a sediment is left when the fermented sap is filtered prior to distillation. This sediment is a rich source of nitrogen due to the high concentration of the yeasts, and would be useful as an animal feed.

### **Polysaccharides**

Under certain environmental conditions the microorganisms in fermenting saps could convert the sucrose into polysaccharides such as dextrans. In the palm sap industry these are produced seasonally (Samara-jeewa *et al.* 1977). In the past dextrans have been used as a filler in blood. Being a polysaccharide similar to cellulose they may be of use in the food industries provided they could be obtained in the pure form.

### **Production of yeasts**

The production of single cell proteins is the quickest method of producing protein today. In alcoholic

fermentation the micro-organisms shift to fermentative mechanism of metabolism to overcome the deficiency of oxygen. If aeration is done their metabolic pathway could be shifted to respiration. This would result in production of biomass which could be used as a source of protein and a source of bakers yeast. Production of yeasts could form a part of an alcoholic fermentation industry where raw materials containing low sugar content, insufficient for alcoholic fermentation, could be utilized. Coconut water had been shown to possess this potential (Smith and Bull 1976 a, b). The requirements of the bakers yeast in Sri Lanka today is in the region of thousand metric tonnes per year. The molasses containing low sugar concentrations could also form the raw material for the production of yeasts.

### **Bottled sweet sap**

The unfermented palm saps are valued for their high vitamin C content and the refreshing effect as a beverage. In India it is bottled and sold. The flavour characteristics of the sweet saps could be further enhanced by the addition of essences, natural fruit juices or by allowing it to ferment slightly so that about 0.5 percent of ethyl alcohol is produced. The inversion of sucrose in the saps to glucose and fructose would yield a juice of higher sweetness. Non-alcoholic beverage industry based on palm saps would be a profitable venture linked with the alcoholic beverage industry.