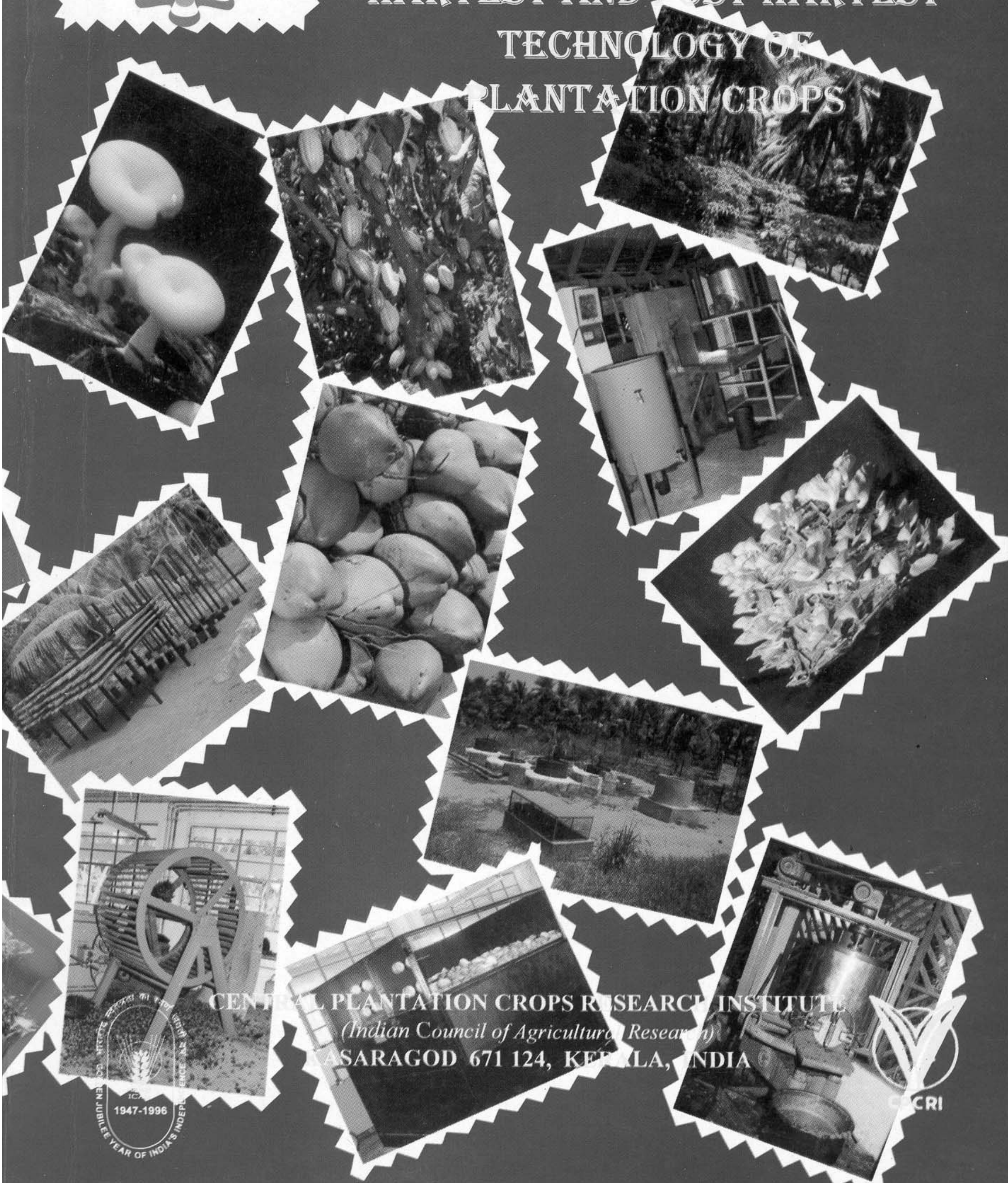
HARVEST AND POST HARVEST TECHNOLOGY OF PLANTATION CROPS



GOLDEN JUBILEE YEAR OF INDIA'S INDEPENDENCE 1947-1996

CENTRAL PLANTATION CROPS RESEARCH INSTITUTE
(Indian Council of Agricultural Research)
KASARAGOD 671 124, KERALA, INDIA

CPCRI

HARVEST AND POST HARVEST TECHNOLOGY OF PLANTATION CROPS

CENTRAL PLANTATION CROPS RESEARCH INSTITUTE
(Indian Council of Agricultural Research)
KASARAGOD 671 124, KERALA, INDIA

Price Rs. 75 / US $ 1[illegible]

Published by :

Dr. K.U.K. Nampoothiri Director, Central Plantation Crops Research Institute
Kasaragod - 671 124, Kerala, India
Phone : (0499) 430893-6 Grams : RESEARCH Kasaragod.
Telex : 08001 202 PALM IN Fax : 91-499-430 322 Email : cpcri@x400.nicgw.nic.in

Compiled and Edited by :

S.J.D. Bosco, C.V. Sairam, K. Muralidharan and C.H. Amarnath

Cover design :

M.B. Sukumaran and K. Shyama Prasad

Photo credits:

K. Shyama Prasad

August, 1998

Printed at :

Codeword Process & Printers, Mangalore

PREFACE

The plantation crops play a pivotal role in Indian economy in terms of commercial importance and export potential. In the present international trade scenario with stiff competition among various countries, India is in a disdvantageous position because the international prices of these crops and their products are below compared to domestic prices. To overcome this, long term strategies are to be evolved for product diversification and higher productivity that are identified as priority areas.

Among the 12 Summer Schools organized during 1998 by ICAR, the Central Plantation Crops Research Institute (CPCRI), Kasaragod has been chosen to conduct a Summer School on "Harvest and Post Harvest Technology of Plantation Crops". This would cater to the needs of participants with varying technical background. The course content of the Summer School was designed based on both theory and practical aspects of Plantation Crops. The lecture notes prepared by the resource personnel form an authentic document with valuable information covering harvest and post harvest technology of 16 important plantation crops. It is hoped that a compilation of this kind will be valued by both research workers and the students which will fulfil the long pending need for a book to cover these aspects.

I wish to thank Dr S J D Bosco, Scientist in Post Harvest Technology and Director of the Summer School for his efforts in the publication of this book. I appreciate the help rendered by Dr K Muralidharan, Mr C V Sairam and Mr C H Amarnath. The resource personnel have done a commendable job in preparing the exhaustive notes which formed part of the compilation. I also thank the ICAR for sanctioning the Summer School and for the financial assistance. CPCRI is proud to make this humble contribution during the fiftieth year of Independence.

CPCRI, Kasaragod
August, 1998

K.U.K. Nampoothiri
Director

CONTENTS

LIST OF CONTRIBUTORS

Ajay M. Pillai, Coconut Development Board, Kochi 682 011

Ananda Alwar, R.P., Officer-in-charge, PHT; Central Coffee Research Institute, Chickmagalur 577 117

Arumugan, C., Head, Oil Seeds Research, Regional Research Laboratory, Thiruvananthapuram

Balachandran Nair, Coconut Development Board, Kochi 682 011

Balasubramaniam, Scientist, NRC for Cashew, Puttur 574 205

Bosco, S.J.D., Scientist (Sr. Scale), Central Plantation Crops Research Institute, Kasaragod 671 124

Chempakam, B., Sr. Scientist, Indian Institute of Spices Research, Kozhikode 673 012

George V Thomas, Sr. Scientist, Central Plantation Crops Research Institute, Kasaragod 671 124

Hudson, J.B., Senior Advisory Officer, UPASI Scientific Department, Coonoor

John Zachariah, T., Scientist (Sr. Scale), Indian Institute of Spices Research, Kozhikode 673 012

Kasturi Bai, K.V., Senior Scientist, Central Plantation Crops Research Institute, Kasaragod 671 124

Madhavan, K., Senior Scientist, Central Plantation Crops Research Institute, Kasaragod 671 124

Mathew, A.C., Scientist, Central Plantation Crops Research Institute, Kasaragod 671 124

Muralidharan, K., Scientist (Sr, Scale), Central Plantation Crops Research Institute, Kasaragod 671 124

Nampoothiri, K.U.K., Director, Central Plantation Crops Research Institute, Kasaragod 671 124

Nagaraja, K.V., Senior Scientist, NRC for Cashew, Puttur 574 205

Naresh Kumar, S., Scientist, Central Plantation Crops Research Institute, Kasaragod 671 124

Rajagopal, V., Head, Divn. Physiol., Biochem. and PHT, Central Plantation Crops Research Institute, Kasaragod 671 124

Ramanujam B., Scientist (Sr. Scale), Central Plantation Crops Research Institute, Kasaragod 671 124

Ratnambal, M.J., Senior Scientist, Central Plantation Crops Research Institute, Kasaragod 671 124

Sairam, C.V., Scientist, Central Plantation Crops Research Institute, Kasaragod 671 124

Sreekumar Poduval, Processing Engineer, Coconut Development Board, Kochi 682 011

Sukumaran, A.S., Sr. Scientist, Central Plantation Crops Research Institute, Kasaragod 671 124

Sundaresan, A., Regional Research Laboratory (CSIR), Thiruvananthapuram.

Vidhan Singh, T., Scientist, Central Plantation Crops Research Institute, Kasaragod 671 124

Vijaya Kumar, K., Scientist (Sr. Scale), Central Plantation Crops Research Institute, Kasaragod 671 124

Viswanathan, R., Associate Professor, TNAU, Coimbatore 641 003

AN INTRODUCTION TO PLANTATION CROPS

K. U. K. Nampoothiri

INTRODUCTION

Plantation crops are high value commercial crops which play very important role in India's export trade. These crops including coconut, arecanut, cocoa, oilpalm, tea, coffee, rubber and spices occupy an area of about 4 million ha which is only 2.3 percent of the total cropped area but generate an annual income of more than Rs 2,98,500/- million and export earning of approximately Rs 30,925/- million during 1994-95. Cultivation of these crops is mostly confined to tropical region between 20° north and 20° south of equator (Table 1). Coconut, arecanut, cardamom and black pepper have a long history of cultivation in India. Cocoa and oil palm are comparatively recent introductions. Large cardamom is an important cash crop of north-eastern India particularly in Sikkim. Among the plantation crops coconut, arecanut, cashewnut, black pepper and cardamom are known as small holder plantations whereas rubber, tea and coffee are known as estate crops or the conventional plantation crops which are generally large plantations. This group of crops serve a variety of human needs not only as food, oil, and industrial raw materials but also pungency, aroma, and flavour to food, beverages, and confectionery items. Plantation crops generate considerable employment opportunities to millions of people during on-farm operations and off-farm processing activities.

Table 1 : Plantation crops - area and production [1995 - 1996]

Crop	INDIA Area ('000 ha)	INDIA Production ('000 tonnes)	INDIA'S Position in the world	EXPORT FROM INDIA Quantity ('000 t)	EXPORT FROM INDIA Value (Mil. Rupees)
Coconut	1795.5	13967.9*	Second	43.6**	1238
Arecanut	235.5	272.4	First	0.4	36.1
Cocoa	10.6	5.7	Very low	0.3	34.2
Oil palm	38.3	10.0	Very low	0.1	5.0
Cashew	635.0	418.0	First	80.5	12400
Small Cardamom	83.7	7.0	Second	0.4	84.7
Black pepper	179.6	55.4	Second	26.2	1963
Ginger	63.5	197.4	First	18.5	389
Turmeric	136.6	435.3	First	29.0	462
Tea	424.5	780.0	First	161.7	-
Coffee	293.1	223.0	Tenth	171.0	15270
Rubber	523.3	506.9	Fifth	0.2 $	7 $

* Coconut production in million nuts ** Coir and Coir product

$ For 1994 - 95

Among the plantation crops, cashew kernel export brings in the largest foreign exchange to a tune of US $ 362 million (during 1996-97). Similarly, spices also fetch large export earnings which are estimated at US $ 223.08 million.

Ginger and turmeric though annuals are also considered as plantation crops. India is the largest producer of arecanut, cashewnut, tea, pepper, ginger and turmeric and second largest producer of coconut and cardamom in the world. The overall trend in area and production of all these crops are positive and significant.

Constraints common to all plantation crops:

(i) Low productivity: Though India tops in production of coconut, rubber, arecanut, cashew, turmeric and ginger in the world map, the yield levels in some areas are lower than the possible potential yields (Table 2).

Table 2: Productivity levels of major plantation crops in India.

Crop	Unit	National average	Res. Station yield	Super potential yield
Coconut	nuts/palm	36	175	471
Arecanut	chali kg/palm	1	5	9
Black pepper	kg/ha	283	1100	13465
Cardamom	kg/ha	65	350	900
Cashew	kg/tree	4	16	125

(ii) Lack of adoption of technology: Though technologies are available, their adoption level is very low due to various reasons.

(iii) Fluctuations in prices: Changes in prices in global and domestic markets have caused positive and negative impacts on the industry. Marketing policy as in the case of coffee, vegetable oil import etc. contribute to these fluctuations.

iv) Perennial problems: These perennial crops always have perennial problems. Root (wilt) disease in coconut, yellow disease in arecanut, pepper wilt, ginger rhizome rot, leaf rot in coffee, Blister blight in tea etc., are some of the examples.

PRESENT SCENARIO

Coconut:

Coconut is a multipurpose palm serving the various human needs such as food, fibre, edible oil, feed, beverage, shelter etc,. Coconut plays an important role in the economic, social and cultural activities of the people of India. With an area of 1.80 million hectares and an annual production of 13,968 million nuts, India ranks second in the world map of coconut. The area under coconut was 0.63 million ha during 1950-51 and it increased to 1.80 million ha during 1995-96. The increase in production for the last ten years alone was about 119 per cent. In India, more than 91 per cent of the area under coconut is in the four southern states viz. Kerala, Tamil

Nadu, Karnataka and Andhra Pradesh sharing about 92 per cent of total production. The trend in productivity of coconut in India is characterised by ups and downs. The average productivity of 5,238 nuts during 1950-51 rose to 7,779 by 1995-96. It is estimated that the production of coconut by 2000 AD may reach 20,000 million nuts from an estimated area of 2.5 million ha.

Production and productivity of coconut in India is influenced by several factors. Diseases such as the dreaded root (wilt) of coconut is affecting its production and productivity. The estimated loss in yield due to root (wilt) disease is 968 million nuts. The productivity can be increased by planting high yielding hybrids and varieties released by CPCRI and State Agricultural Universities and providing irrigation facilities. There is ample scope for product diversification in the crop and area expansion is possible in non-traditional areas.

Arecanut:

India is the largest producer of arecanut in the World, and earns about Rs. 36 million annually by exporting arecanut in various forms. Since we are self sufficient the policy of the Government is not to encourage any expansion in area, but the growers are going in a big way for replanting with the high yielding varieties because of the existing attractive price of the produce.

Arecanut germplasm collection consists of 23 exotic accessions collected from 11 countries and 45 indigenous types. *Evaluation* of the germplasm has led to the release of four high yielding varieties, namely, Mangala, Sumangala, Sreemangala and Mohitnagar. These varieties yield upto 30 per cent over the local cultivars and have played a major role in achieving the self-sufficiency in arecanut production in the country. Yellow leaf disease is a most serious malady affecting arecanut productivity in Kerala and Karnataka.

Area and production of arecanut in India showed an increasing trend during the past 40 years. The area under arecanut in India was 0.106 million ha during 1955-56 which has increased to 0.236 million ha during 1995-96, an increase of 123 per cent over a period of 40 years. The production has increased from 0.081 million tonnes to 0.272 million tonnes (236 per cent increase). The productivity of arecanut remained almost constant from 1957 to 1974 with small ups and downs(around 850 kg/ha); and slightly increased thereafter during the next five years to around to 950 kg/ha, and reached the peak level of 1200 kg/ha during 1988-89. By 2002 AD the production of arecanut is estimated to exceed 3.7 lakh tonnes from an estimated area of 2.5 lakh ha.

Cashew:

It is one of the crops that is introduced for soil conservation purpose. It became a gold mine in wastelands. The constraints faced in cashew production are a) Planting in areas unsuitable for cultivation, b) Incidence of Tea-mosquito bug and c) Low productivity. Area expansion is possible in wastelands suitable for cashew. The National Cashew Gene Bank at NRCC, Puttur consist of 363 clonal accessions including 10 exotic accessions from Brazil and Mozambique. In addition, 1012 accessions mostly the local collections are maintained by the Coordinating Centres under the State Agricultural Universities. Germplasm evaluation has led to the release of 22 location specific selections in the country. In the Crop Improvement programme, 12 hybrids with the yield potential from 1.5 to 2 tonnes of raw nuts per ha were released.

Now India is the largest producer of cashew in the world and earns more than Rs. 12,400 million annually as foreign exchange. Between 1954-55 and 1995-96, the area and production of cashew exhibited a steady of 477 percent and 429 percent respectively. During the year 1955-56 the area under cashew was only 0.11 million ha. It has increased to 0.635 million ha in 1995-96 and the production rose from 0.79 to 4.18 lakh tons. Because of the Indian monopoly of cashew in world market and the ever increasing demand and high price for cashew, the State Governments of Kerala, Tamil Nadu, Andhra Pradesh, Karnataka, Maharashtra and Orissa have taken up large scale expansion programme under the Multistate Cashew Project. However Kerala continues to be the largest producing State in India with a contribution of 40 per cent.

The concerted efforts taken by Cashew Directorate, All India Coordinated Project for the improvement of cashew (established in 1972) and CPCRI, and National Research Centre for Cashew, helped in improving the productivity of Cashew. Evolving of high yielding varieties, standardization of vegetative propagation technique, increasing the availability of grafts for planting and better management practices have improved the productivity of cashew. With some of the varities released recently having an yield potential of 10 kg per tree by the 12th year, it would be possible for us to realise an yield of 2 ton/ha if the plants are well managed.

The price of Cashew kernel in the international market is always increasing and the demand is also showing an increasing trend. Hence the present high rate of expansion in area is likely to continue. Cashew production in India is estimated to reach 0.7 million tonnes from an estimated area of 0.7 million ha by 2000 AD.

Oil palm:

Oil palm was introduced into India in the 19th Century, but the actual cultivation was initiated only in 1960s by the Agriculture Department of Kerala. The first commercial planting of oil palm was taken up by the Oil Palm India Limited in 1971 and by the Andaman Forest Development Corporation in 1973. A boost in oil palm cultivation was given by the establishment of demonstration plots by the Department of Biotechnology and later by the effective development support by Technology Mission on Oil Seeds and Pulses. The present area of 39,413 hectars is targetted to increase to 80,000 ha by the end of the ninth plan. Andhra Pradesh, Karnataka and Tamil Nadu are the main states expected to take up oil palm cultivation.

It is possible to produce *dura x pisifera* combinations (*tenera*) with a potential production of 4.5 MT of oil/ha. Two such hybrids viz., Palode-1 and Palode-2 has been released. Simultaneously, efforts were also made to make available, planting material indigenously. Pollinating weevil (*Elaeidobtus kamerunicus*) was introduced to India during 1985 and this has resulted in increase of fruit set by 37 to 56 per cent and weight of FFB by 40 per cent.

The major problems faced by the oil palm growers are lack of procesing facilities near the plantations, non-availability of sufficient quality planting material and inadequate management practices. If these constraints are removed, this crop can play a vital role in solving our edible oil problem.

Cocoa:

India produces about 5700 tonnes of cocoa beans from an area of 10600 ha.and earns about Rs. 34 million as foreign exchange. It is largely grown as a mixed crop in areca and coconut gardens. The area under cocoa was showing a negative growth since the year 1983-84. The area under cocoa during 1983-84 was 22,230 ha. and it has come down to 10,600 ha during 1995-96, whereas the production was fluctuating between 56,100 to 77,100 kg. By 2000 AD, the national requirement of Cocoa is projected as 14,000 tonnes.

The productivity of Cocoa is on the increasing trend. The negative trend in area under cocoa is mainly due to the lack of interest of the farmers because of severe price fluctuation and unrenumerative price. The marketing of cocoa is controlled by a handful of big companies who preferred to import cocoa at lower rates rather than supporting the Indian growers.

Problems faced by the cocoa growers are inadequate collection points and processing facilities, fluctuation in prices, vertebrate pest problems and lack of availability of grafts for planting. Remedial measures are now attempted to remove these constraints.

Spices:

(i) Black Pepper:

India is the largest producer of black pepper in the world with an annual production of about 0.055 million tonnes from an area of 0.180 million ha. The country earned about Rs. 1963 million as foreign exchange during the year 1995-96. The area *under pepper in India which was only 80,000* ha during 1950-51 has increased to 1,80,000 ha during 1995-96. During the sixties, seventies and upto the middle of eighties the area expansion was negligible with ups and downs. However, after 1985 this was considerable and between 1983-84 and 1995-96 there was an increase of 80 per cent.

The production of pepper in India increased from 21,000 tonnes during 1950-51 to 55,190 tonnes during 1989-90. During the past 15 years i.e. from 1983 to 1995, the increase in production was around 156 percent.

The productivity of pepper was stagnant within the range of 250-300 kg /ha with occasional ups and downs during the past 45 years. The positive trend in area as well as production is likely to continue as the demand is high in the International market. By 2000 AD pepper production is expected to reach one lakh tonnes from an estimated area of about 3 lakh ha. India has the largest germplasm accession of black pepper comprising of 2776 cultivated as well as wild accessions. Evaluation of the germplasm led to the release of six varieties and two hybrids viz., Panniyur-1 and Panniyur-4.

(ii) Cardamom:

India is the second largest producer of small cardamom only next to Guatemala. The country produce 7000 tonnes of cardamom from an area of 83,650 ha. India earned a foreign exchange of about Rs. 84.7 million during 1995-96. This crop is grown in the high ranges of the Western ghats. The expansion of area under cardamom was only 67 percent over the 40 years, indicating that there is not much scope for further expansion because of specific agroclimatic requirements of the crop. The area under cardamom in

India which was only 50,000 ha during 1955-56, increased to 83,650 during 1995-96. The production of cardamom is characterised with an overall increasing trend with almost stagnant production for few years with ups and downs. The trend in productivity was highly fluctuating, from 17 to 84 kg/ha without showing any regular trend. The increasing trend in area as well as production is likely to continue. Though the scope for area expansion is limited, there is scope for increasing the productivity. Five varieties of cardamom with high yield potential have been released so far.

(iii) Ginger:

India tops the world in the production of ginger, producing about 1.97 lakh tonnes from an area of 63,500 ha, and has earned a foreign exchange of Rs. 462 million in 1995-96. Ginger being an annual crop with high export potential, its cultivation depends on its price and demand. Again, it is primarily a rainfed crop and the distribution of rainfall in the cultivated areas also influences the production/productivity. Between 1973-74 to 1995-96, the area under Ginger has increased by about 173 percent.

The production remained around 15,000 tonnes from 1950-51 to 1963-64 with ups and downs and later increased gradually. The production reached the peak level of during 1995-96. The increase in production from 1982-83 to 1995-96 was over 100 percent. The productivity of ginger was found to be highly fluctuating around 1000 kg or below from the year 1950-51 to 1969-70, there after it was showing an upward trend from 952 kg/ha during 1967 to 2996 kg during the year 1995. The productivity of ginger has tripled during the nineties as compared to fifties and sixties.

Turmeric:

India continues to be the largest producer of turmeric producing about 4.35 lakh tonnes of turmeric from an area of 1.37 lakh ha, and earns about Rs 389 million annually. Turmeric being an annual crop with a large export share, its cultivation mainly depends upon the price fluctuation in the domestic and international market. The area under turmeric remained around 55,000 ha with little variation from 1950 to 1962, but there after it was increasing and reached 1,36,600 during 1995-96. The production was found fluctuating without substantial improvement from 1950-51 to 1978-79 and there after it was increasing and reached 4,35,300 tonnes during 1995-96. However the productivity has not improved much and it is less than 2000 kg/ha.

In turmeric the germplasm evaluation led to the release of 13 accessions, namely, Co-1, Krishna, Sugandham, BSR-1, Suvarna, Rome, Suroma, Rajendra Sonia, Sugana, Sudarshana, Ranga, Ranga, Rasmi, Prabha, Prathiba, Mega Turmeric and RCT-1. Some of these have the yield potential of upto 44 tonnes of fresh rhizomes per ha. Tissue culture protocols were standardised for multiplication.

Coffee:

The area under coffee was showing an increasing trend since fifties. The area which was only 92,520 ha during 1950 increased to 2,93,000 ha during 1996. The annual coffee production is about 0.18 million tonnes and the country earned Rs. 15270 million during 1995-96 as foreign exchange. The coffee production in general exhibited an increasing trend and it increased to 2,23,000 tonnes during 1996.

The productivity of coffee which was only 275 kg/ha during 1950-51 exhibited fluctuating trend and reached 760 kg/ha during 1995-96. The Coffee Board has envisaged a production target of 3 lakh tonnes by the end of IX Plan with annual growth rate of 7.5 per cent.

Tea:

India leads the world in tea production. The annual production of tea is about 7,80,000 tonnes from an area of about 0.4 million hectares. The average productivity is about 1790 kg/ha.

For tea, the scope for the expansion of area is very limited. The production may reach 0.95 million tonnes by 2000 AD, through increasing in productivity and target of 1.64 million tonnes of tea is fixed for 2025 AD.

Rubber:

The area and production of rubber were showing an increasing trend. The area was only 59,000 ha during the year 1950-51 had increased to 52,330 ha million during 1995-96, about 34 fold increase over a period of 45 years. During the same period, the production has increased from 0.01 million tonnes to 0.51 million tonnes and the country is self sufficient to meet its domestic requirement. The impressive growth rate in the area and production of rubber is the result of large scale expansion programme implemented by the Rubber Board by way of incentives and subsidies for new planting as well as for replanting with improved clones, supply of planting materials of high yielding varieties and popularizing better plant protection methods.

The productivity of rubber which was only 237 kg/ha during 1950-51 increased to 966 kg/ha during 1995-96. The estimated production of rubber will be around 7 lakh tonnes from an area of 6 lakh ha by 2000 AD and 9.5 lakh tonnes from an area of 7 lakh ha by 2011 AD.

CONCLUSION

While there is no doubt on the economic significance of plantation crops, one cannot set aside the problems faced by the industry in the present context. The major problems to reckon with is the fierce competition in the international market arising out of the policies relating to WTO agreement. Kenya in tea, Brazil in coffee and pepper, Gautemala in cardamom, several African countries in cashew and South East Asian countries in pepper, coconut and oilpalm have been our stiff competitors. The available technology has to be therefore used to attain high levels of production efficiency. Since our agriculture largely depends upon monsoons, a large proportion of the produce continues to be produced under stress conditions. This makes it imperative to evolve varieties which can tolerate biotic and abiotic stresses. Other important aspects in plantation crops are conscious efforts to increase the quality of end products, product diversification and value addition.

REFERENCES

Anonymous (1991). Coconut Root(wilt) Disease : Technical Bulletin No:3, CPCRI, Kasaragod.

Anonymous (1992). Annual Report. CPCRI, Kasaragod. p 104

Das PK (1985). Trends in coconut oil production and trade in the World. *Ole'agineux*, 40(2)

George MV (1997). Status of plantation crops in India. J. *Plantation crops*. 25 (1): 1-14.

George MV, Rawther, TSS and Nayar NM (1984). Incidence of Yellow Leaf Disease of Arecanut in Kerala and Karnataka. India *Cocoa, Arecanut & Spices Journal*. 8(2) : 24-28.

George MV, Thommen KJ and Sukumaran AS (1985). Crop losses due to root(wilt) and leafrot disease affected areas in Kerala, South India. *Indian Coconut* J. 15(9): 3-9.

Menon, KPV and Pandalai, KM (1960). Coconut Monograph

Thampan PK (1989). Coconut Industry in India. APCC, Jakkartha, Indonesia. p 133.

PRODUCE AND PRODUCTS OF PLANTATION CROPS

V. Rajagopal

INTRODUCTION

India is endowed by Mother Earth with a wide range of plantation crops, which serve as the source for diversified products of commercial importance. The crops that come under plantation category represent oil yielders (coconut, oil palm), condiments and spices (cashewnuts, pepper, cardamom, ginger, turmeric, cinnamon), beverages (cocoa, coffee, tea), masticatory (arecanut) and of industrial nature (rubber). As foreign exchange earners most of these crops have great potential at the international market and India ranks first in some of the products in the world trade. Biodiversity of plantation crops are evident in view of the varied agroecological conditions under which they grow in this country. While the area, production and productivity of some of the crops increased over the last five decades, there was late realization of the utilization of products obtained from these crops. With the emphasis being given now in the Indian Agriculture on value added products, the role of post-harvest technology has gained utmost significance.

It has been estimated that there is considerable loss in many of the agricultural products after harvest. This is either because the post-harvest technology has not been developed to the desired extent in some crops or the problems in marketing of produce or both. In the present context, the stress is more not only on the development of techniques to preserve the harvested products but also on identifying and refining the techniques to add value to the products. The objective, therefore, is to enhance the consumer acceptability of the products through improved technologies.

COCONUT

Coconut plays a pivotal role in the socio-economic scenario of Kerala, as it provides employment potential with many industries based on various products. Almost all parts of coconut are useful both for domestic purposes and in industrial units. Thus, the crop is often referred as Kalpa vrikshaí. From the utilization point of view coconut products can be grouped under three categories: (1) Food products, (2) Non - food products and (3) Miscellaneous products.

(1) Food products

a) Wet meat or kernel : The kernel of 7 to 8 month old nuts is consumed either as such or along with sweet tender nut water. At this stage the kernel will be very soft, rich in protein and sugars. In riped kernels of 11 to 12 month old nuts, the chemical constituents show marked changes. In the households, fresh kernel is used in the grated form and in the form of milk or cream obtained by squeezing the gratings with or without addition of water. Processed forms of kernel and milk find applications in the food industry.

(i) Coconut milk (CM) : It is an emulsion of oil in water into which some of the soluble components of the meat has passed. Apart from culinary uses, CM is used as a substitute of dairy cream in beverage type milk, as evaporated and condensed milk in the preservation of soft white cheese, yoghurt and many other food stuffs. Preserved forms of milk such as canned cream milk (40% fat) or whole milk (12.5% fat) are available in markets with high consumer acceptability.

(ii) Coconut jam (CJ) and coconut syrup (CS) : CJ and CS are essentially prepared using whole coconut milk, with different extraction and mixing procedures. The CS with 44.5% soluble solids, which gives a delicious instant milk white drink, is an excellent bread spread and can be used for confectionery purposes.

(iii) Coconut skim milk (CSM) : It is a good source of quality soluble protein for the preparation of many useful allied food products or as supplemental protein source in places where animal protein is deficient.

(iv) Coconut flour (CF) : During the processing of coconut cream and other related products, the fibrous residue obtained after expelling the milk is dried and powdered to obtain CF. Nutritionally CF compares favourably with most of the common seed flours.

(v) Desiccated coconut (DC) : DC is the white kernel comminuted and desiccated to a moisture content of less than 3%. The common grades of DC have particle size of less than 5mm. It is an important commercial product with world wide demand in the confectionery and other industries, as one of the main subsidiary ingredient of filling for chocolates, candies and liquorice.

b) Coconut water : Water from 6 to 7 month old nut is a refreshing drink, effective in cases of gastero enteritis etc. It is a rich source of B vitamins, minerals, sugars etc. Though less nutritious, mature coconut water is the main source for products like Nata de coço, a gelatinous substance, soft drink, coconut vinegar, food yeast, edible mushroom etc. In addition, coconut water can also be used as rubber coagulant to obtain good quality rubber.

c) Coconut toddy : Toddy is obtained by tapping the unopened spadix of coconut palm. Fresh toddy obtained on tapping is rich in sugar and vitamins, while on fermentation the composition differs. Unfermented toddy is a good source of coconut jaggery with high percentage of sugar (88.3 %), whereas fermented toddy is used extensively to produce coconut vinegar and treacle. Arrack is obtained by distilling fermented toddy, while double distillation of toddy gives coconut feni.

d) Dry kernel or copra : The dried coconut endosperm is called copra, with the richest source of fat (65 to 70 %). Two types of copra are: edible copra and milling copra. Edible copra is available as ball copra (fully matured whole unsplit nuts) and as cup copra (matured split copra). The quality of milling copra ultimately determines the quality of oil and the residual cake.

(i) Coconut oil : It is extracted from copra with appropriate devices. The oil is referred as lauric oil in the world market for oil seeds, oils and fats because of its high lauric acid content. Coconut oil is rich in saturated fatty acids, mainly lauric and myristic acids. When compared with other leading vegetable oils, coconut oil is low in unsaturated and polyunsaturated acids, particularly linoleic acid. The quality of the oil depends not only on the quality of copra, but also on storage conditions of copra before milling, as well as storage of oil after extraction.

(ii) Coconut cake : The cake left after extraction of coconut oil from copra is a valuable cattle feed rich in fat.

2) Non - food products

Among the non - food products of coconut, coir or coconut fibre, coconut pith and shell assume commercial importance, other parts being wood and leaves.

(i) Coconut husk (CH) : The husk usually forms 25 to 45 % of the weight of whole ripe nut. When the nuts mature, the quantity of the fibre does not decrease but it is the moisture in the fibrous mass of the husk which disappears. The thickness of husk varies from 2.5 to 3 cm in thin husked nuts to 4 to 5 cm in thick husked nuts. Coir fibre and coir pith are the products derived from coconut husk.

The husk of an average coconut weighs about 0.4 kg, of which 30% constitutes coir fibre and the balance 70% is pith and outer skin. Two types of fibres are white and brown. Lignin and cellulose are the major constituents of pure fibre. Coir pith is a waste product of coconut industry. It can be used for conservation of soil moisture, as a manure and also as a source of furfural, oxalic acid and gypsum. Pith can be added as a substitute in biogas generation and also power gas in industrial engines. Many commercial products like hard boards, insulators, expansion joint fittings can be prepared from coir pith.

(ii) Coconut shell (CS) : It is the endocarp of coconut with major use as a fuel. It is also used to make various domestic utensils, curios, fancy items etc. The commercial importance of CS lies mainly in the production of shell charcoal, activated carbon and shell flour. Activated carbon is extensively used as agents for purifying, refining and bleaching of volatile oils and chemical solution. It is also in demand as an adsorbant of gases. Coconut shell flour is used in the production of glues in plywood industry and as a substitute for bunker oil in boiler operations.

3) Miscellaneous products

Coconut wood is currently a substitute for conventional wood. Extensive processing is involved in making the wood durable for construction purposes. The plaited and unplaited leaves of coconut are used for thatching, fencing and making baskets.

OIL PALM

In oil palm, the main produce is the fresh fruit bunch varying in shape and weight. The products of commercial value are kernel oil and mesocarp oil, differing in chemical composition. Chemical composition of palm kernel oil is similar to coconut oil and is grouped under lauric acid oils. Unprocessed palm oil is rich in carotenes, vitamin E, sterols, etc., while in refined palm oil carotenoids are absent. Because of the presence of vitamin E it is a nutritionally important oil.

ARECANUT

In arecanut, the major produces are green nut and dry nut which differ in their composition. The nuts are mainly used for masticating purposes, besides religious and social occasions. The products of arecanut have alternate uses with the potential for establishing small scale industries.

(i) Arecolin, tannins and fats : Among the alkaloids present in arecanut, arecolin ($C_7H_{13}O_2N$) is the main active compound, other minor alkaloids being arecaidine, guvacoline and guvacine. Tannins in arecanut are used for dyeing clothes, ropes, etc. These are byproducts obtained from the process of preparing immature nuts for masticatory purposes. Areca fat (8 to 12 %) has comparable characteristics with hydrogenated coconut oil. Arecanut fat is used for certain confectionery purposes, along with cocoa butter.

(ii) Arecanut husk : It is used as a cheap fuel and mulch. In Indonesia and Philippines arecanut is used for tooth brushes . It can also be used for the manufacture of thick boards fluffy cushions and non - woven fabrics. Insulation and hardboards of satisfactory quality are also prepared from areca husk. Activated charcoal and xylose can also be produced from areca husk. Other uses of areca husk are fibre and plastic boards, soft cushion pads, etc. Possibilities also exist to use areca husk as manure.

(iii) Leaf sheath : Leaf sheath with its high cellulose content and crude fibre makes a flexible and pliable material for heat moulding. From leaf sheath, domestic items like cups, plates and head caps are prepared. It is also used in manufacturing plyboards, veneer boards, picture mounts, decorative panels, tea poys, file boards, bags, etc.

(iv) Stem and leaf : Due to its hardness the areca stem is used as building material, poles, rulers, shelves, nails, etc. Hollow stem can be used as drainage and irrigation pipes. Areca leaves are a good source of organic manure. They are mostly used for thatching purposes.

CASHEWNUT

The hard kidney shaped nut of cashew fruit is the raw material for cashewnut. The cashew kernel is a nutritious dry nut rich in unsaturated fat (47%), protein (21%), and carbohydrates (22%). The important byproducts of cashewnut are cashewnut shell liquid and cashew apple.

(i) Cashewnut shell liquid (CNSL) : It has wide application in many industries. Anacardic acid (90%) and carol (10%) are the constituents useful as industrial raw material for manufacture of lacquer and varnishes, CNSL and its derivatives are used in the preparation of antioxidants and lubricants. The cashewnut shell gum can be used as thickening agent for ice cream, binder for tablets in pharmaceuticals and as a drilling mud in mining industry.

(ii) Cashew apple : Cashew apple is a juicy fruit rich in carbohydrates, vitamin C, etc. It contains astringent and acrid principles. Conversion of fruits to value added edible products has been undertaken by industries. The products are clarified and cloudy apple juice, blended juice beverages, cashew apple juice concentrate, candy, jam, pickles, chutney etc. The areas of commercial importance are blended juices, mixed jam and feni.

SPICES

(i) Pepper : Pepper is generally referred as the king of spices. The significant quality aspects of pepper are the pungency attributed to the piperine and aroma to pepper oil. There is a wide range of value added products in pepper, which are in great demand in international market. The products are dehydrated green pepper, freeze dried green pepper, frozen green pepper, white pepper, green pepper in brine, pepper oil, pepper oleoresin, organic pepper, sterile pepper and canned tender green pepper.

(ii) Cardamom : There are two types of cardamom generally referred as small cardamom and large cardamom. Like pepper, this also is a spice crop of commercial importance and export potential. Green cardamom, cardamom oil and cardamom oleoresin are the products of this crop.

(iii) Ginger : It is a crop with medicinal value. The fresh produce has culinary importance, while multipurpose uses exist for the value added products. The products include ginger oil, oleoresin, candy, plain and vitaminized effervescent ginger powder, starch from spent ginger, ginger brandy, vine, beer, medicinal beverages, encapsulated ginger oil and dehydrated ginger.

(iv) Turmeric: Like ginger, turmeric also has medicinal value. Byproducts of importance are dehydrated turmeric powder, oil, oleoresin, and curcuminoids.

COFFEE

Coffee is the most widely exchanged commodity in the international trade scenario. Coffee berries and coffee seeds are the produce from the crop. For attaining aroma and taste many processes are involved in coffee industry. The important products are roasted coffee powder, soluble coffee, coffee brew concentrate, decaffeine coffee, monsoon coffee, carbonated coffee, flavoured coffee, coffee-chicory mix. The refined process technology adds much value to these products and attract consumer acceptability.

TEA

Internationally acclaimed to be of the best quality, tea in India has well established estates and processing industries with quality control. Green leaf is the main produce, whereas the products of fermentation processing are black tea and oolong tea. The former is fully fermented and the latter is produced as a result of partial fermentation. The most popular value added product is instant tea, a water soluble product of black tea.

COCOA

It is an intercrop in coconut and arecanut gardens. The crop produces pods with cocoa beans as the main economic component. The major products from the beans are cocoa powder, cocoa butter and chocolate. (i) Cocoa powder: This is obtained by milling and sieving the cake, which is a resultant product after pressing the beans through various processes. (ii) Cocoa butter: It is another byproduct of beans after the processes of roasting and grinding and subjecting the liquor to hydraulic press . (iii) Plain chocolate: This is obtained by mixing the mass with sugar and grinding and coching .

DRY MATTER PRODUCTION IN PLANTATION CROPS

K.V.Kasturi Bai

INTRODUCTION

Plantation crops provide the basic requirements of human being such as food, shelter, beverages and industrial raw material. Crop yield is defined as the weight per unit area of the harvested produce or of a specific part of it and is influenced by several internal and external factors. The partitioning of Dry Matter (DM) towards economically important part is known as Harvest Index (HI). This means that HI= Economic yield/Total biological yield or total dry matter production i.e., the proportion of total DM to the economic yield is HI. Hence understanding of dry matter production (DM) and partitioning is very important for the evaluation of the production potential of any crop. Being perennial in nature, studies on DM production have been very limited in plantation crops. DM production depends on management practices, climatic variables and soil conditions. However, yield in addition to these is influenced by several other internal and external factors.

MEASUREMENT OF DRY MATTER PRODUCTION

Methods employed for the estimation of DM production of crop plants include (1) CO_2 exchange measurements in the field. (2) Growth measurements. The former requires sophisticated equipments for the measurements and various instruments are available in the market for the same. While the latter requires only some morphological measurements of the crop plants in use such as height, girth, leaf production etc. which do not require costly equipments. But the second one is more laborious because large number of plants have to be destructively analysed for getting accurate results. Genetic variability, management practices employed in various places, climatic conditions etc. pose other problems for getting comparable results.

These problems have been tackled to certain extent by innovating suitable methods to the specific location and crop. Non-destructive methods by employing regression equations as well as crop modelling pertaining to the situations have helped in solving the problems and the results are on par with the results obtained with other methods.

DM production:

In coconut non-destructive methods are employed to calculate DM production in the seedlings as well as in adult palms. The DM production of the seedlings ranged between 70 and 130 g whereas in the adult palms it ranged from 70 - 100 kg. palm^{-1} year^{-1}. Genotypic variations are also found in the partition of total DM towards vegetative and reproductive growth. In the adult palms, variation in nut composition i.e in the partition of the nut dry matter towards its components viz; husk, shell and copra content are also seen. The nut DM partitioning is in the range of 40 - 53% in the husk, 22 - 27% in the shell whereas in copra it ranged between 27 and 35%. Between the selected cultivars/hybrids for example in Laksha Ganga, DM partitioning towards husk is found to be higher (53%) while in Chandra Sankara it is only 40%. However the partitioning towards shell and copra is found to be higher in the former than in latter.

Regression equations have been developed in other crops also for the non-destrutive estimation of DM production. In oil palm, DM production ranged from 15 to 40 $t.ha^{-1}$ in well managed plantations. This has been attributed to the variation in the interception and conversion efficiency of solar radiation (Corley, 1983). In case of rubber the process of exploitation and extraction of latex limits DM production to the extend of 10 to 60%. This is mainly due to the fact that rubber production involves partitioning of assimilates and too much draining of metabolic energy. Templeton (1969) reported that Rubber trees produce 26 to 36 $t.ha^{-1}$. DM in a year when untapped whereas tapping reduced the DM production to 15- 20 $t.ha^{-1}$. The latex yield of rubber is observed to be 1 to 4 $t.ha^{-1}.yr^{-1}$.

In tea, the tender leaves are the economic produce and the growing buds are the strongest sinks, and the canopy maintenance foliage acts as source of carbohydrates to these growing portions. Hence only 34 - 46% of DM produced remain in a plucked tea bush and the rest are lost in respiration. Pruning alone account for more than 90% of the loss (Barua, 1987). Mugambo and Cannell (1981) reported about 35% reduction in the DM production of plucked tea bush as compared to unplucked bush.

In most of the crops the harvested product include some waste material such as husk, shell, bunch stalk, leaves, bark portion etc. along with the economic products such as copra, oil, latex and tea leaves. These waste products are used as fuel, activated carbon, biofertilizers etc.

CONSTRAINTS IN THE DM PRODUCTION

Problem encountered in DM production studies is the long life span of the tree crops. In tree crops the entire life span is divided into three stages: 1) Juvenile period, 2) reproductive period and 3) senescence. During the juvenile period a high proportion of the DM produced are diverted towards the vegetative growth. Similarly during reproductive stage for higher productivity a large portion has to be transported towards flowering and fruiting and finally during senescence there is a decline in the partition towards reproductive growth. Hence, DM production and partition in other words source- sink relationship is an important tool for understanding the productivity of the crops. There is no plasticity in DM production in these crops. This means that when assimilates are limiting, the vegetative sink has priority over reproductive sink.

In most of the perennial crops DM production refers to the tissues above ground level. In oil palm the total root biomass is estimated to be only 3 - 5% of the annual DM production.

FACTORS AFFECTING DM PRODUCTION

Agro-climatic conditions, source-sink relationship, light interception efficiency, Leaf Area Index (LAI), photosynthetic efficiency, respiration rates, leaf longevity and Harvest Index influence the DM production. The wide gap observed in the yield realization can be attributed to the above factors.

In tree crops, sink is not found to be a limiting factor for productivity. In annuals such as wheat, rice, etc. where the growth is determinate, the ear is the major sink for DM. However, in perennial crops where the growth habit is indeterminate competition for assimilate between vegetative and reproductive parts even after flowering results in source limitation. Maximum crop productivity depends on the light use efficiency which is related to Leaf Area Index. In oil palm Corley (1976) reported high DM production with a LAI between 8 and 10. But an LAI of four only has been achieved due to the removal of leaves during harvest. In coconut an LAI ranging between 4 and 5 has been obtained. Genotypic differences have been observed in this parameter.

The harvested product has a much greater energy content. Westlake, (1963) reported that energy content of 40, 25, 24 and 19 kJ g-1 for lipids and rubber, lignin, protein and other materials respectively. By knowing the energy content of the harvested products the photosynthetic efficiency can be calculated. For oil palm the photosynthetic efficiency i.e. the ratio of chemical energy of DM formed to the light energy absorbed is about 2.1% which is nearer to the values observed for rubber (2.8%). However, the theoretical maximum value for photosynthetic efficiency is more than 22% of the absorbed energy. But for most of the agricultural crops a value of 2 - 4% only is obtained.

In perennial crops the potential energy fixation is estimated as 1.2 $T.J.ha^{-1}.yr^{-1}$. In tropical crops it is reported that 50% of the photosynthetic production is lost through respiration, but in perennial crops it is 75 %. This is mainly due to the long life span of the leaves which require maintenance of more supporting structures. Estimates of gross or net productivity for perennial tree crops are few because of the high respiratory loss of the DM produced. For tea, the respiratory loss is estimated to be 85% and for oilpalm it is 80% (Corley, 1976). A coconut canopy with high conversion efficiency would yield 51 $t.ha^{-1}.yr^{-1}$ of DM, but the highest value realised is only 31 $t.ha^{-1}.yr^{-1}$. However at Kasaragod condition the highest value recorded is only 17 $t.ha^{-1}.yr^{-1}$. This can be attributed to the lower conversion efficiency of the intercepted radiation.

From the above, it is clear that there is a wide gap in the yield realisation thus showing the potential is not being fully exploited. The main reason for this is the field crops are rarely exposed to the ideal micro climate which would enable the plant to reach its maximum potential. A complete understanding of the crop plant at the whole plant level would only help to solve this problem. This can be achieved only by evolving plant ideotypes through breeding and biotechnological approaches.

In the days of energy shortage the worth of palms like coconut as energy source deserves consideration. The energy contained in the harvest of over 12 billion nuts is equal to $31x10^{-12}$ K.calories. Considering only the energy in the husk and shell this is equivalent to 3.8 billion litres of gasoline. In Phillipines, one of the most important potential source of fuel from plants is coconut oil. Efforts are being made for producing a variety of renewable energy resources such as gas, ethanol and electricity from these tree crops.

REFERENCES

Barua DN (1987). Tea. In *Tree Crop Physiology*. (Eds) MR Sethuraj and AS Raghavendra. Elsevier, Amsterdam. pp. 225-246.

Corley RHV (1978). Photosynthesis and productivity. In. *Oil Palm Research* (Eds.) RHV Corley, JJ Hardon and BJ Wood. Elsevier, Amsterdam. pp. 55-76.

Corley RHV (1983). Photosynthesis and age of oil palm leaves. *Photosynthetica* 17: 97-100.

Mugambo MJS and Cannell MGR (1981). Dry Matter production and partition in relation to yield of tea. *Exp. Agric.* 17: 33-38.

Templeton JK (1969). Partition of assimilates. *J. Rubb. Res.Instt.* Malaya. 21:259-262.

Westlake DF (1963). Comparison of plant productivity. *Biol. Rev.* 38: 385-425.

POST HARVEST TECHNOLOGY OF COCONUT

K. Madhavan

INTRODUCTION

Coconut is an important source of vegetable oil used for both edible and industrial applications. It is estimated that nearly 50% of coconut in India are consumed raw, while the remaining quantity is converted as copra to obtain coconut oil. Coconut meat (kernel), the endosperm of the fruit contains carbohydrate 20%, fat 36% and protein 4% at moisture content of 50%. Coconut oil can be extracted either from fresh kernel or from dried kernel known as copra.

A number of products are derived from coconut and among them copra is the major one.When milled copra yields coconut oil which is extensively used for edible and cosmetic purposes, copra cake is a valuable animal feed. Other products from coconut are the desiccated coconut, coconut cream, coconut milk powder, shell powder, activated carbon etc..

HARVESTING

Coconuts are harvested at varying intervals in a year. The frequency differs in different areas depending upon the yield of the trees. In the West Coast of India, nuts are harvested 6 to 12 times in a year. In well maintained and high yielding gardens, bunches are produced regularly and harvesting is done once in a month. In poor plantations there may be only six harvest in a year. In places where husks are used for retting, 10 to 12 harvests in a year are common in order to obtain husks in a perfect condition. Coconuts become mature in about 12 months. It is the ripe nuts which is the source of major coconut products. Nuts which are 11 months old give fibre of good quality and can be harvested in the tracts where green husks are required for the manufacture of coir fibre.

STORAGE AND SEASONING

It is a common practice to store or season the harvested nuts before they are further processed. The advantages of this procedure are (1) decrease in moisture content (2) increase in thickness of copra (3) increase in oil content (4) greater meat resistance to bacterial sliming while sun drying (5) easier husking (6) cleaner and easier shelling (7) and uniform quality of copra.

HUSKING

Traditionally husking is done manually by skilled workers with the aid of an iron spike driven to the ground. The work calls for skill and is strenuous. There has been long felt need for developing mechanical devices for husking coconut. CPCRI has developed a manually operated coconut dehusker. It consists of fixed and movable sets of blades to pierce and split the husks into three parts. The dehusker can husk 110 nuts per hour. Later CPCRI has developed a power operated dehusker which can dehusk about 600 nuts per hour. The dehusker developed by Agricultural Engineering College, Thavanur (KAU) is very handy and is being used widely.

COPRA DRYING

Fresh coconut meat contains 50 -55% moisture which is to be brought down to 5 - 6% by drying. Drying must be carried out within 4 hours of splitting since coconut meat deteriorates very rapidly due to growth of mould and bacteria. Microbial activity in the form of slime is seen if temperature is 30°C and relative humidity around 80%. The surface shine continues to develop and within 48hrs penetrating mould appears (Nathaneal, 1968). Microbial activity is reported to be more when the moisture is above 20 % (Nair, 1984). The methods generally used for drying of copra are (1) solar drying, (2) smoke drying or kiln drying and (3) indirect hot air drying.

Sun Drying: The conventional system of copra drying is by spreading the cups on any open surface for sun drying. This operation takes about 8 days and quality deterioration due to deposition of dirt and dust of wet meat is nearly unavoidable. Again if atmosphere is cloudy and temperature goes down during the initial days of drying, the copra will get infested with mould.

Solar Dryer: The drying time can be reduced to 3-4 days if proper solar dryers are used. If the dryer is an enclosed type, quality deterioration due to deposition of dirt can be avoided. A batch type solar cabinet dryer developed at CPCRI takes only 3 days for drying (Singh et. al., 1982, Patil, 1984). Solar dryers are classified based on the following criteria: 1) Whether or not the drying commodity is exposed to insolation; 2) The mode of air flow through the dryer; 3) The temperature of the air circulated to the drying chamber. Accordingly, solar dryers can be termed as either direct or indirect. Direct dryers are those in which the copra is exposed to the sun and in indirect dryers it is placed in an enclosed drying chamber and thereby shielded from insolation. In direct drying chambers heat transfer to the drying copra is by convection or radiation and so the rate of drying is greater than that for indirect dryers.

Due to considerable capital investment and high rate of fuel used it is considered earlier that indirect dryers are economical only in large scale. Hence the earlier reported dryers such as Samoa dryer, Camaro dryer, New College copra dryer, Iron hot table dryer, Tonga hot air dryer (Grimwood, 1975) are having larger capacity. But in CPCRI, an indirect type copra dryer of 400 nuts per batch capacity using agricultural waste as fuel is developed. It consists of a drying chamber, plenum chamber, burning cum heat exchanging unit and a butterfly valve to control the rate of combustion and also the drying air temperature. The dryer requires only 3m^2 area for housing and could be carried by 2-3 persons. The drying time required per batch is 36 hours spread over 4 days (Patil, 1984). So far, more than 100 units of this dryer have been sold to various copra makers and they are satisfied with its performance. This dryer is further scaled up and suitably modified at CPCRI to raise its capacity to 3500 to 4000 nuts and is suitable for copra processing societies and for large holdings.

An electrically operated dryer with forced hot air circulation is also developed at CPCRI to dry 1000 coconuts per batch. It consists of 6 nos. of 1 KW strip heaters and a blower. The drying time taken is about 28 hrs.

Copra Moisture Meter: The Indian central coconut committee had prepared standards for grading copra. The grading is mainly based on moisture content (Table 1).

Table 1. Grading of copra as per moisture content.

Description	Approx. moisture content (%)
Wet coconut meat, fresh coconut kernel	50
Wet or half dried copra	20 - 30
Mixed copra, undried copra	10 - 20
Fairly dry copra	8 - 10
Commercially dry copra	6 - 8
Well dried copra	5 - 7
Warehouse dried copra	5 - 6

The optimum level of moisture for safe storage of copra is recommended as 6%. In the field, moisture content of copra is often estimated subjectively by the texture of copra or by seeing its inflammability. This method is only approximate. To estimate the moisture content in a scientific and accurate way, CPCRI has developed a moisture meter which works on the principle of electric conductivity. It is calibrated to read the moisture content from 5% to 40% so that the moisture at the different stages of drying can be found out. This moisture meter is being used by various agencies in Kerala as a quality testing instrument in their copra procurement programmes.

Chemical Treatment to Wet Kernel: Preservation of fresh kernel becomes essential when drying is delayed due to uncertainty in weather conditions. Sreemulanathan et. al. (1979) reported that application of thin coat of glacial acetic acid prevented microbial growth during open sundrying. A chemical treatment of dipping fresh kernels in 1000 ppm propionic acid for 60 min. to preserve it upto 4 days without further drying has been developed at CPCRI. This is found to be useful and simple to overcome the spoilage of kernel due to sudden onset of inclement weather.

Copra Storage: The safe moisture level of 5-6% cannot be maintained in copra if stored under conditions of high relative humidity and wide fluctuating temperature. The wet copra should not be mixed with dry copra and the storage structure should be such that there is minimum fluctuation in temperature compared to ambient to avoid. moisture migration effects in the structure. Studies conducted at CPCRI has shown that copra can be safely stored if kept in saturated atmosphere of either neem leaf gas, bio gas or SO_2. Painting of roof with mat white reflective paint has been reported to reduce temperature fluctuations within 10°C, thus preventing serious condensation effect.

The walls should be provided with sufficient number of adjustable ventilators. The floor of the structure should be water proof, smooth and easy for cleaning. The cracks and crevices in the structure must be regularly cleaned and filled in with mortar so as to eliminate residual population of insects. If the commodity is bagged, it should never be stored directly against the wall, and should be provided with proper dunnage. Marar and Padmanabhan (1960) reported that copra could be safely stored in plastic lined gunny bags even during rainy season.

EXTRACTION OF OIL

In rural areas copra is crushed in the primitive 'chakku' driven by bullocks. The power driven chakkus or rotaries are used in larger establishments and are driven by steam, diesel or electricity. In the organised sector, copra is crushed by expellers. A double crushing unit gives better extraction and hence series of expellers are preferred. The clean copra is passed to disintegrator, where it is converted into a coarse meal. The meal is heated in the cooker by steam up to 88°C. The pulped copra is fed continuously to the expeller from which the oil and the cake are forced in different streams. The first expeller gives 50% extraction and the second extracts the remaining, leaving about 10% oil in the cake compared to 70% in copra.

The oil can further be extracted from cake with hydraulic pressing but these presses have gone out of business due to higher cost of maintenance. For removing this oil , the solvent extraction method with hexane is followed or the cake as such is used as cattle feed

Coconut oil is one of the major edible products of coconut. This is referred to as lauric oil in the world market because of its high lauric acid content. Coconut oil is used in India (a) for culinary/ edible purposes (b) for toiletry purposes (c) for soap making and (d) as an illuminant and lubricant. The industrial application of coconut oil is mainly attributed to the presence of maximum lauric acid and glycerides which are not present in other vegetable oils.

(a) Edible purposes: The oil is largely used for culinary purposes in Kerala and some parts of Karnataka and Tamil Nadu. Because of the high content of saturated fatty acids, coconut oil is highly resistant to oxidative rancidity and retains a pleasing flavour. Hence coconut oil bearing food have a long shelf life.

(b) Toiletary purposes: Coconut oil is used as body massage oil , as hair oil , and for the preparation of hair tonics for which the crude oil is often subjected to one or more processes such as bleaching, refining, deodourising, and colouring. Coconut oil forms an important ingredient in the preparation of cosmetics such as face creams, shampoos, etc.

(c) Soap making: While most oils and fats consist of mostly glycerides of fatty acids viz., palmitic, stearic and oleic, the principal fatty acids of coconut oil are lauric and myristic which are of lower molecular weights. Hence the oil is easily saponifiable even under cold conditions. This property, viz., the ability of coconut oil to combine with alkalies such as caustic soda (in solutions of proper concentrations) even under cold conditions has made it the most widely used oil for the manufacture of cold process soaps on a cottage basis.

Storage of Coconut Oil: Unrefined coconut oil is susceptible to rancidity due to the presence of certain proportion of free fatty acids. This is accelerated by the presence of moisture , air, light and fat splitting enzymes leading to the formation of peroxidation products. These usually originate from the copra itself, if it is not properly processed. Further studies have shown that the shelf life of coconut oil can be improved by the addition of either antioxidants or preservatives. Thus addition of either common salt (1%), tamarind (2%) or citric acid (500ppm) to coconut oil enhance the shelf life to more than 1 year.

COCONUT PRODUCTS AND BYPRODUCTS

This can be classified as food and non-food products depending upon their end use. The products which are utilised as food in the natural form or after processing into various products include the wet meat or kernel ,coconut water, coconut milk and milk products, desiccated coconut and coconut flour. Among non food products also known as byproducts, coir, coconut pith and shell assume commercial importance. Some of the byproducts from coconut can also be converted to value added products such as activated carbon, shell charcoal, shell flour and shell based handicrafts.

Desiccated Coconut: Desiccated coconut is the white Kernel of the coconut, comminuted and desiccated to moisture content of less than 3 percent. This is a very important commercial product having demand all over the world in the confectionery and other food industries, as an ingredient in the fillings of chocolate and candies. Sri Lanka and the Philippines are the major desiccated coconut producing countries. In India, only small units of production are available and the annual production is only around 10,000 tonnes. These small production units however do not utilize modern processing technologies, particularly in the drying and related areas. On an average, 7000-8000 nuts give one tonne of desiccated coconut. The oil content ranges from 68 to 72 %, but should not contain more than 0.1 % free fatty acids.

Husk: The husk usually forms 35 to 45% of the weight of the whole nut when ripe. About 30% of the husk is fibre and 70% is coir dust. Apart from the usual coir and coir products, coir pith finds varied uses as manure, as a mulch material and for making briquettes, with a good export potential. The briquettes can be used as a substitute fuel in place of firewood used in tile and brick industries and for other industrial heating purposes. Coir pith has also been put into trial for the production of biogas, light weight building bricks and also as a soil conditioner for moisture retentivity.

Coconut Shell Based Products: Coconut shell powder is preferred to many other similar materials like wood bark powder, peanut shell powder etc. because of its uniformity in size and chemical composition. Shell charcoal is also another product having extensive demand in the manufacture of activated carbon. Shell charcoal is prepared by burning the shell in a limited supply of air, so that the shells are only carbonized and not burnt in ash. The most modern method of manufacturing shell charcoal is using the Waste Heat Recovery technology. Here, the flue gases evolved during carbonization is burnt in a furnace to produce process heat for application in the coconut processing industry like copra making and desiccated coconut.

Another product which is gaining attention is the activated carbon. Coconut shell based activated carbon is the most superior material for gas absorption because of its small pore size and also its high mechanical strength. This is an energy intensive process and hence technologies for minimizing the operating cost by cutting down the energy utilization should be devised.

COCONUT WOOD PROCESSING

Freshly cut coconut trunks from senile

coconut trees can be used as timber if treated with preservatives, to increase its shelf life. Research work is in progress at CPCRI in this field. Philippines has already developed a technology known as HPSD (High Pressure Sap Displacement) treatment. It is a process of preserving the strength and durability of freshly felled trees by forcing out the sap from the trunk using a waterborne preservative solution. This process uses a high pressure sap displacement apparatus. Treated coconut timber can be used as electric poles, telecom poles and for interior uses such as to make furniture, window and door frames.

CONCLUSION

The coconut based economy should be developed not only on coconut oil and copra, but also on coconut byproducts with a view to integrate the whole processing for fuller utilization. Consumer awareness and acceptance of the products should go hand in hand with this. This will definitely combat the existing situation of confining to the traditional processing technologies in coconut.

REFERENCES

Anonymous (1950). Grade specification of coconut oil and standard contract terms for milling copra. Proceedings of Indian Central Coconut Committee, Ernakulam.

CPCRI Annual Report. 1986, 1988, 1989, 1996; CPCRI, Kasaragod.

Grimwood BE (1975). Coconut Palm Products: Their Processing in Developing Countries, FAO Rome. P. 261.

Nair RR (1984). Factors affecting the quality of copra. Proc. Seminar on Coconut processing and utilization, TVM, pp. 72-84.

Madhavan K (1986). Design and development of copra moisture meter. *J. platn. crops* 16 (Supplement). pp. 113-116.

Nathaneal WRN (1968). Moisture and other quality factors of copra. *Ceylon Cocon. Q.* 17:1-41.

Patil RT (1984). Design and development of solar cabinet dryers. *AMA Japan* XV(2): 59-62.

Patil RT (1984). Design and development of agricultural waste as source of energy. PLACROSYM V. pp. 324-334.

Patil RT (1991). Post Harvest Technology of coconut: In Coconut Breeding and Management, KAU Vellanikkara. pp. 308-312.

Singh J, Nambiar KK and Nambiar CKB (1982). Design, development and testing of batch type solar copra dryer. *J. Agric. Engg.* 19(3): 99-106.

Sreemulanathan H, Jayalekshmy A, Krishnaswamy C and Mathew AG (1979). Oil milling Industry in Kerala. *Indian Coconut J.* 10(6): 1-7

QUALITY EVALUATION OF TENDER NUT WATER, COPRA AND OIL IN COCONUT

M.J. Ratnambal

INTRODUCTION:

The coconut palm, *cocos nucifera* L., is one of the most useful palms grown in the tropical regions of the world. Because of its predominantly cross pollinating nature, cultivars or types widely differ from each other in their gross morphological characters and fruit components in particular.

In coconut, there are two distinct types- talls and dwarfs. Talls are mostly grown on plantation scale in all the coconut growing countries of the world. They are taller in stature, growing to a height of 15-18 m. Their life-span range between 60 to 80 years or more. They normally come to bearing in about 5-7 years after planting. The nuts of tall varieties are generally medium to large in size with good quality and quantity of copra and fairly high oil content i.e, 68-70 %. West Coast Tall, East Coast Tall, Lakshadweep Ordinary and Andaman Ordinary are some of the distinct tall varieties grown in India.

Dwarf palms are characterized by short stature. They come to bearing quickly i.e, 3-4 years after planting, have thin trunk and fully developed fronds rarely exceed 4 m. Dwarfs are identified by the colour of the nuts. In India, three important dwarf types found are Chowghat Orange Dwarf, Chowghat Green Dwarf and Gangabondam.

EVALUATION FOR TENDER COCONUTS

Tendernuts are used in large numbers in all the coconut producing countries. In India, annual consumption of tendernuts is about 200 million. Tendernuts are valued both for sweet water which is a refreshing drink and its gelatinous kernel is a delicious food. Moreover, the tendernut water has a number of medicinal properties and it is an essential component in many of the ayurvedic preparations. The use of tender coconut water is recommended in cases of gastro-enterites and as a useful substitute to saline glucose in intravenous infusion. It is also prescribed in serious case of diarrhoea and vomitting against dehydration of body tissues. It increases the blood circulation in the kidneys and causes profuse diuresis.

The tendernut water has a caloric value of 17.4 per 100 g of water. The following is the composition of tendernut water; water (95.4%), protein (0.1%), fat (< 0.1%), mineral matter (0.4%), carbohydrates (4.0%), calcium (0.02%), phosphorous (< 0.01%) and iron (0.5 mg/100 g)

The percentage of arginine, alanine, cystine and serine in the protein are higher than those in the cow's milk. The pH of tender water varies from 4.8 to 5.3 and the water contains both ascorbic acid (vitamin C) and vitamin B group. The following values for the vitamins of B group have been reported (Anon, 1950): nicotinic acid (0.64 g/cc), panthothenic acid (0.52 g/cc), biotin (0.02 g/cc), riboflavin (< 0.01), folic acid (0.003), and traces of thiamin and pyridoxine.

The tendernut water also contains various minerals of which potash is the major constituent. The mineral composition (in mg per 100 ml of nut water) is as follows: sodium (105), potassium (312), calcium (29), magnesium (30), iron (0.1), copper (0.04), phosphorus (37), sulphur (24) and chlorine (183).

When the nut ripens, the composition of water, especially that of sugar content, undergoes significant changes. The concentration of invert sugar increases and reaches maximum when the nut is about 220 days old. After this period, sucrose appears and the concentration of total sugars falls.

At CPCRI, 46 cultivars, belonging to both exotic and indigenous types were subjected to a preliminary organoleptic screening for quality of tendernut water. Of these, 12 cultivars were subjected for a detailed biochemical analysis like total sugars, reducing sugars, amino acids, sodium and potassium contents. Seven month old nuts were taken for the analysis and the study was carried out during April-May, for 4 years (1988 to 1991).

The mean values for 4 years, for different biochemical parameters of tendernut water is given in Table 1. Significant cultivar differences were seen in total sugars, reducing sugars, free amino acids, sodium and potassium contents. Of these cultivars, Chowghat Orange Dwarf (COD) has maximum total sugars as well as reducing sugars i.e; 7.0 g and 4.7 g/100ml of tendernut water respectively. The sodium and potassium contents in this cultivar is 20 ppm and 2000 ppm respectively. In view of the superior quality of tendernut water, Chowghat Orange Dwarf was recommended for release in 1991 by CPCRI for tendernut purpose.

EVALUATION OF COPRA

Copra is the dried kernel of coconut, which is a highly valued commodity in the world market for oil seeds, oils and fats. With an oil content of about 65 to 70 per cent, copra is the richest source of fat.

The yield of copra depends upon various factors, such as variety, age of palm, soil, climate, maturity of nuts, season of harvest and period of storage.

Among the 100 accessions evaluated for copra, the cultivar San Ramon(from Philippines) has the maximum copra content (350 g/nut) followed by the cultivar Kappadam (from Kerala) with 284 g/nut. Among the 11 released hybrids, Chandra Sankara (CODxWCT) has the highest copra content per nut (215 g) with 4.4 t of copra yield per hectare.

The percentage of copra in the dried whole nuts varied from 15 (in WCT) to 25 per cent in Laccadive Ordinary, the same in husked nuts was highest (48.1 %) in Fiji Tall and lowest (31.0 %) in Fiji Rotuma.

The proximate composition of copra is: moisture (6.8 %), ash (2 %), ether extracts (63.7 %), proteins (7.6 %), fibre (3.8 %) and carbohydrates (16.1 %).

Edible copra is of two types - ball copra and cup copra. Ball copra is made from fully matured (< 12 months) whole unsplit nuts. The cultivar Lakshadweep Micro, a local type grown in Lakshadweep Islands is considered to be the best for ball copra.

The quality of copra:

The quality of milling copra determines the quality of oil and the residual meat. The rubberiness of the copra is determined by the variety from which the product comes and storage conditions of matured nuts. Copra from most of the dwarf palms is soft and rubbery unlike that of ordinary tall variety. Similarly, the endosperm of the unripe nuts from tall palm is soft, difficult to dry and driage loss is heavy. The rubbery copra has a poor extraction percentage and is susceptible to various damage like insect, mould attacks etc.

In some cases, sulphur deficiency causes palm to produce nuts with rubbery copra. The oil extracted from this type of copra contains high amount of unsaturated fatty acids, causing high iodine value and low saponification value (Southern, 1957).

For good quality of copra, fully matured nuts from selected varieties with proper storage, seasoning of nuts for a few days and adequate drying to bring down the moisture content to 5-6% are the basic requirements.

EVALUATION OF OIL

A wide range of variation is reported in the oil content of copra from different countries. In the individual nuts, the oil content of copra shows considerable variation depending upon the storage of nuts, maturity at which the nuts are harvested and the place of origin of the variety. In the tall palms, the oil content of fully matured and properly dried copra varies from 65 % in Benaulim Tall to 75 % in Laccadive Micro. In most of the dwarf palms, the oil content is comparatively lower than talls i.e, around 65 %.

Physical properties of coconut oil:

The coconut oil is a colourless to pale brownish oil. In temperate climate, it appears as greasy, some what crystalline white to yellowish solid fat.

The commercial product has the characteristic odour of coconut. It has the following characteristics(Jamieson, 1943) : Specific gravity at 15°C (0.926), specific gravity at 25°C to 40°C (1.4477 - 1.4495), specific gravity at 60°C (1.4410 - 1.4420), saponification value (251 - 263), iodine number (8.0 - 9.6), polenske value (15 - 18), melting point (23 - 26°C), titre of fatty acids (20.4 - 23.5) and melting point of completely hydrogenated fat (44.5°C)

Chemical properties of oil:

Coconut oil is more or less constant in its composition irrespective of cultivars. It is high in saturated fatty acids in particular, lauric and myristic acids with notable proportions of still lower fatty acids. In comparison with the leading edible vegetable oils, coconut oil is low in saturated and polyunsaturated acids, particularly, linoleic acid (Thampan, 1981) (Table 2).

In addition, coconut oil has the highest saponification value, ie., 253 and the lowest iodine value, ie., 8.0 to 9.6. Coconut oil contains the largest percentage of glycerol compared with other oils (Table 3).

Coconut oil has the maximum digestability coefficient and is more easily digested than any other fat including butter. The popular belief that consumption of highly saturated oils like coconut oil raises the level of blood lipids, has in fact no scientific basis. On the other hand, there are a number of practitioners of ayurveda and nature care, who attribute several beneficial properties of coconut oil and kernel in relation to heart diseases.

A preliminary study conducted at CPCRI has revealed variations among the cultivars in fatty acid composition.

Not much work has been done with regard to the flavour components in coconut. However, a study conducted in 1991 could reveal that pyrazines and its derivatives, α lactones, ketones and fatty acids are responsible for aroma in coconut oil (Jayalakshmi et al 1991).

REFERENCES

Anonymous (1950). A dictionary of Indian raw materials and industrial products. *CSIR II*: 277-278.

Jamieson GS (1943). Vegetable fats and oils, New York.

Jayalakshmi A, Narayanan CS and Mathew AG (1991). *J. Aor. Oil Chem. Soc.* 18(11): 873.

Southern PJ (1957). Sulphur deficiency in coconut: a wide spread field condition in *Papua & New Guinea, II. The effect of sulphur* deficiency in copra quality. *Pap. New Gui. Agri.* J., 18 (1): 38-42.

Thampan PK (1981). Handbook of coconut palm. Oxford & IBH Pub. Co. Pvt. Ltd. p. 311.

Table 1 : Biochemical constituents of tendernut water and nut yield in 12 coconut cultivars (Mean values for 1988 to 1991)

Cultivar	Volume of water (ml)	Total sugars (g/100 ml)	Reducing sugars (g/100 ml)	Free amino acids (mg/100 ml)	K (ppm)	Na (ppm)	Mean annual yield (nuts/ palm)
New Guinea	358	5.8	3.0	1.4	2258	21	73
Phil. Ordy.	451	5.8	3.7	1.3	2273	24	113
Fiji Longtongwan	390	4.9	3.6	1.4	2641	29	105
Spikeless	275	5.3	3.2	1.7	2617	38	149
WCT	240	5.6	3.2	1.3	2797	37	92
Anadaman Ordy.	274	5.3	3.3	2.1	2272	27	94
Jamaica Sanblas	263	6.0	3.4	1.7	2703	28	65
MYD	238	6.2	3.8	1.7	1998	36	53
MOD	303	6.7	4.1	1.8	2142	35	75
GB	267	5.6	3.5	1.7	2125	28	68
COD	351	7.0	4.7	1.8	2003	20	67
Guam III	278	6.0	3.7	2.0	2434	34	96
Gen. Mean	307	5.9	3.6	1.7	2335	30	-
SE/Plot	101.7	1.2	0.79	0.51	258.0	9.0	-
CD	73.0	0.89	0.56	0.36	185.1	6.4	-

Table 2 : Percentage fatty acid composition of coconut oil compared with other oils

	Fatty acids	Coconut	Palm kernel	Babassu	Soybean
Saturated	Caprylic	8.24	1.40	3.50	-
	Capric	7.19	2.90	4.50	-
	Lauric	47.31	50.90	44.70	-
	Myristic	17.00	18.40	17.50	-
	Palmitic	8.85	8.70	9.70	10.50
	Stearic	2.27	1.90	3.10	3.20
	Arachidic	-	-	-	0.20
Unsaturated	Palmitoleic	1.00	-	-	-
	Oleic	6.27	14.60	15.20	22.30
	Linoleic	1.87	1.20	1.80	54.50
	Linolenic	-	-	-	8.30
	Arachidonic	-	-	-	0.90
		100.00	100.00	100.00	100.00
Percent unsaturated		9.14	15.80	17.00	86.00

Table 3 : Percentage of glycerol in oils of different saponification values

Type of oil	Glycerol content (%)	Saponification value
Coconut oil	13.84	253
Palm kernel oil	13.57	248
Olive oil	10.45	191
Groundnut oil	10.45	191
Gingelly oil	10.45	191
Cotton seed oil	10.83	198
Palm oil	10.83	198
Sunflower oil	10.45	191
Rape seed oil	9.57	175

COCONUT BASED BEVERAGES

S.J.D. Bosco

INTRODUCTION

Non-alcoholic beverages may either be carbonated or non-carbonated, naturally or artificially flavoured. In India, the most popular beverages are carbonated beverages or soft drinks and non-carbonated artificial fruit drinks. Carbonated beverages are generally prepared from a flavour base syrup, which is diluted, sweetened, acidified, coloured and treated with chemical preservatives and carbon dioxide. They are usually packaged in cans or returnable bottle. Juice drinks are similarly produced except that they are artificially flavoured and are not carbonated. They are usually packaged in stand-up aluminum pouches or tetra brik containers.

Products of the beverage industry have gained world wide acceptance and are extensively distributed. Indian beverage industry is not an exception. Beverages worth of millions are manufactured annually and marketed. They are low in food value and are prepared using imported material. Popularity of these beverages persists due to their thirst-quenching properties.

COCONUT WATER BEVERAGES

India produces large quantities of coconut water as a byproduct of desiccated coconut and copra industries. More than 250 million litres of coconut water, with a Biological Oxygen Demand (BOD) of 40 g/l is generated and disposed of annually in Kerala alone (Satyavathi, 1995) resulting in loss or waste of food values and causing environmental pollution. The development of food uses for coconut water would greatly help to solve these problems. The use of coconut water to produce vinegar and nata de coco (a gel formed during fermentation and consumed as a dessert) is now being practiced on a small scale. Studies have shown that coconut water can also be used to produce carbonated and non-carbonated beverages as refreshing and more nutritious than other similar products.

Composition of coconut water:

In the early stages of development of the coconut, coconut water is sweet and refreshing. As the nut matures, the sweetness diminishes, but retains much of its chemical components. It is rich in minerals, especially potassium, sterile in its natural form and very widely used in hospitals, for feeding infants and as a beverage by all.

Chemical composition of matured and tender coconut water of about seven month maturity is given in the Table 1 (Satyavati, 1995). After sugars, minerals are the most important in terms of quantity and quality of coconut water.

Table 1 : Chemical composition of matured and tender coconut water

Sl. No.	Component	Mature coconut water	Tender coconut water
1.	Total solids (per cent)	5.4	6.5
2.	Soluble sugars (per cent)	3.0	5.7
3.	Minerals (per cent)	0.5	0.6
4.	Protein (per cent)	0.1	0.01
5.	Fat (per cent)	0.1	0.07
6.	Acidity (mg, per cent)	60	120
7.	pH	5.2	4.5

The mineral composition of matured and tender coconut water is given in the Table 2 (Satyavati, 1995). Among the individual minerals, potassium accounts for more than 50 percent. It can also be seen that matured coconut water also contains considerable amount of nutrients especially minerals. The total reducing sugar and protein contents of coconut water increase as the coconut fruit matures. However, total reducing sugar content reaches a peak of 2.9 g/100 ml on the ninth month and then declines. The sugars include simple sugars such as glucose, fructose, and sucrose, and sugar alcohol, mainly sorbitol (glucitol). For less mature green nuts, the total concentration of sugars is equal to 5.15 g/100 ml. This explains why coconut water from young nuts is substantially sweeter than that from mature nuts. The utilization of coconut water as soft drink can make use of this nutritious produce as well as add to the gross return to the coconut farmers.

Table 2 : Mineral composition of matured and tender coconut water

Sl. No.	Name of the minerals	Mature coconut water (in mg per cent)	Tender coconut water (in mg per cent)
1.	Potassium	247	290
2.	Sodium	48	42
3.	Calcium	40	44
4.	Magnesium	15	10
5.	Phosphorus	6.3	9.2
6.	Iron	79	106
7.	Copper	26	26

Production of non-carbonated and carbonated mature coconut water:

Del Rosario and Rubico (1979) formulated non-carbonated beverages from mature coconut water obtained from a local desiccated coconut plant. They conducted experiments on malic acid, ascorbic acid, citric id and combinations of acidulants and also n various sugar concentrations to increase otal soluble solid content. The formulation which found most acceptable, is that with otal solids adjusted to 10 to 12 per cent and H adjusted to 4.2 using an acidulant and 0.1 o 0.15 per cent sodium citrate. The use of odium citric acid mixture minimize the oiting taste that has developed with the ncreasing amount of citric acid in the formulation.

Gonzalez et al. (1983) have developed the process for the production of non-carbonated and carbonated coconut water beverages utilizing water from mature nuts. The coconut water is filtered immediately through a clean cheese-cloth or mechanically through a suitable filter machine or passed through a basket centrifuge to separate coarse suspended particles. Immediately pH is adjusted with refined sugar. Sodium benzoate is added as preservative at levels permitted by the Bureau of Food and Drug. The prepared solution is pasteurized, passed through a three-way centrifuge to give clear non-oily solution and repasteurized further. Repasteurization may also be accomplished by passing through a High Temperature Short Time (HTST) heating unit in which case addition of preservative is not necessary and also pH and total soluble solids content need not be adjusted. This results in a natural drink.

For the preparation of the non-carbonated beverages, the hot repasteurized coconut water is packaged aseptically in clean containers such as beverage bottles, tin cans, laminated pouches or tetra briks and then sealed immediately. In non-aseptic conditions of packaging in bottles or tin/aluminum containers, processing further over steam at atmospheric pressure is necessary. The time of processing depends on the size of the can or bottle. For the preparation of the carbonated beverages, the repasteurized coconut water is cooled, carbonated and packaged aseptically in suitable sterile containers such as beverage bottle. In non-aseptic conditions of packaging, processing further at low heat in water bath is necessary.

A process has been developed at Regional Research Laboratory, Thiruvananthapuram for upgrading the matured coconut water to the level of tender coconut water and preserve it as a soft drink (Satyavati, 1995). The main operations involve collection, upgradation, pasteurization, filtration and bottling. The entire operations has to be carried out under strict hygienic conditions. The process essentially consists of up grading the flavour of matured coconut water to the level of tender coconut water by supplementation with additives including sugar and preserving by a judicious combination of heat-pasteurization and permitted chemicals.

Non-carbonated beverage from tender coconut water:

The tender coconut water is at its optimum level of acceptability and economical viability for commercial use when the nuts are of 6 month maturity. Later, the quality and the quantity of water decrease and hence its acceptability. So, it is ideal to preserve the tender coconut water at this stage of maturity to derive maximum advantages/benefits. Investigations were carried out at DFRL, Mysore to preserve the tender coconut water in plastic pouches of 200 ml capacity and in aluminum beverage cans of 200 ml/350 ml capacity.

Since it is highly susceptible for heating, it is subjected to minimum heating by use of additives like nisin to achieve commercial sterility. This has helped in maintaining the natural pH of 4.9-5.2, instead of reducing it to below 4.5, which reduces the acceptability. Uniformity of the taste of the product could be ensured by sweetening agents, as there is a wide variation in the quality of the raw material depending upon the species, soil condition, watering and fertilizers (Srivatsa, 1995). Microbiological, chemical and organoleptic analysis have been done upon 3 month storage under ambient conditions. The product is found to be generally acceptable and it remained microbiologically sterile with no significant chemical changes.

Physiochemical, microbiological, organoleptic and storage properties of coconut water beverages:

Non-carbonated and carbonated coconut water beverages possess the characteristic flavour of coconut water, but this is slightly masked by the acid-sweetish taste imparted by different additives. Both products are highly acceptable and are preferred to other artificial fruit drinks. The carbonated and non-carbonated coconut water beverages keep well at refrigerated (5-10°C) and room temperature (28-30°C) storage. Storage at controlled temperature of 37°C does not alter much the acceptability of the products, except for a mild discolouration. The sharp flavour of freshly produced products mellows on storage and acceptability is greatly enhanced. At higher temperature (45-55°C), intense darkening of the product with scorched flavour can occur which is attributed mainly to caramelization and Maillard reaction. High temperature generally hastens these reactions which can adversely affect the quality of the beverages.

Coconut water concentrate:

One of the problems regarding the use of coconut water as feedstock for the manufacture of beverage and other products is the transportation, and prevention of spoilage during transport of the material from the source to the beverage factory. If the coconut water cannot be pasteurized and chilled immediately after collection due to lack of facilities or other constraints, then it must be transported at high cost, under refrigerated conditions to prevent spoilage. A possible solution to this problem is the concentration of coconut water into a form that is easily rehydrated, in order to reduce shipment weight, volume and cost, and to improve product stability. Potential end users of the concentrate include not only the food and beverage industry but also the fermentation industry, hospitals, research laboratories and the beverage consuming public, both in India and abroad.

Concentration of coconut water by Reverse Osmosis:

Coconut water is adversely affected by extended processing at high temperature, so a non-thermal concentration process has to be used. Given this constraint, one of the available techniques for producing coconut water concentrate is reverse osmosis. In the case of concentration of coconut water, the concentration is achieved by applying external pressure in order to overcome osmotic pressure and force the solvent (water) through a semi-permeable membrane capable of retaining all or most of the dissolved substances, in effect reversing the normal osmotic process. Papa et al. (1986) obtained a concentration factor of five to six folds using 90 membranes at 4 MPa after 5 hours of reverse osmosis with continuous retentate recirculation. Maximal concentrations of sugar alcohol and protein for the retentate, namely 16.9 and 0.7 per cent respectively, were attained under these conditions.

A brief description of the process is as follows. Fresh coconut water from newly opened coconuts is collected under hygienic condition. Suspended solids and oil in the samples are removed by means of three-way centrifuge. The removal of the solids and the oil is necessary in order to minimize fouling or clogging of the membranes. The salts present in coconut water may be removed if desired, prior to concentration, to produce a very sweet product. This is achievable by passing the centrifuged coconut water through a mixed-bed ion-exchange resin. However, additional costs are entailed and problems dealing with regenerability of the resin need to be overcome. The concentrate can be frozen or preserved in cans and after dilution to the desired strength, it can be used as base for the production of carbonated and non-carbonated coconut beverages. The concentrated coconut water has also been used successfully in the brewery industry.

COCONUT FRESH KERNEL BASED BEVERAGES:

Coconut kernel have been used as food since ancient times. Men have obtained nourishment from this fruit by drinking the water of the tender nut and by using the pulp of the mature drupe. In the preparation of beverages, desserts and main dishes, the coconut pulp is used either grated or used in the form of coconut milk. In all coconut producing countries, where the people have a local supply of fresh coconuts, they are accustomed to the natural fresh flavour of the coconut pulp. Coconut milk and fresh grated coconut pulp are the basic forms for the utilization of the coconut as food, both at household and at industrial levels.

Fresh coconut kernel contains 151 IU of thiamine, 1 mg of ascorbic acid (vitamine C), traces of vitamin A and 0.2 mg of tocopherol per 100g. Coconut proteins are high in nutritive value and are fairly rich in lysine, methionine and tryptophane (Woodroof, 1970). The average proximate composition of ripe coconut kernel are furnished in Table 3.

Simulated dairy milk beverages based on Non-Fat Dry Milk (NFDM) and/or coconut milk:

Simulated dairy milk beverages are dairy milk substitutes formulated to contain nutrient approximating those of their dairy milk counterparts. The development of such types of products was motivated by the shortage of dairy milk in certain part of the world particularly in tropical countries where an adequate and stable supply of milk and milk products cannot be assured due to lack of a sizeable dairy industry. Dairy milk products in powdered form represent a large fraction of the food imports. These are often repacked for distribution or used in the production of evaporated filled milk, infant food formulations and milk based beverages.

Table 3 : Proximate composition of ripe coconut kernel

Proximate Composition	Authors			
	Menon & Pandalai (1958)	Woodroof (1970)	Grimwood (1975)	Sreenivasan (1967)
Moisture (%)	36.30	46.30	42-48	46.3
Fat (%)	41.60	37.29	36	37.3
Carbohydrate (%)	13.00	11.29	7-12	7.9
Protein (5)	5.60	4.00	4	4.1
Fibre (%)	2.50	3.39	2.0	3.4
Ash (%) (minerals)	1.00	1.03	1.0	1.0
Energy (kcal/100 g)	448.90	-	-	-

Substitution of milk fat with fats of other source reduce the cost of dairy products. Filled milk products are made by combining fats and oils other than milk fat with skim milk. Extensive trials have been undertaken in different parts of the world to study the physio-chemical properties of various dairy products made by partial substitution of milk components with those available from plant and animal sources. Low fat dairy spread is prepared by using vegetable oils to the extent of 10 to 30 per cent for partial replacement of butter fat.The production of filled milk is an important industry in non dairy countries. Canned evaporated filled milk and filled milk powder have become popular milk products which are used as beverages, as whitener for coffee and chocolate and as ingredients for snack foods and confectioneries.

Coconut milk and oil as fat sources of filled milk:

Bhandari et al (1975) prepared flavoured filled milk having 3.5 per cent fat and 8.5 per cent Solids Not-Fat (SNF) using coconut oil and dried skim milk powder. Filled milk of acceptable quality was made by Jenson and Nielsen (1982) using coconut oil. Creamed coconut, an hundred per cent coconut product can be put into use in the dairy industry successfully. Technology for production of coconut butter was developed. Fresh filled milk with coconut milk having pleasant coconut flavour and smooth aroma was prepared by Davide et al. (1987). Agarwall et al. (1991) prepared filled milk which is a product made from non-fat milk solids of liquid or powder origin in which vegetable fats or oil have been incorporated. Escueta et al. (1985) prepared a product named 'Tofu' by incorporating coconut milk and soyamilk. Thampan (1987) reported that coconut cream can be utilized as a fat source for the reconstitution of skimmed diary milk, infant milk powder and filled milk. Malaysian Agricultural Research Institute manufactured powdered coconut milk on commercial basis. The product can be stored for 18 months without refrigeration and antioxidant.

Filled milk products:

Various filled milk products can be developed by using NFDM as major portion along with coconut fat and/or protein. Simulated dairy milk products should be prepared under strict sanitary conditions and pasteurized to destroy harmful bacteria.

Beverage, evaporated and sweetened type:

Banzon (1978) explored the utilization of coconut milk as the main source of fat for the reconstitution of NFDM into three types of milk products viz., beverage type, evaporated type and sweetened condensed type. The milk was extracted single-strength from grated coconut meat, strained through cheese-cloth and pasteurized at 70°C for 2-3 minutes or 62-65°C for 30 minutes, cooled immediately and stored at sub-zero temperature for ready availability. The beverage type reconstituted milk is formulated to contain 3 per cent fat from coconut milk and 3.6 per cent protein contributed by coconut milk and NDFM. The evaporated type of reconstituted milk is more concentrated than the beverage type. It contains 6 per cent fat from the coconut milk and 7.3 per cent protein from the coconut milk and NFDM. This is approximately twice that contains in cow milk and the reconstituted filled milk (beverage type). The sweetened condensed milk requires sugar besides NFDM and coconut milk. The final product contains 8 per cent fat, 7.5 per cent protein and 40 per cent sugar. Sugar enhances the acceptability of the product, as well as improve its keeping quality. It is diluted with water to the desired sweetness prior to drinking or may be applied as bread spread. To prepare the products, NFDM is dissolved in warm water (40°C) and coconut milk is added. This is mixed thoroughly in a blender. For sweetened condensed milk, sugar is added to the blended material. A possible modification of the process is to augment the essential free fatty acid content of the produce using corn oil, which is thoroughly blended with the coconut milk before the products are prepared. Pasteurization of the products is advisable. Coconut milk and NDFM both have emulsifying properties and subsequently minimize coagulation of the proteins during the heating process. These products, which are for immediate consumption possess the wholesome flavour of coconut. They may be frozened or refrigerated if not consumed immediately.

Low-fat filled milk is prepared by dissolving the skim milk powder in water, then blending in coconut milk. The reconstituted milk is then heated to 55°C homogenized hot at 2000 psi, strained, repasteurized at 72°C, then immediately cooled to 3-4°C. The product is packaged in transparent plastic bags previously heated to 105°C for 15 minutes and sealed completely. The product has distinct coconut flavour and aroma and is rated only slightly less acceptable than commercial cow milk. Shelf life of the product is less than 24 hours at room temperature with coagulation after overnight storage. At refrigerated temperature (5-7°C), the product remains acceptable for 7 days.

Sweetened condensed filled milk is more stable than its unsweetened counterparts due to its higher sugar content. Its shelf life can be extended further by canning and then sterilizing over boiling water for about 30 minutes.

Coconut filled milk enriched with legume protein:

The use of coconut milk substitutes is of great nutritional significance in countries where coconuts and legumes grow in abundance. Mungbean, a traditional high protein dietary legume in India, is an ingredient in a number of low-cost, high protein rich foods, such as mungbean cookies and mungbean based patties. Mungbean is rich in lysine, an amino acid deficient in an average Indian diet.

The mungbean proteins isolate is prepared from starch free filtrate of the beans by adjusting the pH to 4.4. Cream layer formation was observed in both of unsterilized beverages and evaporated type products containing either NFDM or the mungbean proteins isolate. Heat sterilization for 15 minutes at 15 psi destabilize the emulsion further at a faster rate of cream layer formation and subsequent formation of coagulated materials in the product. The mungbean protein-treated beverages inhibits gelation during storage. Addition of emulsifiers and stabilizers and passing through the homogenizer of the pasteurized products prior to heat sterilization can minimize these problems.

Coconut skim milk beverages:

Coconut skim milk is the aqueous component of the coconut milk extract. It possesses the delicious sweetish flavour, the characteristic feature of young coconut. Coconut skim milk beverages are nutritious, particularly for pre-school and school-age children. It contains good quality protein as well as soluble carbohydrates including sugars that are originally present in the coconut meat. Its chemical composition depends upon the amount of liquid used for the extraction of the grated coconut meat. With a 1:1 ratio of meat-to-water, the skim milk typically contains 90 per cent moisture, 2.7 per cent protein and 0.6 per cent fat.

Ready-to-drink coconut skim milk:

Several studies were conducted that have resulted in the development of acceptable beverages based on coconut skim milk, either as instant flakes and powder or as liquid. Salon and Maniquiz (1969) developed a process of preparing coconut skim milk beverage The process can be well adopted in the villages using simple utensils, but observing strict precautionary measures in its preparation.

The coconut milk is hand extracted three times with water or coconut water. The extract is strained through a cheese cloth and left to stand in a percolator. The skim milk that separates at the bottom of the percolator is then collected and pasteurized at 60-67°C for 30 minutes in a water bath. After cooling, the product may be consumed immediately or stored at room temperature for later use in the day. The product is microbilogically wholesome and safe for drinking even after 5 hours at room temperature. It contains good amount of iron and niacin, but is deficient in fat, thiamine, riboflavin, calcium and phosphorus. The cream resulting from this process can be heated to produce the oil for cooking. A by-product is the latik or the protein-coagulated material which has a very rich and creamy flavour. The coconut residue can be used as feed for animals or toasted with sugar and used as snack food.

Beverages based on coconut protein concentrate:

Ready-to-drink coconut skim milk

protein can also be prepared by using the protein coagulated material obtained by heating the skim milk. The curdled coagulum is soft in texture and has the delicious flavour of young coconut meat. Gonzalez et al. (1983) formulated a simulated dairy milk product using the coagulum as the protein source and coconut cream and refined oil as fat source.

The mixture is heated, homogenized, packaged hot in tin cans, sealed and sterilized at 118°C for 9 minutes in a continuous agitating retort. Solidum and Genato (1987) likewise developed formulations for chocolate flavoured and unflavoured coconut skim milk beverage using the protein-coagulum.

Coconut skim milk powder:

Instant beverages in powder form are common household items and are popular among school-age children. These artificial drinks are composed of synthetic flavours, colourings and sweeteners and are almost devoid of food value. An attractive alternative to artificial powder drinks would be natural fruit drinks, which cannot be produced in powder form due to technological constraints. It is however possible to convert coconut skim milk into a powder which is easily dissolved to make a nutritious beverage.

Buccat et al. (1973) successfully produced a nutritious instant drink from coconut skim milk. The skim milk is mixed with sugar at 15 per cent level and initially concentrated in a flash evaporator. The concentrate contains 16 per cent moisture, 50 per cent sugar, 0.5 per cent protein and 9.51 per cent fat. It is creamy white in colour has a very viscous consistency and can be diluted with cold water to twice its volume to make a highly acceptable coconut drink. The final product is obtained by further drying the concentrate into flakes using a vacuum oven or a drum dryer. The flakes contain 4.45 per cent moisture and 25.2 per cent protein. The product gives a delicious refreshing drink upon reconstitution with ice-cold water. It is highly hygroscopic and should be packaged in moisture-vapour-proof containers.

Hagenmaier (1980) likewise developed a dry, non-dairy product from coconut skim milk which easily dissolves to make a sweetish, coconut-flavoured drink. Maltodextrin is as optional additive used to improve body and fluidity of the dehydrated product. Powder skim milk (without maltodextrin) has been tested in the preparation of bakery products to replace dairy milk ingredients. De Leon (1976) made cup cakes and nutribuns. However, it has limited prospects from the marketing point of view, partly because of the high cost of skim milk powder relative to wheat flour. As a beverage, the product has good potential. It is reported to have three flavour notes namely sweetish (primarily due to the presence of natural sugars), bitter-salty, presumably due to its high salt content, potassium in particular and fresh coconut flavour.

REFERENCES

Banson JA (1978). Reconstitution of milk using coconut milk and nonfat dry milk. *Phil. J. Coco, Studies* 3(2):1-8.

Davide C, et al. (1985). Utilization of skim milk powder and water extracted coconut milk in low-fat filled milk processing. *Phil. J. Coco studies* 10(1):48- 59.

Del Rosario RR and Rubico SM (1979). Formulation of coco beverage from mature coconut water. *Phil. J. Coco, Studies* 4(14):1-5.

Escueta EE (1980). Stability studies on coconut milk and plant protein isolates based product. 1. Physical Properties. *Phil. J. Coco. Studies* 5(1):63-67.

Gomzalez ON, et al. (1983). Process for preparing non-carbonated and carbonated coconut water. Proc. Mini-Workshop on Coconut Water and Sap Utilization, PCARRD, Philippines.

Papa GM, et al. 1986. Reverse osmosis of coconut water using a suing compoiste membrane. Proc. Third AEAN Workshop on Membrane Technology, Singapore.

Potter NN (1968). Food Science. The Avi. Publishing Co., Inc., Westport, Connecticut.

Child R (1974). Coconuts, 2nd ed. Longuon Group Ltd., London.

Grinwood BE (1975). Coconut palm productions: Their processing is developing countries. Food and Agricultural Organisation, Rome.

Satyavali Krishnamutty (1995). Products from matured coconut water. *Coconut J.* 25(5&6):12-13.

Srivasta AN and Sankaran R (1995). Preservattion of tender coconut water in polymeric pouches and metal cans. *Coconut J.* 25(5&6):13.

Pavithran K (1995). Coconut in dairy foods. *Coconut J.* 25(4):7-8.

COCONUT HUSK MADE PRODUCTS

R. Viswanathan

INTRODUCTION

The most important produce of coconut is its fruit, made up of outer fibre called husk (35%) followed by the hard protective shell (12%). Lining the shell is the white coconut meat (28%) with a sweet coconut water of 25%. For using coconut, it is need to be dehusked for all purposes other than for seed and consumption as tender coconut. Dehusking of coconut is done at various stage in the marketing net work. Except the husk obtained during dehusking at house hold level, all the husk, including the unorganised marketing sector, reaches the coir industry where it fetches a market value. In the coir industries, fibre is extracted from coconut husk.

COIR INDUSTRIES AND PRODUCTION

Coconut husk is the basic raw material of coir industry and about 6.25 lakh tonnes of coconut husk is obtained per annum. At present only 35 % of the total husk available is utilised by the industry while there is scope for utilising at least 50% of the husk produced in the country. The husk of one coconut gives 90 g of coir fibre and 180 g of coir pith. There are two distinct varieties of coir namely white fibre and brown fibre. White fibre is extracted from retted coconut husk. Kerala produces mostly white fibre which is used for making traditional coir products like mats, mattings, rugs and carpets which have an export market. Brown fibre is extracted from unretted husk. It is mainly used for the manufacture of curled coir. Curled coir is used in the rubberised coir matresses, sofa cushion, bolsters, pillows, carpet underlay etc. The bristle fibre is a thick and long variety and is used for brush making. The mattress fibre which is a shorter staple fibre finds use in the upholstery, mattresses etc., for stuffing purpose. The white fibre is extracted from green husks by mechanical defibring process. Seventy five per cent of coir production in India is from Kerala, mostly by natural retting process.

There are about 84,000 retting and coir extracting units in Kerala and about 650 coir units located in Tamil Nadu, Karnataka and Andhra Pradesh. About 500 coir factories are functioning in Tamil Nadu for mechanical extraction of coir fibre. At present, there are 6,044 units in India engaged in various activities connected with coir industry employing 5 lakh people, 82 per cent of whom are women. Of this 4,525 units are in Kerala employing 3.85 lakh people. The total coir production in India during 1993-94 was Rs. 2,39,100 tonnes.

FIBRE EXTRACTION

The thickness of the husk of an ordinary nut varies from 2.5-3.0 cm in the case of thin husked nuts and 4.0-5.0 cm for thick husked ones.

Natural retting:

It involves soaking the husks in water preferably saline water, for 6 - 10 months until the fibre becomes loose and soft. The soaking is done either in the pits dug near lagoons or by the sides of back waters. A pit measuring 2.5 x 2.5 x1.25 m will contain about 1000 husks. After natural retting the husks are taken out of water and washed to get rid of the mud and dirt. The outer skin is then peeled off and the husks placed on wooden blocks and beaten with a mallet for separating the fibre form the pith. It is cleaned and then spread in shade for drying. The fibre spread for drying is occasionally beaten and mossed up with poles to remove the remnants of pith and impurities still adhering to the fibre. This also helps the mixing of long and short fibres thoroughly for making superior types of fibre.

Mechanical extraction:

The non-retting process involves direct decortication or mechanical extraction. The fresh husk before drying gives white fibre and the dried and retted husk gives brown fibre. The yield from retted husks is more than that from unretted husks. The average yield of white fibre from 1000 full husks in India is estimated as 81 kg full husk yield and average of about 50 kg of brittle fibre and 100 kg of mattress fibre.

Fibre grades:

The fibres are used for spinning into yarn for manufacturing mats and mattings, ropes, twines etc., The bristle fibre is long and stiff is used for brushes and brooms. Coir is graded according to the colour and length of the fibre as also its refraction content. Four grades (Table.1) are recognized in India based on the specifications of Bureau of Indian Standards . The first grade is mainly utilized for making superior quality double warp fancy and fibre mats. The second grade constitutes fibre of white lustrous colour and the third slightly reddish or greyish coir containing pith. The fibre in fourth grade is mainly dark in colour containing more pith and is used for making cheap yarn known as Beach yarn.

Table 1. Grading of Coir

Sl. No.	Grade	Maximum impurities	Length of fibre, proportion of medium and short fibres
1	I	2.0	Atleast 70% by the weight, long and remaining medium and short
2	II	3.0	50% by weight, long and remaining medium and short
3	III	5.0	30% by weight, long and remaining medium and short
4	IV	7.0	20% by weight, long and remaining medium and short

Chemical Composition:

Coir belongs to the group of natural celluloic fibre and contains apart from cellulose, lignins and other substances which serve as building materials for the cell structure. The chemical composition of husk and coir are given in Table. 2. Lignin is the main constituent responsible for the stiffness of the coir. It is also partly responsible for the natural colour of the fibre. Complete densification will result in the breakdown of the fibre to the ultimate cells and the subsequent loss in spinning value.

COIR EXPORT

The coir industry is basically an export-oriented industry because almost 60% of the coir products produced are exported to 50 countries around the globe. At present, there are about 200 registered exporters of coir

Table 2. Chemical composition and constituents of coconut husk, coir and coir pith.

Property/constituent	Coconut husk		Cleaned coir	Raw coir pith	Composted coir pith	Coir pith litter
	Fresh	Retted				
Moisture, % (d.b)	-	-	-	11.9 - 20.4	-	-
Ash, %	0.71 - 3.5	8.07	1.46	3.6 - 13.1	-	-
Fats and resins, %	-	-	-	1.8	-	-
Cellulose, %	-	-	32.9 - 43.4	26.5 - 3.5	10.1	-
Hemicellulose, %	-	-	0.15 - 0.25	-	-	-
Lignin, %	45.45	-	40.5 - 45.8	25.2 - 43.7	4.8	-
Pentasan, %	19.15	-	-	7.5 - 13.1	-	-
Loss on boiling with caustic soda in 5 minutes	-	-	-	12	-	-
Sulphur, %	-	-	-	0.2	-	-
Cold water solubles, %	-	-	2.7 - 5.7	3.5 6.0	-	-
Acid value of aqueous dispersion, mg/g. of NaOH	-	-	1.60	1.12	-	-
NaOH required when boiling with 5% NaOK for 1 hour, mg NaOH/g.	-	-	4300	460	-	-
pH	-	-	-	5.89	-	-
Electrical conductivity, mhos/cm	-	-	-	1.50	-	-
Nitrogen, %	0.26 - 0.53	0.74	0.06	0.26 - 0.87	-	-
Phosphorous, %	-	-	-	0.01 - 0.11	0.06	2.9

(Contd...)

Property/constituent	Coconut husk		Cleaned coir	Raw coir pith	Composted coir pith	Coir pith litter
	Fresh	Retted				
Potassium, %	-	-	-	0.78	1.20	2.1
Calcium, %	-	-	-	0.40	0.50	1.3
Magnesium, %	-	-	-	0.36	0.48	1.3
Organic carbon, %	-	-	-	29.0	24.5	-
Ratio of pentasan to lignin	0.42	-	-	0.32	-	-
Iron, %	-	-	-	0.07	0.09	0.10
Manganese, %	-	-	-	12.5	25	167
Zinc, ppm	-	-	-	7.5	15.8	160
Copper, ppm	-	-	-	3.1	6.2	27
Total phenol, mg/g	-	-	-	50	-	-
C:N ratio	-	-	-	112.1	24.1	-
Volume	-	-	-	1	0.52	-

products, of which 131 are from Kerala. France, Germany, Italy ,UK and the Netherlands account for about 60 % of India's coir product exports followed by USA and Canada (18%), the Far Eastern Asian Countries (7%) and the West Asian countries (6%). Small quantities of coir and coir products are also exported to some countries in South Asia and Africa.

In the western world, environmental consciousness is intense and augurs well for coir products which are completely bio degradable. Coir fibre scores over synthetics because of its non-allergic and pollution-free characteristics. It is tough, resilient, damp-proof, flame - retardent and fungal resistant. But synthetics and other technically superior substitutes pose a serious challenge to coir. These are cheaper and because of their lighter weight the cost of their handling and processing is lower.

COIR PRODUCTS

Even though coconut palm is grown abuntantly in all countries in the tropical belt, India and Sri Lanka stands first and second in the utilisation of coconut husks for the manufacture and marketing of coir and coir products. India accounts for 71 % of the world fibre production while Sri Lanka's share is 23%. While almost entire producton of white fibre is from Kerala, other states like Tamil Nadu, Karnataka, Andhra Pradesh and Orissa are the major brown fibre producing states. It is estimated that about 27% of the coconut husks produced in Kerala is utilised for the coir industry as against a national average of less than 27%.

The ability of coir yarn and ropes to withstand the prolonged action of sea water makes them especially suitable for use on boats and ships, similarly as coir yarn stretches beyond its elastic limit without breaking and can take up a permanent stretch when so loaded, coir ropes are singularly useful where intermittent or jerky strains are likely to be encountered. Coir fibre has also been used successfully in the manufacture of shock proof packing materials, hard board suitable for table tops, doors, pencil and battery containers. Hard boards obtained possess an attractive glaze, high tensile strength and high density and are suitable for internal pancling of railway coaches and cuttings.

Artificial animal hair: Bristle fibre and decorticated fibre are boiled for one hour in caustic soda solution.Then the fibre is dyed by immersing in a dye bath composed of direct black dye, soda ash and salt for two hours and then cooled for 12 hours. Then the fibre is dried, polished with emulsion of paraffin, washed with soap and soda ash and twisted. By these processes simulated animal hair (animal - hair like fibre) is produced. This is used as filling material for upholstery.

Curling: Mattress fibre, bristle fibre ansd decorticated fibre are twisted into ropes to produce curled fibre. Curling imparts special resilience to the fibre and the curl is permanent. Curled fibre is impregnated with rubber latex to produce rubberised coir, which is used for making car seats, filter pads, carpet underlays, cushions etc.

Flagging: Ends of trimmed bristle fibre are immersed in a chemical solution and then split lengthwise by rotating pins or similar devices. This gives a soft feathery feel to the ends and improves sweeping efficiency of the brooms and brushes.

Spinning : Mat variety of coir fibre is spun into yarn. In India coir-spinning is organised on a cottage industry basis and three methods of spinning are currently followed viz., (i) hand spinning, (ii) wheel spinning and (iii) mechanised spinning by using treadle operated machines. There are no power machines for spinning coir in India. Hand spun yarn is soft, and has even twist and thickness. Wheelspun yarn has harder twist, higher strength and more uniformity in size and twist. Yarn produced by treadle - operated machine is less hairy, more regular in twist and has continous length than wheel - spun yarn. Hand - twist yarn is used for mattings and ropes. Soft-twist yarn is used for mats. Finer variety of soft-twist yarn is used for matting. Estimated production of coir yarn in India is around 120,000 tons (70,000 tons spindle-spun,36,000 tons hand-spun). About 2.5 lakhs of workers are employed in the coir spinning industry.

Rope Making: Ropes and cordages are made out of coir yarn. Plain, hawser-laid and cable laid ropes are made in India.

Weaving: Coir Yarn is woven into mats, mattings, carpets, rugs and mourzouks. Mats and mattings are woven on wooden handlooms; wheelspun yarn is used for warp and hand spun yarn for weft. Power-looms are seldom employed in India; on account of coarseness of fibre the yarn produced is coarse, and shuttles take only short lengths of yarn and need frequent replacements.

Mats: According to quality of yarn and method of weaving used mats are classified into three main classes (i) coir mats (ii) fibre mats in which unspun coir is used for piles and (iii) speciality mats.

Mattings: Patterns requiring upto 8 treadles are usually woven on ordinary looms. For designs requiring more than 8 treadles Jacquard machines are employed. Ordinary, basket, twill, herring-bone, etc weaves are used for mattings for these 2-3 treadles are required.

Rugs: These are mattings in rug sizes in attractive stenciled patterns.

Mourzouks: The method of weaving mourzouks is different from that employed for matting. In this Special cross - Weaving looms are used. Surface and patterns are formed by weft and not by warp. This method of weaving enables production of intricate geometrical and floral designs. Aloe and jute yarn may also be used as warp yarn.

Carpets: These are woven on matting looms.Warp strands are varied in thickness and number to produce thick and heavy fabric with a ribbed finish. Required design is secured by inserting coloured weft yarn.

Bleaching and dyeing: Colour and design are important for marketing of coir products. For dyeing to bright tones prior bleaching is necessary. Coir fibre may be bleached by SO_2 fumes from burning sulphur. Coir yarn may be treated with dilute. H_2SO_4 solution to improve its colour and give it some amount of brightness. For dyeing of coir different classes of dyes are used, viz, natural colouring matters like logwood, acid dyes, acid - mordant dyes, basic substantive dyes,sulphur dyes etc.,. Dyed yarn is exported from India to Australia for manufacture of matting.

Printing : Simple geometrical patterns and floral designs are printed on coir products by employing stencils and screens. Dye paste, resin thickners and chemicals to fix colour are applied through stencils. Dried prints are steamed for fixing . Fine designs of intricate configerations cannot be applied because of stiffness of coir fibre and roughness of coir products.

Coir fabrics for ground water recharge: Compared to other natural fibres, coir fibres degrade very slowly and hence coir woven fabrices with loop construction retain moisture in the soil. This property can be used in water harvesting. Besides this, when the degradation of lignin starts, the acidic phenolic leachates may decompose even hard laterites and make the soil porous and helps in down ward seepage of water enriching the ground water table. It has been the experience of the agriculturists to condition the hard soil by stacking the coconut husk in pits surrounding the plants. This can be used in improving ground water level in hard lateritic terrain. Infilteration trenches at suitable locations with bore holes at the bottom to a significant depth (i.e. rocky bed or water table) can be made. These bore holes can be lined with reinforced and treated coir felt and metal chips can be loosely filled inside the trenches and bore holes. The top of the trenches can be covered with coir net with loop structure and fixed to a bamboo frame. This arrangement will ensure the collection of surface rain water and encourage percolation enriching the collector wells, besides raising the ground water level.

Coir Geo- textiles: Erosion of the fertile top soil is a grave problem to the human kind. It is reported that about 18 % of the top soil is being eroded every year all over the world. Wind, rainfall and natural calamities cause soil erosion which will eventually convert fertile lands into deserts. Increasing population and depletion of fertile land affects the agricultural activities to a great extent. It has been established that coir nettings is an ideal material for prevention of soil erosion. Coir geo-fabrics are woven coir nettings or mesh mattings. They are inexpensive, ready-to-use and effective items for a variety of applications including control of soil erosion, control of landslides, slope stabilisation, seepage of water through canals and in other civil engineering applications like road embankments etc. In these applications, coir is used because it is natural, hard fibre with high tensile strength, durability and moisture resistance. Coir board had conducted several studies on the use of coir geo-textiles to prevent soil erosion in different ares. Coir mattings (mesh mattings) are firmely laid on the slopes of cannals, railway embankments, road embankments and sown upon with grass seeds or slips are planted. With passage of time, the grass takes root and furnishes a permanent coverage, thereby stabilising the mortle soil The coir matting also degrades and mergers with the soild adding to nutrient content of the soil. The coir matting serves to hold the seed and soil intact, there by preventing erosion during heavy rain storms. The typical netting has adequate opening between the thread, giving the grass, plenty of room to grow. It also serves to dampen the kinetic of flowing water and keep both soil and seeds in place.

Poly Coir: The Central Coir Research Institute of the Coir Board in collaboration with the Regional Research Laboratory (CSIR), Thiruvananthapuram has developed "Poly Coir" which is made out of brown fibre.

The coir needled felt, a non woven material from coir fibre, is cut into the appropriate width and coated with desired quantity of phenol formaldehyde resin by weight to form rolls of prepeg. The composite products from prepeg sheets are prepared by hot press moulding. The prepeg sheet is cut into the required size and stacked one over the other. The number of layers used is decided on the requirement of thickness of the component and the pressure applied for moulding varies depending on the density and surface finish of the product. Trimming and polishing of the edges and wastage can be minimised by taking care of the size of prepeg sheet used for moulding. The major advantages of poly coir over plywood are (i) termite proof, (ii) water resistant, (iii) fire resistant, (iv) mouldable to desired shapes and (v) very good aesthetic appeal.

Coir Matting Decorative Boards: Coir matting cut into required sizes is treated with Phenol formaldehyde resin and hot pressed to make the boards. The number of matting pieces can be suitably increased so as to make high density boards.

Coir Ply Boards: Coir needled felt treated with Phenol formaldehyde resin is sandwitched by plywood veneer and hot pressed in the process of making coir ply boards. This product is cost effective when compared to ordinary plywood but equally strong and durable.

Coir Cement Composite Panel:

Reinforced composite panels are made using coir fibre of 50 to 350 mm long and 0.1 to 0.40 mm diameter. The fibres soaked in water initially for 1 to 2 hours is thoroughly mixed with predetermined quantity of portland cement and chemical admixture. The coated fibres are uniformly spread on a mould and pressed for 6-8 hours to the required thickness. The pressed panel is moist cured for 10 days and dried under natural conditions for 4-6 days and trimmed to required size. The strength properties of the boards are given in the Table.3

Table 3. Strength characteristics of fibre and coir cement board

Property	Fibre	Coir-Cement Board
Colour	Brown/white	-
Moisture content, %	-	6 - 12
Fibre length, mm	50 - 350	-
Fibre diameter, mm	0.1 to 0.4	-
Bulk density, kg/m^3	145 to 280	1300 - 1400
Ultimate tensile strength, N/mm^2	80 to 160	$(3.2 - 3.5) 10^{-3}$
Modulus of elasticity, KN/mm^2	19 - 16	$(3.2 - 3.5) 10^{-3}$
Elongation at break, %	10 to 25	-
Water absorption, %	130 to 180	14 - 16
Thickness swelling, %	0.8 - 1.2	-

Husk Particle Boards:

Merits of particle boards include saving of natural resources and waste utilisation and this leads to environmental pollution control. Husk of matured coconut is unique raw material to prepare particle boards, in view of the fact that wood particle boards use 8-10 % adhesives on weight basis, while coconut husk boards require upto 0.25 % adhesives. However, care has to be taken to see that the ingredients in pith should not be allowed to separate out from the fibre, while the chips should be of free flowing nature. It should not inter lock into bundles during handling and storage. Such boards would give a density of 250 to 1300 kg/m^3 (Table 4) and strength properties meeting relevent specifications.

Laboratory studies have also been carried out with husk as core and wood basis, a surface to prepare layered particle boards. The layered particle boards showed good strength and low water absorption properties (Table 5). These boards are found to be fire resistant. These studies have clearly shown the feasibility of preparing the particle boards using coconut husk and its by-products which confirms to the specification of wood. However, there is no structural study carried out to understand the observed properties.

Table 4. Properties of particle board from coconut husk

Adhesive, %	Other adhesive, %	Density, kg/m3	Modulus of rupture, kg/cm2	Water absorption in 24 hrs, %
0.0	Paraformal-dehyde - 1%	250	22	113.5
0.5	-	510	138	151
0.5	-	760	233	97.8
0.5	-	900	368	88.5
0.0	Paraformal-dehyde - 1%	1070	373	23.6
0.0	-	1210	365	16
0.0	-	1310	254	10.6

Table 5. Properties of three layer wood - coconut husk particle board.

Species of wood used	Adhesive, % in board	Adhesive, % on wood particles	Density, Kg/m^3	Water absorption (24 hrs), %
Phenol formaldehyde:				
Cederla loona	2.8	10	740	56.3
Cedal	3.2	7.1	680	58
Teak	3.9	8.2	550	76.5
Urea formaldehyde:				
Mango	7.1	12	700	59.4

UTILIZATION OF COIR PITH

Fibrous coir and non- fibrous pith are the two important constituents of husk. The coconut husk is constituted by 70 per cent pith like material and 30 per cent fibre. The elastic cellular cork like material forming the non-fibrous tissue of the husk is referred as coir pith. This is obtained as a waste after the extraction of coir from the husk by the coir industry. For every one tonne of coir fibre produced from coconut husk, nearly 2 tonnes of coir pith gets generated. It is assessed that in India 7.5 million tonnes of coir pith is produced annually. For want of proper utilisation, this is dumped outside the coir industry.

Structure of coir pith

Coir pith is an open cell foam. The cells are of almost uniform size and cylindrical in shape. The walls are very thin and empty cavities (lumen) are comparatively large. Average lumen size of the pith is 50 mm. Observation of broken cell walls stained with Schulz's solution has shown that cellulose is seen in the form of thin fibrills as in the case of other ligno-cellulosic materials. Water absorption studies have shown existence of capillaries measuring 2 micro mm in the cell walls, which contributes about 15 per cent of the total free space.

Physical properties:

The physical properties of the biological materials depends on various parameters and are much useful in the design of the process and handling systems. The physical properties of coir pith are: bulk density - 0.15-0.19 g/cc%, specific gravity - 0.149%, particle density - 0.49 g/cc%, porosity - 76.77%, maximum water holding capacity - 624.0%) and volume expansion of 100 ml - 22.92%).

At moisture content of 12.2 % (db) the angle of repose coir pith increased from 35 and 43°C with increase in particle size and then decreased. The bulk density decreased from 240 to 96 kg/m^3 for the particle size increasing from 1.55 mm to 0.21 mm. The porosity increased as the particle size increased which is due to the increase in the void space created with the increase of particle size.

Chemical properties and composition of coir pith:

A number of researchers have determined and reported the various chemical properties and the constituents of coir pith. Such of those properties/constituents of coir pith are also compared with that of fibre and composted coir pith and presented in Table 2.

Utilization of coir pith:

Direct application to soil: The continuous application of coir dust for 8 years has influenced a reduction in bulk density, improved the water holding capacity and organic carbon status of soil resulted in early flowering of palms. The coir pith has the ability to absorb and retain 10 times its weight of water. Alternate layers of coir pith and soil are placed in the pit of size 2 x 1.25 x 0.75 m for 8 and 5 cm thick respectively. In gravelly soils, burying of coir pith gave a 20% increase in the number of nuts and 15% increase in copra yield. Also when coir dust is used for a long period, the water holding capacity of the soil is considerably improved and becomes more porous allowing better root penetration.

The ligno cellulosic coir pith is free from heavy metals or man made polymers. Direct application of coir pith resulted a reduction in soil microbial population and soil bio-polysaccharides, soil dehydrogenases and soil respiration in all soils except those high in organic matter. The undecomposed coir pith with 8-12% of soluble tannin related phenols apparently inhibit plant and microbial growth and also immobilies nutrient nitrogen in the soil during polymerisation.

Composting of coir pith:

Composting of coir pith has the advantages of detoxifying phenolic compounds which are deleterious to microbial growth, reducing the bulk of the material and converting plant nutrients to a form more readily available to plants. Tamil Nadu Agricultural University, Coimbatore has developed a technology using Basidiomycetous fungus, *Pleurotus sajor, Caju* which is capable of detoxifying phenolics and producing bio-polymerizing enzymes. Cellulosic compounds present in the coir waste support the initial growth of this fungus and act as co-substrates for lignin degradation.

The required quantity (300 g per bottle) of sorghum, maize or pearl millet grain with an equal volume of water is half cooked in a pressure cooker. The excess water is drained. After cooling, calcium carbonate (20 g per kg of grain) is mixed with the half cooked grain. The contents are poured into 500 ml bottles and the bottles are plugged with non-absorbant cotton and sterilised in an autoclave for 2 hours at 1-4 kg/cm^2 pressure. After cooling, the media is inoculated aseptically with *Pleurotus* fungus culture. The contents are incubated at about 23°C for 15 days. By this time, the mycelium grows and covers the entire bottle.

One hundred kg of coir pith with 50-100 % moisture is spread uniformly to a size of 5 x 3 m. One bottle (350 g) of *Pleurotus* fungus culture raised on sorghum or pearl millet grain (spawn) is spread on the coir pith. Another layer of 100 kg of coir pith and one kg of urea are applied. Urea has been found to increase the enzymatic activity of the fungus and accelerate degradation of coir pith. The process of sandwiching the fungus spawn and urea alternatively with 100 kg of coir pith is repeated till the heap reaches an height of one metre. The water content of the heap is increased by sprinkling water and finally covered with a thin layer of coir waste to conserve moisture. To compost one tonne of coir pith five spawn bottles and five kg of urea are required. After 30 days of decomposition, coir pith turns into a black mass of compost with reduced lignin, cellulose, organic carbon and C:N ratio. The volume of the material is also reduced by 50 per cent. The chemical properties/ constituents of composted coir pith are given alongwith those properties of raw coir pith in Table 2.

The efficiency of coir pith could be improved by enriching with other organic manures as well as inorganic nutrients by the addition of required nutrient element during composting. The nutritive value of the coir pith as compared with cattle manure is given below:

Value in kg/t	Cattle manure	Coir dust
Nitrogen	9.86	4.42
Phosphorus	4.82	0.71
Potash	1.81	1.02

The sun dried coir pith is used as a bedding material for poultry farming in deep litter system. The manurial value of coir pith based poultry litter is also presented along the decomposed coir pith in Table 2. Application of coir pith based poultry litter at 6.25 tonnes per hectare along with the recommended level of nitrogen, potassium and phosphorus registered 20 per cent increased yield in sorghum (CO 25).

Densification of composted coir pith:

Tamil Nadu Agricultural University has developed a pelletizer for making pellets from composted coir pith. The com enriched according to the nutrients requirement is extruded into pellets of 6 to 8 mm diameter and 10 to 12 mm length. The unit is operated by a 5 hp electric motor and had a capacity of 100 kg/h. Decomposed coir pith is made into pellets using this pelletizer at 25% moisture content. The coir pith pellet with optimum durability, compaction and expansion ratios of 0.82, 3.14 and 1.33 respectively obtained.

Briquetting of coir pith:

A continuous extruder type briquetting machine, consisting of screw shaft, barrel housing, extruder die pipe and gear box has been developed at Tamil Nadu Agricultural University. The unit has a capacity of 125 kg per hour. Cow dung and molasses at various proportions to the coir pith are added (0, 10, 15, 20 and 25%) as binder and the briquettes produced are evaluated for their calorific value and thermal efficiency. The calorific value ranges from 3000 to 3200 kcal/kg and cow dung mixed at 15 % of coir pith resulted in better stability to the briquettes.The thermal efficiency of the fuel briquettes in Maccan chula is about 15.6 %. The length of the hollow briquette ranges from 5 - 15 cm depending on the self weight of the briquette extruded from the pipe. The central hole in the briquette enables the movement of air which aids good burning. This can be utilised as an alternative source for fuel.

Production of building materials:

A technology for the production of coir-cement corrugated roofing sheet has been developed by the Tamil Nadu Agricultural University. Dry cement at the rate of 20 kg for every 1.5 kg of coir pith, soaked in water for 3-4 hours and mixed well. The mix is spread in corrugated sheet mould lined with polythene sheet and tightened and allowed for 10-12 hours. The sheet is dried under shade for 2 days and a coating of cement with water is given and the edges are trimmed. It is observed that the temperature is lowered by 1 to 4°C in coir-cement corrugated roofing than in asbestos.

Coir pith of -16/+30 mesh and -30 mesh size with plastic clay in different proportion of 60:40 to 90:10 are mixed and bricks of 5 cm diameter are moulded by applying a pressure of 3 KPa. These bricks are dried for 72 hours in air and in an oven at 105.5°C for 48 hours. Firing of bricks is carried in an electrically operated furnace at 700, 800 and 900°C after soaking for 4 hours.The total volumetric shrinkages on firing the bricks at all composition increases with increase in the pith content and firing temperature. The strength values at zero porosity are 1.47 MPa at 900°C and 5.60 MPa at 700°C for the bricks made out by incorporation of with below -30 BS mesh size and 7.16 MPa at 900°C and 1.42 MPa at 700°C for the bricks made from -16 +30 BS mesh sieve. The possibility of commercial production of light weight bricks using coconut pith in the proportion of upto 80:20 (clay and pith) by weight has been successfully brought out.

In a soil block making machine, bricks of 30 x 14.5 x 10.5 cm is made without any binders. The density of the block is 203.6 kg/m^3 and it expands rapidly at the initial period and then the rate of expansion decreases. However, the bricks are not put into utility. Such blocks are already being made for easy handling and transportation.

Particle boards of size 30 cm x 30 cm using coir pith with gelatinized cassava starch as binder are produced and evaluated. The binder-pith ratio varied as 0.6, 0.7, 0.8, 0.9 and 1.0 and the pressing time as 10, 20 and 30 minutes. Boards made with resin-pith ratio of 1.0 exhibited higher physical properties, mechanical properties and utility characters. For acoustic insulation, resin-pith ratio of 0.7 is found to be good.

Low density particle boards from coir pith using 6 % urea formaldehyde resin as binding material are produced by hot pressing under 1.47 MPa at 170 C for 15 minutes. The various physical, mechanical, thermal and acoustic properties are determined as given in Table 6.

Table 6. Strength and utility characteristics of coir pith particle boards

Properties	Resin		
	Phenol formaldehyde	Urea formaldehyde	Urea formaldehyde
Density, g/cc	0.9	0.9	0.29
Modulus of rupture, KPa	1.16	0.81	0.58
Tensile strength, KPa			
parallel to surface	0.25	0.13	0.052
perpendicular to surface	0.01	0.006	-
Screw holding capacity, N			
along face	680	676	414
along edge	307	262	38
Nail holding capacity, N			
along face	500	331	40
along edge	10	128	28
Lateral nail resistance, N	425	330	-
Impact strength, N	556	262	-
Water absorption, per cent			
after 2 hours	34.4	50.1	-
after 24 hours	76.7	94	-
Swelling along surface, per cent			
after 2 hours	1.1	1.8	
after 24 hours	2.9	2.0	
Swelling along thickness, per cent			
after 2 hours	29.4	53.9	-
after 24 hours	39.5	98	-
Thermal conductivity, w/m°C	0.23	0.13	0.08
Noise reduction coefficient	0.183	0.183 (125-4000)	0.5 (125-2000 Hz)
Transmission loss, dB (A)	4.4-20.5	4.4-20.5	2.4-23.8
Sound Absorption Coefficient	0.01-0.30	0.01-0.30	0.23-0.60
Cost Rs. per square foot	50/-	33/-	-

A process for the production of particle board using coir pith has been optimised. The process include the prepartation of the coir pith, mixing well with resin, mat formation and hot pressing. The resins used are phenol formaldehyde and urea formaldehyde. From the studies, the following process parameters are found to be optimum for two types of resins for the mixed size of particles of coir pith.

The particle boards prepared using coconut pith with and without veneered layers on both sides by M/S Kerala State Industrial Development Corporation, Thiruvanathapuram are evaluated for the physical and mechanical properties. These boards are found to be resisitant to burning and those strength characters of the particle board are given in table 7.

Table 7. Properties of coconut pith based particle board

Property	Coir pith board	Veneered coir pith board on both sides
Thickness tolerance (cm)	1.63 - 1.75	1.7 - 1.82
Apparent density, kg/m^3	668.5	672.3
Water absorption, %		
after 2 hours	5.3	7.7
after 24 hours	13.6	20.9
Swelling in thickness, %	4.9	4.34
Tensile stress perpendicular to face, kg/cm^2	1.5	2.57
Moisture content, %	10.2	10.5
Resistance to screw withdrawl, kg		
along face	146	159
along edge	67	71

REFERENCES

Aggarwal LK (1991). Development of coir fibre reinforced composite panels. Research and Industry. 36(12): 273-274.

Ayyar TSR (1997). Coir Fabrics for infrastructure development. Coir News. 26(9):15-19.

Dan TK (1992). Development of light weight building bricks using coconut pith. Research and Industry. 37(1): 11-17.

Dan TK (1993). Develoment of Light Weight Building Bricks using Coconut Pith. Indian Coconut Journal, 37(3):12-19.

Das Anita and Ravindranath. (1991). Coir pith potential wealth in India. In: Proceedings of the seminar on utilisation of coir pith in agriculture. 20th Nov.1991. Tamil Nadu Agricultural University, Coimbatore. pp.1-8.

Devadas CT (1996). Densification and combustion studies on coirpith for utilization as a fuel briquettes. Ph.D thesis sumitted to Tamil nadu Agricultural University, Coimbatore.

Kandaswamy P, and Natarajan S (1993). Use of coir pith in agricul ture. In: Proceedings of the workshop on utilisation of coir pith held at Pollachi on 13 February 1993, Coir Board, Cochin.

Nair VR (1992). Manufacturing, testing and application of coir as geotextiles with particular reference to erosion control. Indian Coconut Journal. 23(6):5-8.

Natarajan G (1995). Commercial exploitation of coconut pith - problems and prospects. Indian Coconut Journal. 25(10):9-11.

Pillai KM (1995). Product Diversification in Coir Industry. Coir News.4:11-14.

Pillai MK (1996). Brown Fibre Sector - can it be a feed Sector to the export Oriented Production Sector of Kerala?. Coir News. 25(9):17-19.

Sampathrajan A., N.C.Vijayaraghavan and K.R.Swaminathan. 1991 Acoustic aspects of farm residue - based particleboards. Bioresource Technology. 35: 67-71.

Sampathrajan A, Vijayaraghavan NC and Swaminathan KR (1992). Mechanical and thermal properties of particleboards made from Farm Residues. Bioresource Technology. 40: 249-251.

Sathyanarayana KG, Sukumaran K and Pillai SGK (1985). Physical and mechanical properties of particleboard from coconut pith. Research and Industry. 30(4): 341-348.

Varadjaraju N and Gothandapani L (1998). Design and development of equipment for pelleting decomposed coir pith. AMA. 29(2): 33-34.

Viswanathan R (1996). Optimisation of Process Parameters in the Production of Particle Boards using Coir Pith. Unpublished Ph.D thesis submitted to the Tamil Nadu Agricultural University, Coimbatore-3.

COCONUT SHELL MADE PRODUCTS

S. J. D. Bosco

INTRODUCTION

Coconut is probably the only tropical crop commercially cultivated extensively in about 86 countries especially on the small and marginal holdings over an area of 11.1 million hectares and produces about 51.3 billion nuts per year. The endocarp of the coconut is known as shell. It is estimated that in India over 1.7 million tonnes of shell is theoretically available per year. Much of this is lost in the form of tender nut shell and shell of coconut is used for culinary purpose.

Major portion of the shells are used as fuel, for domestic and for copra production. Much of the available coconut shells is scattered in small quantities on individual farms through out the coconut growing area. Under these circumstances, setting up of a viable industry based on coconut shells is unlikely. Such a venture is likely to succeed only where large quantities of shells are available at one point as in the concentrated coconut growing area or large plantation or desiccated coconut factory or centralized copra processing plant etc.

The commercial utilisation of coconut shells for the production of shell charcoal, activated carbon, shell flour, etc., is now gaining importance in the producing areas with an expanding market demand. The shell charcoal is already in demand in the world market. Coconut shells are not favoured as boiler fuel due to the corrosive effect of the combustion vapour that are intensified by high temperatures.

COMPOSITION OF SHELL

Coconut shells are similar in composition to the hardwoods, but have a higher lignin and a lower cellulose content. The composition of coconut shell as reported by a number of workers is given in Table 1.

Table 1 : Composition of coconut shell

Constituent	Percent		
	a	b	c
Moisture	10.15	-	8.0
Extractives	2.72	-	4.2
Nitrogen	0.23	-	0.11
Cellulose	26.41	33.61	26.6
Lignin	57.77	36.51	29.4
Pentosans	20.49	29.27	27.7
Ash	2.59	0.61	0.6
Uronic anhydride	-	-	3.5
Methoxyl	-	-	5.6

[a] Serrano, D. J. et al. (1975)
[b] Woodroof, J. G (1970).
[c] Child, R. (1974)

The methoxyl content does not differ much from that of hardwoods. The moisture content varies according to environment, variety and maturity of the nut. Under average conditions, air-dried mature shells contain 6-9 per cent moisture. The heat value of the shell is 7500-7600 cal/g (d.b).

COCONUT SHELL CHARCOAL

The most important produce derived from shell is charcoal. The yield of shell charcoal is about 30 per cent of the weight of the shells used, and it is generally reckoned that about 17000-24000 whole shells makes one metric ton of charcoal. In India, production of shell charcoal is still a very primitive industry. To obtain charcoal, the shell of fully matured nuts are burned in a limited supply of air, so that they do not burn away to ash as in open fire but are only carbonized. Several methods are in vogue for the production of charcoal.

The shells are often burned in pits in the ground. A simple pit suitable for producing a charcoal for copra drying can be described as follows: A hole 1 m deep, 75 cm long, and 75 cm wide is dug in the soil. Some dry shells, clean and free from adhering fibres of the husk, are placed at the bottom and set on fire. When the shells emit flames, they are slowly piled together, and more and more shells added until the whole pit is filled. The pit is then covered with a zinc or iron plate, and the hole is made airtight by packing earth around the edges. It is preferable to use fire-resistant bricks for the lining, but ordinary locally made bricks will stand up for a considerable time. Mud mortar is found to be more satisfactory than cement. Regarding the shape of the pit, circular pits, narrower at the top than at bottom or bottle-shaped are preferable, as the firing is more easily controlled.

In Indonesia, a simple technology for producing coconut-shell charcoal is developed. The conversion efficiency is about 25percent, which is high as compared to traditional methods. The production time per batch is 20 hrs. The technique involves the use of a 200 l drum as a kiln. The coconut shells are put into the drum through a 30 cm hole in the top. Small holes in the bottom part of the drum allow air to enter. A little kerosene is used to allow the shells to catch fire. After 5 minutes, the lid is put on the drum to put out the fire. Shells are added to the drum when white smoke is emitted. More shells are added to the drum when black smoke is emitted. This process is repeated until the drum is filled with charcoal. The drum is sealed and kept overnight, and in the next day the charcoal can be taken from the drum.

Success in operating these types of kiln greatly depends on the experience of the operator. Some practice is required to attain exactly the right conditions. If the combustion is smothered too much and carbonization is complete, a mass of woody half-burned charcoal results. If, on the other hand, the burning is not smothered enough, there is a poor yield of charcoal, which is brittle, thin, and dusty. When the pit is full, the slow burning proceeds, while much acidic smoke is given off. During this process the pit is covered as described above, leaving only sufficient space for a smoke outlet. It is not usually possible to open the pit until the third day. When it is opened, the mass of charcoal may catch fire, and it is therefore sometimes necessary to sprinkle it with water until it cools off.

There are many modern kiln available for the manufacture of coconut-shell charcoal, and most kilns suitable for wood charcoal can be used for this purpose. Where a large supply of shells is regularly available at one spot, the carbonisation can be done in kiln, in which the heat energy producing at the time of carbonisation is effectively used. An advanced coconut shell carbonization unit, *otherwise called* as waste heat recovery unit, has been developed by National Research Institute, United Kingdom. This unit carbonizes shell whilst simultaneously producing a combustible gas which is used to provide process heat. In the traditional methods of carbonization to produce charcoal, this heat is lost to the surroundings and large volume of obnoxious smokes are evolved. This smoke problem is virtually eliminated by using the waste heat recovery unit. During carbonisation of coconut shell using traditional pit methods, approximately 65 per cent of the heat in the feed stock is wasted. The charcoal produced in the waste heat recovery unit , contain approximately 40 per cent of the original heat content of the shells and approximately 75 per cent of the remaining heat, which would normally lost to the surroundings, could be used for processing, this heat being approximately equivalent to 235 liters of fuel oil, when one tonne of shell is carbonised. This technology has been commercialized in Sri Lanka.

Good shell charcoal is uniformly dark and snaps with a clean shining fracture and produces a metallic sound, when dropped on hard ground. Under-burnt shells do not give a metallic sound and a clean fracture, while the over-burnt ones are friable and the surface of the fracture sounds dull when dropped and easily crumbles. Shell charcoal contains the highest percentage of fixed carbon of all the ligneous charcoals. Better quality charcoal can be obtained from more matured coconut shell. The dead ripe matured shells and turning brown matured shells can be mixed during carbonisation **without** reduction in charcoal quality.

Other than the traditional uses of shell charcoal such as culinary fuel, dentifrice, etc., it has other important uses as base material for activated carbon. The charcoal has a high absorption capacity for gases and colouring matter and can be used as a refining agent, both as a deodourizer and a decolouriser. The shell charcoal also finds way to laundries, smitheries, etc. The ash obtained from the shell, at the time of carbonization, is found as a useful substitute for potassium fertilizer.

ACTIVATED CARBON

Coconut shell charcoal, is a material with a very limited surface area. The absorption capacity for gases and colouring matter is, therefore very less. This can be increased by activation with chemicals. On activation, it is transformed into a product with the ability to absorb effectively even trace quantities of either unwanted or valuable liquids and gases. Activated carbon plays a very important role in solvent recovery processes, water and effluent treatment, and in treatment of flue gas before discharge into the atmosphere.

In the activation process, shell charcoal is fed continuously into a retort. The normal activation process involves the use of steam at selected temperatures for the selective oxidation of material, resulting in production of carbon with pores of molecular dimensions. Shell carbon, having a cellulose base, produces a material with a finer pore structure than obtained from coals. Approximately three tons of shell charcoal are needed to produce one ton of activated carbon. Retorts designed to produce activated carbon usually operate in one of the three ways-vertically, horizontally, or by means of a series of hearths. In a vertical retort, utilizing steam, activation is controlled by the rate at which the material is withdrawn from the discharge hopper. Activation can be carried out with a variety of gases, including oxides of carbon, chlorine, and mixtures of steam and air. After withdrawal from the retorts, the material is cooled and passed through a series of granulators and screens, thereby attaining carbon of a known quality, available in variety of grade sizes to suit many applications.

For certain specific purpose, different process is used to prepare the activated carbon. This process consists of the treatment of crushed coconut shells with surface active chemicals followed by drying and subjecting the material to carbonisation. The carbonised material is activated with steam followed by air to facilitate oxidation. The activated material is subjected to steam quenching to reduce the bed temperature and is then discharged in a receptacle. The material is subsequently subjected to acid treatment to adjust the pH value. The acid treated activated material is then washed with water, dried and stored.

Granular activated carbon produced from shell charcoal is an important industrial material, and the prospects for the intermediate charcoal appear to be good as long as quality is maintained. In general, activated carbon is used where the compound to be absorbed has a small molecular diameter or, if it is a gas, when a boiling point is below 100°C. The use of this type of carbon is also specially indicated where the concentration of the absorbate is very low.

While the shell based activated carbon is considered superior to those obtained from other sources because it is generally dense, very hard, and highly retentive. They have a very fine pore structure, and their rate of absorption is generally faster than that of coal carbons.

DESTRUCTIVE DISTILLATION

In ordinary methods of charcoal making, the recovery rate is less than 30 per cent of the weight of shells. By subjecting shell to destructive distillation, charcoal of excellent quality constituting about 35 per cent of the original quantity of shells used and a variety of other useful products are obtained. The shell charcoal obtained in the process is of the best quality and has a good demand for the manufacture of activated carbon. When coconut shells are heated in a retort to a sufficiently high temperature, they are broken down in the absence of air into a number of produce. The yield and the composition of the products are likely to vary considerably with the maturity of coconuts from which the shells are derived and even more, with the conditions under which the destructive distillation is carried out. The products generally obtained are charcoal, pyroligneous liquor, settled tar and incondensable gases.

The settled tar is a complex mixture of products. By fractional distillation, it yields phenol and neutral oils, pitch, settled tar, methyl alcohol, crude creosote oil and acetic acid. The acetic acid is a good substitute for the coagulation of rubber latex.

SHELL FLOUR

A second important product derived from shell is shell flour. It is prepared by grinding clean coconut shells to a fine powder, the particle size depending on the end use. Typical grades are 100, 200, and 300 mesh.

The shells are first precrushed in a beater type disintegrator into, 5 cm pieces which are then conveyed to the first hammer mill. Suction in the conveying system draws the particles of flour into a cyclone, where they are separated into coarse and fine particles. Ultrafine particles are drawn away and collected separately. From the cyclone the coarser particles pass to the second hammer mill, and the ground products are subjected to the same air separation as the particles from the first grinding. The fine particles from the cyclone are fed into a vibrator sieving unit and graded into the required mesh size.

It is used mainly as a filler, replacing wood flour either partially or wholly in the manufacture of phenolic moulding powders by the thermoplastics sector of that industry. The inclusion of shell flour results in an improvement in the surface finish of the mouldings, and because of its higher resinous content and lower absorption properties, it can be used in higher concentrations than wood flour. Shell flour has a variety of other uses. It is used as a filler in phenolic glues for plywood and laminated sheets manufactures, filler for mosquito incense coils and filler in specialised surface finishes, resin castings, etc. As a mild abrasive it is used as a soft blast to clean piston engines. It has been incorporated into hand cleaners and used as a diluent for potent insecticides.

OTHER USES

Shell has a variety of other uses. It is used for the manufacture of hookah shells, various domestic utensils, curios, fancy items, souvenirs, etc. It is also used for the collection of rubber latex from rubber estates.

EXPORT POTENTIAL FOR COCONUT SHELL PRODUCTS

There is a good demand for activated carbon world wide, not only from buying countries such as Japan, South Korea, France and United Kingdom, but also from the producing countries such as the Philippines, Indonesia, Malaysia and other countries. Export of shell charcoal and activated carbon by selected countries during 1992-1997 is given in Table - 2. The combined exports of coconut shell charcoal and activated carbon increased from 2,24,251 MT in 1996 to 2,47,900 MT (expressed in coconut shell charcoal basis) in 1997 exhibiting about 10 per cent increase. This increase will be more if the supply increases from emerging countries such as Malaysia, Thailand and India. There is an increased desire to set up more activated carbon processing facilities in a number of coconut producing countries. As a result, few countries such as Malaysia, Thailand and India have emerged as regular suppliers of activated carbon in recent past.

In the importing countries, the main usage is said to be the gold mines which use the C-I-P (Carbon In Pulp) process. The increased demand for activated carbon is also increasing in Indonesia, Malaysia and Philippines. This is to meet the growing demand from the increasing vegetable oils and oleochemicals industries and from water treatment plants.

Table 2 : **Exports of shell charcoal and activated carbon by selected countries (in MT)**

Destination	1992	1993	1994	1995	1996	1997
Shell charcoal	65640	67332	60761	52332	66861	73000
Philippines	43423	51975	39645	34235	41065	46000
Sri Lanka	8081	2995	6729	3820	9941	10000
Indonesia	14136	12362	14387	14277	15885	17000
Activated Carbon	35869	40226	36753	34361	47694	53000
Philippines	15785	19458	15806	9489	19490	20000
Sri Lanka	14363	13605	13302	16422	15879	17500
Indonesia	5721	7163	7645	8450	12325	15500
Total*	184008	200078	182046	165723	224251	247900

* aggregate of coconut shell charcoal and activated carbon in shell charcoal basis

CONCLUSION

Shell is a very important raw material for the manufacture of many useful products of commercial importance. Among the various shell products, shell charcoal is having more demand in the international market and Sri Lanka meets 90 per cent of the demand, the rest being met by the Philippines. In India, effective utilization of coconut shell is not popular because, the availability of shell at a place may not be adequate for further processing and the processing margins may not justify transportation cost of the shell. Shell or waste heat recovery technology offers coconut processors the opportunity to take one small step towards reducing CO_2 emission to the atmosphere. It is through a combination of many such steps, the present damaging impact of combustion on the environment will be eliminated.

REFERENCES

Anonymous (1979). Technical data handbook on the coconut, its products and by-products. Philippine coconut authority, Philippines. P. 324.

APCC (1980). Shell products and other processes. *Coconut Processing Technology Information Documents (UNIDO)*, Jakarta, Indonesia. 7: 71.

APCC (1984). The design, construction and operation of a unit for the carbonisation of shell with recovery of waste heat. *Cocomunity Quarterly* Supplement. 48:13-30.

APCC (1997). The cocomunity. 37(21):4-5,13.

Breag GR, Harker AP, Paddon AR and Robinson AP (1984). The design, construction and operation of a unit for the carbonisation of coconut shell with recovery of waste heat.

Tropical Development and Research Institute Report No. G182. p 18.

Child R (1974). Coconuts. Tropical Agriculture Series, 2 nd ed., Longman Group Ltd., London. P. 105.

Drew PJ, Breag GR and Marder RC (1993). Copra production using the shell carbonization with waste heat recovery technology. *Tropical Science.* 33(3):246-267.

Fremond Y, Ziller R and Lamothe MN (1966). The coconut palm. International potash Institute, Switzerland. pp 227.

Grimwood BE (1975). Coconut palm products; their processing in developing countries. FAO Agricultural Development Paper no. 99. pp279.

Little ECS (1978). The mini-Cusab kiln for rapid small-scale manufacture of charcoal from scrub, coconut wood and coconut shells. Appropriate Technology. 5(1) :12-14.

Montenegro HM (1977). Shell charcoal and activated carbon industries. *Cocomunity.* 23:29-35.

Paddon AR and Harker AP (1979). The production of charcoal in a portable metal kiln. Tropical Products Institute. Series-G. 119:29.

Palcon RS, Creencia BP, Tabora PC and Estudillo CP (1977). Properties of shell charcoal from three stages of nut maturity. Philippine Agriculturist. 61(7/8):291-303.

Serrano DJ, Madriaga H and Logman P (1975). Industrial utilization of the condensable by-products from the carbonization of coconut shells. National Institute of Science and Technology Annual Report 1974 -1975:85.

Thampan PK (1988). Glimpses of coconut industry in India. Coconut Development Board, Cochin. P 219.

Thampan PK (1975). The coconut palm and its products. Green Villa Publishing House, Cochin, Kerala (India). pp314.

Woodroof JG (1979). Coconuts: Production, Processing, Products. Avi Publishing Co., Westport, Connecticut. pp150.

WOOD MADE PRODUCTS

A C Mathew

INTRODUCTION

Primary species of timber such as teak, rosewood and other exotic hardwoods are becoming scarce and expensive. In this context, secondary species of timber, available at lower prices, seem to be the right alternative. Plantation timbers like coconut wood, rubber wood etc. when chemically treated and seasoned to make them durable are suitable for most applications. Coconut wood & Rubberwood are now available in plenty in India, and this trend will continue.

COCONUT WOOD

Physical properties:

The physical properties of cocowood depend largely on its density, moisture content and shrinkage (Table - 1).

Table 1 : Physical properties of cocowood

PROPERTIES	COCOWOOD		
	Dermal	Sub-Dermal	Core
Moisture content (%)	87	182	356
Basic density (kg/m^3)	697	473	286
Shrinkage (Green to ovendry) :			
Radial (%)	6.3	5.9	5.6
Tangential (%)	6.6	6.1	5.8

Its basic density (Oven-dry weight divided by green volume) decreases with increasing height of the stem and increases from the core to the cortex at any given height. In addition, the basic density at any particular height increases with age of the palm. Overall, the basic density ranges from 110 kg/m^3 at the top core portion to 850 kg/m^3 at bottom dermal portion of old coconut palm.

The moisture content is negatively correlated with the basic density, i.e., moisture content decreases with increasing basic density and vice versa. The amount of moisture in coconut stem increases with increasing stem height and decreases from the core to the cortex. The moisture content ranges from 50% at the bottom dermal portion to 400% at the top core portion of the stem.

The dimensional stability of the wood is determined by its shrinkage or swelling, which accompanies a change in moisture content below fibre saturation point. Shrinkage and swelling cause drying defects such as checks and split. Unlike conventional wood, where tangential shrinkage is almost twice the radial shrinkage, the tangential and radial shrinkage of cocowood are not significantly different.

Mechanical properties:

The mechanical properties of cocowood, which define its end use are positively correlated with the basic density. Accordingly cocowood has been classified in to three basic density groups as follows: High density wood (dermal), medium density wood (sub-dermal) and low density wood (core) with respective basic density as 600 kg/m^3 and above, 400 to 599 kg/m^3 and below 400 kg/m^3.

Table-2 presents the mechanical and related properties of the three density groups of cocowood based on green and dry samples. All values of the strength properties decrease with decreasing basic density. Except for impact bending, the values of other mechanical properties of cocowood at 12% moisture content are significantly higher than under green condition.

Table 2 : Mechanical and related properties of cocowood

		Static bending			Compression parallel to grain		Compression perpendicular to grain	
Basic density (kg/m^3)	**Moisture content (%)**	Modulus of Elasticity (MPa)	Modulus of Rupture MPa)	Stress at proportional limit (MPa)	Modulus of Elasticity (MPa)	Maximum crushing Strength (MPa)	Stress at proportional limit (MPa)	**Impact bending (N)**
600 and above	57	10857	86	51.6	7988	49	8.3	20.2
	12	11414	104	61.7	9747	57	9.0	20.1
400 to 599	107	6880	53	30.4	5151	31	2.8	18.3
	12	7116	63	38.4	5282	38	3.4	10.1
250 to 399	240	3100	26	13.1	2287	15	1.3	8.4
	12	3633	33	13.4	2914	19	1.7	9.0

Chemical properties:

Coconut wood is comparable to conventional hardwood/softwoods and bamboos as far as hemicellulose (62.0%), lignin (25.1%) and pentosan (22.9%) content are concerned. However, it contains higher ash than conventional woods.

SAW MILLING

Sawing pattern and grading:

In sawing coconut log, the hard dermal and the medium subdermal portion are the important and valuable materials to recover. A sawing pattern should be employed to segregate the three density groups of sawn coconut timber. The round method of sawing assures that the hard, medium and soft lumber are separately sawn. The first cut is a thin slab followed by a cut of 25mm or 50mm thick hard material depending on the diameter of the log. Then the log is either turned 90° or

180° following the same sequence of cutting until the hard portion is recovered. Similar sawing is done after each turn ensuring that the medium and soft materials are extracted separately. The optimum thickness and width of high density lumber recovered from coconut logs are 50mm and 125mm, respectively.

Grading can be done visually, based on the physical defect and colour of newly sawn timber. However, mechanical grading can also be employed by determining the basic specific gravity and/or the stiffness of the lumber immediately after sawing.

DRYING

Freshly-sawn coconut wood contains water as much as 1/3 to 1/2 of its total weight. Except for few uses, like in marine piling, green materials are not advisable to be used particularly for furniture, panels, internal woodworks and flooring. The wood has to undergo seasoning process to minimize the problems in its utilization.

Generally, different species of the wood have marked variation in their drying characteristics. Coconut wood being a monocot, exhibits varying wood structure that influence its drying behaviour. The differences in wood densities across the stem coupled with variable green moisture contents creats problems in drying. The very high moisture content of the soft central portion of the trunk is related to its susceptibility to collapse. On the other hand, the peripheral high density wood is more prone to surface checks and tends to develop twist.

The common drying methods include air drying under shed, forced-air and kiln drying.

1. Air drying:

Air drying is the simplest and economical method of moisture removal from the wood. The sawn timber are fillet-stacked under shed or exposed outside protecting the top layers from direct sunlight or rain. The drying rate mainly depends on prevailing humidity and temperature. Depending on existing weather conditions, 25 mm and 50 mm boards take 4 to 11 weeks and 16 to 21 weeks air drying, respectively, to attain equilibrium moisture content of 17% to 19%.

2. Forced-air drying:

Forced-air drying involves the use of blower where air under atmospheric or heated condition is forced to pass once or circulated through a stack of sawn timber. This process accelerates the removal of free moisture from the wood even under relatively low temperature. At an average atmospheric air temperature of 29°C and air velocity of 3.50 meters per second, 25 mm and 50 mm boards can be dried from green moisture content to equilibrium moisture content in 22 days and 40 days, respectively.

3. Kiln drying:

Kiln drying is the process of exposing green or partially air-dried sawn timber which are fillet-stacked in an enclosed chamber. The kiln is either heated by steam, electricity or the products of combustion of wood or gas. The humidity, temperature and air circulation are controlled in the drying chamber, hence the boards are dried to any desired moisture level within a short period. The 25 mm boards can be dried from green moisture content to the final moisture content of 13% in 14 days employing initial dry bulb temperature of 45°C and wet bulb temperature of 41°C to final dry bulb temperature of 50°C and wet bulb temperature of 37°C. The 50 mm boards can be dried to 16% final moisture content from green condition in 19 days with temperature range of 48°C to 50°C DBT and 39°C to 45°C WBT.

MACHINING

Cocowood furnitures and other finished wood products are gaining nation wide acceptance. However, secondary processing of cocowoood is not an easy task unless effective machining techniques are applied. Technically, the principal limiting factor is the adverse and difficult working properties of cocowood which result to rapid dulling and blunting of woodworking tools. Machining is the process of cutting and dressing wood into the desired shapes and sizes by various woodworking machineries. The process include rip and cross cutting, planing, turning, boring and sanding.

FINISHING

Finishing refers to the application of transparent or semi-transparent liquid coating to enhance the beauty of the grain, colour and figure of wood products. Good quality finish for cocowood requires the preparation of the surface by sanding to remove the knife marks and produce smooth surface. The schedules for finishing cocowood products are influenced by the kind of coating materials to be used, wood substrate which refers to the density of wood, individual skill and appropriate working methods.

Coating involves the sequential application of stain, filler, sealer and top coating materials such as lacquer, polyurethane, polyester and oil finish. Usually, two or more coats of finishes are applied to cocowood to improve the appearance and quality of wood products. Table - 3 shows the finishing schedules for cocowood.

Table 3 : Finishing schedules for cocowood.

TYPE OF WOOD FINISHES	FINISHING SCHEDULES *
Shellac	Apply non-grain-raising stain and filler as required. Sand the wood surface with the fine sand paper. Apply shellac by brushing or spraying. Sand after 2 hours drying and apply second coating. Follow the same procedure for final coating. Dry for 5 hours.
Lacquer	Apply NGR stain and filler as desired. After 2 hours drying, sand with fine sandpaper and apply sanding sealer by brushing. Sand and dust properly. Brush or spray one coat lacquer. Dry for 2 hours. Scuff with very fine sandpaper and dust. Apply second coating and after 4 hours drying, apply final coating of lacquer.
Oil finish	Apply oil finish with soft cloth by rubbing the wood surface until oil is absorbed. Allow one day interval between the first and second coats. Sand with very fine sand paper between coats. Two to 3 days interval is needed for subsequent coats. The quality of luster desired depends on the number of coats.
Polyurethane	Apply desired stain and filler, sand with fine sandpaper. Spray polyurethane finish. Dry for one hour and then sand. Apply second coating and dry for another one hour. Sand and wipe the surface clean. Apply final coating.

* Sand the wood until smooth surface is attained before applying finishes.

PRESERVATION

Cocowood belongs to the non-durable group of timber. When used in situations favourable for attack by decay fungi and wood boring insects, the hard dermal portion of the trunk will last only for one to two years. The soft inner portion will deteriorate in few months when left exposed to the weather. Its low natural durability requires preservative treatment to ensure that the wood is used within a reasonable service life. Cocowood should be properly treated to protect it against attack of wood destroying organisms especially when used in ground contact and exposed to the weather.

(1) Preparing the material for treatment

A preservative treatment can only be effective if the wood is properly prepared. Selection of defect-free cocowood prior to treatment is necessary to obtain optimum results and good performance. Machining operations like cutting in sizes appropriate to the end-use, planing the surfaces and boring should be undertaken before preservative treatment. In addition, the wood surface must be free from sawdust, paint or any other coating and there must be no sign of attack of wood destroying insects and fungi. Treatment of cocowood by diffusion process should be done in green or freshly-cut condition to permit free movement of preservative solution into the inner cavities of the wood. For other method, drying before treatment is necessary to allow adequate penetration and uniform distribution of preservative into the material. For round coconut wood, debarking should be made to minimize the atttack of insects and decay fungi during air drying. In sawn form, the lumber is easily attacked by mould and stain fungi during the air drying process leaving discoloured surfaces of wood. To prevent this problem, the newly-sawn lumber should be dipped at once into a tank containing anti-sapstain chemical before seasoning. However, the dipped timber receives only temporary protection from staining and it should be retreated with wood preservative to ensure adequate protection from wood destroying organisms.

(2) Wood preservatives

Wood preservatives fall into two types viz., oilborne such as creosote, pentachlorophenol, cuprinol and solignum; and waterbone salts which are applied as water solutions. The standard wood preservatives used in water solution include chromated copper arsenate. Another water-borne preservative applied successfully to cocowood is Disodium Octaborate Tetrahydrate.

(3) Preserving Processes

Preservative treatment of wood is generally composed of two methods viz., the pressure and non-pressure. The former, in which wood is impregnated in a close cylinder under pressure, requires high capital investment and skilled technicians to operate the plant. The latter, which varies according to procedures and equipment used, can be easily adopted in rural areas due to their simplicity in operation and low-cost capital outlay. In general, the non-pressure process provide inferior control over preservative retention and penetration than the pressure process. The treatment methods discussed below apply only to the non-pressure process since they have been found equally effective in protecting cocowood from wood destroying organisms.

3.1 Brushing or Spraying:

These methods consist of brushing or spraying preservative solution over the surface of dry wood. Oil or waterborne preservatives are used for applying two to three coatings. The preservative solution penetrates to wood due to the capillary attraction between the wood cells and the liquid flooding the surface. In most cases, the treated wood materials are used indoor.

3.2 *Dipping:*

This process involves immersing well-seasoned wood in a tank or container of cold or heated preservative solution for 3 to 5 minutes. This method is better than brushing or spraying because wood absorbs liquid freely and time of immersion is suited to the standard of treatment required. Wood treated in this manner is used for building construction.

3.3 *Soaking/Steeping:*

The soaking process involves the use of oilborne preservative while steeping involves waterborne preservative. Both methods consist of immersing dry wood in a tank of preservative solution for few days to number of weeks. The extent of preservative penetration and amount of absorption are dependent on the duration of immersion of the materials. Wood treated by this method is used for outside walling and fascia boards in house construction.

3.4 *Dip Diffusion:*

This process relies on movement of waterborne preservative solution into freshly-sawn wood from a higher to lower concentration. The method involves the immersion of green wood for 2-3 minutes in a tank containing preservative. The preservative coated wood are then block-stacked and stored under restricted drying condition. The stacked wood should be covered with polythene sheet, to prevent evaporation of moisture during the diffusion period. The diffusion time ranges from 4 to 6 weeks. The treated wood is generally used in building construction.

3.5 *Double Diffusion:*

This process involves two separate preservative solutions usually water borne preservative where freshly-cut materials are immersed first in one chemical and then in the other. The two chemicals diffuse into the wood cavities and then react to form precipitate which ultimately produce an effective preservative with high resistance to leaching. A good combination of these chemicals consists of copper sulphate and mixture of sodium dichromate and arsenic pentoxide. Treatment time is from 2 to 3 days for the first chemical and another 3 days or more for the other. The treated materials are used outdoor but not in contact with ground like sign boards and wood roof shingles.

3.6 *Hot and Cold Bath:*

This method involves heating of oilborne preservative with the material totally immersed during treatment. The dry wood materials are heated in an open tank for several hours and subsequently, either transferred to a cold preservative solution or allowed to cool down in the same tank. During the hot bath of about 80°C to 100°C, the air in the wood cells expands forcing some of it out of the wood. At this stage, small amount of preservative is absorbed by the wood. In the cold bath, the air in the wood contracts thereby creating partial vacuum and the preservative solution is forced into the wood by atmospheric pressure. Treatment time of each bath varies from 1 to 12 hours, depending on the condition of the material and desired retention and penetration of the preservative in the wood. The treated wood are used in ground contact like posts and poles.

3.7 *Recommended Treating Processes:*

The treatment schedules of the different processes have been established through a series of experiments, field and service tests. Table-4 presents the treating processes, preservative concentrations and target retentions in treating coconut timber for various end products.

Table 4 : Recommended treating processes for coconut timber

Service condition	Preservative and concentration	Processes & treatment schedules	Timber condition	Retention (Kg/cu.m)
Ground contact (poles/posts)	CCA:4-6%	Pressure: First vacuum, 45 min; Pressure, 120 min; Second vacuum, 10 min.	Dry	14 - 20
	Creosote - bunker oil: 70:30 mixture	Pressure: First vacuum, 1 to $1^1/_2$ hrs; Pressure, 2-3 hrs, Temp, 160-180°F; Second vacuum, 1 hr	Dry	160 - 192
	Creosote - bunker oil: 70:30 mixture	Hot and Cold Bath: 8-10 hrs. heating and overnight cooling	Dry	128 - 192
Outdoor, not in contact with ground: (sign boards, benches, roof shingles, etc.)	CCA: 2-3%	Pressure: First vacuum, 30 min; Pressure, 60 min; Second vacuum, 10 min	Dry	7 - 12
	Copper sulphate, 3% arsenic pentoxide plus sodium dichromate, 3%	Double diffusion: First soaking in 3% copper sulphate for 2-3 days and Second soaking in 3% arsenic pentoxide plus sodium dichromate for 3 days	Green	7 - 12
Indoor, not in contact with ground: (beam, rafters, jambs etc.)	PCP: 5% in oil; cuprinol or solignum: ready mixed	Dipping/Brushing: Dip for 3-5 min., or brush 3 coatings	Dry	1.8.2.0
	CCA: 2%	Steeping/Dipping/Brushing: Dip for 10-20 min. or brush 3 coatings	Dry	0.5 - 0.8
	Timber: 20-30%	Dip Diffusion: stack and cover with polyethelene sheet for 4-6 weeks.	Green	8 - 10

USES OF COCONUT WOOD

1. Building and Housing:

The structural application of cocowood depends mainly on its density. The high density materials should be used in building components such as posts, trusses, door and window jambs, girders, bearers, vertical studs, floors, floor joists, purlins and other load bearing structures. The medium density boards can be effectively used for walling, horizontal studs, ceiling joists and door/ window frames. As a rule, cocowood with densities below 400 kg/m^3 should not be used as a structural framing material. However, they can be utilized in internal parts of building like ceiling and wall lining in the form of boards and shingles.

2. Furniture, Novelty and Handicraft Products:

Cocowood can be a promising material for the manufacture of furnitures, novelties and other handicrafts due to its beautiful grain and attractive natural appearance. The hard portion, although can be used for furnitures, imposes some limitations on the density requirement for ideal furniture. This problem can be overcome by adopting a suitable design requiring small size components without sacrificing the strength requirement. The medium density wood is a good material for furniture and novelties including handicrafts as this is more or less the required density range for manufacturing furnitures.

3. Poles, Piles and Fence Posts:

Trunks of the coconut palm for poles, piles and fence posts are perishable in untreated condition as they are easily destroyed by termites, marine borers and decay fungi. The long usefulness of cocowood used in ground contact and exposed condition is influenced by successful preservative treatment. The recommended practice of preparing coconut trunks for poles, piles and fence posts includes (a) cutting to the desired length and debarking immediately after felling, (b) the logs should be stacked in a concrete or treated wood bearers of about 20 cm height to provide adequate movement of air through the stacks during air drying and the stacks should be covered during rainy days and (c) the materials should remain in the stack to the required drying period of 16 to 20 weeks.

RUBBER WOOD

Rubber trees have necessarily to be felled when the yield of latex decreases. Most of the timber from these trees now goes for use as fuel and cheap packing cases. If even a fraction of rubberwood available at present can be converted to useful products, a portion of the timber requirements of wood working factories can be met.

Rubberwood can be compared in physical and mechanical properties to most commonly available hard wood species. It can be used for the manufacture of joineries, furniture, parquet tiles, slatted flooring and so on. Rubber wood flooring for sports facilities such as for squash and badminton offers a reasonably priced alternative to the conventional hardwood floors. The potential use of this versatile timber is now hardly being exploited. However, rubber wood in its naturally occuring form is easily perishable.

This wood needs to be chemically treated before it can be put to use.

Chemical Treatment:

Rubber wood is easily susceptible to borer, fungi and insect attack within days of its felling. Much work has been done over the past few years to process rubber wood by impregnating the wood with preservative chemicals and drying to make it durable. Different chemical preservative treatments can be imparted with a prophylactic solution to prevent the growth of fungi. After this initial treatment, the planks are loaded into a special treatment plant where the timber goes through a prescribed cycle of vacuum and pressure, during which preservative chemicals are impregnated. The treated planks are then loaded into the seasoning kilns for drying.

Seasoning:

Artificial seasoning kilns are used to dry the rubber wood, after impregnation to moisture levels between 8 and 15 percent, depending on the end use. This is achieved by forced circulation of air over the timber under controlled conditions of humidity and temperature in a closed chamber. Moisture is drawn out from the timber until the required moisture levels (normally 10 to 12 percent) is reached. Rubber wood thus treated is durable and inexpensive.

Rubber wood properly treated and seasoned is an easily machinable timber and the surface obtained is excellent. It can be finished by painting, staining, lacquering, etc. The market for treated and seasoned rubber wood is good.

The functional uses for which the wood is currently being employed is estimated as (i) packing cases (4,70,000 m^3), (ii) veneer and plywood (1,20,000 m^3), (iii) safety matches (10,000 m^3), (iv) fuel wood (4,20,000 m^3) and (v) processed wood for building components and furniture production (30,000 m^3).

ARECANUT STEM

Arecanut stem forms a useful building material in the villages and it is widely used throughout South and South-east Asia for a variety of construction purposes. Because of its hardness and its golden yellow colour, the timber can be used for making a variety of elegant utility articles. Stationery articles like rulers, shelves, waste paper baskets etc. made of arecanut stem are both durable and attractive. In South Asia, the stem after sharpening is used for husking coconuts. Nails made of areca stem are widely used in furniture industry. Hollow stems lend themselves as drainage and irrigation pipes in the villages.

TECHNOLOGIES FOR PRODUCT DIVERSIFICATION AND BY-PRODUCT UTILIZATION IN COCONUT

Sreekumar Podual, Ajay M. Pillai and Balachandran Nair

INTRODUCTION

India is one of the leading coconut producing countries in the world with an annual production of about 13 billion nuts. However, unlike in other coconut growing countries viz. Philippines, Sri Lanka and Indonesia, the post harvest processing and marketing sector of coconut in India is still at its infancy stage. While other countries have made substantial progress the field of coconut product diversification and by-product utilization, India is yet to tap the full potential. In a country like India, where about 57 per cent of the coconuts produced is diverted for house-hold use, the coconut based economy is surprisingly contrôlled by the coconut oil industry, which consumes about 30 per cent of the total nuts produced. It has therefore become necessary in evolving strategies for diverting a major portion of coconut produced in the country for coconut based products. With the increase in per capita income and standard of living, the consumption pattern of food products is undergoing a tremendous change in the country. The demand for processed and ready-to-use packed foods is on the increasing trend. Today, technologies are available to produce an array of coconut based food products like coconut cream, coconut milk powder, sweet coconut flex, coconut milk based consumer product, spray dried coconut milk powder, coconut jam, nata-de-coco, coconut vinegar etc.,. Tender coconut water is another produce which has an immense potential as a beverage and as an health drink.

The Technology development Centre functioning under Coconut Development Board (CDB) has been successful in developing of technologies for the preservation and packing of coconut milk in cans, manufacture of dried coconut milk powder, preservation and packing of tender coconut water, production of vinegar and nata-de-coco from matured coconut water. The Board has recently setup a pilot testing-cum-demonstration centre for promoting integrated processing of coconuts. In the first phase, pilot plants for coconut oil extraction, coconut cream, spray dried coconut milk powder, desiccated coconut, production of coconut vinegar and nata-de-coco are being established. In the second phase, it is proposed to set-up pilot plant for other value added coconut kernel based food products and shell based industrial products.

FEASIBLE TECHNOLOGIES AT SMALL SCALE LEVEL

Apart from traditional coconut products like copra and coconut oil, technologies catering to small scale sector for the manufacture of desiccated coconut, tender coconut water, coconut vinegar, nata-de-coco, shell charcoal and shell powder are available today in the country.

DESICCATED COCONUT

The manufacture of Desiccated Coconut (DC) with a capacity of 5000 nuts per day adopting the latest fluidized bed drier technology involves an investment ranging from Rs.30-32 lakhs covering building, plant and machinery and margin money for working capital and an employment potential of 50 personnel. DC is obtained by drying graded or shredded coconut kernel after removing the brown testa. The kernel is dried in an hot air drier at a temperature of 80-90°C for 10 hours to bring down the moisture content to below 3 %. The product is packed in polyethylene pouches. A study conducted by CDB has revealed that the growing consumer demand for DC powder can sustain by resorting to organized market promotion activities. The investment analysis has realized an internal rate of return of 37.5 % with a pay back period of 3 years.

TENDER COCONUT WATER

The processing and packing of tender coconut water with a capacity of 10,000 tender nuts per day involves an investment ranging from Rs.35-40 lakhs covering plant and machinery and margin money for working capital with a direct employment potential of 30 personnel. The profitability after taking into account the prevailing prices of finished product is about 20% with a pay back period of 3 years. Tender coconut water has a great potential as a health drink both in Indian and International market. The Coconut Development Board in collaboration with Defence Food Research Laboratory, Mysore has developed the technology for packing tender coconut water in pouches/aluminum cans, which is available to entrepreneurs at a total lumpsum transfer fee of Rs.3 lakhs.

COCONUT VINEGAR

The manufacture of coconut vinegar with a capacity of 500 litres per day involves a low capital investment of about Rs.7 lakhs with an employment potential of 10 personnel. The profitability taking into account the prevailing price of finished product is about 20 %. The technology for the manufacture of coconut vinegar is now available with CDB. It is produced from matured coconut water by fermentation of fertified coconut water after inoculating the solution with yeast. After acetic fermentation for about 4-5 days, the clear liquid is siphoned off and inoculated with mother vinegar. The resultant solution is then acetified in vinegar generators where the ferment is oxidized to acetic acid. The process is repeated till a strength of 4 % is attained. Coconut vinegar enjoys a wide market segment as a preservative in pickling industry and as a flavouring agent for food stuffs. The know-how fee for licensing the technology is Rs.10,000.

NATA-DE-COCO

Nata-de-coco production from matured coconut water with a capacity of 250 litres per day with a yield of 50 kg of Nata involves a low capital investment ranging from Rs.2-2.5 lakhs covering building, laboratory equipments and working capital, with maximum employment potential of 5 personnel. The profit margin works out to be about Rs.12 per kg of Nata. The technology is available with Coconut Development Board. The product has great export potential in Japan, Taiwan and Korea for use as a dessert and as an ingredient in ice cream and fruit cocktails.

COCONUT SHELL POWDER

Coconut shell powder is manufactured from matured coconut shells. A raw material of 12,000 shells yield about one tonne of shell powder. The capital investment is around Rs.23 lakhs covering building, plant and machinery, power and operating expenses, contingency and working capital excluding land cost for about 40 cents, with an employment potential of 6-10 personnel. The profit margin works out to be around 20 per cent on investment. The product finds extensive demand in plywood and laminated board industry as a phenolic extruder and as a filler in synthetic resin glues, mosquito coils, agarbathy industry. Coconut shell powder is preferred to other alternate materials available in the market such as bark powder, furfurol and peanut shell powder because of its uniformity in quality and chemical composition and also have better properties in respect of water absorption and resistance to fungal attack.

The manufacture of shell powder is not an organized industry in India. It is manufactured in sizes ranging from 80-200 mesh. Keeping in view the vast industrial uses, the demand for coconut shell powder appears to be promising.

SHELL CHARCOAL AND COPRA PRODUCTION USING WASTE HEAT RECOVERY TECHNOLOGY

Now there are modern methods for commercial production of shell charcoal. The waste heat unit technology is one such indigenous method for production of good quality carbonized charcoal. The gas evolved during carbonization is burned in a furnace producing heat energy for application in the coconut processing industry. The technology also maximizes the carbonization of shell feed stock for charcoal production. On an average 3 tonnes of shells would yield about one tonne of shell charcoal. A waste heat recovery unit of capacity 30,000 nuts/day would involve an investment of about Rs. 30 lakhs with an employment potential of 25 skilled and unskilled personnel.

There exists tremendous market potential for shell charcoal as a fuel in smitheries, bakeries and iron/steel industries and as a base material for the manufacture of activated carbon. The export market for shell charcoal is mainly concentrated in USA, Japan, Korea etc.

FEASIBLE TECHNOLOGIES AT LARGE SCALE LEVEL

Technologies suitable for large scale set-up are today available in the country for manufacture of coconut milk/cream spray dried coconut milk powder/skim milk powder, vinegar, coconut oil from fresh coconut, skim milk based beverages in tetrapacks, and shell based activated carbon. The range of investment and potential markets for these products are mentioned below.

Coconut milk/cream

Coconut milk/cream is the concentrated coconut milk extracted from fresh matured coconut kernel. For a raw material capacity of 10,000 ripe green coconuts, the yield is around 2,500 kg of cream/milk and a by-product residue of 500 kg. The capital investment is ranging from Rs.1.49 crores covering plant and machinery, preliminary and pre-operative expenses, contingency other overheads and working capital margin money excluding land cost of one acre, with an employment potential of 15-20 personnel. The profit margin works out to be about 30 % on investment. This is an instant product which can either be used directly or diluted with water to make various preparations such as curries, sweets, desserts, puddings, etc. It can also be used in the manufacture of bakery products and for flavouring food stuffs. Processed and packed coconut cream has a shelf life of six months and once opened it should be stored in refrigerator for subsequent use. The technology has been developed by the Regional Research Laboratory, Thiruvananthapuram under a sponsored project of CDB. Now the technology is available with the Board for a lumpsum transfer fee of Rs.3 lakhs.

Spray dried coconut milk powder

This can be used in place of fresh coconut milk for food preparations/ beverages in households and food industries. The Coconut Development Board in collaboration with Central Food Technological Research Institute, Mysore has developed the technology for spray dried coconut milk powder. The total capital investment for the plant, machinery and working capital margin is about Rs.2.36 crores. The internal rate of return works out to be about 16 per cent with a pay back period of about 3 years. On an average one thousand coconuts would yield about 99.6 kg of spray dried coconut milk powder. Spray dried coconut milk powder has a tremendous market potential both in India and in international market. It could be used as a substitute for freshly squeezed coconut milk in household/hotels for food preparation, kheer and beverages. Direct employment potential is around 40 personnel.

CONCLUSION

The development strategy for coconut needs a new orientation with a thrust on product diversification, product development, marketing and export promotion. Coconut processing sector can be strengthened by focussing attention on non traditional products from coconut. Research undertaken in the past has generated viable technologies for the manufacture of diversified products from coconut. A few of them are in their infancy stage due to the refinement needed in packaging and quality upgradation. There is an urgent need therefore to undertake pilot scale trials for commercializing some of the products in their infancy stage and to organize various market promotional activities and consumer awareness campaigns to strengthen the coconut based economy.

POST HARVEST TECHNOLOGY AND PRODUCT UTILIZATION IN ARECANUT

B. Chempakam

INTRODUCTION

Arecanut is traditionally used as a masticator in the countries of Indo- Malayan Peninsula. The ethano religious importance of arecanut in India is unique. Chewing of supari with betel leaf with a dash of slaked lime and a pinch of tobacco of the chewing variety is a ritual for many Indians. Almost the entire quantity of arecanut produced in India goes into the traditional habit of chewing either in the cured or uncured form. But, there is a steady decline in the masticatory habit for the last three decades. Added to this, the trade of arecanut is also not attractive often causing high degree of price fluctation. Hence studies on the alternate and better uses of arecanut was taken up in the early fifties, by the erstwhile Central Arecanut Committee and ICAR as a collaborative programme with various organisations/ research institutes like CLRI, Madras, IDRL, Pune, CFTRI, Mysore, Department of Chemical Technology, Bombay University, Oil Technological Research Institute, Ananthapur and Punalur Paper Mills, Kerala and was monitored through CPCRI, Kasaragod. Majority of the post harvest technological aspects of arecanut had been worked out in these institutes.

CHEMICAL COMPOSITION OF ARECANUT

The nut contains fat, polyphenols (tannins), polysaccharides, fibre and protein. The mineral matter contains Ca (0.05%), Phosphorous (0.1 %) and Iron (1.5 mg/100 g). It also contains Vitamin B6 (286.92 mg) and Vitamin C (416.2 mg).

The chemical composition of arecanut changes with different stages of maturity. Polyphenols decresae with maturity, while polysaccharides, fat and fibre increases. The free fatty acids shows a decrease, indicating the biosynthesis of fat. Fat increases from 1-4% in the tender stages to a level of 10-15% in the ripe nuts, while the hydrolyzable polysaccharides increase from about 5% in the tender stage to 25% in the ripe stage. Fibre increases from 1-2% steadily to a value of 15% in the ripe nut. Among alkaloids, ripe arecanuts have a higher arecoline content of 0.2 to 0.3 % compared to tender nuts with 0.05 to 0.1 %. Thus, the overall pattern shows that at tender stages, water extractives containing polyphenols, nitrogen and ash contents are high.

USES OF INDIVIDUAL CONSTITUENTS

Tannins : Polyphenols or tannins form the major constituent of the nut. Tender nut contains about 38-47 %, while ripe nuts have only 16-22 %. Tannins are obtained as a byproduct from the process of preparing immature nuts for masticatory purposes. Tannins from whole nut has got better tanning properties and hence can be utilized for retanning chrome leathers. These are widely used for dyeing clothes, ropes etc.

Tannins especially tannin - formaldehyde adhesive is used in ply board manufacture. Another possible use of tannins is as a food colour. Isolation of the colouring matter is possible which can be used to dye food products and as dyes. In the present scenario of increasing ban on synthetic food colours, this natural product assumes greater significance.

Arecanut fat : The nut contains about 8-12 % fat, which is extractable with organic solvents like hexane or chloroform. The fat has a white plastic appearance on cooling with no particular odour.

The fat contains both saturated and unsaturated fatty acids and is highly rich in myristic acid. Hence it can be a good indigenous source for preparing myristic acid and its derivatives. Refining of the fat can be done with alkali, which makes it as an edible fat, which is harder than cocoa butter. Sweets, savouries and biscuits prepared from this fat are comparable with those from vanaspathi. The blended fat with cocoa butter in the ratio 1:1 can be substituted for cocoa butter or hydrogenated coconut oil.

Alkaloids : Arecanut has 1.5 % alkaloids viz., arecoline, arecolidine, arecaidine, guvacine, isoguvacine and guvacolidine of which arecoline alone accounts for 0.24 %. They possess potential medicinal properties and are antihelmintic and effective against tape worms and round worms. It is also used as a CNS depressant drug. Orotund (full and round arecanuts) has got antibacterial property and it inhibits the growth of *E. coli.*, *S. typhi* and *S. aureus*. The blood sugar lowering effect of arecoline is mentioned in Ayurveda.

PROCESSING OF ARECANUT

The processing method of orotund differ in each state. In Assam, fresh nuts are preserved in thick layers of mud to have a moist chewing feel in the mouth when consumed. The product is known as bura tumul. In Kerala, fresh fruits are stored by steeping in water. These preserved nuts are known as Neetadaka and a favourite of many chewers.

TYPES OF PROCESSED NUTS

Chali or Kottapak : Ripe nuts are dried in the sun for 35-40 days, dehusked and marketed as whole nuts. This is known as chali. The different grades of decreasing order of chali are Moti, Srivardhan, Jamnagar and Jini. The main producing areas of chali are Kerala, Karnataka, Assam and Maharashtra. Sometimes the fruits are cut longitudinally into two halves and sundried for 10 days. The kernels are scooped out and given a final drying. This product is known as parcha and is popular in Kerala and Karnataka.

Mechanial driers are also used to make chali. The material is kept in a tray and hot air is allowed to penetrate through a centrifugal blower. Drying takes 60-70 hrs over a period of 7-8 days at 45-70°C. The dehusking can be done using arecanut dehusker developed by CPCRI (in 1980), which is manually operated. About 40 kg of chali can be made within a period of 8 hrs.

Kalipak : Nuts of 6-7 month old maturity are dehusked, cut into pieces, boiled with water or a diluted extract from previous boiling, coated with kali and dried. This is prevalent in Kerala and Karnataka.

Kali coating can be repeated 3-4 times to get a good glossy appearance. (Kali is the extract obtained after 3-4 batches of boiling and then concentrated 10-fold, tannins are its major components).

In interior parts of Karnataka, the boiling and kali coating operations are combined using a thicker extract known as chogaru. The kalipak is rated with a dark brown colour, glossy appearance, crisp chewing feel and absence of immature nuts. The major adulterants are sago palm nuts, sweet potato and tapioca which can be identified either by physical examination or through chemical analysis.

The kalipak is known by different names depending on the number, shape and size of the cuts. Api or unde (without any cuts), Batlu (transverse cut into two halves) Choor (several longitudinal cuts), Podi (both longitudinal and transverse cuts) and Erazel (transverse thin slices).

Iylon is another variety made from green arecanuts in which nuts are cut transversely into 5-6 discs and without kali coating. These are mainly used in Tamil Nadu and Andhra Pradesh.

Scented Supari: Here, dried arecanuts are broken into bits, blended with flavour mixture and packed in butter paper. In South India, kalipak is used for this purpose, by adding spices and synthetic flavours. Instead of raw spices essential oils are used for easy blending, with coconut gratings to avoid microbial growth. In Central and North India, supari made from chali are more popular. Saccharin is occasionally used for sweetening, with additives like colour and flavour.

MARKET PREFERENCES FOR PROCESSED NUTS

Kalipak and scented suparis are used as masticatory, while chali nuts are used alongwith slaked lime and betel leaf. Combination of these are known as beda, which are flavoured with spices like clove. About 75% of the marketed produce is consumed after processing either as kalipak or chali.

Market preferences differ with region. In Bombay market, big size of nut is preferred, while in Nagpur and Allahabad, smaller ones are in great demand. Superior quality of nuts have light brown skin colour and a clear core with a smooth cut surface with well-defined brown veins. Interior cracking of nuts indicate proper drying and is desirable. Maturity is another important factor in trade. Bacterial spoilage and infestation and excessive astringency are considered as defects.

PROCESSING OF ARECA HUSK

The husk of arecanut constitutes about 60-80 % of the total weight of the nut. About one lakh tonnes of dry husk is produced in India annually, which is used only as an inferior fuel or mulch. The major constituents in the husk are Pectin (1.5-3.6 %), protopectin (1.5-2.1 %), hemicellulose (35.0-65.8 %), lignin (13.0-26.0 %), furfuraldehyde (18.8 %) and ash (4.4 %).

The husk fibres are prodominantly made of cellulose, with lower amounts of hemicellulose, lignin, pectin etc. "Hard fibres" are those adjoining the inner layer, while soft fibres form the middle layer. During maturity of the nut, the hemicellulose content decreases, while the lignin content increases.

On comparison of areca husk fibre with the characteristics of jute fibre, it is seen that the average filament length is only 2.4 cm, while for jute, it is 68 cm. The course fibre filament is 10 times as strong as jute, while the fine filament is similar to jute fibre. Based on the work of JTRL, Calcutta, areca husk fibre could be used for thick boards, fluffy cushions and non-woven fabrics. Fibre extraction is done by soaking the husk for 3 weeks and beating with a mallet.

PRODUCTS FROM ARECA HUSK

1. Hard boards and plastic boards: Detailed studies at Forest Research Institute, Dehradun have shown that plastic and hard boards of comparable strength properties could be made from areca husk. CNSL can be used for tempering the boards which gives good water resistance, higher strength and less microbial growth. So far, these processes have not been commercially exploited.

2. Insulation wool: This is prepared by air-dry husk with wooden mallet. The wool is comparable in thermal conductivity, packing density etc. with standard products like Palcowool, defabricated teak bark etc. Its utility in thermal installation, packing etc. is promising.

3. Cushions: Softened husk using pectinolytic bacteria is an excellent cushion material . Work done at CFTRI, Mysore revealed that soft cushion pads obtained from spongy fibres are comparable with standard cushion pads. Thick mattresses can also be made from areca husk fIbre in admixture with coir fibre.

4. Pulping and paper boards: Areca pulp be chemically prepared by digesting with chemicals at 170°C for 4 hrs. With 45-50% yield and with a fibre length of 0.96 mm. The strength properties are not satisfactory for kraft wrapping paper, but brown wrapping paper can be prepared when mixed with jute or bamboo pulp.

Areca husk when treated with 17.5 % NaOH at 170°C for 2 hrs. and beaten for one and a half hours, give pulp material having ordinary kraft paper quality. Good quality kraft paper could be produced by beating banana pseudostem pulp to areca husk pulp. Commercial exploitation of the whole process is hindered by two factors viz., high cost of transporting husk to the factory and the high amount of chemicals required for digesting the husk.

5. Furfural, Xylose, Activated carbon and Charcoal: Areca husk contains 18.75% furfuraldehyde, which on acid hydrolysis gives 5.5% furfural. The residue after distillation can be used as a filler in plastics. Areca husk is a good source of xylose. Xylitol can be obtained from xylose , which can be used instead of sucrose in diabetic patients. The residue after extraction of xylose when mixed with $ZnCl_2$ and heated to 800°C for 2 hrs gives charcoal, which is comparable with that of E.Merck. The yield is about 25-28 %.

PROCESSING OF ARECA STEM AND LEAF SHEATH

Arecanut stem is a useful building material. The timber can be used for making variety of elegant utility articles due to its hardness and golden yellow colour. Stationery articles like rulers, shelves, waste paper baskets made of arecanut stem are both durable and attractive. Sharpened stems are used for dehusking coconuts.

A large portion of arecanut leaf sheaths are wasted except for use as inferior fuel, making head caps for farm workers, eating bowls, containers for toddy, art objects etc. It can also be used for making ply boards (3-ply) and found to have a tensile strength of 1/3 rd of that of conventional 3-plyboards and better flexibility. These are suitable for making cases like tea chests, for medicine, tobacco etc.

The flexibility and mouldability of the sheath, when wet, makes it a good material for heat moulding. CFTRI has developed a machine for making tea cups and throw-away plates with areca leaf sheath. The machine is manually operated and can produce 100 cups / hour. Here the leaf sheath is subjected to 158°C for 2 hrs for moulding. Recently, small scale units have been opened in South Karnataka for this purpose. Due to the natural colour and grain variation of leaf sheath, it is suitable for making decorative veneer panels and picture mounts. Even house chappals can be made from areca leaf sheath due to its easy yielding for stiching and resemblance to animal hide. Brief cases, brief bags, spectacle cases, tea or coffee trays are other products that can be made from areca leaf sheaths. Establishing small scale rural industries based on arecanut leaf sheath generate additional income to the arecanut growers and also additional employment for the rural sector in our country.

POSSIBLE AREAS FOR PRODUCT DEVELOPMENT

There are good prospects for product development in arecanut. The possibilities of using various constituents of arecanut like fat and polyphenols including it as a colouring agent for food and as an ingredient in tooth paste, as chewing gum etc. can be studied in depth. Developing an integrated processing unit wherein the individual components are serially extracted and utilised will be ideal and economically feasible.

HARVEST AND POST HARVEST TECHNOLOGY OF COCOA

T. Vidhan Singh

INTRODUCTION

The cocoa beans are derived from the matured cocoa pods. The major products from cocoa beans are cocoa powder, cocoa butter and chocolate.

HARVESTING

The change of colour of cocoa pods indicate their maturity. The green or green white pods turn yellow or orange and red pods turn dark as they ripen with traces of orange colour and these pods gives a metallic sound when tapped. The cocoa harvesting is done in two seasons, viz., April-August and October - January. The process involves cutting of matured pods from the tree and opening them to extract the wet beans. Pods are harvested by different types of knife. While harvesting care has to be taken to avoid damage to the flower cushion.

A special knife for harvesting cocoa pods costing Rs. 450/- has been designed at CPCRI, Kasaragod, Kerala. The curved blade is made of steel with both edges sharp and is attached to a long aluminium handle.

Harvesting may be done at 7-10 days intervals. Fallen, disease infected, immature, over riped and partially riped pods are to be discarded. Harvested pods may be kept for 2-4 days before they are opened. For breaking the pods, wooden mallet or hitting the pods against hard surface may be adopted and the use of metallic knifes should be avoided. While breaking, the placenta in the pods should be removed and the beans with adhering pulp should be collected for fermentation. Fermentation should be done at the earliest and for transportation of wet beans, non-metallic containers may be used.

The characteristics of cocoa beans are (i) initial moisture content (52-55 %), (ii) final moisture content (6-8 %), recovery of dry beans in terms of wet beans (35-40 %), weight of 100 dry beans (100-110 gms), fat content (55-58 %) and acidity (5.8)

The characteristics of pod husk are (i) crude protien (6-8 %) and crude fibre (24-56 %).

The average shell percentage is 14 % and shell contains crude protien (14-18 %) and crude fibre (9-20 %).

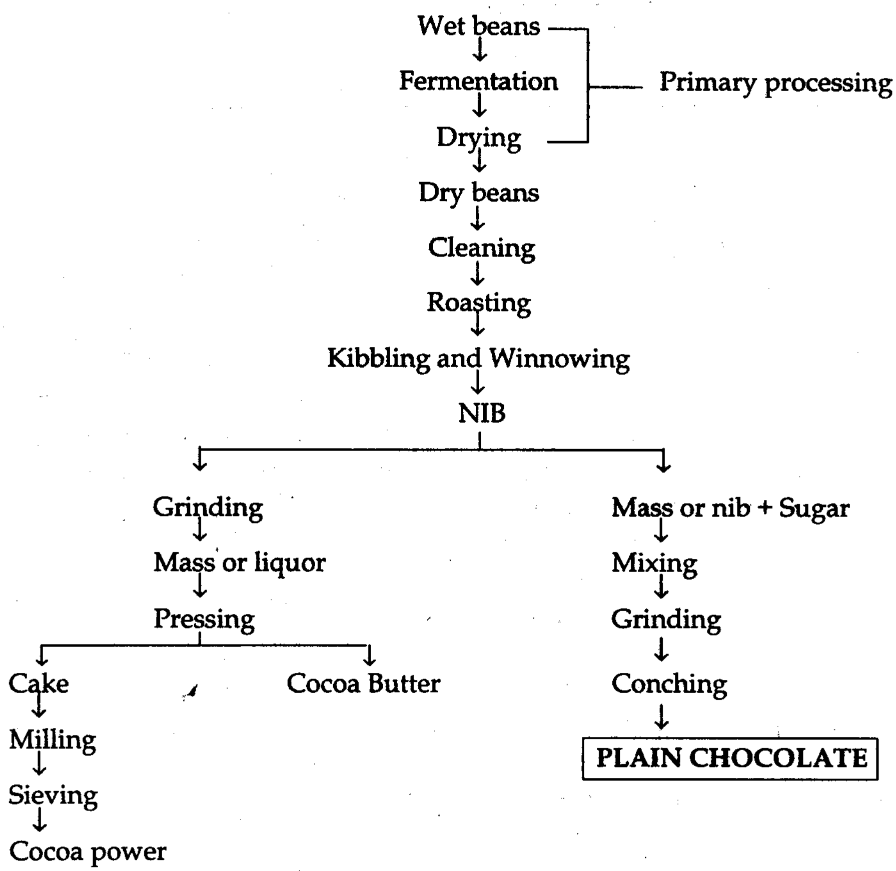
CURING

Curing of cocoa beans is an important step in cocoa processing. It comprises of two unit operations namely fermentation and drying. The chocolate flavour is developed in the beans during this process.

Fermentation:

Fermentation involves keeping a mass of cocoa beans well insulated so that heat is retained while allowing air to pass through it. During the process, which lasts six to seven days, the pulp or mucilage adhering to the beans disappears and the colour of the cotelydons which is originally purple or violet (for forastero variety) changes to light brown. The process involves complex chemical changes which are at to be fully understood.

Cocoa bean processing flow chart



An important requirement of proper fermentation is that the beans must have attained proper maturity so as to have sufficient pulp sugar for the micro organisms to act upon. The second requirement is that the germination of beans should not occur since these beans do not develop the desired flavour during fermentation. The temperature of the fermenting beans must be maintained around 50°C for the period after initial fermentation is yet another important requirement. Lower temperatures of 45-46°C and below gives rise to underfermented purple beans or unfermented beans which are devoid of chocolate flavour. For this reason, large scale fermentation is always preferred. Another requirement during this process is the carbon dioxide surrounding the beans must be removed by turning the mass.

In practice, several methods are employed for fermenting of cocoa beans, the choice being dependent on the quantity of beans available and the circumstances prevailing. Irrespective of the method adopted, it needs to be ensured that the beans are put for fermentation immediately after taking out of the pods and the fermenting mass is provided with proper insulation for retention of temperature and adequate facilities for aeration of the beans and drainage of the sweat liquor. Boxes and trays made of thick hard wood with perforated bottoms or bamboo and cane baskets are suitable containers and depending on the quantity of beans available, one of these could be used in carrying out the process.

Bulk of the wet bean production is purchased by Co-operative organisations and private agencies which are fermented and dried in big batches. However there are a number of areas where there is no marketing arrangement for wet beans and the farmers themselves have to resort to on farm processing before disposal of the produce. In order to meet the requirements of different categories of farmers and large scale processors, the procedure for fermentation and drying of beans of different batch sizes of 5-10 kg, 40-100 kg, 200-500 kg. and above have been standardised. The methods recommended for each size group is given below:

Batch size 5 kg to 10 kg:

Fermentation of small quantities of wet beans ranging from 5 to 10 kg can be carried out in a small closely woven bamboo or cane basket of suitable size. The inner side of the basket is provided with a lining of one or two layers of banana leaves kept with the midrib side upward and the ends projecting slightly above the brim of the basket. Freshly collected beans are filled in this basket, and after giving a slight pressing by hand, the top surface is covered by folding in the ends of the banana leaves projecting out of the basket. A small weight is placed over to hold the banana leaves in position. The basket is then placed over a brick or on a raised platform to facilitate drainage of the sweatings. On the second day, the basket is covered with a thick gunny sack and kept in position by a light weight. The basket is uncovered, the beans are taken out and mixed thoroughly, and again kept covered with the banana leaves and the gunny sack as described above, on the third and fifth day of initial setting. Under normal weather conditions, the beans can be taken out for drying at the end of the sixth day.

Batch size 40 to 100 kg:

For fermenting quantities of 40 kg. to 100 kg. of wet beans at a time wooden boxes of suitable dimensions can be used. Care should be taken in making the box to ensure that metallic nails used, do not come in contact with the beans when filled. The box should have a minimum height of 15 cm. and a maximum of 45 cm. depending on the quantity of beans. Bottom of the box should be made of reapers (2.5-4 cm) keeping a space of 0.3-0.4 cm. in between. After filling the box with freshly collected beans the top is covered with a gunny sack. The box is kept raised about 15 cm. from the ground to allow the sweat liquor to drain away and for better aeration. After 24 hours, the beans are thoroughly mixed or transferred to another similar box and reset as before. Mixing is repeated again 24 hours, 48 hours and 96 hours. At the end of sixth day beans can be taken out for drying.

Batch size 200 to 500kg:

For this scale of operation. the tray method can be adopted. Wooden trays with their bottom made up of reapers 2.5-4 cm. kept at 0.3-0.4 cm. apart can be used. The trays may be of size 90 cm. x 60 cm. x 12 cm. each capable of holding 40-45 kg. of wet beans. After filling the trays to an height not exceeding 10 cm. the trays are left for 24 hours on a raised platform for draining of the sweat liquor. On the second day the trays are stacked one over the other to a minimum of 4 and maximum of 12 and the stack is covered completely with gunny sack. No mixing or turning of the beans is required in this method. Under normal weather conditions fermentation will be over at the end of the fifth day and on the sixth day the beans can be taken out for drying.

Batch size 500 kg and above:

For fermenting large quantities of beans wooden boxes of dimension 120 cm. x 90 cm. x 60 cm. may be used conveniently. Four boxes are arranged in a cascade for fermenting each batch of beans. The cascade is built in such a way to provide sufficient space at the bottom of each box for the flow of sweat liquor through the perforated bottom planks. The front planks of individual boxes are fitted in grooves to permit their easy lifting one by one for transfer of beans from one box to another.

For fermentation the beans are put in the topmost box to a depth not exceeding 40 cm. and left uncovered. After 15-18 hours, they are transferred to second box. In doing so, it is to be ensured that their positions are changed i.e. the top beans in box-1 occupying the bottom of box-2 and vice versa. This is done by removing the front planks one by one and allowing the beans to fall through a 5 cm. x 5 cm. G.I. wire mesh placed at the mouth of box-2. The beans are then transferred from box-2 to box-3 and box-3 to box-4 after 48 hours of fermentation in each, following the same procedure. However, they are left uncovered in box-4. Depending upon the type of drying that follows, the beans are taken out from box-4 after 24 hours of fermentation. When forced air electric dryers are used, the beans are allowed to remain in box-4 for 48 hours.

Judging the end point of fermentation:

Under normal conditions the duration of fermentation can be taken as a satisfactory guideline for judging the end point of fermentation when a particular method is followed. Nevertheless seasonal variations, quantity of the beans etc. may lead to changes in the fermentation process. The following checks may therefore be made to ascertain proper fermentation viz., (i) portion of pulp adhering to the beans should be reddish brown as against original dull white, (ii) the fermented beans when squeezed, the colour of the exudate that comes out should be reddish brown and (iii) fermented beans when cut, the colour inside should be brown as against the original purple. The cut half of the bean when bent should reveal irregular cracks on the cut surface.

DRYING

At the end of fermentation, the moisture content of the bean is about 55% and this must be reduced to 6-7% for safe storage. The rate of drying varies greatly according to the method employed. If drying is too slow there is a danger of mould development, consequently leading to off flavours. The beans must therefore be skin dried within 24 hours. On the other hand, too much quick drying using artificial dryers may lead to the beans remaining acidic. Weather conditions and facilities permitting, sundrying is the best method. When artificial drying has to be resorted to, it must be spread over a period of 48 to 72 hours at moderate temperatures of 60°C to 70°C. Interrupted drying with short period of drying and long resting period which allows migration of moisture to the surface during the rest period, gives good quality beans besides being economical.

Sundrying:

The beans can be dried on mats or concrete floors. They are spread in one or two layers thickness and turned over periodically to expose the beans uniformly to the sun and are heaped during night.

For good results the following schedule may be followed.

1st day	:	8 - 10 hours drying
2nd to 5th day	:	8 - hours drying per day
6th day	:	No drying
7th day	:	8 - 10 hours drying

Artificial drying:

During periods when sunshine is not available, artificial drying can be adopted. There are three main types of artificial dryers viz., tray type, bin type and samoan type. End product quality, thermal efficiency and energy cost are the major criteria to be considered for designing artificial dryers. The method to be adopted for different batch sizes are as follows:

Batch size (5 - 10 kg):

For smaller batches, the dryer developed by Kerala Agricultural University can be used. This consists of a wooden box of size 90 cm x 60 cm x 60 cm with three wooden matted trays spaced at 15 cm. Holes of 2 cm. diameter (10 numbers each) are to be provided at the front bottom and rear top of the box. The source of heat consists of four 100 watts bulbs, fitted at the bottom. The box can hold upto 25 kg of wet fermented beans. Drying will be completed (with a load of 25 kg fermented beans) in 45 to 72 hours depending upon the season. The beans are to be mixed frequently to ensure uniform drying. The cost of the dryer is about Rs. 500/- and the cost of drying is estimated as 50 paise per kg of dry beans.

Batch size (40 - 100 kg):

For drying of beans upto 40 kg per batch, the dryer designed by Central Plantation Crops Research Institute, Kasaragod, Kerala can be used. This dryer consists of a heat source, plenum chamber, drying chamber and exhaust air chamber and materials used for construction are hard wood, G.I.Sheet, aluminium sheet, aluminium angles and 500 watts industrial air heater. Perforated aluminium trays are used as drying beds. These dryers can handle upto a maximum of 40 kg of fermented beans at a time. With a 500 watts heater, the maximum temperature obtained is not more than 75°C. The temperature inside the dryer can be regulated by opening/closing the outlets. This dryer can also be fabricated with gas burning system. In this method the tray positions are interchanged every 8 hours to ensure uniform drying.

A 30 kg batch can be dried in 48 hours and a 40 kg batch in 65 hours. The beans after drying should be allowed to cool down in the dryer itself for about 2 hours. The fabrication cost of the dryer is estimated at Rs 1,500. Alternatively, commercially available cross flow dryers of suitable size with electrical heating system can also be used.

Batch size (200 kg and above):

For drying batches of this size, conventional Samoan dryers (commercially available cross-flow dryers) with the required number of trays can be used. It is reported that Samoan type of dryers though cheaper to install, are costly to operate due to high cost of firewood and poor heat transfer. For large quantities, since sun-drying is cheaper and would give better quality produce, it is suggested to transfer the fermented beans to nearby areas where sun-drying is possible.

To examine completion of drying the dry beans when shaken should give a metallic sound or when the beans are pressed against hard surface, vertically, it should crumble to small pieces. Handfful of dry beans when pressed gives a crackling noise.

STORAGE OF DRIED BEANS

The dried beans after cooling to room temperature, should be cleaned to remove shell and shrivelled, discoloured, mouldy and flat beans and any extraneous materials. The beans are then packed in polythene lined (150-200 gauge) gunny bags and are kept on a raised platform made of wooden planks. If required to be stored for longer period, they have to be fumigated. Dry cocoa beans should not be stored along with spices, oil seeds, copra and other strong odorous materials since the beans may absorb odour from these commodities.

FINAL PROCESSING

Effective laboratory control at all stages of production is important in the processing of cocoa beans. The beans before cleaning and roasting should be subjected to laboratory tests which should continue through all stages of production.

Cocoa liquor can also be used directly to produce chocolate bars. Its important applications are in the manufacture of chocolates and preparation of certain sweets. It is used for pharmaceutical and perfume industries too. But these uses are very minimal. Cocoa powder is used in confectioner's coatings, cakes, cake mixes, breakfast foods, chocolate mild, other beverages and ice creams.

There are two types of techniques used in the final processing of cocoa - the expelling method and the roasting method. The press system, as the latter is called, is the modern method and has been adopted by all large scale processing plants. The expeller system is considered as less economical but still prevails in some parts of the world.

Press system:

The fermented and dried cocoa beans are first inspected for moisture content and then classified by colour. Then they are cleaned by removing all extraneous materials and passed into roasters which reduce the moisture content, lower acidity and deepens the colour. Then the beans are passed to huskers to remove the shells and the nibs are separated. The shells are disposed as fertilizers, mulch or fuel. In this process, the beans lose weight by 20%. The roasted and husked nibs are fed into heated disc crushers for grinding. The cell walls of the nibs are broken and a substance named as liquor or paste or mass, which contains about 55 per cent fatty matter comes out. The cocoa liquor subsequently is passed through a cooling tunnel and solidified into liquor blocks or kibbled liquor. These processes constitute the first stage of conversion of beans into various products. In modern plants, all these activities are well integrated, mechanised and fully sealed. Once the beans are fed, cocoa liquor comes out packed, ready for distribution. Sealing protects the liquor from contamination. Laboratory checks for quality and cleanliness of the products are carried out.

In second stage, the cocoa liquor is pressed to extract cocoa butter. The butter contains some amount of fatty acids and through deodourisation, these are removed. Two types of methods of deodourisation are practiced. Batch deodourisation method used by many plants consists of passing bubbling steam through a stagnant pool of butter for several hours. The Parkinson method, offers a saving of large amount of energy as the butter is passed through a heat exchanger for very short period. The butter is then cooled and disposed either in the form of liquid or slabs. Another product obtained is the cocoa cake during the pressing of the liquor.

Next, the cake is pulverised and passed through breakers and grinders. To remove acidity and deepen the colour, it is treated with alkaline substances. This also increases the solubility of the powder.

Expeller system:

In the expeller system, the beans are cleaned and fed into the crushers. Natural butter is pressed out. The cake residue containing the shell is sent for solvent extraction. Residual butter can be extracted from these defatted cakes and the residues are good cattle feeds.

CHOCOLATE PROCESSING

Milk chocolates and plain chocolates (without milk solids) are two important types of chocolates. Milk chocolates are manufactured by mixing the mass with cocoa butter, pulverised sugar, milk powder and lecithin. The resultant paste is refined over steel rolls in roll refiners. To develop flavour, the paste is subjected to conching for 12 to 48 hours till the desired quality is obtained. Additional cocoa butter may be added at this stage and the flavours are added at the end. The liquid chocolate thus obtained is made into (i) moulded chocolate, (ii) enrober chocolate, (iii) panned chocolate, and (iv) covering chocolate.

Tempering of Chocolates:

Tempering the chocolate is essential to make it appear smooth and appealing. Cocoa butter contains a number of fats having different melting points. Tempering creates a finely balanced crystalline state of fats in the chocolate mass. On cooling, the crystals, coat the particles of solid cocoa.

Cooling:

In the chocolate mass, the latent heat is generated progressively as the crystalline point of each fat is reached and not at a specific temperature. Efficient extraction of this heat during the cooling process is necessary to improve the shelf life and appearance of the chocolate.

Moulding:

Tempered chocolate is deposited into tin, stainless steel or plastic moulds. On shaking the mould, the chocolate spreads and air bubbles are removed. On passing the moulds through cooling tunnels, the chocolates get solidified. Moulds are collected and the chocolate is extracted.

Enrober Chocolates:

Centres like creams, marsipan, caramael, jellies, etc. are passed over a wire belt into an enrober. Here, a curtain of chocolates completely enrobes these units. The coated centres are passed through cooling and then they are wrapped.

Panned Chocolates:

Nuts which are round in shape are made to revolve in stainless steel pans. Tempered chocolate is gradually added to build up a thin layer of chocolate. Cool air is blown to help the setting. The coated chocolate is given a final finishing of protective shellac before packing.

REFERENCES.

Asopa VN and Narayanan S (1980). Cocoa Production and Marketing in India. Oxford & IBH, New Delhi.

Directorate of Cocoa, arecanut and spices development, Calicut. Fermentation and drying of Cocoa beans (1983).

PROCESSING TECHNOLOGY OF OIL PALM

C. Arumughan and A. Sundaresan

INTRODUCTION :

Processing is one integral part of oil palm plantation development. Modern Palm Oil Mils (POM) therefore are designed to match with plantation size for their captive use. In palm oil processing, there exists two contrasting situations; (a) Modern large scale POM designed to process 20 to 80 tonnes Fresh Fruit Bunches (FFB)/hr, and (b) traditional processing. While a high degree of process efficiency and good product quality have been achieved by large scale mills, the traditional processing suffers from lack of efficiency and quality problems. There is therefore, a need for intermediate technology between these two extremes to cater for the specific requirements of small sector, with emphasis on

1. the use of locally available infrastructure for design and fabrication of equipments,
2. the design of appropriate size POM to match the plantation size in the small sector (100-1000 ha),
3. process optimization to achieve process efficiency and product quality comparable with international standards, and
4. modification of technology to produce end products to suit local needs.

There have been attempts in the past to disign small scale POM. The Pioneer Mill introduced in the late 1940s was the first venture in this direction. This mill was Reproduced from Nair MK and Nampoolhiri KVK (1996). Oil Palm Production Technology CPCRI, Kasaragod designed to process loose fruits using centrifugal extraction technique. Poor efficiency and oil quality coupled with high labour requirements adversely affected its success. Subsequently Stork-Amsterdam introduced the Junior Oil Mill with a capacity to process 1-3 tonnes FFB/hr. Later using de-wecker, Luxembourg designed the mini-mill with a capacity of 1.5-3.0 tonnes FFB/hr. These two designs had incorporated techniques to produce good quality palm oil with higher efficiency unlike the Pioneer Mill and they were primarily designed for the African plantations. The oil palm plantations of Africa suffer from low productivity. Higher capital outlay in hard currency for these mills therefor, deferred the small Co-operatives from going for these technologies. Concurrently there had also been indigenous attempts in Africa to evolve low cost technology commonly known as village oil mill using locally available talents and resources. These were basically attempts to improve the traditional methods. Higher labour requirements, low throughput, poor oil recovery and oil quality problems have been the disadvantages of village oil mills.

Looking into the evolution of palm oil mill from earlier traditional methods of Africa, through Pioneer Mill to the present day most modern large mills of South East Asia, it is apparent that palm oil extraction requires certain minimum level of technology for process and product quality. With this understanding, a judicious mix of the modern technology and manpower is employed in the design of the small mill with emphasis on the indigenous resources and domestic needs.

TECHNOLOGY FOR EDIBLE RAW PALM OIL :

Palm oil is derived from the fleshy mesocarp of the fresh oil palm fruit of right maturity essentially through a wet rendering process. Presence of an extremely active lipase in the mesocarp renders the oil inedible unless proper care is taken from harvesting through transport to subsequent processing of the fruits. Laboratory studies have shown that this enzyme is bound to the membrane of fat globules and any damage to the membrane triggers the activity and the free fatty acid (FFA) released thus, could be as high as 60 per cent depending on the severity of damage. High FFA not only makes the oil inedible but also makes rate of rancidity faster, fixes the colour and increases refining loss. Palm oil mills, therefore, should be located in the palm plantation in order to process the fruits imediately after harvest. Modern mills have been disigned to match the size of the plantation to cater to the fruit yield of the captive area. Unlike in Malaysia and elsewhere, in India smaller plantations with mills of matching capacities are suitable. RRL therefore, has developed the technology to process fruits from 200 hectare oil palm plantation with a capacity of one tonne FFB/ hr. The steps in the process are briefly described as follows:

Harvesting :

Harvesting of fruits at the right maturity is important with respect to yield and quality of palm oil, since immature fruits yield less oil and over mature fruits have high FFA. Excessive bruising of the fruit bunches should be avoided during harvest and transport for the reasons already stated. Processing of the FFB within 24 hours after harvest is essential to obtain edible quality raw palm oil. Various devices and methods are available now to avoid damage to the fruit during harvest and transport.

Sterillization :

This serves the dual objectives of inactivation of the enzyme lipase and loosening of the fruits from the bunch. It also softens the cell wall and coagulate proteins that facilitate oil extraction in the subsequent stages. A horizontal type steriliser is adopted to minimize bruising of fruits. The FFB are loaded in a perforated cage and is placed in the steriliser. The sterliser is a long cylindrical vessel provided with steam inlet and outlet, pressure guage etc. Sterilization of FFB for 60 minutes at 45 psi has been found to be optimum to achieve the objectives mentioned above.

Stripping :

The processing of sterilization loosens the fruits but does not separate them from the bunch, the loose fruits are stripped off with the aid of a mechanical bunch stripper. This device is a rotary drum with baffles and perforations. When the sterilized bunches are thrown into the rotating drum (20 rpm) the fruits are separated from the bunches and loose fruits fall through the perforaters and the empty bunch pass through the other end of drum.

Digestion :

Purpose of digestion is to convert the loose fruit pulp and in the process the cell walls are broken facilitating release of oil with the help of thermal and mechanical energy. The digester is a vertical jacketed cylindrical vessel fited with a centrally mounted agitator having specially designed blades rotating at slow speed (25 rpm). The loose fruits are charged into the digestor from the top with the aid of an elevator. Live steam is injected into the jacket and into the vessel to maintain the temperature at 95°C. The digested mash with semi-solid consistency is discharged through a discharge chute at the bottom.

Pressing :

The digested mash consisting of oil, water, seed, fibre and other suspended matter is charged into a perforated cage and subjected to pressing. The hydravlic press is fitted with a plunger matching with the cage diameter. The pressing is done while the mash is hot (80-90°C) at 750 psi. The hot oil-water mixture with suspended solids is expelled through the perforations leaving the solid press cake in the cage.

Clarification :

The oil-water mixture is filtered to remove the fibrous debris and is collected in the clarification tank. Clarifier is a vertical cylindrical vessel fitted with steam coil. The oil-water mixture is diluted with hot water (1:2) and heated at 95°C. The oil being lighter, rises to the top and is decanted continuously into a collection tank. The watery sludge at the bottom is discharged as waste.

Purification :

The crude palm oil from clarifier is passed through a high speed centrifuge at 80°C to remove the traces of solid impurities and water. The pure raw palm oil thus obtained is stored in tanks.

Vaccum drying :

Excess moisture in the oil leads to FFA release and quality deterioration on storage. Vaccum drying is adopted in the process to remove excess of moisture.

Oil storage :

The raw palm oil is stored in tanks provided with steam coils.

Nut recovery :

Palm kernel oil is derived from the palm nut recovered from the press cake. After extraction of palm oil, the press fibre has a moisture content of 45-50 percent. Mechanical recovery of the seeds involves braking and drying the press cake, followed by separation of the nuts. The meat recovery has been designed to match the one tonne FFB/hr palm oil mill. The unit consists of a steam jacketed paddle, conveying and cake breaking section. During the passage, the press cake is broken with the help of the rotaing paddles and the press cake is also dried as it is heated in the steam jacket. The dried press cake is separated into fibre and nut in a vertical separating column using suction. The lighter fibre is drawn into a cyclone and the heavier nuts are allowed to fall into a horizontal rotating nut polishing drum. The fibre thus separated is used as boiler fuel. Final removal of residual fibre from the nuts is achieved in the polishing drum along with grading of nuts based on size.

The small palm oil mill envisages only upto the nut recovery stage and the nut as such as a saleable product. The palm kernel and shell mixture obtained is separated into kernel and shell in a clay bath maintained at particular specific gravity. The shell being heavier, sink and the kernel being lighter floats and is skimmed off. The separated kernel is dried to a final moisture of 6-8 percent. The kernel is powdered and steam conditioned followed by expression of oil in expeller. The kernel oil is similar to coconut oil in fatty acid composition. The palm kernel oil recovery is about 2 percent on FFB and it fetches a premium price.

THE INDIGENOUS SMALL MILL :

To suit the requirements of socioeconomic conditions prevailing in India and considering the prospects of small sector plantations, Council of Scientific and Industrial Research in collaboration with Indian Council of Agricultural Research has designed and established a commercially viable small scale extraction mill at Central Plantation Crops Research Institute (Research Centre) Palode.

Its essential factors are

* Capacity to process one tonne FFB/hr.
* Waste fired boiler to generate high pressure steam. Adoption of horizontal steriliser and rotary drum stripper.
* Integration of digestor and hydraulic press.
* Continuous clarification.
* Very low oil loss through sludge and hence elimination of sludge oil recovery.
* Purification of raw palm oil by high speed centrifugation.
* High quality raw palm oil with less than 2% free fatty acids.
* Process efficiency of 90%.
* Compact layout and self-contained plant building with service facilities.
* Low investment and low cost of production. Totally indigeneous design and fabrication.
* Easy maintenance.
* Suitable for 200 ha plantation.

Capacity :

Mill capacity of one tonne FFB/hr was arrived at, considering capital cost for the process equipments and utilities. This can serve a plantation of 200 ha. The basis of calculation has been average annual yield of 15 tonnes FFB/hr; 15 percent/month of it being harvested during the peak 3-4 months. The mill therefore, has to operate three shifts as the case may be during the remaining months.

Design Considerations Steam generations :

A loco type boiler that makes use of the mill and plantation waste has a capacity to generate 600 kg steam/hr, with a maximum pressure rating of 10kg/cm^2. Better thermal efficiency has been made for both natural and induced draft. Fuel feeding is done manually.

Sterilizer :

Two horizontal type sterilizers with a capacity of one tonne FFB are employed. Each sterilizer can accommodate two perforated cages on trolley wheels. Sterlization is carried out at steam pressure of 3kg/cm^2 as practised in large mills. Total sterilization time including weighing, loading, and unloading weighing, loading, and unloading ranges from 90 to 120 minutes. At present, loading and unloading are done manually.

Stripper :

A standard model mechanical rotary drum stripper is employed that can handle about two tonnes of bunches/hr.

Digestor and hydraulic press :

The loose fruits from the stripping area are fed manually to the bucket elevator which in turn feeds the digester. The digester is a vertical jacketed vessel provided with beater arms, feeding and discharge chutes and live steam injection facilities. While in operation a temperature of 95°C to 100°C is maintained for the mash. With a holding capacity of 400kg, the digester can handle about one tonne of fruits/hr and feeding and discharge can be made continuous. Hydraulic press of 100kg capacity is used for the expression of the hot mash. The perforated cage can hold about 60 kg mash and each pressing cycle is of 5 to 6 minutes duration. Both digester and press are integrated with a platform to facilitate handling of the hot mash. The crude oil from the press is collected by channels and is discharged into a transit tank.

Clarification :

Clarification is carried out by overflow technique. The clarifier is a cylindrical vessel of 400 l capacity provided with steam coils, Clarification is done continuously. With proper digestion and oil-water ratio in the clarification, the oil content of the sludge is less than 20% and hence oil recovery from the sludge is avoided here.

Purification :

The clarified oil is further purified by using a bowl type high speed centrifuge of 500 l/hr capacity. This operation facilitates the removal of sludge impurities and excess moisture. The purified raw palm oil from the centriguge is discharged into a storage tank fitted with steam coils.

Process efficiency and product quality :

Data from a few trials are presented in Table 1. Oil loss at sterilization, pressing, clarification stages were calculated from the analytical data. Loss of oil through the unstripped fruits is not accounted here. It was observed that some bunches could not be stripped completely inspite of maintaining a steam pressure of 3kg/cm^2. Densely set fruits in these bunches resulted in inadequate steam penetration and this aspect requires further standardization. Oil content of the press fibre is also fairly high which again demands optimization of pressing conditions.

The overall efficiency of about 90% suggests that the performance of the small mill is comparable with that of large mill. The free fatty acid content of less than 20 percent in the raw palm oil demonstrate that high quality oil could be extracted in the small mill. Detailed analytical data of raw palm oil support the soundness of the oil in terms of chemical and physical quality parameters (Table 1).

Table 1. Analytical data on oil recovery and loss

Sl. No.	Oil loss: Sterilizer %oil	Condensate % oil	Sludge % oil	% oil FFB	Fibre(Dry): % oil	% oil on FFB	Oil recovery: % Recovery	% oil on FFB	Oil Quality: % FFA	% Moisture
1.	0.40	0.05	1.90	0.70	15.00	0.90	89.00	18.30	2.00	0.21
2.	0.40	0.05	1.61	0.66	14.50	0.88	92.00	20.00	1.44	0.18
3.	0.35	0.04	1.80	0.66	16.20	1.00	88.80	19.00	1.50	0.20
4.	0.36	0.04	1.30	0.68	13.40	0.80	92.00	21.40	1.20	0.22
5.	0.31	0.03	1.70	0.73	14.30	0.93	92.20	21.80	1.82	0.20
Average	0.36	0.04	1.66	0.68	14.70	0.90	91.00	19.80	1.80	0.20

Inspite of the good performance of the small mill, higher labour requirements is a major disadvantage. Though complete automation is not feasible, some of the present manual handling processes need to be mechanized; for instance, loading and unloading in the sterilizer, feeding to the stripper etc. With this mechanization about 15 persons (unskilled, skilled and a qualified engineer) per shift are required for the operations of the small mill. The energy requirement part from steam is about Table 2: Investment for establishing a mill of one tonne FFB/hr capacity 15 KWh/tonne of FFB. Subsequently a full-fledged commercial palm oil mill with a capacity of processing one tonne FFB/hr has been commissioned by the Regional Research Laboratory, Trivandrum in West Godavari district for the Andhra Pradesh Oilseed Growers Federation.

INVESTMENT :

Capital investment for establishing one tonne FFB/hr mill is presented in Table 2. This mill is sufficient to cater to the need of a 200 hectare of oil palm plantation. The investment includes plant building with a roofed area of 800m^2, equipments and material handling systems and the site fabrications. Utilities such as steam, power and water supplies are also included. The total investment for this mill at the present price level (1991-92) is Rs. 8 million. Investment per unit throughout for the small mill is still lower compared to that of large mills, primarily because of total indigeneous design and fabrication. This small mill also has easy maintenance, amenability to local situations etc.

Table 2. Investment for establishing a mill of one tonne FFB/hr capacity.

	Equipments		Cost (Rs. in million)
1.	Horizontal sterilizers with cages	2 Nos	0.60
2.	Rotary drum stripper with screw conveyor	1 No.	0.45
3.	Digester, complete with bucket elevator	1 No.	0.50
4.	Hydraulic press (100 tonnes)	1 No.	0.30
5.	Clarifier	1 No.	0.06
6.	Centrifuge	1 No.	0.18
7.	Vaccum drier	1 No.	0.18
8.	Vibrating screen	1 No,	0.05
9.	Industrial balance	2 Nos.	0.05
10.	Storage tanks (40 Kl)	2 Nos.	0.25
11.	Nut recovery unit (cake breaker, polishing drum and cyclone collector)	1 No.	0.65
12.	Material handling systems		0.40
13.	Process pumps, pipes etc.		0.08
14.	Steel structures (for supports, staging etc.)		0.20
15.	Spares and accessories		0.20
16.	Miscellaneous items		0.15
17.	Contingencies and other over heads		0.50
			4.80
Utilities			
1.	Locotype agrowaste fired boiler		0.58
2.	Steam line		0.17
3.	Electricity		0.38
4.	Water supply		0.15
5.	Plant building (800 cm^2)		1.40
6.	Miscellaneous		0.52
			3.20
	Total		8.00

ECONOMICS OF PALM OIL MILL :

This palm oil mill produces raw palm oil as the main product and palm seed as the byproduct., *The sale price of raw palm oil* can be taken as Rs. 20,000 per tonne and that of palm seed can be taken as Rs. 2,000 per *tonne. The one tonne mill catering 200* hectares would produce 600 tonnes of raw palm oil and 300 tonnes of palm seed. The mill capacity can be increased as there is sufficient flexibility in the design and capacity utilization. The cost of production is Rs. 15,500 per tonne of palm oil of which Rs. 10,000 constitute the cost of raw material. *After the pay back period (10 years)* the cost of production comes down to Rs. 12,500 per tonne. The mill may be commissioned when the plantation is 4 years or 5 years old so that the full capacity utilization would be achieved within 3 to 4 years. Though this may cause some wastage of fruits in the 3rd or 4th year, it is advisable since capital investment on the mill in the 3rd year itself may result in more economic loss compared to wastage of fruits in the early years. It is estimated that the loans taken for establishing the mill could be paid back in 8 years. Therefore, the one tonne FFB/hr palm oil mill is commercially viable.

Generally, oil palm plantation and palm oil mill function as an integrated system; the plantation being a captive unit for the mill. This is to ensure assured supply of fruits to the mill which is vital for the economic viability. In the present situation the palm oil extraction mill is treated as an independent unit managed either by a co-operative or by a group of farmers owning plantations. The procurement price of FFB is taken as Rs. 2000 per tonne. This is equivalent to 14 percent value of FFB, assuming that 20 per cent is the recoverable oil from FFB. More information is required with regard to productivity, oil content, seasonal fluctuations etc. to fix the procurement price under Indian condition. Price upto 15 percent on oil value could be adopted considering all aspects which may take some more time to arrive at the optimum level without affecting the producer and processor.

The countries where oil palm is grown differ widely in their infrastructural facilities and capital investment capabilities. Therefore, there is greater need for a flexible approach to the design and size of a palm oil mill to suit the local requirements. The capital cost on per tonne basis could be brought down, provided local infrastructure is fully utilized in terms of efficiency and product quality could be brought to the level of larger mills by proper design of the mill as demonstrated here. The small mills are suited for small holdings, scattered plantations and during the initial years of large scale plantations. Neverethless, large mills with capacities ranging from 5 to 10 tonne/hr can co-exist if situation warrants.

REFFERENCES

Arumughan C, Sundaresan A, Prasad KVSV Damodaran AD and Nampoothiri KUK. (1989). Studies on the extraction and evolution of raw palm oil for edible use. *J. F. Sci. Technol.* **26** : 277-282.

Black, G. 1979. A village palm oil mill. *Oil Palm News.*

Cornelius, JA (1963). A recent development in the small scale extraction of palm oil. *Trop Sci.* **5** : 34-38.

Hartley CWS. (1988). The Oil Palm. Longman London.

Nwanze SC. (1965). The hydravlic handpress. *J Nigerion Inst. Oil Palm Res.* **4**(15) : 290-316.

Van Looy R. (1981). Palm oil mills. *Oleagineux* **36** (3) : 147-151.

(Reproduced from Nair MK and Nampoothiri KUK (1996). Oil palm production technology, CPCRI, Kasaragod.)

POST HARVEST PROCESSING OF SPICES

T. John Zacharia

INTRODUCTION

Spices and spice products are the most important natural flavouring materials available to the food processor and it has wide application in field of food and nonfood items including meat and fish, baked foods, sugar, confectionery, beverages, tobacco, pharmaceuticals and fragrance. Most of the herbs and spices are composed of different types of ingredients like (i) non volatile components-which may be extracted as oleoresin or resinoids by using selected solvents and (ii) inert matter which is mostly cellulose comprising the basic cellular plant structure and of value as natural carrier or diluent as well as contributing bulk or weight.

BLACK PEPPER

In Kerala the harvest of pepper is from December to March. Generally pepper takes about 180 to 230 days after flowering to reach full maturity. In high ranges it takes more time for maturity. Harvesting at immature stage reduce the bulk density. Harvesting is done when some of the spikes in the vine turn red. If in a particular vine wide difference in maturity is observed between spikes selective harvesting has to be adopted.

Despiking:

If the harvested spikes are kept in a bag for 12 to 24 hours or heaped and covered for overnight, despiking will be easy. Trampling with legs is the traditional method followed for despiking. Mechanical devices are also available for this purpose which are more convenient, hygienic and time saving.

Moisture:

During ripening wet weight records a decrease. Moisture content is found to reduce from 82.5% at pin head stage to 60% and then there is a significant drop to 40% at ripening stage. This is a process to ensure more black colour and to reduce the drying time. Generally pepper is dried after despiking and the product may assume a brownish tint. If the despiked berries are taken in a perforated vessel and dipped in boiling water for one minute and then put for drying, it fetches a black shining product. This process enhances the activity of the enzymes responsible for black colour. The colour change is due to a phenolase enzyme which catalyzes oxidation of colourless phenolic compounds to black polymeric compounds.

Drying surface:

Traditionally pepper is dried under sun. It requires about 6-7 days for complete drying to a moisture level of 8-10%. Fenugreek coated bamboo mat is ideal to dry pepper. Another ideal surface is cement floor. Low density and high density polyethylene sheets are also found to be good for drying pepper. The main advantages are (1) black polyethylene sheets absorb more heat and hence reduce the drying time. 2) The sheets can be folded along with pepper and hence the daily routine of spreading the material in the morning and collecting them in the evening can be avoided. However great precaution is necessary to prevent the scattering of berries as it is very smooth.

Solar driers can also be used for drying pepper. Even though the initial cost is high, it considerably reduces the drying time. Mechanical driers using electricity or kerosene can also be employed for drying. To reduce the cost partial sun drying followed by mechanical drying can be adopted.

Dry recovery :

The dry recovery of pepper varies with varieties. On an average it ranges from 2 to 37%. Some of the precautions to be followed in pepper processing are i) select varieties which ripens uniformly, having good berry size, oil and oleoresin. ii) avoid residues of chemicals by effective management of pest and disease. iii) harvesting before reaching maturity lead to loss of weight and delay in harvest lead to berry shedding. iv) berries treated for red ants while harvesting may be washed thoroughly before mixing with usual harvested spikes. v) strict hygiene should be maintained in harvesting, despiking, heaping and drying. vi) maximum moisture content in dried produce is 11%. vii) store pepper in clean bags and the bags should not touch walls/floor directly. viii) rooms where pepper is stored should be safe guarded from rodents, insect pests, birds, animals etc. ix) do not mix immature and riped berries, have two or three harvests if necessary. x) pepper should never be stored in rooms where fertilizers, pesticides etc. are stored.

VALUE ADDED PRODUCTS

The important value added pepper products include (1) black pepper, (2) white pepper, (3) pepper powder, (4) pepper oil, (5) pepper oleoresin, (6) dehydrated green pepper, (7) piperine, (8) pepper in brine, (9) pink pepper, (10) frozen green pepper and (11) encapsulated spices. The bulk density of pepper ranges between 42.5 and 8.50g/litre. Starch accounts for 34% in black pepper and 56.5% in white pepper. The Kerala types like Kottanadan, Kumbhakodi and Kuthiravalli are high in piperine while the North Kanara types are low in piperine.

White pepper:

It is prepared by removing the outer pericarp (skin) of the harvested berries by any one of the following methods. a) Water steeping technique: (i) Using ripe fresh berries: This is a traditional method in which the harvested ripe spikes or berries are packed in gunny bags or steeped as such in water tanks or running water for 7-10 days. The pin heads and light berries which float are separated. Once the skin is softened they are rubbed by hand or trampled to remove the outer skin. The deskinned berries are sun dried and sold as white pepper. Recovery of white pepper varies from 22-27% of the green pepper. (ii) Using dried berries: White pepper can also be prepared from black pepper by steeping it in water for 15-20 days and there after it is rubbed, washed, steeped in bleaching solution, washed and sun dried.

b) Steaming or boiling technique: This process consists of steaming or boiling fresh matured berries for about 15 minutes. The boiled or softened berries are deskinned, washed, bleached and sun dried.

c) Decortication technique: White pepper is also prepared by decorticating black pepper in decorticating machines. However this incur loss of berries to about 20-25% due to breakage.

Pepper oil:

The characteristic aroma of pepper is

due to the volatile oil present which ranges from 2-5%. Generally slightly immature pepper will have more oil. Balankotta, Subhakara etc. are some of the pepper varieties with high oil content.

Pepper oleoresin:

It is concentrate of all the flavour components (aroma, taste, pungency and related sensory factors) and it truly recreates, when diluted the sensory quality of the original material. It is extracted from powdered black pepper using solvents like acetone, ethylene dichloride etc.

Piperine:

The alkaloid piperine is the major constituent responsible for the biting taste of black pepper. Other pungent alkaloids are chavicine, piperidine and piperettine. Piperine content in pepper ranges from 3-6%.

Green pepper in brine:

Bottled green has great demand in non-traditional areas. The green colour is maintained under high salinity of steeping liquid. Minimum salt level should be 12%. Addition of small percentage of citric acid will prevent the discolouration due to phenols.

Dehydrated green pepper:

Keeping the freshly harvested despiked pepper in boiling water for over 10 minutes inactivates the bleaching enzyme. Treatment with sulphur dioxide will reduce the chances of darkening. As sun drying destroys chlorophyll and green colour, to make dehydrated green pepper drying should be done in hot air oven or microwave oven.

Frozen green pepper:

It is prepared using blast freezers. Such pepper on thawing will be almost equal to fresh material.

Many other products such as spice essences and emulsion, spice decoctions, encapsulated spices, fat based spices etc. are also prepared from pepper.

CARDAMOM

The peak period of harvest is October-November. Just ripened fruits or physiologically ripened fruits are generally harvested. More splitting of capsules is observed in case of matured capsules. Percentage of dry recovery is highest (20%) in the fully ripened capsules followed by the one harvested at physiological maturity (24%) and in immature stage (14%).

Capsules may be washed in water to remove the adhering soil and a treatment with 2% washing soda (alkali) for 10 min. enables to retain green colour and prevent mould growth.

Curing:

In this process moisture of green cardamom is reduced from 80% to 12% (wet basis) at an optimum temperature (50°C) so as to retain its green colour to the maximum extent. a) Natural (Sun) drying: Requires 5-6 days and the green colour get bleached by this method. b) Electrical drier: In which 50 kg. capsules can be dried in 10-12 hrs. at 45-50°C retaining the green colour. c) Pipe curing: It is the best method of curing from which high quality green cardamom can be obtained. The structure consists of walls made of bricks or stones and tiled roof with ceiling. A pipe made of iron or zinc sheet starting from the furnace passes through the chamber and opens outside the roof. The heated air current generated in the furnace passes through the pipe and increases the room temperature. The fans located on either sides of the wall uniformly spread the temperature. Inside the room, cardamom to be dried is kept in wooden/aluminium trays arranged in racks. Fire in the furnace is adjusted to maintain the temperature between 45-50°C. It may take about 18 to 22 hrs. for drying. Many other types of mechanical driers are also available.

Bleached cardamom:

Bleached cardamom is creamy white or golden yellow in colour. It can be done with either the dried or freshly harvested capsules. It is prepared using sulphur dioxide, potassium metabisulphite (25 containing 1% HCL for 30 min.) and hydrogen peroxide (4-6% pH 4.0). However bleached cardamom tend to lose more volatile oil.

Cardamom oil:

The major value added product from this spice is the oil. Most varieties contain 5-9% oil. Immature cardamom has more oil. Unlike pepper and ginger, cardamom oil imparts the full taste of the spice. Major chemical constituents of the oil are 1,8-cineole and α - terpinyl acetate. A high terpinyl acetate and low cineolic content in the oil impart sweet flavour while an high cineolic content impart more of an undesirable camphorace-ous note to the oil.

GINGER

The quality of products of ginger depends on the variety used and cultivation practices. Appropriate variety has to be selected for various end products such as dry ginger, raw ginger, oil, oleoresin etc.

Raw/Dry ginger:

Himachal, Maran, Mananthody, Kuruppampady, etc. are good varieties to prepare dry ginger. Rio-de Janeiro, China, Wynad, Varada etc. are good varieties for raw ginger. Only recommended doses of pesticides and other chemicals should by applied so as to avoid residues. Ginger rhizomes should be thoroughly cleaned before peeling. Extreme care is necessary while peeling to prevent loss of volatile oil. Wooden scrapers of bamboo stick is ideal for peeling. Knives or sickles may leave dark spots. Ginger can be dried on clean bamboo mats or cement floor. Depending on availability of sunlight full drying period may vary from 7-14 days. Desirable moisture level is 10%. Above this may cause development of aflatoxin. Collect the dried ginger in air proof polyethylene bags and stack on wooden pieces. Rhizomes affected with rot should not be used for preparing dry ginger. Do not fumigate stored dry ginger without consulting experts as many importing countries imposed ban on fumigated materials. Mixing of fully dried ginger with half dried ones may be avoided as it will damage both the materials. Rodents, birds, pests and animals should not be allowed in the area where ginger is stored. The major Indian trade types are Cochin and Calicut ginger. Cochin ginger is more superior in quality. Appearance, contents of volatile oil and fibre, pungency level and a subjective assessment of aroma and flavour are important in the quality evaluation of dried ginger. This depends on the cultivar, stage of maturity at harvest etc. Oil and oleoresin decreases as maturity progress.

Ginger oil: It varies from 0.5 to 3.0%. Oil possess only the aroma and not the flavour of the spice.

Ginger oleoresin: It is a blend of oil and resinoides. It is extracted from ginger powder using organic solvents like acetone, ethylene dichloride etc. Its content range from 3.5 to 9.5%. Major pungent principle gingerol (a phenyl ketone).

Fresh ginger products: Ginger preserve or Muraba, ginger cangy, soft drinks like ginger cocktail (which aids in digestion), ginger pickles, salted ginger, salted in vinegar or vinegar mixed with lime, green chillies etc.

TURMERIC

Turmeric is once known in the west as "Indian Saffron". Curcumin is the principal colouring pigment in turmeric. Indian turmeric is popular for its intrinsic quality. Following precautions are necessary to preserve the quality of turmeric. Seed turmeric should be immersed in suitable fungicide and pesticide for half an hour. Thereafter they may be dried in shade and kept safely. Robust rhizomes are suitable for seed material. Larger rhizomes can be split and used. As maturity of different rhizomes vary uniformity may be maintained. Harvesting should be done at correct maturity without damage and the rhizomes may be washed. Turmeric should be boiled and dried. For boiling use clean water. The bulbs and the finger should be boiled separately. While boiling, water should be filled into cover the turmeric. Cover the turmeric using gunny bag or jute bag to restrain the stem within.

Heating should be uniform. After the commencement of boiling it will take 45 to 50 mins to complete the cooking process of turmeric. It can be tested by passing between fingers or by piercing a small stick through the rhizome which will easily pass through if properly boiled. The odour of the smoke too indicates that it is fully cooked.

Clean terraces or cemented yards or clean bamboo mats should be used for drying turmeric. It should be heaped and covered during night in order to protect it from rains. It may take about 10-15 days and if the drying is complete turmeric will break with a metallic twag. Dried turmeric can be marketed as such or after polishing. Polishing can be done by sprinkling turmeric power using a mechanical drum. It should be kept in clean sacs and stored over wooden pallets in store rooms. The room should be kept clean, free from pests, spiders and rodents. Cowdung smeared floor or mats should not be used for drying. Dried turmeric should be stored safely to prevent further absorption of moisture.

Alleppey Finger Turmeric (AFT) is very famous and established for its colour in trade. In turmeric curcumin content vary from 4-7%. Now there are quite a few varieties available with more than 6 % curcumin.

CINNAMON

Cinnamon bark and leaves are commercially very important. Bark is used to extract oil and oleoresin and leaf for oil. Bark oil has high cinnamaldehyde content and leaf oil has high eugenol. Cinnamon bark is extracted generally after the rains at the time when the red flush of the young leaves is beginning to turn green and the sap is flowing freely. The process consists of stripping the bark and preparing quills from the inner bark. The outer bark is first removed using a crude curved knife. The stripped stem is rubbed briskly with a heavy brass rod to loosen the inner bark. Two cuts are made round the stem about 30 cm apart and two longitudinal slits are made on the opposite side of the stem. The inner bark is then carefully eased off the wood with the pointed side of the knife. The curled pieces of inner bark are next assembled into quills or pipes.

Oleoresin: It is extracted from powdered cinnamon bark using solvents like acetone, ethylene dichloride etc. Cinnamon has about 7-10 % oleoresin.

Bark Oil: Bark yield 0.5 to 2.5% oil. It contains about 65% cinnamaldehyde and 5 to 10% eugenol.

Leaf oil: Leaf contains 0.5 to 1.5% oil. The main constituent is eugenol (70-80%) which is used in dental preparations and synthetic vanillin.

Cassia oil: *Cinnamomum cassia* is another important spice with great commercial potential. Its bark and leaf has cinnamaldehyde as the main ingredient.

NUTMEG AND MACE

It is generally harvested when the fruits split. The seed with the surrounding scarlet aril is removed from the pericarp. Later the mace is taken off and is dried separately from the nutmeg in its shell. The proportion of dried shelled nutmegs to dried mace is approximately 20:3. After harvesting nutmegs are dried in their shells either under sun or by mechanical drying.

Nutmeg butter: It contains 25-40% fat which can be recovered using solvents or by mechanical pressing. It is highly aromatic. Major constituent is trymyristicin.

Oleoresin: Extracted with solvents. It may have butter also.

Nutmeg oil: Yield ranges from 7-16%. Aromatic ethers, myristicin and elemicin are present in oil and oleoresin. These two have hallucinating property. Hence the oil may be used for consumption only in small quantities.

Mace oil: Yield ranges from 4-17%. Similar to nutmeg oil.

CLOVE

Clove clusters are picked by hand when the buds have reached their full size and most of them develop a pronounced pink flush. From these clusters, cloves are separated from the stems consisting of peduncles and pedicel. Then it is dried. Dry cloves weigh one third the weight of green, freshly harvested cloves. Quality of the dried spice is influenced by a number of factors which include the care taken in harvesting, drying and storing. Traditional method of drying is exposing it to sun on mats. Green buds are spread out in a thin layer on the drying floor and are raked from time to time to ensure uniform colour. it may take about four or five days to produce a spice of desirable colour. When properly dried, they will have a bright brown colour and will snap cleanly and not bend when pressed across the thumb nail.

Essential oils: Clove bud oil: Superior in odour and flavour to the stem and leaf oil. Bud yield about 17% oil. It contains about 85% eugenol. Methyl-n-amyl ketone is present only in bud oil.

Stem oil: Yield about 5-7% oil containing 70-90% eugenol.

Leaf oil: Yield about 1.5 to 1.8% oil.

Oleoresin : It is prepared by cold or hot extraction of the crushed spice using organic solvents. Volatile oil content of oleoresin is usually 70-80%.

PIMENTO (ALLSPICE)

Dried berries are the major item of commerce. It has about 3-4 % of aromatic steam volatile oil and fixed (fatty) oil. Resin, protein, pentosans, starch, traces of alkaloids, pigments, minerals etc. are its other components. Volatile oil from berry is yellow to brownish in colour possessing a warm spicy, sweet odour with a peculiar fresh and sweet top note. Main components are eugenol (68%), methyl eugenol(8%), beta-caryophyllene (4.2%), humulene(2.7%) and cineole(2.3%).

Leaf oil: Dried leaves yield 0.7-2.9% oil similar to clove leaf. Eugenol content is higher than that of berry oil.

CASHEW NUT PROCESSING INDUSTRIES IN INDIA

D. Balasubramanian

INTRODUCTION

India is the largest producer of raw cashewnut in the world and accounts for 43 per cent of total world production. The importance of cashew (*Anacardium occidentale* L.) in Indian economy is due to its vital role in agricultural exports and also its employment generating capacity in its processing sector. Cashew processing in India started as a small cottage industry and has developed into an highly organised labour intensive industry. Since the world demand for cashew kernels is on the increasing trend, the processing of cashew remains as an highly profitable industry.

Cashew, one of the most important export oriented commercial crops in India. The country produces 4.30 lakh tonnes of raw nuts per year from an area of 6.59 lakh ha. Export of cashew kernel in the year 1996-97 was 68,758 MT valued Rs 1281.04 Crores and Cashew Nut Shell Liquid (CNSL) export was 1350 MT valued Rs 1.99 Crores. It is being grown in different states like Kerala, Karnataka, Maharashtra, Goa, Tamil Nadu, Andhra Pradesh, Orissa and West Bengal. The average productivity is about 725 kg/ha with maximum of 1570 kg/ha in Maharashtra and minimum of 430 kg/ha in Tamil Nadu.

CASHEW NUT PROCESSING INDUSTRIES

In India, there are about 1132 cashew processing factories employing more than 3.5 lakh workers with an estimated capacity of 7 lakh tonnes per annum. Cashew industries have a simple organisational structure and are mostly under private management i.e., either proprietorship (63%) or partnership (19%). Since it requires large amount of initial investment and running capital, most of the industries depends on commercial banks and state financial agencies for running capital. About 62% of the industries are categorised under "Manufacturer exporter". This is primarily due to encouraging export policy and low per capita domestic consumption. Tiny processing units (upto 100 MT/year) and medium capacity processing industries (100-500 MT/year) account for 39% and 42% respectively. This is due to raw nut shortage and financial constraints. Most of the industries utilise below 50% of their capacity.

About 90-95 % of rural women force is employed in these industries at different stages of operation. Total employees strength varies between 50-400 per factory. Men labourers are involved in drying, stacking, roasting, kernel drying and packing. Labour wages are fixed by the State Government and it varies between the states.

Raw cashew nut:

Raw cashew nut is kidney shaped one with approximately 3.5mm thick leathery outer skin (Epicarp) and thin hard inner skin (Endocarp). Between these two walls of the shell is a honey comb structure which contains the phenolic material, commercially known as Cashew Nut Shell Liquid (CNSL). The kernel is inside the shell wrapped in a thin brown skin known as testa.

Physical properties:

Physical properties of raw nuts and

their dependency on operation parameters for the design of processing machineries have been determined. The average length, width, thickness of raw cashew nuts at 8.46% db are 31.00, 22.86 and 16.91 mm respectively. While the corresponding values of kernels are 24.67, 12.99 and 12.06 mm. About 52 % of nuts have length between 30-35 mm, where as 11.5 % and 36.5 % of nuts are categorised as > 35mm and < 30mm respectively. The average unit mass of the nut and kernel is 5.96 g and 1.89 g respectively. The average sphericity of raw cashewnut and kernel at a moisture level of 8.46 % db is worked out to be 0.74 and 0.63 respectively. 100 nut mass of raw nut varies between 610.6g to 735.1g and it increases linearly with increase in moisture content. The porosity increases from 48.03 to 52.33%, while the bulk density decreases from 642.2kg/m3 to 591.9kg/m3 as the moisture content increases from 3.15% to 20.06% db. The static co-efficient of friction for nuts increases linearly with the moisture content irrespective of the surface.

Raw nut procurement:

Cashew nut being a seasonal crop, harvesting of nuts is carried out during March to June. It has been found that the processors obtain raw material in four ways. (i) directly from producers, (ii) direct purchase from local market, (iii) through commission agents and (iv) through imports. While procuring the nuts, normally 3 tests are conducted by the processors, they are; (i) Visual test (Size and colour of the nuts to check the maturity) (ii) Floating test (About 5kg of sample is put in a vessel containing water. After Continuous stirring floaters are collected and counted) (iii) Cutting test (Raw cashew nut sample of 5 kg is collected from different bags and mixed together. One kg raw nut is taken from the bulk and cut open using hand cutting tool. Based on the kernel appearance ie., white, shrivelled, dotted or rejects, the percentage of good kernel is calculated. This test also forms a basis for fixing the price.

In order to run the factory throughout the year, 50% of the factories import rawnut during off season from Brazil, West and East Africa, Ivory Coast, Vietnam etc. and about 1,92,285 MT rawnuts was imported during 1996-97.

Cashew nut processing:

It can be defined as the recovery of edible kernel from raw nut by manual or mechanical means. In India, the processing is mostly done manually and it consists of moisture conditioning, roasting, shelling, kernel drying, peeling, grading and packing.

Grading of raw cashewnuts before processing reduces broken kernel. Usually, the graded nuts are pre-collected by sprinkling water and allowed to remain in moist condition for 24-48 hours.

Roasting of raw cashewnuts is done to make the shell brittle and to loosen the kernel from the shell. At present three methods of processing is followed in India. They are: (i) Drum roasting; (ii) Oil bath roasting; (iii) Steam boiling.

Drum roasting:

In this method the nuts are fed into an inclined rotating drum which is heated initially to such an extent that the exuding oil ignites and burns, thus charring the shell. The drum maintains its temperature due to burning CNSL oozing out of the nuts. Roasting generally takes about 3-5 minutes and the drum is rotated by hand during this period. The roasted nuts which are still burning are covered with ash to absorb the oil on the surface. The shell becomes brittle and the rate of shelling and the outturn of whole kernels is reported to be highest in this method.

Raw nuts
↓
Drum roasting
↓
Hand shelling → Shells → Fuel
(mallet/stone hit)
↓
Borma drying
Hot air →↓
Hand peeling
↓→ Testa → Tannin extraction
Grading
↓
Packing (Vita/flexible packing)

Oil bath roasting:

This is a traditional method being followed only in few processing industries of Kerala and Karnataka. In this method, rawnuts are passed for 1-3 minutes through a bath of heated CNSL maintained at a temperature ranging 190-200°C by means of screw or belt conveyor. The roasting equipment consists of a rectangular vessel, 2-3 feet wide and 3 feet deep, with a flat bottom. The whole assembly is embedded in brickwork furnace which uses spent cashew shell as fuel.

Raw nuts
↓
Water Conditioning
↓
Oil bath roasting
↓→ CNSL
Centrifuging
↓→ CNSL
Shelling → Shells → Fuel
↓ └→ Expeller → CNSL
Borma drying ↓
Hot air →↓ Shell cake
Peeling
↓→ Testa → tannin extraction
Grading
↓
Humidification (permissible limit 5%)
↓
Packing (Vita/flexible method)

Steam boiling:

This method is adopted in the factories where hand and leg operated shelling machines are used. The nuts after conditioning are given a mild roasting in an equipment for 20-25 minutes at 100-120 PSI to loosen the kernels from shell and make its removal easy.

```
                         Raw nuts
                            ↓
          Steam  →  Mild roasting
                            ↓
                        Shelling         (Hand cum pedal operated unit)
          Shells ←──────────┘
            ↓           Borma drying  ←  Hot air
         Expeller           ↓
  CNSL  ←┘              Peeling          (manual)
         Residue            ↳ Testa → Tannin extraction
                        Grading
                            ↓
                   Rehumidification   (Permissible limit 5%)
                            ↓
                        Packing  (Vita/flexible packing)
```

SHELLING

Manual:

Nuts after roasting are shelled (decortication) manually in most of the units in Kerala and Tamil Nadu. Manual shelling is an operation requiring some amount of dexterity. Nuts are knocked 2-3 times on each of the long edge by a wooden mallet or light hammers taking care to see that the whole kernels are released without damage or breakage to the extent possible. The outturn will be 90 per cent of whole kernels. Individual workers' output is about 15-20 kg per 8 hrs working day. Workers smear ash or clay on their hands to avoid contact of corrosive shell with the skin.

Mechanical:

The mechanical shelling gadget consists of two blades, between which the raw nut is inserted. The gap is adjustable and therefore it will be advantageous if the raw nuts are pre-graded on the basis of size. By means of lever operated by leg, the blades are brought together which will cut the shell without damaging the kernel inside. The nut is cut to the depth of the shell and a hand lever is pressed to open the shell into two parts. The pressure exerted by the foot and hands should be regulated so as to cut only the shell and not the kernel. The kernel is then scooped out by means of sharp needle. The output per worker (for 8 hours) is estimated to be 14-22 kg of kernel. The main disadvantage of this method is while handling the mild roasted kernels the CNSL oil may contaminate it, and varying size of the nuts requires careful manipulation during cutting to avoid injury *to the hands.*

KERNEL DRYING

The kernels after separation from the shells are dried to reduce the moisture and loosen the adhering testa. The most commonly used drier is Borma dryer. The nuts are placed in trays with wire mesh bottom and loaded into metal chambers. The chambers of the dryer are indirectly heated by the gases from the furnace at the bottom. Spent shells from the decortication process are burnt as a source of heat. There are 4-6 chambers and in each chamber wire mesh trace of approximately 90x45 cm and 10-15cm depth are loaded. Air winds are provided at the top and sides for the moisture to escape. Each tray can hold 10kg of material to a depth of 5-7 cm, temperature ranging from 70-100°C will be prevailing inside the whole chamber. In order to get uniform drying the position of trays is changed at intervals of 10-30 minutes. The normal duration of heating is about 6-12 hours. Recently developed through-flow dryer is having the capacity of 250kg in a 4 hour shift works at 80°C. Besides saving labour, drying can be completed in 3 hours with satisfactory peeling and good quality cashew nuts. The moisture content of the dried samples will be in the range of 2-4 per cent (db).

PEELING

Peeling is the operation of removal of the testa from the kernels. As the kernels are quite brittle after removal from the dryer they have to be cooled for 24-48 hours for moisture absorption. The testa is then separated by applying mild pressure between the fingers. Sharp bamboo sticks are also used to remove the adhering testa. The average peeling capacity is 7-10 kg/person/day.

GRADING AND CONDITIONING

Kernels are graded on the basis of specification prescribed by Govt. of India under the export (quality control and inspection) Act 1963, which recognises 26 different export grades of kernels. The kernels are conditioned before packing in sealed tins. If the kernels are over dried at the time of packing, they are liable to break during transport. If the moisture exceeds the limit of 5 %, kernels become susceptible to microbial and oxidative spoilage.

PACKAGING OF KERNELS

Cashewnuts are subjected to rancidity and they quickly go stale. Therefore packing should have low permeability of oxygen and moisture. Method of packing should involve either vacuum or inert gas inside the packing material. At present the bulk of cashewnuts is packed in tin containers weighing 25 lbs. Tins kept on a vibrating platforms are filled by a chute. After filling and weighing the tins are evacuated filled with CO_2 with the help of "VITAPACK" machine and sealed.

CASHEW NUT SHELL LIQUIT (CNSL)

CNSL is a naturally occurring phenol which is contained in the soft honey comb structure between the shell and the kernel of the cashewnut. It is obtained during the processing of nuts in isolation of kernels.

Hot oil bath, expeller, kiln, solvent extraction processes are the various processes for the extraction of CNSL.

Hot oil bath:

The raw nuts are passed through a bath of hot CNSL itself by which the CNSL is extracted from the shells of the nuts. In this method, only 50% of the oil is extracted. Only few factories in Kerala follow this method.

Expeller:

This method is used for shells from which the oil has already been extracted either by 'hot oil process' or by roasting. The shells from steam boiling method are subjected to expeller operation for extracting CNSL. About 90% of the liquid present in the shell can be extracted by this method.

Kiln method:

This method is extensively employed in Tamil Nadu and to some extent in Kerala. In this method, the oil extracted is crude and contaminated with shell pieces and other foreign matter.

Solvent extraction:

The solvent extraction is the most efficient method since it is possible to extract maximum quantity of CNSL from the shells. But this process is expensive and needs considerable technical skill.

Most of the industries uses 15 HP oil expeller for CNSL extraction. After extracting oil, it is transferred to boiling unit where it is subjected to 100°C for 4 hours to evaporate moisture and cooled for 10-12 hours in settling tanks. *It is estimated that 7kg crude oil can be extracted from 100kg shell and sold at the* rate of Rs.12/- per kg. CNSL is a versatile industrial raw material. It finds wide use in the formulations of resins, detergents, insecticides, dyes, antioxidants for mineral oils, lubricants, drugs etc. The major products for industrial application are given below:

The Cashew Lacquer:

The cashew lacquer manufactured from cashewnut shell liquid is found to be superior to the conventional oil, cellulose or synthetic resin paints. The cashew lacquer has optimum toughness and elasticity, excellent gloss and superfine adhesive qualities.

Insulating varnishes:

These varnishes have good film-forming, heat-resistant, water-repellent and electrical insulating properties.

Electrical windings:

Electrical windings impregnated with CNSL improves mechanical properties and rate of heat dissipation. For this purpose, the electrical winding is impregnated with a composition containing condensation product of Cardanol.

Electrical conductor:

Films, impregnations and moulded compositions made from CNSL are insoluble in petroleum spirits and oils, are impervious to water and moisture, and can be successively and repeatedly heated to temperatures of 500° F and higher, and cooled without lowering their dielectric value.

Cashew cements:

Cashew polymers react with *formaldehyde to give a rubbery gel which* can be used as a cement. This gel hardens within few days, but if required the hardening rate can be accelerated by gentle heat.

Quality standards:

A draft standard concerning the marketing and commercial quality control for international trade has been prepared and it applies to cashew kernels obtained by heating, shelling and peeling the true fruits of cashew tree. The purpose of the standard is to define the quality requirements of the cashew kernels at the export stage after preparation and packaging.

(a) Minimum requirement:

(i) free from any deterioration likely to affect the natural keeping quality of the kernels or make them unfit for human consumption. (ii) sufficiently developed. (iii) clean practically free any visible foreign matter. (iv) free from living or dead insects, mites or other parasites. (v) free from mould or rancidity. (vi) free from adhering testa and shell liquid and (vii) free of any foreign smell or taste.

(b) Moisture content:

Cashew kernels shall have a moisture content equal or greater than 3% but not greater than 5%.

(c) Classification:

Alternative acceptable designations for each classes are shown in the table below

PROBLEMS IN CASHEW PROCESSING INDUSTRIES

Procuring quality raw nut

At present procurement of rawnuts is done mostly based on personal experience and floating or cutting results which form a criteria to fix up the price. Moisture content of raw nut has strong bearing on quality of final product and fixing up the price. Therefore, raw nut moisture content along with prescribed quality standards have to followed during price fixation.

Increasing the shelf life of raw cashewnuts

The ware house for raw nuts has to be given particular care to maintain the nuts at safer moisture level by controlling the environment of the ware house. Control can be achieved through good ventilation and usage of new fumigated bags is an effective measures against insect infestation. There should be free space between two stacks in a row for sufficient aeration.

The storage life of raw nuts in the godown also depends on the quality of nuts and its environmental condition during storage. Fluctuating temperature in delirious during storage due to condensation of moisture in the godowns at certain pockets and consequent microbial growth. Atmospheric relative humidity plays a key role in safe storage of raw nuts as the nuts absorb or desorb moisture to maintain equilibrium with atmospheric relative humidity. Therefore equilibrium moisture content of raw nuts has to be determined.

Increasing white kernels recovery:

In steam boiling and drum roasting the different operating parameters have to be optimised for various nuts origin in order to improve the whole kernel outturn.

Drudgery of labourers in shelling process:

In order to minimise the drudgery of labourers operating shelling unit and to avoid the effect of CNSL effect on the hands of the operator improved cashew shelling unit has to be developed.

Scorching of kernels in borma drier:

Maintaining uniform circulation of hot air at constant temperature throughout the process in tunnel drier by providing thermostatic control. For medium capacity, electrical borma drier may be recommended.

Maximising whole kernel recovery in peeling process:

In manual peeling the production capacity is very much lower. Therefore, the mechanical means to automatically peel the testa has to be tried.

To overcome cumbersome Vitapacking system:

Either flexible packaging system with NO_2 gas infusion or moulded vacuum packaging may be followed. It will considerably reduce the packaging cost.

SUMMARY

The growing demand for kernels in the international market and the availability of cheap labour (mainly women) in India possessing the required skills in processing are the two important favourable factors in the rapid growth of cashew processing industry in India.

The quantity of rawnuts available for processing has however fallen far short of the requirements for full use of the capacity. The inadequacy of raw nuts has resulted in curtailment of the days of employment for the large number of workers dependent on cashew processing. In addition, due to requirement of less capital investment and high level of profit expectations, incentives are provided for creating new factories and such expansion has proceeded along with the increased under utilisation of the existing factories and severe under employment of labour in the existing factories.

Oil bath roasting which has additional advantage of obtaining CNSL is adopted by only a few processors, presumably because the capital investment required is ten times more than the drum roasting method. More over the unpurified CNSL does not attract sufficient market. Therefore, creation of additional capacity in the industry and emergence of new industry have to be discouraged.

Cleanliness of processing units has to be given utmost importance. Authorities issuing license for cashew processing industries has to be very critical in this direction.

Optimisation of every processing step has become urgent. The major requirements for the development of mechanised cashew processing plants will be based on the efficiency in the production of unscorched kernels and maximum recovery of CNSL. Highly mechanised plant will create social problems like unemployment and under-employment. Therefore, simple mechanisation to increase the whole nut yield has to be tried without creating social upheaval.

Acceptable designations of cashew

Class	Quality	Colour	Designation
Extra	Superior quality, characteristic of variety or commercial type.	White Pale ivory Pale Ash-grey	"White" "First Quality"
I	Good quality	Light Brown Light Ivory Light Ash-grey Deep Ivory	"Scorched" "Second Quality"
II	Do not qualify for inclusion in higher classes, but which satisfy minimum requirements specified above.	Light brown Amber Light Blue	"Scorched Seconds" "Third Quality"
	Immature and speckled kernels are permitted provided they do not affect the characteristic shape of the kernel.	Deep brown Deep blue Discoloured Black spotted	"Dessert" "Fourth quality"

QUALITY AND PROCESSING ASPECTS OF CASHEW

KV Nagaraja

QUALITY ASPECTS

Cashew kernel contains proteins, sugars, starch, amino acids, lipids, minerals and vitamins. Cashew testa is quite rich in tannin which is extracted and used in leather industry. Cashew kernel proteins contains all the essential amino acids and the PER of cashew kernel meal is comparable with casein. Trypsin inhibitor like activity has not been detected in the varieties analysed. However, a report from Brazil indicated its presence.

Among different varieties analysed for biochemical composition, the kernel protein content varies from 32 to 43%. Similarly, the variation noticed in the case of starch is 21 to 33%. Sugar content among different varieties exhibits a variation from 9 to 19 %.

Cashew kernel is rich in lipids constituting 50% by weight. The lipid content among different varieties do not show much variation. Major fraction of kernel lipids is neutral lipids (96%) followed by glyco and phospho lipids (2% each). Varieties exhibit differences with regard to composition of neutral and glyco lipids. Among different fractions of neutral lipids, free sterols formed the major fraction (50 to 80%) in most of the varieties except Morgaon, M 10/4, Vetore 56 and M 6/1 where triglycerides formed the major fraction. Cashew kernel triglycerides are rich in unsaturated fatty acids with unsaturated to saturated fatty acids ratio of 5.9:1. Glycolipids are very rich in saturated fatty acids with unsaturated to saturated fatty acid ratio of 0.08:1. Thus varieties with higher triglyceride content is preferable from the point of nutrition. The fatty acid composition of cashew kernel is oleic acid (73.7), linoleic acid (7.7%), stearic acid (11.2%), lignoceric acid (0.15%) and rest as unsaponifiable matter.

Wide variation among different varieties has been observed with respect to *in vitro* digestibility by proteolytic enzymes such as trypsin, chymotrypsin and pepsin indicating the possibility of variation in the protein amino acid composition.

In cashew shell besides Cashew Nut Shell Liquid (CNSL), lignin and cellulosic material contains 3 to 5% protein. Cashew shell contains 13.2% moisture, 6.7% ash, 17.3% cellulose and ligin, 4% proteins, 20.8% sugars and rest as CNSL. The sugar content among different varieties varied from 0.6 to 2.4%. The CNSL content, estimated as phenols, did not vary much among varieties.

Table 1 : Vitamin Content (mg/100g) of Cashew Kernels

Thiamine (B_1)	0.56
Niacin (PP)	3.68
Tocopherol (E)	210
Riboflavin (B_2)	Traces
Pyridoxine (B_6)	Traces
Axerophtol (A)	Traces
Vitamins D	Traces

Table 2 : Mineral Content of Cashew Kernel (%)

Ca	0.04	Fe	0.008
P	0.88	Cu	0.002
Na	0.005	Zn	0.004
K	0.57	Mn	0.002
Mg	0.28		

Studies during storage of cashew nuts both at ambient and low temperature upto a period of 2 years have indicated that sugars, starch and CNSL content decreased during storage, while total lipid does not change. Neutral lipids tend to decrease and glyco and phospholipid tend to increase. Processing of floaters and immature nuts resulted in higher per cent of kernel as rejects with lower shelling percentage, poor peeling outturn and lower per cent wholes recovered. Storage period upto 16 months, processing with and without steam roasting time, initial moisture content ranging between 5 and 14 per cent and time lag upto 60 days in drying the freshly harvested nuts did not influence per cent kernel rejects. With this, a stage has come where we have to define our varieties in terms of Quality standards to get better price in international market.

A variety with a protein content of >35g, lower sugar content (<14g), higher protein lysine content (>50%/mg protein), low free sterols and higher triglyceride content (>50% of neutral lipids) is preferred.

PROCESSING ASPECTS

Development of cashew nuts and apples is not parallel. Cashew nut develops earlier to cashew apples. Cashew nut develops in size till 30 days after fertilization and during subsequent 10 days the nuts get hardened. At this stage, the development of cashew nuts ceases and that of apple starts. Normally, it takes 60 days from fertilization to its full development.

It is the usual practice to harvest nuts just before it matures because of pilferage. This is not a good practice because this reflects on the quality of the kernel. Hence, only fully matured nuts are to be harvested. Nuts turn brown when they fully mature and weigh between 5 and 8 g. Usually nuts are picked after they fall off from the tree. However, if one intends to use the cashew apple for processing, it is better to harvest from the tree without damaging the fruit. The nuts will sink in water if they are fully mature and filled, and they will float in water if they are not filled completely. This test could be used to test their maturity. It is very essential to dry the nuts after harvest to prevent spoilage during subsequent storage. The moisture content of the nuts harvested could be as high as 25%. The maximum permissible moisture content would be 8.7 to 9.1%. Hence, nuts immediately after harvest are to be sundried and stored in a godown till they are processed.

Cashew apples when fully mature will have colour ranging from red, yellow and reddish yellow depending on the variety. The weight of the mature fruit varies between 50 and 80 g. For processing of cashew apple, apples are to be picked from the tree. Usually this is done by a locally devised device consisting of long hooked stick with a sickle and a bag fixed near the hook. By this one could harvest fruits without damaging them which is very essential for processing. Any damage to the fruit leads to spoilage due to microbial infection. The fruits harvested cannot be stored long. They have to be processed immediately to prevent microbial infection. Main difficulties noticed in shelling the cashew nuts are the irregular shape of the nut, tough leathery nature of the shell and the CNSL within the shell which should not contaminate the kernel during processing.

On a small scale, cashew nuts are processed by roasting nuts in a perforated pan. When nuts are roasted like this, CNSL from the shell leaks out and just gets burnt. The nuts processed by this method are usually contaminated with CNSL. Moreover, CNSL the important byproduct cannot be recovered. Roasted nuts are shelled and kernels are removed. The quality of these kernels will however be poor. If one wants to process large quantity of cashew nuts, this has to be done in a factory.

Cashew apple is quite rich in ascorbic acid. Presently, cashew apple that is produced is used for the manufacture of "Feni", an alcoholic beverage in Goa. Extensive research work has been done towards development of technology for alternate uses of cashew apple. In this regard, CFTRI at Mysore has done considerable work for manufacturing of various products from cashew apple such as fruit bars, jam and jelly, chutney, fruit juice, wine, spirits and vinegar.

The major constraints in processing of cashew apple is their seasonal production. Cashew apple contains tannins which are responsible for the astringency one notices. This needs to be removed before apples could be used for juice preparation. The work from CFTRI has revealed that tannins could be precipitated by the addition of gelatin. Description of processing of cashew apple for different products is given below:

(1) Cashew apple juice: During juice preparation contact with iron should be avoided. Cashew after thoroughly cleaning with water is steamed for 5-10 lb. This facilitates extraction of juice and inactivation of enzymes. The juice extracted from the cooked fruits is clarified by the addition of gelatin (430 mg/litre) and stirring for 15 min. Sugar may be added after filtration. Sodium benzoate (0.7g/litre) should be added as a preservative and can be stored in bottles, preferably at refrigerated temperature.

(2) Syrup: Extract juice-precipitate tannins. To this 60 ml lime water is added and 0.2 to 0.3% gelatin to precipitate suspended matter. Sugar at the rate of 2kg/3 kg juice is to be added. Sodium benzoate (0.7 g/litre) is added as preservative.

(3) Canned fruit: Apples peeled in 0.5% boiling lye for 3 to 5 min followed by rinsing in water and subsequent boiling for about 4 min in 0.2 N solution of sulphuric acid. After washing, apples are steamed for about 4 min at 5 lb pressure. Then they are washed with water. Fruit is canned in sugar syrup of 40°C brix employing an exhaust for 4 to 5 min in boiling water and an autoclave treatment of 30 min in steam at 10 lb pressure.

(4) Jam: Cleaned apples immersed in 2% salt solution for 3 days (to reduce tannin content) and steamed for 10 to 15 lb pressure. Apples are crushed and mixed with equal weight of sugar and boiled. Some quantity of citric acid may be added towards the end to improve the taste.

NATURAL RUBBER - COLLECTION AND PROCESSING

K.T. Thomas

INTRODUCTION

Seventy to eighty five per cent of the crop harvested from rubber plantations is in the form of latex. The remaining portion is collected in coagulated forms which are collectively known as field coagulum rubbers or scrap rubbers. Latex in the latex vessels of the rubber tree is sterile, but gets contaminated during collection and processing, by bacteria which leads to premature coagulation of the latex.

PRESERVED FIELD LATEX

The main attributes of a latex preservative are (a) it should enhance the pH of the field latex, (b) it must be able to deactivate the harmful metallic ions and (c) it should hinder the growth of bacterial population.

As ammonia meets the above requirement conventionally it is being used as a preservative. For use as an anti-coagulant, 0.01 per cent ammonia should be present on the volume of latex. However as a preservative, higher dosage [0.7-1%] of ammonia is used. But, use of ammonia as a preservative leads to increase in Volatile Fatty Acid (VFA) number of the High Ammonia latices (HA) and the stability of the latex decreases during storage. In addition, the deammoniation process poses serious environmental problems. Hence low ammonia preservative systems are suggested and among them, the most commercially viable system is the LATZ latex. It uses ammonia (0.2-0.3%), TMTD (0.0125%) and ZnO (0.0125%).

PRESERVED LATEX CONCENTRATE

The process of latex concentration involves removal of a substantial quantity of serum from field latex. It is necessary to reduce the cost of transportation and to get high drc, better uniformity in quality and higher degree of purity. The two important commercial methods of latex concentration are (i) Centrifuging and (ii) Creaming.

Centrifuging:

In centrifuging, field latex is subjected to strong centrifugal force (several thousand times that of the gravitational force) in a bowl rotating at high speeds. As a result, the individual rubber particles tend to seperate into a layer surrounding the axis of rotation, leaving an outer serum layer having a comparatively low rubber content. Each layer is removed through annular spacings around the axis of rotation. By centrifuging process, the drc of the latex can be increased to 60% or more. Centrifuged latex is mainly used in all dipped goods.

Creaming:

Creaming is comparatively cheaper method and requires no machinery. Usual creaming agents used are tamarind seed powder, sodium or ammonium alignates etc. The concentration of the creaming agent frequently used is 0.2-0.3 per cent of dry material calculated on water phase of the latex; 0.3-0.5 percent of fatty acid soap is added as a secondary creaming agent.

Latex is collected and ammoniated to

one percent and preferably kept for a few days for ageing. Creaming agent is added and the latex is stirred for one hour. After stirring, the latex is allowed to remain undisturbed till the desired level of creaming is obtained. The major disadvantages of this process are, it is slow, dependence of the efficiency of the process on the quality of latex and post creaming tendency.

The other forms of natural rubber are (i) Sheet rubber, (ii) Crepe rubber, (iii) Technically specified rubber and (iv) Speciality rubbers.

Sheet rubber:

Converting natural rubber latex into Ribbed Smoked Sheet (RSS) is the oldest method of processing. The sheeting process is simple, cheap and viable even if the quantity of latex is small. Seventythree per cent of the total rubber produced is processed as sheet. The important steps adopted in the production of sheet rubber are collection, sieving and bulking, dilution, addition of chemicals, coagulation, sheeting and dripping and drying.

The latex collected from different field is bulked and seived through 40 mesh and 60 mesh sieves. It is then diluted to a drc of 12.5. Dilution helps in settling denser and finer impurities at a faster rate and in obtaining a softer coagulum which can be easily sheeted. Few chemicals are incorporated into the latex to improve the quality of the sheet. Sodium bisulphite (1.2 gms/kg drc) is added to prevent the surface blackening of the coagulum. Another chemical which is added to latex is paranitrophenol (PNP) and it prevents mould growth on the surface of the dried sheet. The usual dosage is 0.1 % on drc. The diluted latex is then transferred to coagulation pans or tanks. Coagulation is the process of destabilisation of latex by some means to recover the rubber from it. The popular coagulant is formic acid. But acetic acid is also used, though it is weaker acid.

Acid requirement for coagulation of 4 litres of diluted latex containing 1/2 kg rubber is given below

	Acetic acid	Formic acid
1. For next day sheeting	3 ml diluted to 300 ml with water	1.5 ml diluted to 300 ml with water
2. For the same day sheeting	4 ml diluted to 400 ml with water	2ml diluted to 400 ml with water

The required quantity of diluted acid is added to latex and mixed throughly by stirring, and the froth is removed. If the coagulation is done in tanks, the partition plates are inserted and the tank is covered.

The coagulum is washed with water before sheeting. The sheeting rollers consists of a pair of plane rollers and another set of grooved ones. The rollers, usually made of cast iron are of length 60 cm and diameter 15 cm. The sheeting battery consists of a set of 3 or 4 pairs of plane rollers and the pair of grooved ones. The nips of the plane rollers and grooved roller are set in decreasing order so that after the final pass through the grooved roller the thickness of the coagulum is reduced to 2.5 - 3.0 mm.

Crepe rubbers:

When coagulum from latex or any form of field coagulum or RSS cuttings after necessary preliminary treatment is passed through a set of creping machines, crinkly, lace-like rubber is obtained. This when dried is, called crepe rubber. Different grades of crepe rubber are available in the market. (a) Pale Latex Crepe (PLC): These are produced from field latex under controlled conditions. Pale latex crepe are mainly used for the production of surgical and pharmaceutical articles, light coloured and transparent goods, adhesives and tapes, derivatives such AS chlorinated rubber, cyclised rubber etc. PLC is paper-white in colour. Hence latex used for its production should be free from yellow pigments. Yellow matter in latex has been identified as carotenoid pigments. These are removed either by fractional coagulation of the latex using dilute acetic acid or by bleaching agents. Xylyl mercaptan (RPA No. 3) is most widely used. But due to its high toxicity, it is being replaced by sodium/potassium salt of tolyl mercaptan. The potassium salt is more soluble than sodium salt and it is marketed under the trade name Cureó bleach. The major steps adopted in the production of PLC are collection, sieving and bulking, standardisation of latex, addition of chemicals, removal of yellow pigments, bleaching, coagulation, creping, drying, inspection and packing.

Minimum essential set of creping machines for production of pale latex crepe consists of a coarse macerator, an intermediate macerator and a set of smooth rollers. The size of the rollers depends on the width of the crepe to be produced.

The moisture content of the crepe, reaching the drying chamber is in the range of 7 to 12 per cent. This has to be reduced to 0.2 per cent before it is inspected and graded. In drying chamber, hot air at 33-35°C is circulated. The drying time depends on the atmospheric conditions in the drying shed and usually it takes 7 to 10 days for drying the crepe.

FIELD COAGULUM CREPE RUBBERS

The crepes prepared from field coagulum material fall into five types (a) Estate Brown Crepes (EBC): The EBC is the most popular among the crepes. These are prepared from crep lumps and other grades of scrap and mainly it is a produce of estates. (b) The brown creps or remilled scrap: These grades are manufactured from wet slab, unsmoked sheets and other high grade scrap. (c) Thick blanket crepes or ambers: Crepes of this category are manufactured from wet slabs, unsmoked sheets or other high grade scraps. (d) Flat bark crepes: Crepes of this type are prepared from all types of field coagulum grade rubber including earth scrap. (e) Smoked blanket crepes: Another type of crepe, viz., pure smoked blanket crepe is also available in the market. This is prepared exclusively from RSS cuttings.

The processing of crepe rubber in general can be summarised as soaking of the coagulum (which involves creping, drying and packing). For production of crepe rubber from field coagulum, the minimum set of machinery required consists of a macerator, creper and one finalising machine. Such a creping battery with three machines having roller size 60x30 cm can produce about 500 kg dry crepe rubber per shift of 8 hrs. For higher output and for making fine textured crepe, additional crepers and smooth rollers are to be installed.The wet crepe obtained after machining is dried in air, shade or heated drying chambers.

The main defects observed in crepe rubber processing are mould growth, tackiness on surface, uneven thickness presence of coloured spots, dirt and sand particles.

TECHNICALLY SPECIFIED RUBBER (TSR)

The main shortcomings of the conventional forms of natural rubber are (i) multiplicity of grades, posing problems to the consumer, (ii) non-availability of technical information on quality of natural rubber and (iii) poor presentation of rubber in large bare back bales are prone to contamination. Hence attempts are made to evolve better methods of processing and grading based on technical parameters. The major advantages of TSR are its improved consistency in properties and the availability of different grades to suit individual requirements of the user. This new method enabled NR producers to process both latex and field coagulum, using almost the same set of machinery. Also the processing period is reduced to less than 24 hrs. The production of TSR involves a series of unit operations which may vary slightly depending upon whether latex or field coagulum is used as a starting material. The steps involved in the production of TSR can be generalised as given below:

Latex → Reception and bulking → Coagulation → Crusher → Creper

Field coagulum → Soaking → Prebreaker → Blending → Creper

Creper - hammer mill/Granulater → Washing/blending → Drying → Weighing → Pressing → Grading → Packing

Crumbs of coagulum may be prepared by purely mechanical means or by a mechano-chemical process.

MACHINERY FOR PRE-CLEANING AND INITIAL SIZE REDUCTION

The machinery required for pre cleaning and initial processing of latex or field coagulum for production of TSR are the following. (a) Slab cutter: It consists of a heavy duty rotor working in tandem with fixed knives on the housing (b) Coagulum crusher: It consists of a pair of wavy grooved heavy duty cost iron rolls rotating at even speed with low rpm. The coagulum block is fed into the nip between the rolls and crushed to form a continuous ribbon of coagula suitable for processing in subsequent machinery. (c) Prebreaker: It is a machine, designed to breakup large blocks of rubber into small discrete lumps (d) Macerator/ creper: This consists of a pair of cast iron rolls, mounted on a rigid frame work. The rolls rotate in opposite direction towards the nip with a differential speed. The speed ratio normally varies from 1.2 to 1.5. The surface of the rolls is machined usually with diamond grooves or with various patterns of grooves in order to increase the grip.

Hammer mill:

It has a set of free swinging hammers, rotating in a housing. The hammers are made of hard carbon steel and are held by pins to the motor discs. The size of the crumbs is controlled by the aperture of the screen fitted to the bottom of the chamber.

Driers:

The drier is one of the critical items of equipment in TSR production. Different types of driers are in use. The driers varies in design, air flow arrangement, nature of fuel, number of heating units, recirculation mechanism, mode of feeding etc. The commonly used driers for TSR in India are of two types. (a) Diesel fired drier: In such driers the fuel is burnt in a chamber and combustion gases are directly utilised for drying of rubber (b) Electrical drier: In electrically heated driers, modular heaters are used for heating air. This hot air is passed in to the chamber for drying the product.

SPECIALITY RUBBERS

The main objective of improving the processing technology of natural rubber is to make it more attractive and acceptable to the consuming industry. Speciality rubbers are prepared by different methods such as blending of different grades of rubber, chemical modification of natural rubber and by incorporation of compounding ingredients in definite composition. Commercially, important speciality rubbers are briefly discussed below:

Superior Processing (SP) rubbers:

Superior processing rubber consists of an intimate blend of vulcanised and unvulcanised rubber prepared at the latex stage. The outstanding feature of this rubber is its reduced tendency to recover from deformation. This makes it as an ideal material for calendered and extruded goods.

The field latex to be vulcanised is sieved through a 60 mesh sieve and ammoniated to 0.3 per cent (w/w) on latex. Dry rubber content of latex is then determined and the required quantity of vulcanising ingredients are added to it. Latex is treated to 80-85°C for one hour by passing live steam and is maintained at this temperature for one hour under gentle stirring. The partially vulcanised latex can be converted to any of the conventional forms such as sheet or crepe. However other forms of superior processing rubber such as PA 80 and PA 57 are more popular. For the preparation of PA 80, vulcanised latex is first diluted to 20 per cent total solids. This is then mixed with fresh field latex in the ratio 4:1. The latex is seived and coagulated with 5% sulphuric acid. The coagulum is then processed as solid block rubber. PA 57 is the low viscosity version of PA 80 master batch. It consists of 70 parts by weight of PA 80 and 30 parts by weight of a non staining process oil.

Constant viscosity and low viscosity NR:

Natural rubber undergoes hardening during processing and subsequent storage. This makes the mastication of raw rubber, a high energy demanding operation. The hardening occurs due to the crosslinking reactions involving the carbonyl groups which are distributed at random along the rubber molecule. Hydroxylamine hydrochloride was recommended earlier as the viscosity stabiliser for production of constant viscosity natural rubber. At present, hydroxylamine neutral sulphate (0.15 per cent by weight on rubber content) is used for the above purpose. Low viscosity rubber contains four parts of a non-discolouring oil for hundred parts of rubber. The oil is added to latex in the form of an emulsion.

Oil extended natural rubber (OENR):

The concentration of the oil while functioning as an extender in rubber is usually in the range of 20-40 percent. Oil extension of natural rubber can be carried out in latex stage or in the dry stage. Extension at latex stage is effected by adding an acquous emulsion of the required quantity of selected oil into the latex and co-precipitating the two. In case of extension at dry stage, the process consists of incorporating the required quantity of selected oil into rubber using a two roll mill, internal mixer or an extruder type oil blender. This eliminates pre-mastication, improves resistance to crystallisation, low heat build up, better skid resistance on icy roads.

GRAFT NATURAL RUBBER:

Graft rubbers are generally prepared by polymerisation of Vinyl monomers in the presence of rubber under suitable conditions, when some of the vinyl polymeric chains become attached to rubber molecules. Among these, the most popular is the methyacrylate graft series, known as Hevea plus MG Methyl methacrylate monomer containing cumene hydroperoxide is emulsified and added to ammoniated field latex. The concentration of cumenehydroperoxide is 0.25 parts per 100 parts of rubber present in the latex. When a homogeneous disperson is obtained an equal amount of tetra ethylene pentamine (10 %) is added and stirred. Coagulation is effected by pouring the modified latex into boiling water containing 2 per cent formic acid. Hevea plus MG finds application as adhesives in shoe industry, floorings, tyre cords and beltings.

DEPROTEINISED NATURAL RUBBER

Latex contains about 2 per cent of proteins by weight. Processing of latex by any of the usual methods do not eliminate this from the final product. It can affect the rate of vulcanisation and the efficiency of cross linking, thus giving rise to loss of processing saftey and modulus variability. It can also adversely affect resilience, creep and stress relaxation. The electrical properties are also impaired. Hence for those applications where the above properties are critical, natural rubber having a low protein content is preferred.

The DPNR is usally produced by treating field latex with a bioenzyme and dilution of the treated latex before acid coagulation. The enzyme changes proteins in latex into water soluble forms which are subsequently washed away during processing.

EPOXIDISED NATURAL RUBBER

The mechanical properties of natural rubber (NR) are generally superior to synthetic rubbers. However, it cannot compete with speciality synthetic rubbers such as butyl and nitrile with regard to gas permeability and oil resistance. Epoxidation is carried out to modify the above properties of NR.

Two reagents that are used for epoxidisation of NR latex are peroxy acetic acid and performic acid formed *in situ* by the reaction between formic acid and hydrogen peroxide. Two grades *viz.*, ENR 25 and ENR 50 have assumed commercial importance.

Wet grip, wear and rolling resistance of ENR suggest that the same could be used in tyre tread. The low air impermeability properties of ENR 50 can be utilised in tyre inner tubes. ENR finds applications in other fields such as flooring materials and sports shoe soling compounds due to high wet grip properties.

The specifications for raw-natural rubber (TSR) as per the Bureau of Indian Standards is given below.

Sl. No.	Characteristic	Requirement for					
		ISNR 3 CV	ISNR 3L	ISNR 5	ISNR 10	ISNR 20	ISNR 50
1.	Dirt content, per cent by mass, Max	0.03	0.03	0.05	0.10	0.20	0.50
2.	Volatile matter per cent by mass, Max	0.80	0.80	0.80	0.80	0.80	0.80
3.	Ash, per cent by mass, Max	0.50	0.50	0.50	0.75	1.00	1.50
4.	Nitrogen, per cent by mass, Max	0.6	0.6	0.6	0.6	0.6	0.6
5.	Initial Plasticity Min	40±5	30	30	30	30	30
6.	Plasticity Retention Index (PRI), Min	60	60	60	50	40	30
7.	Colour (Lovibond scale) Max	-	6	-	-	-	-

Max - Maximum
Min - Minimum

ON FARM COFFEE PROCESSING VIS-A-VIS QUALITY - AN INSIGHT

R P Ananda Alwar

INTRODUCTION

Coffee processing is the most critical activity in coffee production from the quality point of view. Production of quality commercial coffee is not an easy matter as formation of physical, chemical and organoleptic characters of beans are influenced by various factors at each stage of production.

Coffee is processed either by wet method or by dry method to produce washed coffee and unwashed coffee respectively. The wet processed coffee is superior in quality to dry processed coffee and this method predominantly followed in processing India's arabica coffee (75%) and part of robusta (15%). In most of the arabica coffee producing countries, wet process is followed, exceptions being Brazil and Ethiopia which largely use the dry process. A very large amount of robusta is dry processed except in Indonesia where they are wet processed. Wet-processed coffee is appreciated all over the world and they command substantial premium. The factors determining the method to be used is governed by tradition and market forces.

DRY PROCESS

In dry process, the entire cherry is directly dried immediately after harvest. The outer skin dries out to from the husk, which is then removed mechanically during hulling. The harvested cherries, contain moisture 65% in most cases, are subjected to sun drying, spread to a thickness ranging from 4-8 cms with periodic stirring, at least 4-5 times a day. The cherry coffee need to be protected from rehydration at night or by rains. Drying in the sun takes 12 to 15 days, depending on the thickness of the layers of cherries, the ambient temperature and the amount of daily sun shine. The cherries are usually dried on fixed or movable, raised drying trays, cemented, tiled floor or on plastic sheets. It is preferable to initially dry coffee on trays for 2 or 3 days and later on in patios.

Drying coffee on bare ground or cow-dung smeared earth is highly inadvisable as the cherries become tained by dust and earth and acquire an earthy smell and taste. During drying process, the cherries have to be turned over at hourly intervals, to ensure even drying and to avoid fermentation of the lower layer.

Drying is completed when the moisture content of the bean is around 11 to 12 %. At this stage, the beans rattle when shaken. If these precautions are followed, upto final drying, a fine "dry processed" coffee is guaranteed. Under adverse climatic conditions or in large plantations, artificial drying or mixed drying (pre-drying in the sun, then artificial to finish) may have to be followed. Artificial drying is a tricky operation. Use of high temperatures during humid phace of drying, can lead to taste deterioration. Mixed drying remove the problems that occur during humid phase of drying. In Brazil (which is a major producer of coffee), the cherries are dried on concrete or paved patios, while in Ivory Coast and Cameroon trays are used. In Thailand, Vietnam and other smaller West African countries cherries are dried on the ground and India is not an exception in this regard.

The dried cherries, to the desired moisture level are bagged and stored for several weeks in the estates and during this period, the green bean inside the dried shell will attain uniform moisture. The approximate out-turn of clean coffee (in Kg), from arabica and robusta is given below.

	Arabica	Robusta
1. Weight of dry cherry	34.0	38.0
2. Weight of moisture loss	66.0	62.0
3. Weight of clean coffee	19.04	21.25
4. Weight of cherry hust	14-15	16-17

The dry-processed coffee will have strong body, strong aroma (fruity) and low acidity. Body and aroma are acquired due to long contact with the mucilage and pulp.

WET PROCESS

Harvest quality: Harvesting the right type of fruits is an essential stage in production of quality coffee. Coffee fruits are to be picked as and when they become ripe. In arabica, 31-35 weeks after blossom showers, the fruits start ripening and in robusta, it takes 40-45 weeks. The duration between initiation of ripening, to over-ripe stage, is around 10-14 days. To ensure good quality coffee, only riped cherries are harvested by selective picking. This operation requires large work-force which is often difficult to find. Hence at times, strip picking is also carried out. By this method, fruits of various stages of ripeness are harvested like, unripe green-yellow, ripened and overripe brown cherries. The green coffee obtained by such harvest is heterogeneous and its liquor is very hard. In wet processing, berries of mixed stages of maturity and ripeness will cause pulping and fermentation problems.

Cherry sorting:

The harvested cherry should be sorted prior to pulping. Sorting is intended to remove immature, disease, pest infested, dry berries and also leaves, twigs and other extraneous matter. It is also necessary to remove small berries which will escape pulping by the alternative dry method described earlier. Only fully riped and matured berries which have adequate mucilage and natural pectinolytic enzymes are to be taken for wet processing of coffee.

Pulping:

Pulping refers to the mechanical removal of the red outer skin from the fruit, to obtain parchment coffee. Pulping is dependent on lubrication from the mucilage layer between the pulp and parchment. Pulping is done by using a stream of water, which carries berries to the pulper and it also facilitates in seperation of products and by products. There are two types of pulpers in India. Recently vertical type pulper called Penagos is also used. In 1991, Penagos pulpers of 183 LT and 256 LT model were installed at CCRI and CRSS-Chettalli respectively. Studies were conducted to assess their sutability to pulp arabica and robusta and for the water usage. These two models were found to take a fruit load of 850 kg and 2200 kg per hour with a power requirement of 1.5 hp. The water requirement is about 3 litres for every kilogram of fruit, as against the conventional horizontal pulper, which uses 6 litres/kg of fruit. Out-turn of the wet parchment is 45-47% as compared to the conventional pulper with a value of 43-45%. Robusta coffee pulping is not satisfactory as 30-35% of skins are associated with the pulped beans.

The pulping operation has two steps. First, the fruit is squeezed between the roughened surface of either a rotating cylinder in drum type or a disc in another type and a stationary member called a breast with smooth, channeled or slotted surface. The distance between the moving member and the breast is carefully adjusted, so that the space narrows as the fruit is carried through. This passage, causes the squeezing action. In the second step of operation, the seeds are seperated from the skins. This is accomplished by means of a plate with a carefully ground straight, sharp edge.

It is always desirable to adjust the gap between the breast and disc, based on trial run with the representative sample of the day's harvest. If the gap is not properly adjusted, the pulper will not pulp the coffee efficiently and can even crush the beans. Wornout knives nip the beans and impairs seperation between the parchment and skins. Pulper damaged beans, increase the number of defects in coffee sample and the presence of pulp with the fermenting patchment, produces tainted coffee, which lowers the quality. Pulper-nipped beans age rather rapidly and are also susceptible to chemical, dust and other adverse environmental effects. The performance of a pulper is never quite perfect on account of the fact that berries have different diameters. It is difficult to recommend suitable diameters for the apertures of the sieves. Studies are being conducted to assess the diameter of the fruits of popular cultivars at CCRI and to arrive at suitable aperture size of sieves. The diameter for the cultivars S.795, S.274 and Cauvery is 13.76, 12.55 and 14.77 mm respectively.

NATURAL FERMENTATION METHOD

The pectin degrading enzymes which are inherent to mucilage itself hydrolyse in about 24-36 hours for arabica and 72 hours for robusta. The rate of degradation of mucilage depends on the location (altitude) and ambient temperature. Over fermentation induces onion flavour-defect in coffee. Fermentation is complete when parchment feels gritty and no longer sticky when rubbed between the hands.

ENZYMATIC METHOD

For accelaration of mucilage degradation, pectinolytic enzymes are to be used to hasten the fermentation process. The recommended dose of Bio-coffeezyme is 350-750 g/tonne of arabica fruits for a contact time of 12 hours at 20 degree celsius ambient temperature with occasional agitation. An additional amount of Rs.550-1200/- will be incurred per tonne of clean coffee produced.

CHEMICAL METHOD/ALKALI TREATMENT

A solution of 10 litres of sodium hydroxide (1 kg/10 litres of water) is required for 1200 kg. pulped beans to process arabica and robusta. A contact time of 30 minutes and 60 minutes is required for hydrolysing the mucilage in arabica and robusta respectively. The process should be closely monitored by hand feel method within time frame. The use of sodium hydroxide however, presents various problems in practice.

REMOVAL BY MECHANICAL/ATTRITION METHOD

In this method, the pulped parchment is directly fed to the machine called aqua-washer in which the mucilage is removed by mechanical scrubbing/friction and washed by a jet of water. Production of naked and bruised beans can be avoided by carefully adjusting the flow rate of seed, adjusting the gap between stationary cylinder and inner rotating cylinder and also finer adjustment of the flood-gate system. Sorting of fruits into different sizes and uniform feeding through siphon arrangement will rectify this defect. The percentage cuts/bits normally produced in aqua-washed coffee is around 2-4%. Pre-fermentation of pulped coffee for 12 hours in case of arabica and 24-36 hours in case of robusta is desirable before letting into aqua-washer for effective removal of mucilage. In Costa Rica, the use of aqua-washers are not in use and they follow dry fermentation method for 24-48 hours.

POST FERMENTATION SOAKING

Soaking refers to complete immersion of washed parchment under clean water, for a period of 8-12 hours. Soaking greatly improves the colour of the coffee and increases its quality. The coffee should be agitated during soaking. To soak around 2700 kg of wet parchment, equivalent to one metric tonne of clean coffee, around 2000 litres of clean water is required.

PREPARATION ERRORS IN WET PROCESSING

Prolonged cherry storage, prior to pulping results in stinker taste. Cherries should be processed immediately or within 10-16 hours after harvest. The cherries should not be kept in water for more than 24 hours under certain conditions during pulping. Poorly regulated pulper damages the parchment thereby facilitating microbial attack and contamination. Improper hygienic conditions result in contamination and induce unpleasant taste. Over-fermentation causes sour, fermented and stinker tastes. Use of impure water imparts off flavours. Ferric ions of 5mg/l concentartion in water induces metallic flavour in coffee. Polluted water having dissolved organic matter causes foul flavours. Beans fermented and washed in dirty water retain muddy or earthy odour.

DRYING

Drying is an important and tricky stage in coffee preparation. It contributes greatly to the quality of the end product and can prove detrimental if not carried out properly. It may be emphasised that proper drying contributes to the healthy colour of the bean and other quality factors. Under-drying leads to rapid deterioration of beans. It turns mouldy and gets bleached durng storage and subsequent operations.

The wet parchment coffee has a water content of around 50-55% and this has to be brought down to 10% for safe storage. At this moisture level, enzymatic activity and mould growth is at minimum.

As soon as coffee is washed, the excess water should be drained on a specially constructed drainage platform. Drying of surface moisture on the beans should be carried out at the earliest. Surface drying is carried out in trays with wiremesh bottom.

These trays may be mounted on wooden poles at an height of 75-90 cms above floor level. The parchment is apread in trays to a thickness of about 4-7 cms. The coffee may be turned repeatedly to facilitate quick drying and to prevent cracking of parchment skin. Surface drying on trays may be carried out for 24-48 hours. A tray of 1.75x1.75 meters with 7 cm height side walls can hold 3 forltis of parchment or cherry. Initial drying on wire mesh bottom trays helps in more uniform evaporation of moisture due to air circulation.

Dry yard requirement for drying 1000 kg clean coffee for different thichness are (i) parchment equivalent (4cm spread) =

9.5x9.5 m, (ii) parchment equivalent (7cm spread) = 7.3x7.3 m and (iii) cherry equivalent (7 cm spread) = 11.0x11.0 m.

After surface drying, the parchment is spread to a thickness of 7 cm, on a clean tiled or concrete drying yard. At any cost coffee should not be dried on mud and cow-dung smeared drying yard, as it induces off flavours. Drying at this stage should be steady and continuous. Stirring and turning over once in an hour is necessary to facilitate uniform drying. It is desirable to keep coffee covered on the 3rd and 4th day of drying during the hottest part of the day (12-2.30 pm) to avoid cracking of parchment.

If the parchment spread is too thin (single or double bean thickness) rapid drying takes place and causes the parchment skin to split, leading to shrunken and boat shaped bean. The parchment should be heaped up in the evening and kept covered until next morning. For covering, polythene sheet may be used. The cover may be removed and spread coffee again during next morning, when there is sunshine and no mist. Sun drying of parchment coffee takes about 7-8 days under bright weather condition. At the right stage of dryness, the parchment becomes 'Crumbly' and the beans will split into two, when bitten between the teeth. The parchment is now ready for test weighing. The standard test weights prescribed for different types of coffee are as follows.

Type of coffee	Test Weight (Kg/forlit)	Moisture level (%)
Arabica parchment	15.5	10
Robusta parchment	15.5	10
Arabica cherry	16.0	10.5
Robusta cherry	18.0	11

A tolerence of +0.5 Kg/forlit is permitted in respect of each type of coffee. Drying of coffee is complete when sample forlits of coffee, record the same weight for two days consecutively.

Because of heterogeneity in the size of beans, the test weight method need not ensure the desired moisture level in the beans. It is preferable to use standardised moisture meters for coffee, to arrive at proper moisture content.

PRECAUTIONS

Coffee left to improper drying conditions like thick layers of coffee, inadequate stirring/homogenisation, rehydration by mist/rain, results in mould/bacterial growth that causes earthy tastes. Many moulds releases mycotoxins which are harmful to human health. Routine analysis for aflatoxins is being conducted to check the contamination as per the requirement of the importing countries. Chances of black bean production is also high under such conditions from unripen berries which give hard and sour liquors. Over drying of coffee to a moisture level of 8 % will result in marked loss in quality.

Rules for drying to good quality:

1. Rapid drying surface moisture of parchment coffee is carried out in wire mesh-bottom trays, for first 2 days of drying.

2. Slow drying for the next 2 days, to allow slow moisture loss without breaking the parchment (at white stage)

3. Slow drying of the resultant parchment coffee to a moisture level of 10-11 % under strong solar radiation from fifth day onwards.

Mechanical drying parchment:

When machine drying is followed to

dry the parchment, it may be noted that coffee will tolerate a temperature of 40°C for a day or two, 50°C for a few hours and 60°C for less than one hour, without damage. At 80°C coffee will be completely damaged. It is preferable to dry the parchment coffee in the sun to reduce the moisture content around 20% and resort to mechanical drying, to arrive at final moisture content of 11%.

On plantations, drying is finished in conditioning bins (Brazil and Kenya) where dry air is blown through coffee by fans. Parchment coffee can be held for several weeks in these bins because the periodic air flow prevents further fermentation and the coffee mass develops a homogeneous moisture content.

Approximate out-turn (Weight in Kg) from 100 Kg coffee fruits in wet method:

	Arabica	Cauvery	Robusta
1. Wet parch	46	41	50
2. Pulp+mucilage	54	59	50
3. Dry parchment	24	20	26
4. Clean coffee	19	16	21

STORAGE OF DRIED COFFEE AT ESTATE LEVEL

The dried parchment or cherry coffee should be bagged in clean jute bags. It is important that coffee is evenly and properly dried before storage at farm-level, otherwise discolouration and mustiness will develop, which reduce the market value. Stores should be kept ventilated and dry, without letting in moisture or rain water. The bags containing dried parchment and cherry should be stored on a raised wooden platform in separate compartments. Other crops like cardamom, pepper and materials like fertilizers, pesticides etc., should not be stored in the same room.

When coffee is stored in farms, care should be taken to protect the cherry or parchment from contamination by insects, rodents, smoke, odours from chemicals, petrol, diesel or heavy oil.

Coffee should not be stored for long periods in areas where relative humidity exceeds 70% unless facilities to regulate humidity and temperature are provided.

Generally, arabica coffee storage in farms affect the quality adversely, as its cupping quality deteriorates rapidly. Robusta can be stored for longer periods than arabica as it is resilient to incorrect storage conditions and its cupping quality deteriorates less rapidly. No dry cherry or parchment should be stored in the farm for more than one year.

REFERENCES:

Ananda Alwar RP, Krishnamurthy Rao W and Ramaiah PK (1991). Effect of different washing methods on quality of coffee and their economics. *J. Plantn. Crops.* 18 (Suppl.) :323-327.

Ananda Alwar RP, Krishnamurthy Rao W and Ramaiah PK (1992). Studies on keeping quality of parchment and cherry coffee with different test weights or bulk densities. *J. Plantn. Crops,* 20(Suppl.): 342-345.

Barel M and Jacquet M (1994). Coffee quality its causes, appreciation and improvement. Plantations, recherche, development. pp 10-13.

Mburu JK (1995). Notes on coffee processing procedures and their influence on quality. *Coffee,* 60:2131-2135.

Sunalini N Menon (1989). Quality improvement on the estate and processing technology in coffee. *Indian Coffee.* pp 15-20.

HARVESTING IN TEA

J. B. Hudson

INTRODUCTION

Harvesting in tea involves the removal of young, growing shoots comprising the apical bud, the internodes and two or three leaves immediately below it which constitute the crop. It is considered to be the most important cultural operation as it influences the three vital parameters that determine the bottom line of the industry viz., yield, labour productivity and quality of tea. More than 70 per cent of the labour force in any estate is engaged in this task at any given time and as such it is the most expensive operation. There is an intricate relationship between harvesting and the health of the bushes and consequently the productivity of the fields. The quality of made tea also depends on the type of shoots harvested. Various morphological and physiological factors need to be understood to appreciate the recommendations on harvesting.

MORPHOLOGICAL AND PHYSIOLOGICAL FACTORS

Growth of Tea Shoots: The primary shoots arising from the pruned frames and the flush shoots developing from the auxiliary buds behave differently and are called aperiodic and periodic shoots. Aperiodic shoots expand leaves in a steady succession without any temporary cessation of growth. On the other hand in periodic shoots the growth is phasic; it exhibits a marked rhythym of growth pattern, each cycle terminating in the production of banji bud.

Development of Flush Shoots: When a leading shoot is growing, it prevents to a great extent, the growth of buds which occur in the axils of all leaves down the stem. When the crop shoot is plucked off, the apical dominance is temporarily destroyed and generally the bud in the top most leaf remaining on the stem developes into a new crop shoot. The bud is at first very small and during its development the first to appear are two scale leaves (Caterphylls) which are protecting the rest of the bud. The first scale leaf usually drops off, but the scar can be seen at the base of every shoot. The scale leaves are followed by a leaf that has smooth edges and in oval shape (i.e., unserrated blunt leaf) called fish leaf. It varies in size, sometimes remaining quite small and some other times it grows like an ordinary leaf but the serrations will be confined to the tip. This is followed by a series of three to four normal leaves, first of which is called the mother leaf, after which the banji bud is exposed. During later years of the pruning cycle flush shoots may often turn banji after producing just about two foliage leaves. Under South Indian conditions it takes about 60 to 90 days for the auxillary bud to develop into a pluckable shoot depending on the climate, altitude, jat/clone, age of the fields from pruning and plucking style.

Banji: Banjiness is an inherent pattern in the rhythmic growth of tea plants. The proportion of banjies in the harvest may depend on factors such as climatic checks like drought, heavy monsoon and wind, height of pruning, age of bushes from pruning, lack of nutrients, jat of tea, style of plucking etc.,. If banjies at the plucking level are left on the bush there is a direct crop loss because the one leaf which should have contributed to the crop is left on the bush, the flushing of next generation of shoot is also delayed resulting in crop loss.

Maintenance Foliage: All mature leaves retained on the bush below the plucking surface at the time of tipping and while plucking constitute the maintenance foliage. Photosynthates move from the mature foliage the source where they are produced to sinks the sites where they are consumed namely tender growing shoots wherein the very young leaves cannot support their growth. The growing buds are the strongest sinks and the young expanding leaf upto the third from top of a flush shoot import assimilates from mature leaves. The top most mature leaf lying on the plucking surface from whose axil the flush shoot originates contributes maximum photosynthates to the growing shoot, the contribution from lower leaves decreases progressively downwards. The recent tracer studies have indicated that the photosynthetic rate of a leaf increases upto four months, stabilises for another two months and declines slowly thereafter. In about nine months the leaf attains senescence.

Plucking Standard: Plucking standard is the term used in the factory to describe the average size of the shoots harvested. Fine plucking implies that the shoots have no more than two opened leaves and a terminal bud, medium plucking relates to harvesting three leaves and a bud and coarse plucking is harvesting shoots that have more than three leaves and a bud. Superior quality teas are produced from two leaves and a bud compared to the corresponding composition of three leaves and a bud. However in majority of the tea growing areas three and a bud is harvested in view of the total economy.

RECOMMENDED PLUCKING PRACTICES

Plucking Systems: Plucking system is the level at which the flush shoot is removed which may be just above the scale leaf (hard plucking) or fish leaf or mother leaf (light plucking). Plucking system thus detemines the severity of the operation and also the amount of mature foliage that is left behind on the bush while plucking.

Considering the various factors governing the cropping and the optimal ratio between the maintenance foliage and crop, an harmonious blend of different plucking systems is imperative. It is recommended to carry out mother leaf plucking during January to March and level plucking during remaining periods. This system of plucking facilitates addition of required cushion for foliage maintenance which is essential to sustain the health and vigour of the bushes and to ensure a continuous supply of photosynthates to growing buds.

Plucking interval: Interval between successive plucking rounds is another important factor that influence productivity and the type of shoots harvested. Plucking rounds shoud be spaced at such intervals so as to harvest the shoot of prescribed standard at its maximum size and weight, but before it turns coarse. Many theories have been putforth for optimising the plucking intervals. The most reliable concept appears to be the one based on leaf expansion time i.e, the number of days taken for two leaf and a bud to become three leaf and a bud. Adoption of plucking intervals in tune with the growth pattern based on LET renders maximum harvest with an acceptable plucking average and quality. The leaf expansion time depends on the altitude, climatical conditions prevailing in the division, age of the bushes for pruning, height of pruning, jat tea etc.

Mechanical harvesting: South Indian tea estates have a distinct cropping pattern in which high cropping periods alternate with low cropping periods. The availability of adequate labourers has become a serious constraint in harvesting the crop completely during the high cropping months. It is estimated that annually about 10 per cent of crop is lost due to ineffective harvesting. However this has been successfully overcome by integrating shear harvesting in the plucking schedule. Shear harvesting is recommended during both the high cropping seasons in a year, i.e., between April and June and again between September and November.

Motorised shears operated by one worker as well as two workers are available in the market and they have been used on a limited extent in some planting districts. Most of these machines require an additional worker for leaf collection and to ensure that the leaf collecting bag is drawn properly behind the shears. It has been found that by using the single man operated machine, plucker utilisation could be brought down to 50 per cent as compared to hand held shears. With two man operated machines the plucker utilisation could be further reduced. However, its use is difficult in areas with undulating terrain.

REFERENCES

Barua DN (1989). Science and practice in tea culture. Tea Res. Association, Calcutta, India. P. 509.

Ramaswamy S (1983). Quality of tea in relation to harvesting. UPASI Tea Sci. Dep. Bull. 38: 107-116.

Satanarayana N and Sharma VS (1984). Role of maintenance foliage in tea (Camellia L. Spp.) Proc. PLACROSYM-VI: 67-72.

Satynarayana N, Spurgeon Cox, Govindarajulu V, Surendra Mohan M, Hudson JB and Sharma VS (1991). Implication of mechanical harvesting in tea. J. Platn. Crops (Suppl.) 18: 332-341.

Sharma VS, Haridas P and Venkatram CS (1981). Mechanization of harvesting in tea. UPASI Tea Sci. Dep. Bull. 37: 106-114.

Sharma VS, Plucking styles. UPASI Tea Sci. Dept. Bull. 38: 33-48.

Sharma VS (1987). Harvesting in tea. Planters Chronicle 81: 261-266.

Sharma VS and Murthy SBKK (1987). Breaking back - an essential sanitary measure while harvesting tea. Planters Chronicle 81: 94-98.

Murthy SBK and Sharma VS (1989). Rationalisation of plucking intervals in tea: Forecasting system - UPASI Tea Sci. Dept. Bull. 43: 6-15.

UPASI Handbook of Tea culture, Section 8.

Hudson JB (1997). Crop management in tea. UPASI Tea Sci. Dept. Bull. 50: 29-36.

TEA MANUFACTURE

J B Hudson

INTRODUCTION

Tea is the most widely consumed stimulating beverage with pleasant aroma and unique taste. The tea leaf has to undergo several physical and chemical changes before it can be rendered fit for consumption. Commercial tea is of different types, based on the method of manufacture it is broadly classified as (a) green tea, (b) black tea and (c) oolong tea. The basic difference lies in the degree of fermentation (enzymatic oxidation, in a true sense) adopted to each type of tea during manufacturing process. While green tea is produced without fermentation, black tea is fully fermented and oolong tea is produced as a result of partial fermentation. Besides these three types, instant tea (a water-soluble form of black tea) is also manufactured in a limited quantity. Of all, black tea is produced to the maximum extent, which accounts for about 75% of world tea production.

BIOCHEMISTRY OF TEA LEAF

Quality is the ultimate objective in manufacturing technology. The quality of black tea begins in the field where the leaves accumulate the necessary substances. However, biochemical changes that develop during the course of processing the tea leaf and process conditions complete the formation of quality of manufactured tea. Thus, the quality of green tea shoot primarily determines the chemical composition and the quality of made tea. It is, therefore essential to know the chemical constituents and bio-chemical properties of raw material besides the rational way of processing the tea flush.

Tea shoot, like any other plant material contains the full complement of enzymes, biochemical intermediates, carbohydrates, proteins and lipids. In addition, the tea shoot is distinguished by its remarkable content of polyphenols and methyl xanthines (caffeine and other purines such as theobromine and theophylline). The great popularity of tea as a beverage may be due to the presence of these two groups of compounds which are mainly responsible for the unique taste of tea, in addition to various compounds associated with tea aroma. The chemical composition of the tea shoot varies with the plant variety, cultural practices and the conditions under which the plant is cultivated.

Young green tea shoots are extremely rich in polyphenolic compounds which constitute upto 30 % of the dry weight of the material. The tea polyphenols primarily comprise flavanols or catechins which are major oxidizing compounds present in the leaf. Dried tea shoots contain 17 to 28 % catechins. These group of compounds are located in the cytoplasmic vacuole of polysade cells. The catechins undergo a series of biochemical changes during fermentation by the action of enzyme polyphenol oxidase into oxidation and condensation products which gives the characteristic colour and taste to the infusion of black tea. Polyphenol oxidase is a copper containing enzyme and its activity is higher in the internodes compared to the leaves. Among the leaves, tender leaves have higher enzyme activity than matured leaves. In the intact tissues of the plant, this enzyme is associated with the chloroplasts and localized within the epidermal cells.

A tea shoot contains 74 to 77 % moisture (surface dry shoot) and the rest are solid matter. About half of these matters are insoluble in water and are made up of crude fibre, cellulose proteins, lipids etc., Some of these compounds like proteins, inorganic materials (ash), polysaccharides other then cellulose are partially soluble in hot water. The cold water soluble portion includes aminoacids, caffeine, simple carbohydrates, organic acids and of course, polyphenols.

Caffeine content in fresh tea ranges from 2.5 to 4.0 per cent. During tea processing, caffeine combines with polyphenolic compounds to form a complex which has a pleasant taste and aroma although, separately each has unpleasant and bitter taste. Thus, caffeine possibly has an effect of softening the mouth feel of the liquor. Similarly caffeine associates with theaflavins to form a compound which imparts briskness to the tea infusion. Lipids make up between 4 and 9 % of dry weight of the fresh tea leaf and are composed mainly of free fatty acids esters. Fatty acids are broadly classified into two groups: Unsaturated fatty acids and saturated fatty acids, of these, the former degrade to form aromatic compounds and the fate of the latter during tea processing is not clearly known. Proteins are significant constituents of the tea plant. However, since proteins combine with oxidation products of fermentation and lead to insoluble products, a high protein content in the leaf is an undesirable factor. Amino acids form aldehydes and brown red pigments in the course of their oxidative interaction with catechins during fermentation, this is very important for the formation of aroma and colour of the infusion. Amino acids constitute about 4 % of the dry matter of tea shoots, theanine is the most abundant amino acid present in tea leaf.

CHEMISTRY OF TEA MANUFACTURE

Black tea manufacturing technology essentially involves disruption of the cellular integrity of tea shoots, in doing so, the mixing of substrates, polyphenols and the enzyme, polyphenol oxidase is facilitated. This results in the initiation of a series of biochemical and chemical reactions with the uptake of atmospheric oxygen and formation of pigmented hot water soluble polyphenolic compounds, characteristic of black tea. Black tea processing consists of the following unit operations : a) Withering (partial removal of moisture) b) Rolling/disruption (size reduction) c) Oxidation/Fermentation (bio-chemical reactions in the presence of oxygen) d) Drying (completion of moisture removal) e) Sorting (fibre removal; grading based on size) Of these, chemical changes occur primarily during withering, fermentation and drying.

Withering :

Withering is carried out to prepare the green tea shoot biochemically and physically for subsequent manufacturing operations. Withering essentially consists of storage of green shoots for about 12 to 24 hours with the partial removal of moisture (known as physical wither) from the leaf. Withering is accompanied by certain chemical change (known as chemical wither) which may affect fermentation and thereby, the quality of the final product. Chemical wither is essentially a time - temperature dependent senescence process. A minimum storage period of nine hours is absolutely essential to allow chemical changes to take place. Some of these changes are dependent on moisture loss while others are independent.

The major physical change during withering is the increase in cell membrane permeability and consequently, the leaf becomes flaccid. The increased permeability of the membrane has a great effect on the mixing of substrates and enzymes during fermentation. Withering is also accompanied by the activation of oxidative, hydrolytic and proteolytic enzymes, causing significant changes in the chemical composition of tea shoot, as a result the levels of soluble proteins, free amino acids and simple sugars increase due to the breakdown of proteins by the enzyme pepsidase. Amino acids are primarily the precursors of the aromatic compounds.

Caffeine content increases with withering. The increase in caffeine content is greater if the withering is accompanied by loss of moisture. The significance of caffeine in softening the mouth feel of liquor has already been discussed. Caffeine also forms a complex with theaflavins and thearubigins and creams down from the liquor, this creaming down is a desirable cup character for black tea.

The chemical wither also increases the level of organic acids and improves polyphenol oxidase (PPO) activity. The increase in organic acids will have an obvious effect of reducing pH and TF formation increases as pH tends towards 5.0, and the effect of increased PPO activity is beneficial for more TF Formation provided oxygen availability is not limited during catechin oxidation. Volatile compounds essentially impart aroma to the finished product. Volatile compounds present in the tea are classified into two groups, Group I compounds, which are deleterious to the tea quality and the ratio of Group II compounds to Group I compounds is known as the flavour index and it is a semi-quantitative method of describing the aroma quality. Withering improves flavour index and thereby gives sweet aroma.

Fermentation:

Tea fermentation is essentially the oxidation of simple substrates into complex characteristic substances by endogenous enzymes present in the tea leaf. This distinguishes tea manufacture from other food processes in which exogenous fermentation inducing agents are added to the raw material. Fermentation is not confined only to the period during which the leaf lies in the fermenting drums, racks or floors. It commences from the time the cells are bruised and extends until the enzymes are deactivated in the drier. As a first step during fermentation, the catechins are oxidized to highly reactive transient orthoquinones by polyphenol oxidase. The quinones in turn dimerize to produce theaflavins (TF), which are orange red substances that contribute significantly to astringency, briskness, brightness and the colour of tea beverage. Theaflavins comprise 0.3 to 2.0 % of the dry weight of black tea. Further transformations of dicatchins and theaflavins yield compounds which are known as thearubigins. Thearubigins, comprising about 9 to 19 % of black tea, are red brown in colour and contribute to colour, strength and mouth feel of liquor. While theaflavin content of tea increases during fermentation and starts declining after reaching a peak thearubigin content continuously increases throughout the fermentation. In actual practice, the completion of fermentation is judged by the change in colour (green to coppery) and the pleasant aroma that develops. However, chemically optimum fermentation may be assessed by monitoring the profile of TF content and taking the time required for the production of maximum TF. Proper balance between theaflavins and thearubigins is also essential for a good cup of tea. The optimum ratio is 1:10 to 1:12.

Drying:

The drying of fermented dhool (the macerated leaves) has three major objectives: to terminate the biochemical functions by heat denaturation of the enzyme; to reduce the moisture to increase the shelf stability of black tea and finally, to enhance chemical reactions responsible for black tea character and flavour. The polyphenol oxidase enzyme which convert catechins into theaflavin are not inactivated as soon as the leaf enters the drier. In fact the fermentation process is actually accelerated and continues at a faster rate till the temperature of leaf reaches 55°C at which the enzyme is completely inactivated. Hence, any unoxidised catechin will continue to be converted into theaflavin until oxidase enzyme has been inactivated. It has been reported that 10 to 15 % of theaflavin content in black tea is formed during the first 10 minutes of drying (using ECP drier). A noticeable effect of drying is the change in colour of dried leaf brought about by the transformation of chlorophyll into pheophytin, which imparts the desired black colour. During drying, the reduction in astringency of fermented dhool occurs due to the combination of polyphenols with tea leaf proteins at the elevated drying temperature. The fermented dhool prior to drying tastes harsh and metallic, but the taste mellows after drying. During drying, the sugars present in the fermented leaf are caramelised. Drying causes an overall reduction in the quantity of volatile compounds, although certain aromatic compounds continue to be formed.

CHARACTERISTICS OF TEA

Quality:

Exactly what constitutes quality as from the chemical point of view is not known at present and the term used both in common language and by professional tea tasters is far from clear. In its broadest sense, this term is used to describe all the characteristics of a tea, inclusive of its appearance. It is however commonly used to denote the presence of some desirable characteristics of the liquor. When used in this sense it serves to distinguish the fundamental difference between tea produced in the low and high elevation estates.

Appearance:

The term is self explanatory. This character is usually gauged by the amount of stalk and fibre a tea contains and the degree of twist it possesses. The colour of made tea is also taken into consideration while assessing appearance.

Colour:

Denotes colour in liquor which may be red or brown, varying in intensity. A colour liquor is one having good colour and is bright red and clear. While referring in colour a liquor is described as light, not to be confused with thin, a term used to indicate a liquor lacking in strength.

Strength:

Denotes concentration of substances contributing to taste and not associated with colour. Light liquors can be strong and over fermented liquors are weak.

Pungency:

This is the vaguest of all terms. It can perhaps be best detected by a tickling sensation in the salivary glands, similar to the effect of smelling a sour orange or lime. It must not be confused with 'greenness' or bitterness. It is a most desirable characteristic which is accentuated at certain times of the year.

Flavour:

This is a character prevalent only at higher elevation and under certain conditions. It is a rare attribute indeed during periods of fine weather accompanied by cold nights and dry winds. Rain destroys it.

Infusion:

Means really the infused leaf. The trade attaches much importance to it, although sometimes it bears no relation to the properties of a liquor. The colour of the infused leaf and its degree of evenness are the criteria. A bright, even infusion is considered to be a valuable asset. A dull is brownish in colour and this may be due to some fault in manufacture or an inherent property. For similar reasons an infusion may be green in colour.

BLACK TEA MANUFACTURE

Two types of black tea manufacture, viz., CTC (Crush, Tear and Curl) process and Orthodox process, are widely employed. Black tea manufacture in general, may be divided into 5 main stages, such as (a) withering, (b) leaf maceration or rolling, (c) fermentation, (d) drying and (e) grading. Excepting the method of leaf maceration/ rolling and fermentation, all the other stages are more or less same in both the types of tea manufacture.

Withering:

Withering is an indispensable operation in tea manufacture to produce tea with desirable qualities. If attempts are made to roll fresh leaf in the conventional tea roller without withering, it will result in cutting and not in twisting the leaf and the tea turned out will be flaky. The sap from the broken leaf which contain the full content of moisture are dilute and drain away from the broken leaf very freely thereby thus losing potential strength of liquor. The main objectives of withering are: 1. Partial expulsion of moisture and thereby saving fuel consumed in the drying operation. 2. Condition the leaf physically and bio-chemically for the subsequent stages of manufacture. The evaporation of moisture in the green leaf is brought about by blowing or moving air over it in the withering trough. The current of air performs a two-fold function: viz., conveying heat to the leaf as well as carrying of water vapour released from the leaf. Ambient air with a hygrometric difference of over 3°C is normally forced through a bed of green leaves to achieve physical withering. Whenever the hygrometric difference is below 3°C, hot air is mixed in suitable proportion or heat energy is supplied to increase the hygrometric difference with the concommittent rise in the dry bulb temperature of air. But the dry bulb temperature of air after mixing should not exceed 35°C.

Currently, in most of the South Indian tea factories trough withering is practised. The dimensions of trough in most of the factories vary considerably. The width of the standard (conventional) trough is 6' and its length varies between 60' to 120'. The leaf is usually loaded in the trough @ 2 to 3 kg per sq. feet of area and the air volume required for withering is calculated @ 20 cfm per kg of leaf to be withered. During withering, moisture content of tea shoots is brought down to about 50 % for orthodox manufacture and 60 to 70 % for CTC process from the green shoot moisture level of 75-80% . The weight of withered leaf expressed as percentage over that of green leaf is known as 'percentage wither', in tea trade. CTC process requires only light wither (70-75 %), while the orthodox process requires hard wither (50-55%). Therefore withering is carried out for a duration of 10 to 15 hrs for CTC manufacture and for 18 to 24 hrs in case of orthodox manufacture. During withering the leaf becomes flaccid and is reduced from its turgid condition to a pliable form by uniform and gradual loss of moisture. The sap gets concentrated.

Maceration/rolling:

CTC Processing:

In CTC process, CTC machine consists of two cyllndrical rollers, generally 61 or 91 cm long and 20 cm diameter, having stainless steel segments with fine tooth-like sharp ridges (3-4 ridges/cm lengthwise and 50-60 ridges over circumference). The two rollers are fixed in parallel with only marginal clearance between them. The two rollers rotate in opposite direction at difference speeds. A slow speed roller : high speed roller speed ratio of 1:10 with speeds between 70:700 rpm and 100:1000 rpm has good effect. The slow speed roller acts as a conveyer apart from providing a surface for cutting. Before charging the withered leaves into the CTC machine, the leaves are preconditioned by macerating lightly in a shredder, followed by rotorvane machine. In shredder, a rod fitted with sharp knives rotates in the axis of a cylinder, and facilitates fragmentation of withered leaves. The macerated leaf from the shredder has to be in the form of 'Chutney'. The rotorvane essentially consists of a vaned cylinder equipped with a rotor shaft and a pressure cap at the end that determines the residence time and degree of maceration. The speed of the rotor varies between 30 and 40 rpm. The rotorvaned tea ìdhoolî (the macerated leaves) is then passed through 4 or 5 CTC machines arranged in tandem for adequate maceration. The CTC type of maceration takes hardly a few minutes.

Orthodox processing:

a) Rolling :

In the orthodox process, rolling is done in rollers as if the leaf is rolled between palms of two hands. Normally 36" or 46" diameter rollers are used. A tea roller consists of three principal parts, a table fitted with cones and battens a bottomless receptacle called jacket and pressure cup fitted with an adjusting screw to enable pressure to be applied to any desired extent. The roller may be table moving or jacket moving or table and jacket moving; in the latter case the table and jacket move in opposite direction. The rollers normally rotate at 45 r.p.m.

The primary purpose of the battens is to form an obstruction in the path of the leaf. It increases the frictional effect of roller table and breaks up the leaf at the same time. The battens also help in cutting the leaf in rollers; the amount of cutting depends on the shape and depth of battens as well as the pressure put on the leaf. The cone fitted at the centre of the table intensifies the circulation of leaf by causing a greater turning action than that provided by battens alone. Also, with each turn of the roller, the leaf caught between the cone and the roller jacket is subjected to hard squeeze under heavy pressure and results in greater extraction of sap. The withered leaf is charged into the jacket. The height of the jacket should not exceed 3/4th of its diameter. The roller charge for 36î rollers should be between 120 and 140kg of withered leaf; in case of 46î it should be 280 and 300kg of withered leaf.

b) Roll breaking:

After rolling for about 45 minutes, the leaf is passed over a sifter to remove the well rolled leaf called as ìfinesî. The sifter may be rotary or reciprocating. Meshes of size No.4 to No.6 are generally used. The main objectives of roll breaking are :

i) To separate dhools from the unrolled leaf which will otherwise clog and impede circulation and further twisting of the larger leaf.

ii) To prevent excessive heat developed during rolling i.e., to cool the bulk of the leaf.

iii) To prevent over fermentation of dhool

iv) Separation of fine leaf from coarse leaf.

The first dhool will always contain a larger proportion of tender shoots from fine leaf. After roll breaking the fines are taken for fermentation while the residue left after sifting is put back into the roller and the rolling and roll breaking process is repeated. The rolling followed by roll-breaking is carried out about four times.

Fermentation:

Fermentation is an important stage in black tea processing, because during this stage, the most important properties of tea are produced. In the orthodox process, fermentation is carried out by spreading the rolled leaf in a layer of 1 to 3" thickness. The duration varies between 2 to 3 hours. During fermentation low temperature (about 20°C) and high humidity (about 95% RH) are desirable. In the CTC process, the macerated tea 'dhool' is fermented in a revolving large fermenting drum for 60 to 90 minutes with conditioned air. Rotation of the fermenting drum facilitate granulation of the tea particles and increases the bulk density which is a desirable character of South Indian CTC tea. In drum fermentation, the whole process is dynamic and the leaves are constantly rotating. Every bit of tea that is being fermented is constantly layered and exposed to the fresh air or conditioned air. Rubbing of leaf against leaf takes place and the juices present in the micro cells of leaf are evenly coated on the exterior portion of the tea leaf. Drum fermentation produces blacker tea as compared to floor fermentation. These are usually brisker due to better aeration. The fermenting drum is a simple cylindrical drum with conical shaped feeding and discharge arrangements at both ends. The diameter of the cylinderical portion of a standard drum is five feet; the length is normally either 16 or 20 feet. The total length of conical segment is four feet.

Since most of the biochemical reactions occurring during fermentation are oxidative in nature mass transfer of oxygen to the tea particle is a critical parameter in the design of any fermentor. The fermenting drums are equipped with spiral flights on the interior for lifting and showering the solids through the air stream and to accelerate the forward flow in the drum. Optimum dry bulb temperature of the air used in the fermenting drum ranges between 25°C and 27°C. Relative humidity of the air should be about 95 per cent. Optimal load for a 20 feet fermenting drum is 550 to 600 kg and for a 24 feet drum it is 700 to 800 kg. While under loading of the fermenting drum produces less denser tea, over loading causes insufficient fermentation.

Drying:

The objectives of drying are to arrest fermentation and to remove moisture and produce tea with good keeping qualities. Drying is the most expensive process in the manufacture of tea. The capital investment on the drier is also the highest among the different processing machines.

a) Conventional drying:

The principle involved in the conventional driers is that fermented leaf is subjected to a blast of hot air in such a manner that the hottest air first comes in contact with the tea having the least moisture content. In these driers, the fermented leaf falls on a series of moving perforated trays on which it is passed and repassed through a moving stream of hot air. The perforated trays are mounted on an endless chain and arranged in a tier of six or eight units which alternate the direction of motion. The design is such that at each stage of the drying operation, the leaf is subjected to different temperatures. As the leaf passes from tray to tray, it progressively comes into contact with higher temperature. When the air takes up moisture, the dry bulb temperature falls. The most important factors which influence the drying process are temperature and volume of air, loading rate and drying time. A final moisture content of between 2.5 and 3.0 % should be the aim. If the tea is dried below 1 %, it loses some quality. Tea dried to 3.5 % moisture content and above does not keep well. The optimal inlet temperature is 100 +/- 5°C. The exhaust temperature should be maintained at 54.4 +/- 2.7°C. If the exhaust temperature is less than 49°C the post fermentation process will continue for a considerable time and will soften the liquor. This condition is referred to as 'stewing'. If the exhaust temperature is greater than 57.2°C the rate of moisture removal is too rapid and results in case hardened tea in which the particles are hard on the outside but incompletely dried within; such teas yield harsh liquors and do not keep well. So, it is of paramount importance to ensure that temperatures are kept steady to this extent.

Time required to dry the tea varies with temperature, load and flow rate of air. For the optimal inlet and exhaust temperatures mentioned above, the normal drying period is 20 to 25 minutes. While too long a drying time is detrimental to quality and flavour, too short a drying time results in thin tea and with high temperature produces bitter tea. Whatever combination of temperature and time is employed, the exhaust temperature regulating the firing process should be at the correct level.

b) Fluidized bed drying:

The tea industry presently enjoys a variety of fluidized bed drying equipments like vibrobed five zones and three zones cross flow fluid bed driers. All of them strive to get increased fuel economy without affecting quality. One of the virtues of fluidized systems is that they have high rates of heat and mass transfer while maintaining uniform temperature characteristics on the bed. Consequently conditions such as case-hardening are seldom encountered with fluidized systems. Good thermal contact between the tea particles and the drying medium results in improved fuel performance. Particle to particle attraction in a fluidized drier is minimized because each particle is surrounded by its own fluid cushion. In practice, too, this expectation is realized by the production of blacker teas with better appearance and bloom. The fluid bed drier essentially consists of a drying chamber, plenum chamber, dust collectors and flow control dampers. The drying chamber normally consists of three drying zones and one cooling zone. Fermented leaf is loaded on a grid plate of the drying chamber. The top of the drying chamber is totally closed and two sets of centrifugal exhaust fans provided with cyclones; one for refiring and the other for dust extraction. Beneath the drying chamber is a plenum chamber where the air pressure is equalised. The direction of the hot air entering into a grid plate is controlled by the flow control dampers which can be operated independently. The flow control dampers have dual purposes - during the operation their direction determines the residence time of tea particles in the drier and at the end of manufacture, they serve to evacuate the drier completely. In each zone, the required volume and pressure of air is maintained by independent air valves. In some commercial driers, a blow-hole suppresser is provided in the drying chamber to facilitate easy cleaning of the grid plate. When the fermented leaf enters the drying chamber, it has a very high moisture content which is rapidly reduced in the first zone. At this point, maximum volume of air is introduced since rapid evaporation is required. As the moisture loss occurs place, density of the material is reduced. The material tends to move away from the feed end as it is being displaced by fresh materials which contain more moisture and hence have high density. The movement of the tea particles within the drying chamber is thus governed by the principle of displacement. When the material is fully dried, it is expelled into a cooling chamber wherein ambient air is introduced by a forced draft fan.

STORAGE AND PACKAGING

Tea is a markedly hygroscopic material and while cooling and sorting, it picks up moisture. The amount of moisture uptake depends on the ambient temperature and humidity to which it is exposed. In general, drying tea to 3.0 % moisture level is advisable and when packed, it should not be higher than 5.0 to 6.0 per cent. If the moisture content of tea crosses 6.0 per cent, the keeping quality is likely to be impaired and in extreme cases, it will go mouldy before reaching the market. This means that tea may be packed safely with a moisture content of up to 6.0 %. However, as a precaution against the liner getting torn or improperly sealed, it would be better to aim at a lower level of moisture content say about 5.0 per cent. So, it is desirable to finally fire tea when its moisture content goes over 5 % to reduce the risk of its 'going of' during transit in the event of faulty packaging. Being a hygroscopic material, tea should not be stored under open conditions in the sorting or packaging room. Bins are essential to store the finished product. It has to be ensured that after grading tea should be cooled to ambient conditions before it is taken to the bins. Bins are normally lined with galvanised iron sheets and have a conical base for efficient discharge. For export purposes, teas are currently packed in plywood chests. The chests should be made of dry, well seasoned materials and strong enough to withstand transport conditons and damage. Lining material commonly used is aluminium foil backed up with tissue paper. Certain polymeric materials like metallized polyester biaxically oriented poly propylene (BOPP), high molecular high density poly ethylene (HM HDPE) have proved to be excellent in keeping the moisture content at low levels as alternative lining materials to the aluminium foil. The advantages of these polymers are that they are cheap and have better physical strength. For domestic market, while leaf grades are packed in tea chests, most of the dust grades are packed in HM HDPE lined gunny bags. Multiwall paper sacks have been found satisfactory for bulk packaging of tea. There is a growing resistance to the use of chests from regions like USA and Europe from environmental angle, as they pose problems of dismantling and disposal, involving high costs. The poly lined jute bags are also not accepted in these markets. Alternative packaging that is increasingly gaining acceptance is Multiwall paper sack.

REFERENCES

Keegel EL (1983). Monographs on Tea Production in Ceylon; No.4. Tea Manufacture in Ceylon: Published by Tea Research Institute of Sri Lanka.

Werkhoven J (1993). Tea Processing; FAO. Agricultural Service. Bulletin. 26.

Ramaswamy V (1995). Tea Manufacture, Published by The United Plantersí Association of Southern India.

UTILIZATION OF WASTES OF PLANTATION INDUSTRY

George V. Thomas

INTRODUCTION

Plantation crops cultivated in an area of nearly four million ha in the country have a unique role in the national economy as they earn the major share of export earnings of all agricultural commodities. The cultivation and processing of plantation crops results in the accumulation of large quantities of wastes which are lignocellulosic in nature. These waste materials accumulate in plantations and nearby processing units often causing disposal and pollution problems. Research work has been undertaken to develop suitable technologies for profitable utilization of wastes from plantation industry such as coffee pulp, tea factory wastes, rubber wood saw dust, coir pith, oilpalm mesocarp waste etc.and by-products from plantations such as coconut leaves, bunch wastes of arecanut and coconut, arecanut leaf sheath, oilpalm bunch refuse and cocoa pods. Mushroom cultivation is an economically feasible and ecofriendly process for bioconversion of these wastes into high quality protein food. These organic wastes can also be converted to good quality organic manure by composting methods and by vermicomposting.

MUSHROOMS

Mushrooms have been devoured by the mankind for its flavour and texture. Scientific investigations led to the recognition of their nutritional and medicinal attributes. In India, the cultivation of mushrooms is limited to three species viz., white button mushroom (*Agaricus bisporus*), paddy straw mushroom (*Volvariella volvacea*) and oyster mushroom (*Pleurotus* spp.). Oyster mushrooms are the ideal ones for the plantation sector due to its ability to utilize lignin rich plantation wastes and the climatic conditions prevailing in plantations is also ideal for its growth.

Oyster mushrooms:

Oyster mushrooms, known as wood fungi or Dhingri in North India are endowed with ligninolytic and cellulolytic properties to utilize a wide range of agricultural residues as substrates for growth and fruit body production. Paddy straw is the most widely used substrate for its cultivation. But its increasing cost and decreasing availability are factors which prompted research workers to look for alternate substrates for oyster mushroom cultivation. Conditions have been standardized for cultivation of oyster mushrooms using wastes of plantation industry such as rubber wood saw dust, mesocarp waste of oilpalm, coffee pulp, tea factory waste, arecanut leaf sheath and bunch waste, coconut leaf stalk and bunch waste, fermented coirpith etc.. The steps in OM mushroom cultivation include development of spawn, substrate preparation, spawning, incubation for spawn running and opening and maintenance of beds for cropping.

Spawn:

Spawn, the vegetative seed of the fungus, can be obtained either from research institutions or can be prepared with adequate training. An efficient and stable strain of *Pleurotus* isolated from sporocarps should be used for spawn preparation using grains such as wheat, sorghum, maize, jowar or paddy straw as substrates.

Substrate preparation:

Pasteurization of substrates is necessary to avoid contamination and to obtain higher yield. Steam sterilization, hot water treatment and chemical sterilization are the effective methods. Steam sterilization at 1.02 kg/cm^2 pressure in an autoclave for one hour is an efficient method of sterilization. Hot water dip of the substrate at 80°C for 60-120 minutes is another method which can be easily adopted. Chemical sterilization method involves treatment with formalin (500 ppm) and bavistin (75 ppm) in substrate soaking water for 18 hours.

Spawning:

Polythene bag method is the commonly followed method of cultivation. Polythene bags (150-200 gauge) of 60 x 45 cm size are punctured to facilitate cross ventillation. Spawning is done by multilayered technique using 3% spawn.

Spawn running and cropping:

The filled up bags are incubated in cool dark place for spawn run. In 15 to 20 days white threadlike mycelium covers the entire substrate and the whole mass turns into a solid cylindrical structure. At this stage the polythene bags are ripped open and incubated for cropping by hanging or by stacking on the shelves of mushroom house with watering daily twice after two days of opening of beds.

Low cost mushroom house:

Low cost mushroom sheds can be built with coconut/areca stem and pleated coconut inside areca, oilpalm or coconut gardens or rubber plantations in between two rows of trees. Multilayer rack can be prepared with coconut/areca stem inside the shed to keep the spawned substrate for spawn running and cropping. Ventillators with insect proof nets are to be provided on all sides of the shed.

COCONUT WASTES

Coconut bunch waste, leaf stalk, mixtures of leafstalk + coir pith (1:1) and coir pith + bunch waste (1:1) are found to be suitable substrates (Thomas et al., 1997). Supplementation with 5% rice bran helps in the initial spread of mycelium. Mushroom yield of 531 and 453.8 g can be obtained from three kg. wet substrate of leaf stalk and bunch waste in an extended cropping period of 72.6 and 59.3 days, respectively (Table 1). Spraying the beds with a solution of 1% urea and 1% superphosphate helps to reduce interval between flushes.

Table 1. Mushroom production on different by-products of coconut

Substrate	Mushroom Yield g bed^{-1} (%)	Biol. Efficiency (days)	Cropping period
Leafstalk	531.0	53.0	72.6
Bunch waste	443.6	48.3	59.3
Coir pith + leaf stalk	356.0	60.3	75.0
Coir pith + bunch waste	326.0	43.0	53.4

ARECANUT WASTES

Arecanut bunch waste and leafstalk are pasteurized by soaking in a solution of 500 ppm formalin + 25 ppm bavistin (Chandramohan and Murthy, 1991). BE of mushroom production is 69% and 49.8% in a cropping period of 47 to 52 days in arecanut bunch waste and leaf sheath, respectively.

OILPALM WASTES

Mesocarp waste of oilpalm is found to be an ideal substrate for OM production. The availability of mesocarp waste is about 3 tonnes per ha in oilpalm plantations under irrigated condition. BE of 58.4% and 55.7 % are obtained with *P. florida* and *P. sajor caju*, respectively when mesocarp waste is used without pasteurization.

Other species such as *P. flabellatus* and *P. citrinopileatus* also gave better yield.

Table 2. Mushroom yield of *Pleurotus* spp. On oilpalm mesocarp waste

Mushroom	Weeks	Mushrom yield g bed $^{-1}$	BE (%)
P. pulmonarius	1-4 5-9	493.0 181.0	74.3 25.7
P. ostreatus	1-4 5-9	275.8 292.1	41.4 58.6
P. flabellatus	1-4 5-9	721.9 123.1	80.7 19.3
P. citrinopileatus	1-4 5-9	817.0 177.5	72.0 28.0
P. Sajor caju	1-4 5-9	8-00 313.0	75.8 24.2
P. florida	1-4 5-9	851.7 85.3	86.3 13.7

RUBBER WOOD SAW DUST

In a comparative study, rubber wood saw dust is found to be superior to paddy straw in yielding higher quantities of mushrooms. Higher BE of 88.8 % is obtained in rubber wood saw dust when cultivated in plastic containers with 5% spawn of *P. florida* by thorough spawning method.

COFFEE WASTE

Coffee pulp when mixed with 25,50 and 75% of paddy straw gave significantly higher yields as compared to pure straw. Maximum BE of 95 % is reported in a combination of 75% coffee pulp and 25% paddy straw.

TEA WASTE

When tea waste is mixed with paddy straw at different ratios of 25, 50 and 75%, there is decrease in yield with increase in the ratio of tea waste. Spraying with tea waste extract at various concentrations significantly increased the yield of mushroom.

PADDY STRAW MUSHROOM ON OILPALM BUNCH REFUSE

The availability of bunch refuse from a hectare of oilpalm under irrigated condition is seven tonnes. For bulk utilization of bunch refuse, paddy straw mushroom (*Volvariella volvacea*) cultivation can be taken up in regions where the temperature ranges from 25 to 35°C. Its cultivation can be easily done in thatched sheds, varandas or corridors and under shade of trees. At a BE of 3%, about 30 kg of paddy straw mushroom can be produced from one tonne of bunch refuse (Kochu Babu, 1992).

COMPOSTING OF COIR PITH

The process of coir manufacturing from coconut husk results in the accumulation of coir pith as a waste material near coir processing units. Application of fresh coir pith as a manure to the crops is not advisable due to its higher C:N ratio of 112:1. Nagarajan et al. (1987) reported a process to convert coir pith to compost using the mushroom fungus, *Pleurotus sajor caju*. To compost one tonne of raw coir pith 5 kg of urea and five *Pleurotus* spawn bottles are required. By this process, coir pith compost with a C:N ratio of 24:1 is formed within a period of 35 days. Coir pith compost with low C:N ratio has been prepared by chemical method at CPCRI, Kasaragod.

Vermiculture:

Vermiculture technology involves the use of earthworms as versatile bioreactor for effective recycling of non-toxic organic wastes to produce manure of high quality for sustainable agriculture. The byproducts from coconut plantations are converted to vermicompost with a nutrient content of 1.8% *nitrogen, 0.2% phosphorus and 0.2%* potassium using a locally isolated earthworm species at CPCRI, Kasaragod. Vermicomposting of cocoa leaves, cocoa pod husk and areca leaves are done with the earthworm species *Eudrilus euginae*.

REFERENCES

Anonymous (1996). Studies on vermicomposting for recyling the palms and cocoa wastes. Annual Report 1997-98. CPCRI Kasaragod pp. 72-74.

Chandramohanan R and Moorthy VK (1991). Utilization of areca leaf as a substrate for cultivation of *Pleurotus sajor caju*. In India Mushrooms ed. M.C. Nair, KAU, Vellanikkara pp. 140-142.

Kochu Babu M (1992). Cultivation of mushrooms on oilpalm factory wastes. In Oilpalm production technology (eds M.K. Nair and KUK Nampoothiri), CPCRI Kasaragod pp.77-80.

Kochu Babu M and Nair KR (1991). Mushroom cultivation on oil palm factory wastes, performance of six species of *Pleurotus*. *Indian Mushrooms* 104-108.

Kothandaraman R, Kochuthresiamma J, Mathew J and Jayrathnam K (1991). Preliminary investigations into the feasibility of growing oyster mushroom in rubber wood saw dust. *Indian Mushrooms* 88-90.

Pandey M and Tewari RP (1991). Evaluation of tea and coffee waste for *Pleurotus florida* cultivation. *Indian Mushrooms* 88-90.

Nagarajan R, Manickam TS and Kothandaraman GV (1988). Composting of coir dust for better utilization as manure in agricultural farms. *J. Plantation Crops*, 16: 59-62.

Thomas GV, Prabhu SR, Reeny MZ and Bopaiah BM (1997). Evaluation of lignocellulosic biomass from coconut palm as substrate for cultivation of *Pleurotus sajor caju*. Indian Mushroom Conference - 1997, NRC Solan.

Thomas GV, Reeny MZ and Prabhu SR (1997). Variation in oyster mushroom production in coconut byproducts as influenced by mixing of substrates. VII Swadheshi Science Congress Nov. 6-8, CPCRI Kasaragod.

STORAGE OF PRODUCE, PRODUCTS AND BYPRODUCTS OF PLANTATION CROPS-MICROBIAL AND PATHOLOGICAL ASPECTS

B. Ramanujam

INTRODUCTION

Fungi and bacteria are known to colonize the produce of several crops including plantation crops and cause post harvest spoilage/losses during processing/ storage. Such losses are reported especially in coconut, arecanut, cocoa, cashew, black pepper, cardamom and coffee.The produce of the plantation crops like coconut kernel, arecanut seeds, cocoa beans, cashew nuts, are very rich in nutrients and hence are more prone for microbial infection during processing/storage. Improper drying leads to, high moisture content in these produce and as a result of this, the produce become highly susceptible to fungi and bacteria. When microbial infection occurs during processing or storage, not only there is a quantitative loss but also it affects the quality of the produce. In certain cases it may lead to health hazards of the consumers due to the production of mycotoxins by the fungi. Fungi and bacteria which cause the spoilage of these produce are distributed abundantly in the air and soil and invade various produce under suitable environmental conditions. The fungi which commonly attack the produce of plantation crops are *Aspergillus, Penicillium, Mucor* and *Rhizopus*. *Aspergillus flavus* is reported to produce aflatoxin in copra which may pose serious threat to the human and animal health. The commercial value of plantation products are very high and hence the post harvest losses may lead to severe economic loss. Hence there is a great necessity to take proper steps to prevent the post harvest losses of these crops.

POST HARVEST DETERIORATION OF COCONUT

Spoilage of copra:

Copra is the dried kernel of coconut and copra making involves drying of the fresh kernel to bring down the moisture content of the wet meat from 50 - 55% to 5-6%. Deterioration sets in during the different stages of copra preparation and also in storage. The defective methods of processing and high moisture content of copra are major factors responsible for subsequent damages. Sun drying is the most commonly practised method for making copra. Since drying is done under open conditions in this method, spoilage of copra due to fungal infection is very common. Coconut kernel is a favourable substrate for the growth of microorganisms. Humid condition prevail in the coconut growing regions and as a result of this, post harvest losses in copra are very high. Under conditions of bright sunshine, it takes about 7 days to make copra having 6% moisture. However, this is possible only during the dry months. Sun drying becomes very difficult during monsoon because of high RH and intermittent rains. Kiln drying and drying using hot air dryers are the other alternative methods that can be used for making copra during rainy seasons. However, these methods are practised only to a limited extent because of the extra cost involved. Since coconut is grown mostly as a small farmer's crop, the cheapest method of copra making through sun drying is practised by the majority of the farmers.

In the deterioration of copra, usually bacterial action starts first during the initial stages of drying and later mould infection occurs. A gap of more than 4 hours between splitting and drying facilitates the activities of bacteria on the wet surface of the kernel. With RH of 80% and above and temperatures above 30° C, bacteria multiply rapidly and within 4 hours, a surface slime begins to develop on the wet kernel. The slime continues to develop and it becomes more pronounced during the first and second days of drying. The bacteria are active at moisture levels above 20%. As a result of the bacterial growth, the copra turns red and becomes slimy. *Serratia marscessens, Staphylococus aureus* and *Bacillus* sp., are the common bacteria which cause discolouration, sliminess and softening of the copra. By reducing the interval between splitting and drying to less than 4 hours, bacterial action can be slackened/prevented and thus subsequent damages minimized. By avoiding overloading in kiln drying, bacterial development can be prevented.

The penetrating moulds make their appearance after the bacterial growth. Four different moulds cause deterioration of copra. Though the optimum conditions for favourable growth of these fungi are different, they are sometimes found together at the same time on badly moulded copra. *Rhizopus* sp., or the white mould thrives on wet meat and destroys high percentage of oil and the oil from the infected meat has a high percentage of free fatty acid (FFA). *Aspergillus niger* group or the black mould has a lower moisture requirement (18 - 20% being the optimum and 12% minimum). This mould causes considerable loss of oil almost upto 40%. The *Aspergillus flavus* group or brown mould is the most serious of all the moulds. It flourishes at 8 - 12% of moisture and the oil loss may be more than 40%. This fungus is reported to produce aflatoxin B1 in copra which can be injurious to humans and animals (Susamma Philip et al. 1991). It causes maximum colour change in the oil and rancidity. The *Penicillum glaucum* group or the green mould is commonly found on copra at a moisture content of 6 - 7%. This fungus did not penetrate deeper and cause minimum reduction in oil content. In addition to these four fungi, *Mucor hiemalis* and *Aspergillus tamarii* (yellow mould) are often found on copra and cause considerable loss.

For making good quality copra and its proper storage without microbial spoilage, the following things are to be considered. Fully matured nuts (11 or 12 month old) are to be used for making copra. Varieties which give rubbery copra should be avoided for making copra. It is important that the split nuts are taken for drying within four hours after breaking to avoid initiation of the bacterial spoilage. The nut water should be drained completely and this could be done by inverting the split nuts face downward for 1-2 hours in the sun. Split nuts should be covered with the polythene sheets during night or when it rains. In the large copra making units, cement or concrete yards may be used for drying along with big screens of bamboo and coconut fronds for covering the yard during night or rains. Alternate methods of drying like kiln drying or through hot air dryers should be adopted during rainy season. The moisture content of the copra should be brought down to 6% before storage. Electronic moisture meters which are available these days may be used for accurate determination of the moisture of the copra before storage . After making good quality copra, it should be stored under proper storage conditions. The copra should be stored in gunny bags lined with polythene sheets in well ventilated godowns. Sulphuring should be carried out peridically when copra is to be stored for longer periods.

Rancidity of coconut oil:

Pure coconut oil is not a suitable medium for the growth of micro organisms. The production of free fatty acid and accompanying bad odour and taste originates in the copra itself due to microbial contamination which sets in long before the oil is extracted. Oil derived from the spoiled copra contains varying amounts of nutrients and moisture which supports the growth of various microbes. Later, the moulds attack the oil itself. Moulds produce free fatty acid in the copra and bacteria cause decomposition of albumin in the moist copra. Oil prepared from such spoiled copra becomes rancid quickly and results in bad taste and odour. For obtaining better quality oil, it is necessary to crush copra having moisture content of less than 6%. The crushing process should be done in clean surroundings and the oil should be collected in clean containers. The crude oil should be filter pressed without much time lag and the storage tanks cleared of sediments and other settled impurities frequently. The oil should be free from moisture (less than 0.25%). In case of refined oil it must be heated to 110 - 120°C to remove even the last traces of moisture. The oil must be stored as far as possible away from the direct light and air. The containers should be filled to the maximum possible extent in order to reduce surface area exposed to the light and air. Small quantities can be successfully stored in soldered aluminum tins and large quantities in storage tanks. Studies conducted on preventing rancidity and prolonging shelf life in coconut oil have shown that vacuum heating at 130 - 150°C for 30 minutes was beneficial. Storing in brown bottles was found to improve the stability and prolong its shelf life. Addition of antioxidants like Butrarylated hydroxyanisole and propyl gallate within permissible limits showed beneficial effects on storage of coconut oil.

Coconut cake:

The coconut cake easily absorbs moisture and as a result of this it is prone to mould attack while in storage. In India, a study on the shelf life of coconut cake revealed that 15.2% was the critical moisture content at which it could be stored to be free from moulds at an RH of below 79%. The study also showed that the cake could be stored without any spoilage for a period of 6 months , if alkathene bags are used. The rancidity of the cake could be effectively checked if its moisture content is kept below the critical level of 15.2%.

POST HARVEST DETERIORATION OF ARECANUT

Lack of proper drying yards, improper spreading and turning of nuts and exposure to rains during the drying period of arecanuts lead to microbial infection of the husk as well as kernel. These infections affect the quality of the nuts rendering them unsuitable for consumption and thus lowering their market value. The invading fungi first attack the embryo and then spread to the central white core. In the advance stage of infection the kernel would present a hollow cavity due to the complete disintegration of the tissue by the fungi. The affected nuts when cut open show the discolouration of the tissues of white core, the colour being dependant on the fungi involved.

The extent of damage due to fungi and other biological agents aiding deterioration depends upon the nature and season of drying. When nuts are stored for one year, the infection increased to 60.7%. It is observed that the fungal infection is highest in the nut dried during October (62%) and lowest in February (21%). The high incidence of fungal infection during October is attributed to the prevailing low temperatures and high RH. The low infection in February is due to high temperature and low RH . Majority of the nuts were infected during the first 5-10 days, presumably from husk.

Usually the microflora associated with husk and kernel of arecanut are *Aspergillus* sp., *Diplodia* sp., *Fusarium* sp., *Mucor* sp., *Thielaviopsis* sp., and certain aerobic bacteria. Fungi associated with spoilage of dried arecanuts are *Aspergilus* group (6.4%) *Botryodiplodia theobromae* (19.3%), *Penicillium* sp., (1.3%), *Rhizopus* (1.8%), *Mucor* sp., (0.7%), *T.paradoxa* (0.2%) (Bavappa *et. al.* 1982).

Elimination of soil contact by the harvested nuts is beneficial in reducing nut infection since it is the prime source of infection. Harvested nuts treated with Copper oxychloride showed less infection. Steeping the nuts in bordeaux mixture followed by drying on cement floor reduced the percentage of infection significantly. Polythene lined gunny bags can be used with advantage over plain gunny bags for storing nuts. Storage of arecanut in air tight bins also minimizes the fungal infection.

POST HARVEST DETERIORATION IN COCOA

Moulds have been described as the worst enemies of cocoa beans as their infection affects the flavour. It is possible to detect the mould off - flavour in the samples with as little as 4% mouldy beans. The other effects of moulds on cocoa beans are increase in free fatty acid content of the cocoa butter and production of mycotoxins harmful to the health of the consumers. Moulds can develop in the beans during the process of fermentation or drying or during the storage. Studies (Bopaiah *et. al.* 1980) on the microflora associated with the processed cocoa beans in India indicate *Aspergillus* group (*A.niger*, *A flavus* and *A.fumigatus*) and *Mucor pusillus* were the predominant fungi causing spoilage of cocoa beans. *Aspergillus* group of fungi increase the fat content of cocoa butter while *Mucor* sp., decrease the fat content . Contamination with Mucor sp., is common in the beans from black pod affected pods, as this saprophyte develops easily after the invasion of the pathogen. Beans derived from charcoal pod rot affected pods show blackish discolouration due to the infection of *Botryodiplodia theobromae*. Riped pods should be used for proper fermentation . It is advisable not to store the pods for more than four days after harvest, as other wise it will result in the germination of the seeds. Diseased or damaged pods should be discarded. Damage to the beans should be avoided while removing from the pods. Good quality beans with acceptable acidity level can be obtained by providing lateral aeration holes in the boxes or properly turning the beans on second and fourth day of the fermentation in the heap method. The adoption of suitable fermentation and drying process reduces the microbial load in the processed beans.

For the safe storage of cocoa beans the moisture content should be brought down to

6-7%. When the moisture content is above 8%, it could lead to development of moulds within the beans. When the moisture content is below 5%, beans become very brittle and hence the beans should be dried to the correct moisture content. The dried beans when rubbed with fingers, it produce a crackling sound. These beans can be stored safely for 2 or 3 months, however, if the cocoa is to be stored for much longer period, special precautions must be taken to prevent deterioration. Cocoa beans are hygroscopic and hence absorb moisture under humid conditions. Cocoa beans with moisture content of 8% or more are in equilibrium at a RH of 80-85% and such beans turn mouldy. Therefore the RH of cocoa stores should not exceed 80%. Proper ventilation of the godown is essential. The mould development during storage can be minimised by the usage of polythene liners in the storage bags. However, it is essential that the beans packed in liners should be dried to 6 - 7% moisture.

POST HARVEST DETERIORATION IN CASHEW NUTS

The moisture content of cashew nuts at harvest depends on the climatic conditions and the moisture of the soil on which the nuts have fallen. The moisture percent of the harvested cashew nuts can be as high as 25% and this may cause deterioration of the kernel due to mould or bacterial attack or enzyme action. It is therefore important that the nuts are frequently harvested during the *conditions of high rainfall and RH*. The whole nut moisture content should be brought down to 9% or below for safe storage. Drying the nuts immediately after harvesting is essential to preserve their quality. The quality of the nuts, especially on those stored in heaps are often affected by fungi. Deterioration is irreversible and cannot be made good by subsequent drying. As the main damage in the kernel quality occurs at farmers level, it is very important that the farmers are adequately instructed about the drying and storage of nuts. Sun drying can be done on drying floors or mats made of palm leaves or bamboo during summer periods. The nut should be dried until they make a rattling sound when fallen on the floor. This may take several days depending upon the climatic condition. As soon as the nuts are dried they should be stored in godowns. Nuts exposed to RH of above 75% turn mouldy within few weeks and hence the godowns should be properly ventilated to avoid development of humidity above 70%.

The moisture content of the processed kernel should be dried to a moisture content of 5% before packing. As cashew kernels are subject to rancidity and go stale very quickly, packing should be air tight and impermeable to moisture. It was observed that the cashew kernels remain in good condition for a period of more than one year when stored in air tight containers.

POST HARVEST DETERIORATION IN OIL PALM FRUITS

Palm oil is derived from the freshly harvested oil palm fruits. In the palm oil extraction process, harvested bunches are processed immediately (within 24 hours) and as a result of this, chances of microbial contamination of the fruits are limited. *However, fruits which have been kept for* several days without processing are prone for mould attack. Several lypolytic fungi like *Oospora, Rhizopus, Aspergillus, Penicillium, Marasmius, Sclerotium, Diplodia* and *Phoma* have been reported to increase the free fatty acid in the oil palm fruits (Hartley, 1977).

Under normal plantation practice, this cause is insignificant as compared to the lipase enzyme activity originating in the oil palm fruit itself. Harvesting of the fruits at right maturity, avoiding damage to the fruits during harvest and transport and immediate processing of the fruits are important with respect to yield and quality of palm oil. Since immature fruits yield less oil and over mature fruits have higher amounts of free fatty acids (FFA), proper and timely harvesting of fruit bunches is an important operation which determines the quality of the oil. The degree of ripeness of the bunches is based on the fruit detachment and the bunches are usually harvested when the number of fallen nuts or easily removable fruits from each bunch varies between 5-10 depending upon the age of the palm. Harvesting rounds should be made as frequent as possible during peak period of production and less frequent during lean period of production. Excessive bruising of the fruits should be avoided during harvest and transport, since damage to the fruits result in increased activity of lipase enzyme and release of FFA. High FFA not only makes the oil inedible but also increases the rate of rancidity, fixes colour and increases refining losses. Suitable methods should be followed to avoid damage to the fruits during harvest and transport. Processing of fresh fruit bunches within 24 hours after harvest is essential to avoid release of FFA Therefore palm oil mills should be located nearer to the plantations in order to process the fruits immediately after harvest. The quality of palm oil obtained should have less than 1% FFA and 0.2% moisture and other impurities and carotin content of 700 ppm, good colour, flavour and consistency. In India, there is no report of lypolytic fungi causing spoilage of palm oil during extraction stages.

POST HARVEST DETERIORATION IN SPICES

Black pepper:

The traditional methods used in the preparation of black and white pepper results in heavy contamination by microbes and the levels found are the highest for commonly used spices. A number of species of *Aspergillus* and *Penicillium* have been found in pepper. An American study found very low concentrations of aflatoxins in pepper. Mould contamination has been found to be essentially on the surface of the seeds of black pepper, whereas internal contamination is also found in white pepper. The level of contamination of micro organisms is dependant on the care taken during drying and preparation of black and white pepper. It is imperative to dry the berries as quickly as possible to a safe moisture content of 11% or less. During sun drying, it is important to rake the berries regularly and to cover during wet weather or when overnight dew occurs to avoid mould attack. Sun drying takes seven to ten days during which , the moisture content is reduced to 10 to 15 %. In recent years artificial drying using flow hot dryers have been reported in India and Brazil. However, the temperature used in this dryers should not exceed 55° C. Maintaining the moisture content at low levels during storage, not only prevents further mould development but also inhibits propagation of other micro organisms. Mould contamination of pepper detracts from its appearance and odour and may cause health hazard. Bacterial contamination is an inherent risk in the traditional methods of black and white pepper preparations. However, mould development can be controlled to a greater extent by exercising proper care in drying and subsequent storage. Artificial drying methods being more rapid and efficient, it provides a product with much lower microbial contamination level. A number of sterilizing treatments for pepper, including exposure to the ethylene oxide and ionizing radiation have been reported . However, the possibilities of toxic residues and deterioration in flavour is likely in these methods. Since much of the contamination is on the surface of the spices, washing is quite effective in reducing the contamination level and re-drying to below 11% moisture and storing under good storage conditions. Pepper if adequately cleaned and dried can be stored without quality deterioration under dry conditions.

Cardamom:

One of the characters used for assessing the quality of cardamom is the appearance. Drying of the fruit must be done efficiently to avoid mould formation which results in skin blemishes that detract from its appearance. At harvest, fruits have a moisture content of above 75%. It must be reduced to less than 10% for safe storage. In the trade circles, 8 - 9 % of moisture is considered ideal for storage. Moisture levels above 10% is detrimental to chlorophyll and will result in fading of the green colour. Well dried samples should produce typical tinkling noise on shaking and such well dried cardamom can be stored under dry conditions without any deterioration.

Ginger:

There are three main primary products of ginger rhizome viz., fresh (green) ginger, preserved ginger in brine or syrup and the dried ginger. Normally fresh green ginger is sold in the market immediately after harvest and is being used directly as vegetable. Fresh ginger can be stored in sand lined pits for three months without deterioration. Dried ginger is generally prepared by sun drying method and during drying care must be taken to avoid mould growth and the moisture content is brought down to 7-12%. Artificial drying minimizes microbial contamination. Dried ginger is susceptible to mould attack and hence should be stored in dry atmosphere. Even after bagging, it should be exposed periodically to the sun to avoid mould attack during storage.

POST HARVEST DETERIORATION IN COFFEE

The practice in India for preparation of cherry coffee is to dry the fruits immediately after harvest in the drying yards directly exposed to sun light. In the evenings the fruits are heaped together and this condition enhances microbial contamination which results in reduction in the quality of coffee beans. Since coffee berries have high moisture content it provides a fertile medium for microbes such as moulds and bacteria. *Aspergillus niger* was found to develop on cherry heaps and form stinker beans. Fungi like *Penicillium* sp., *Aspergillus* sp. and *Cladosporium* sp. were found associated with ripe cherries of Robusta. It is important to keep the temperatures around 30°C to minimise the incidence of fungal contamination by proper turning of the heaps during drying. Coffee beans should be dried to a moisture content of less than 13 % before storage.

POST HARVEST DETERIORATION IN TEA

The micro organisms occur as

contaminants on the layers of fermented juice covering on the processing machines and other equipment employed during tea processing. Proper sanitation and cleanliness throughout the process of fermentation during black tea manufacture are essential, as the presence of bacteria imparts taint, maltiness, flatness and other undesirable properties, resulting in the reduction of the quality. The commonly adopted practice to prevent microbial contamination is to meticulously clean the processing machines with detergents, followed by repeated washing with plain water. Although several antimicrobial chemical agents are being used to avoid microbial contamination in tea manufacture, these cannot be employed in the manufacture of export quality tea in view of the stringent food laws enforced against the toxic residues in tea by various countries. UV irradiation during fermentation was found to be effective in the microbial eradication without affecting the quality. However, complete inhibition of microbes could not be achieved with UV irradiation because of its poor penetration.

REFERENCES

Bopaiah BM, Chandramohanan R and Radha R (1980). Microflora associated in the processed cocoa beans. *PLACROSYM-III*: 48-61

Bavappa KVA, Nair MK and Prem Kumar T (Eds.) (1982). The Arecanut Palm-Monograph CPCRI, Kasaragod

Eden T (1976). Tea. Longman Group Ltd. Essex, UK. pp.166-196.

George Varkey A, Gopalakrishnan M and Mathew, A.G. (1980). Rapid method for determination of moisture in cardamom capsules. *PLACROSYM-III*: 8-13

Hartley CWS (1977). The Oil palm. 692-780. Longman Group Ltd. Essex, UK.

Puseglove JW, Brown, EG, Green CL and Rbbins SRJ (1981). *Spices, Vol.* I& II.

Pruthi JS (1992). Microbial infestation of black pepper and its control measures. J. Spices and Aromatic crops. 1(2) 113-124.

Satyavathi K, Balachandran C, Krishnaswamy C and Sreemulathan M (1980). Studies on improving storage life of coconut oil. *PLACROSYM-III*:180-188

Stephan Thanaraj SN, Chandra Mouli B and Rangaswamy S (1980). Effect of Ultraviolet radiation on CTC processing of tea. *PLACROSYM-III*:105-114

Thampan PK (1981). Hand Book on coconut palm. Oxford and IBH publi. Co, New Delhi. pp.195-274.

Susamma Philip, Krishnan Nair,M and Menon, MR (1991). Aflatoxin B1 production in copra, a potential threat to consumers. In Adv.Coconut Research and Development (ISOCRAD-II) Oxford and IBH publi. Co, New Delhi. pp.671-673.

Susamma Philip and Menon MR (1996). Changes in quantity and quality of coconut oil due to fungal infection of copra. *J. Plantn. Crops (suppl.)*: 722-726.

Wood GAR and Lass RA (1985). Cocoa. Longman Group Ltd. Essex, UK. pp.444-505.

STORED PRODUCT PESTS OF PLANTATION CROPS AND THEIR MANAGEMENT

A.S. Sukumaran

INTRODUCTION

Excess moisture, mould, insects and rodents are known to be responsible for damage and loss to stored products of plantation crops and also for the deterioration in quality of stored material.

COPRA

At various stages of production, distribution and utilization, heavy quantitative losses occur due to insects, rodents, fungi and other micro organisms. The important insect pests recorded in copra are *Cadra Cautella* walk, *Necrobia rufipes* De Geer, *Oryzaephilus surinamensis* Linn, *Abasverus advena* weltl., *Hypothenemus hampeii* De Geer, *Lasioderma serricorne* Fab., *Carpophilus diminiatus Fabricius, Tribolium castaneum Herbst* and *Dermestes ater* De Geer.

1. Almond moth (*Cadra cautella* Walks) (Lepidoptera:Phycitidae)

The caterpillar of this moth is a serious pest of products such as cocoa beans, cotton seed, nuts and copra and dried fruits. In Copra, it is injurious when the product has not been properly dried and suitably stored. Well prepared copra is too hard for the caterpillar to attack. The adult moth lays eggs on the inner surface of copra,the emerging larvae make a silken mat on the inner surface of the cup and remain within. Remaining inside the silken mat, the larvae feed by scarping the copra from the surface.

2. Ham beetle (*Necrobia rufipes* De Geer) (Coleoptera: Cleridae)

This beetle occurs in the wet season in many countries of South-East Asia and the Pacific and is popularly known as "the copra bug". In addition to copra, it feeds and breeds on salted meat, dried fish, prawns, bones, skins, cocoa beans and nutmeg. It is a serious pest of mouldy copra of poor quality where as the larval mortality is high when they feed on properly prepared copra. Both the adults and grubs cause damage. The larvae make ramifying tunnels inside copra and feed from within whereas the adults remain on the surface of the copra and eat inwards from the cut edges.

3. Saw Toothed Grain beetle (*Oryzaephilus surinamensis* Linn.) (Coleoptera: Silvanidae)

This is a serious pest of poor quality copra but does not seriously infect well-dried copra. The adults bore through the cut end of the copra pieces. They make extensive galleries between the kernel and testa and lay eggs there. The emerging larvae feed within the galleries and cause damage. The existence of galleries within the copra cannot be indicated externally by holes or frass. The presence of the pest can be detected only when the pieces are broken up.

4. Foreign Grain Beetle (Abasverus advena weltl.) (Coleoptera: Silvanidae)

This is a small reddish brown oval beetle with smooth elytra and clubbed antennae. The adults bore into the copra in between the dried endosperm and testa and the damage is caused by adults and larvae in the same manner as *O. surinamensis.* It does not feed on good quality copra but only on copra on which the mould *Penicillium* is growing.

5. Coffee Berry Borer (*Hypothenemus hampeii* De Geer) (Coleoptera: Anthribidae)

This greyish beetle has small dark patches on the elytra and prothorax. Adults bore into the copra through the innerside and their entry holes could be prominently seen. The beetles make galleries within the copra and lay eggs there. The larvae also feed on copra within the galleries and cause severe damage.

6. Cigarette beetle (*Lasioderma serricorne* Fab.) (Coleoptera: Anobidae)

This is a light brown round beetle with thorax and head bent downward which gives a humped appearance to this insect. The adults bore into the pieces of copra through the testa and the entry holes can be seen prominently on the surface. The beetle feed by making galleries and lay eggs there. Emerging larvae feed on copra within the galleries and the life cycle is completed inside the copra.

7. Short winged beetle (*Carpophilus diminiatus* fab.) (Coleoptera: Nitidvlidae)

This is a dark brown flattened beetle with short elytra which cover two or three abdominal segments. In the tropics, it feeds on copra, cocoa beans, ginger, nutmeg, palm kernels etc. It is seldom found on copra of good quality.

8. Red grain beetle (*Tribolium castaneum* Herbst) (Coleoptera : Tenebrionidae)

This is a very well-known pest of stored products. Though regarded primarily as a pest of cereal products, including flour and bran, it is also destructive to oil seeds and copra. Like all the other insects that damage copra, it shows a marked preference for poor quality material with an abundance of the mould *Pencillium.*

ARECANUT

The husked arecanut known as chali is stored in godowns, sometimes even upto one year in gunny bags before marketing. Insect damages by feeding on the inner central core and due to this holes appear on the surface of the nuts. More than 21 species of insects and mites are recorded infesting stored arecanut in the country. The insect damage is maximum during the rainy months when the humidity is high and minimum during winter and summer months. The moisture content of the stored arecanut varied from 8% to 28.3%. The tender arecanut chips show maximum resistance to infestation by insects. The important insect pests recorded are:

1. Arecanut beetle (*Cocotrypes carpophagus* Horn) (Coleoptera: Scolytidae)

This is the most important storage pest of arecanut. The damage is maximum even upto 100% during November. The Damage is mainly caused by adult beetles which bore into the nuts and feed on the inner contents. The infested nuts show holes of 0.6-1.0 mm in diameter.

2. Coffee bean weevil (*Araecerus fasciculatus* D.) (Coleoptera: Anthribidae)

Both adults and grubs have been reported to damage stored arecanut. Infested nuts show holes 1.5-2.5 mm in diameter. Unhusked nuts with intact perianth are not infested by this insect even after one year of storage.

3. Cigarette beetle (*Lasioderma serricorne* F.) (Coleoptera: Anobiidae)

This is a widely distributed storage pest infesting stored arecanuts throughout the year. Both the adult and grubs damage the nuts and make them as powder.

4. Rice moth (*Corcyra cephalonica* stainton) (Lepidoptera: Galleriidae)

The caterpillars of this moth construct galleries of silk and frass over stored nuts, remain within and feed on them.

CASHEW:

Processed cashew kernels during storage are damaged by some insect pests. About 20 species of beetles, five species of caterpillars and mites are reported to be infesting cashew nut kernels in storage. Among these, many species contaminate the kernels with their presence and excreta. The important storage pests are:

1. The Ham beetle (*Necrobia rufipes* De Geer) (Coleoptera: Cleridae)

The adult beetles are about 5 mm long and greenish blue. The larvae are 4 mm in length, slender and tapering towards the head, purplish in colour with short hairs on the body. In addition to cashew kernel they feed on fish, hides and copra.

2. The cadella (*Tenebroides mauritanicus* Linn.) (Coleoptera: Ostomidae)

The adults are dark brown to black in colour and about 12 mm in length. The larvae are white in colour with black head and measure about 15 mm in length when fully grown. Two prominent black horns are present on the terminal abdominal segment. Grubs and adults feed on all sorts of stored products particularly dried fruits.

3.Saw toothed grain beetle (*Oryzaephilus surinamensis* Linn.) (Coleoptera : Silvanidae)

The adults are flat bodied, dark brown in colour measuring about 2 mm in length. They resembles the head-louse because of the presence of 6 tooth-like projections on each side of the thorax. The larvae are whitish, elongate and about 3 mm in length. The head is brown and the abdomen tapers towards the tip. The insects feed on variety of food materials like grains, dried fruits, seeds and nuts.

4. Red grain beetle(*Tribolium castaneum* Herbst) (Coleoptera: Tenebrionidae)

The adults are actively moving insects with flat, elongate, reddish brown body. They are about 3 mm in length and their antenna terminates in a club. The larvae are brownish-white flatted and measure about 4 mm in length. *T. Castaneum* is mainly a pest of milled and processed articles and it attacks oilcakes, dried fruits, nuts etc.

5. Fig moth (*Cadra cautella* walker) (Lepidoptera: Pycitideae)

The adult moths have a wing expansion of about 2-5 cm, greyish in colour with transverse stripes on fore wings. The larvae are about 1.5 cm long and spin webs among food particles. This insect is a serious pest of harvested figs and attacks dried fruits such as dates, almonds, walnuts, tamarind etc.

6. Indian meal moth (*Plodia interpunctella* Hubner) (Lepidoptera: Phycitidae)

The adults have a wing expansion of about 1.8 cm. The base of the forewings is greyish-white and the distal portion is reddish-brown. The larvae are about 1.5 cm in length, whitish with pinkish tinges. The larvae feed on whole grains, milled products and fruits.

7. Rice moth (*Corcyra cephalonica* stainton) (Lepidoptera: Pyralidae)

The moths are dull-coloured with pale greyish-brown markings on the wings. The wings when expand is about 1.8 cm. The larvae are dirty-white with yellowish head and measure about 1.5 cm in length. They live inside webs made of silk and broken grains.

COCOA

Cocoa beans are damaged in godowns by several insect pests. The important pests are: 1. *Cadra cautella* walks (Lepidoptera: Phycitidae) 2. *Necrobia rufipes* De Geer (Coleoptera : Cleridae) 3. *Abasverus advena* waltl (Coleoptera : Silvanidae) 4. *Carpophilus diminiatus* Fab (Coleoptera: Nitidulidae)

SPICES

Several species of insect pests damage different spices in godowns and cause severe economic loses. The important pests are:

1. *Necrobis rufipes* De Geer (Coleoptera: Cleridae)

Damages Nutmeg

2. *Oryzaephilus surinamensis* Linn. (Coleoptera: Tenebrionidae)

This insect is primarily a pest of oilseeds spices and dried fruits.

3. *Abasverus advena* Waltl. (Celeoptera : Silvanidae)

Damages ginger and nutmeg.

4. *Carpophilus diminiatus* Fab. (Coleoptera: Nitidulidae)

Damages ginger and nutmeg

5. *Aspidiotus hartii* Green (Hemiptera: Diaspididae)

It is an important pest of ginger and turmeric both in the field and during storage.

Management: Management of stored product pests of plantation crops involves both preventive and curative measures.

Preventive measures:

1. Cleaning of godowns / store rooms

Clean the floor, corner and roof of the godown. The dust and debris (containing egg, pupae, dead larvae and adult stages of insect) collected should be burnt.

2. Plastering of cracks and crevices in the store rooms

The cracks and crevices developed in the store house walls may harbour storage pests,hence they should be plastered before storing

3. Cleaning and drying of the stored products

The materials to be stored should be cleaned and dried in the sun to reduce the moisture content, failing which will lead to development of mould giving rise to disagreeable odour and color.This mould also attracts the pest developing on copra. The partial decomposition and increased acidity of the mouldy copra coupled with insect infestation further deteriorate their value through their moulted skin and excreta.Hence uniform drying of the copra is necessary to reduce the moisture content to or below the specified level.

4. Cleaning and disinfecting the storage structures

Gunny bags previously used for storing

other commodities should be steamed to ensure disinfestation.

5. Provide dunnage

The storage bags or bins can be piled over the dunnage made by bamboo poles, mats or wooden crates to make them damp proof.

6. Proper stacking of storage structures

The storage bags should be piled up neatly and systematically. Proper space should be left between the piles and walls to increase the ventilation and to facilitate periodical inspection and cleaning.

7. Provide plinth structures around the store house to prevent the entry of rodents.

8. The ventilators should be covered with wire mesh to prevent the entry of avians and reptiles.

Curative measures:

1. Periodical inspection of the stocks and if any insects noticed they should be removed and the stock should be sundried and cleaned.
2. Spraying malathion 25% dispersable powder @450 g in 5 l of water per 100 m^2 at monthly intervals to disinfect the storage sheds and to ensure the insect population maintained at harmless level. 3. Fumigation: Use of aluminium phosphide tablets@1 tablet / tonne with an exposure period of six hours to control the major pests. The tablets are placed between the sacks and the entire sacks covered with rubber sheets and plastered with mud along the edges to make it air tight. Methyl bromide is used at 2.5-3 kg/100 cu.m. The exposure period is 48 hrs.

Ethylene di bromide (EDB) has been developed in the form of tablets under the trade name mini fume by CFTRI,Mysore and it can be used @ one tablet per quintal. However fumigation should be done with care for those commodities with higher oil content. If they are fumigated, longer waiting period should be allowed before using. The fumigated store should be kept opened for sufficient time before entering in.

REFERENCES

Jacob SA (1980). Biology and bionomics of ginger and turmeric scale, Aspidiotus hartii Grean - Proceedings of the National Seminar on Ginger and Turmeric, April 1980. pp. 131-132.

Nair MRGK (1980). Pests of Ginger and Trumeric - Proceedings of National Seminar on Ginger and Turmeric. pp. 101-103.

Nalinakumari T et al. (1992). Occurance and nature of damage caused by pests of stored copra in Kerala. *Indian Coconut J.* 23: 7-9.

Radhakrishnan Nair CP and Mariamma Daniel (1982). Pests causing major crop loss - storage pests. The Arecanut Palm. pp. 174-177.

Rai PS (1984). Hand book on cashew pests. pp. 76-80.

Russell DC (1969). Agricultural seminars Bulletin no. 6, Cashewnut processing. pp. 67-69.

Vasantharaj David B and Kumaraswamy (1975). Elements of Economic Entomology. pp. 163-167.

PLANTATION PRODUCTS AND BYPRODUCTS - BIOCHEMICAL ASPECTS

S. Naresh Kumar

INTRODUCTION

Plantation products and by-products have high commercial value. These are used for edible and industrial purposes. Commonly known consumables such as tea, coffee, coconut, copra, coconut oil, palm oil, cashewnuts, arecanuts, etc. are direct plantation products whereas some other consumables contain modified plantation products like chocolates contain cocoa product. Apart from these, plantation products and by-products are widely used for industrial purposes. Use of coconut oil in soap, detergent, dye and shampoo making , rubber usage in various industries, etc., come under this category. Since the market value of these products is mainly influenced by the quality of product, which in turn is predominantly determined by the biochemical composition, it is important to assess their quality in terms of biochemical parameters. This chapter deals with the biochemical composition of plantation products and by-products. The plantation crops dealt with are coconut, oil palm, rubber, cocoa, coffee and tea.

COCONUT

Coconut has a number of products and by-products. Main edible products of commercial importance are coconut oil, copra and tender nuts. Non edible products include oleochemicals, fibre, etc.

Biochemical composition of edible parts: **(i) Coconut kernel or copra:** The ripe kernel derived from 11-12 month old nuts consists proteins (5.5%), fat (44%), carbohydrates (10%), crude fibre (3%) and minerals (2.1%). However, desiccated copra with a moisture content of 2% consists of fat (67%), proteins (9.3%), carbohydrates (5.9%), minerals (2.4%), fibre (3.9%) and pentosans (8.9%). It also has vitamins A, B, C and E.

(ii) Coconut oil: Dry copra contains about 65 % coconut oil which is mainly a triglycerol, a substance consisting of fatty acids chemically bound to glycerol in the ratio of 3:1. It contains around 87% of saturated fatty acids, causing oil to have a high melting point (23-26°C). These fatty acids have a carbon chain mostly of 12 and 14-C (medium chain fatty acids). Saponification value of coconut oil is the highest and iodine value is the lowest among oils so it is classified as non-drying oil. The physio-chemical property of oil are: Specifi gravity at (25°C) 0.918, Vircosity at (25°C) 1.45, Iodine value 8.0-9.6 and Saponification value 251-263.

(iii) Coconut milk: Coconut milk contains protein (2.4-4.1%). The fat content varies from 12.5% in dehydrated whole milk to 40% in canned cream milk. Coconut skim milk is rich in proteins and fats (26.4 and 19.6% on dry weight basis, respectively). Reducing sugars are also present in small amount. The milk has a slightly acidic pH (6.0 - 6.3).

(iv) Coconut flour: Coconut flour, nutritionally comparable to most of the common grain flours, contains protein (22 - 24 %), crude fibre (10%) and ash (5%).

(v) Coconut water: Coconut water is rich in minerals and vitamin B, apart from other components like sugars.

(vi) Coconut cake: It consists of moisture (7%), fat (6.7%), protein (21.2%), nitrogen free extract (47.4%), fibre (11.2%) and minerals (6.5%).

Biochemical composition of non-edible products:

(i) Oleochemicals: Coconut oil is split into various industrially useful component chemicals like glycerol, fatty acids, fatty acid methyl esters, fatty alcohols and fatty amines. This oil has the highest percentage of glycerol (a major by-product) compared to other oils and fats. Because of its high lauric acid content, coconut oil is also catageorized under lauric oils. These oleochemicals are used in soap, non soap detergent, textile and cosmetic industries.

(ii) Coconut husk: A mature ripe nut contains 35-45% of its weight as husk.From husk several coir products like coir dust or pith and fibre are obtained.

Coir pith: Coarse coir pith or dust contains more lignin (43.65 %) and pentosans (13.1 %) as compared to the fine coir pith which has 37.71% lignin and 11.5% pentosans. Coir pith is a source of furfural, oxalic acid and zypsum.

Fibre: Fibre obtained from mature nut is mainly made of lignin (46%) and cellulose (43%). Pectin (4%) and hemicellulose (1%) are also present in lesser amounts.

(iii) Coconut shell: It is rich in cellulose (50.99%) and lignin (32.22%). Other components include moisture (6.76%), pentosans (3.01%), hot water extract (1.76%), ether extract (0.17%), ethanol-benzene extract (1.98%) and Ash (1.32%).

Storage of copra and oil - biochemical aspects:

The important aspects in storage of copra and oil are i) proper drying of copra, ii) storage conditions of dried copra and oil and iii) shelf life of oil. A systematic investigation is carried out at CPCRI, Kasaragod , on different methods of drying and storage of copra using various preservatives and storage containers for increasing the shelf life. The study, based on the data collected on quality parameters, indicates that the most effective treatment for storage of copra in rainy season is to keep them in an atmosphere saturated with either biogas, neem leaf gas or sulphur dioxide. The fungal and bacterial infestations are negligible in the successful treatments. Other experiments revealed that soaking of copra in 1000 ppm propeonic acid arrests the microbial activity during drying.

The quality of oil mainly depends on 1) quality of copra, 2) extraction conditions and 3) storage conditions. Unrefined coconut oil contains Free Fatty Acids (FFAs) and hence has a tendency to become rancid due to the hydrolysis and oxidation of FFAs. With storage time, the peroxide value and FFAs of oil increase thus developing rancidity. The shelf life of coconut oil can be improved by adding either citric acid (500ppm), common salt (1%) or tamarind (2%) and packing it in plastic containers or brown bottles to prevent the rancidification of oil.

OIL PALM

Oil palm has two commercially important oil products, the mesocarp oil and the kernel oil. Oil extracted from fleshy orange-red mesocarp is known as crude palm oil (CPO). It contains two fractions, the palm stearin and the palmolein. Stearin fraction contains mainly saturated fatty acids and is solid at room temperatures. While palmolein has more unsaturated fatty acids and remains liquid at room temperatures.

Mesocarp oil also contains carotenoids, antioxidants (tocopherols and tocotrienols - Vit E), triterpenes, phytosterols, phospholipids, glycolipids, aqualene, sterols, aliphatic alcohols and Cu and Fe in trace amounts. Among the edible oils, palm oil has the highest concentration of carotenoids (500-700 ppm) in which α and β carotenoids constitute about 90%. These are the precursors for Vitamin A synthesis. Carotenoids are generally removed or destroyed while refining. Palm kernel oil contains high proportions of saturated fatty acids. One gram of palm oil provides 9 kcal of energy. The presence of antioxidants in abundance make palm oil stable against developing rancidity.

Processing biochemistry:

The mesocarp consists of fat globules. The lipase enzyme is bound to the membrane of fat globules. This enzyme is extreamly active and catalyses the cleavage of acyl groups from glycerophospho lipids and glycosyl acyl glycerols thus releasing the free fatty acids. Any damage to the membrane triggers the activity of enzyme and the free fatty acids (FFAs) released thus can be as high as 60% depending on the severity of damage. The released FFAs not only make the oil inedible but also hasten the rancidity development apart from fixing colour and increasing the refining losses. So, proper care should be taken during harvesting of fresh fruit bunches, transport, handling and subsequent processing of fruits. The fruits should be processed immmediately after harvest (within 24 hrs.) Sterilization of fresh fruit bunches inactivates the lipase enzyme and also loosens the fruits from bunch. It also softens the cell wall and coagulates the proteins that faciliteate oil extraction in later stages. Immature fruits have less oil and over mature fruits have high FFAs. For milling a good quality oil, the FFAs should be less than 2%.

RUBBER

Major source of rubber is *Hevea brasiliensis*. Rubber is a latex, formed in the laticiferous vessels present in the bark of the rubber tree.This latex is the modified cytoplasm from the inner regions of the laticifers. Latex consists of rubber particles and non-rubber particles. All these particles are suspended in a soluble phase called C-serum constituting an isotonic osmotic medium. C-serum posseses large amount of carbohydrates, proteins and ions like K^+ .

Presence of active acid phosphatase in high concentrations in latex damages the lutoids. The disruption of lutoid vesicles releases B-serum which causes the flocculation of rubber particles leading to the stoppage of latex flow. So, high lutoid stability increases the latex stability and flow. Increased concentrations of triglycerides and phosholipids in latex lead to a high stable lutoid vesicles and thus stable rubber. Volume of the latex tapping can be increased by application of ethylene generating chemicals as ethylene is found to lower the plugging and prolong the duration of latex flow.

COCOA

Beans are the commercially important products of cocoa plant. The cocoa powder and cocoa butter are the products obtained from beans. After harvesting the fruits the beans, embedded in pulp inside the fruit, are fermented and roasted, during which the chocolate flavour develops. The quality of the product is determined during fermentaition. For good fermentation, the mass of cocoa beans should be well insulated to retain the heat generated during fermentation and ensuring good circulation of air is important.

The beans along with pulp (minimum of 90-100 kg) are put for fermentation. Pulp contains 80% water, 10 -15 % glucose and fructose, 0.5% non-volatile acids (largely citric acid), and small amounts of sucrose, starch and salts. The low pH (3.5) of pulp facilitates the good growth of micro-organisms. Beans covered with mucilage or pulp are pink to white and have a pH of 6.6. They turn reddish brown upon fermentation and the cotyledons become pale in the centre with a brownish ring around the outerside.

During fermentation, yeasts proliferate and convert sugars in pulp to alcohol. Increase in CO_2 due to yeast activity causes anaerobic condition facilitating the development of lactic acid bacteria which assists in breaking down of sugars to alcohol. During this period the liquid (sweatings) run off takes place. When bean mass is physically turned, aerobic conditions are restored and acetic acid bacteria grows. These bacteria convert alcohol to acetic acid. and thus the pH decreases further and temperature increases approximately to 48°C. These conditions make the testa of the bean to become more permeable. Citric acid penetrates into the bean lowering its pH to 4.8. However, fermentation of bean increases its pH to 5.5 and this is the usual pH obtained in the dried bean. During fermentation of bean, break down of internal cellular structures and proteins takes place. The polyphenolic compounds are hydrolysed to cynidin, reducing sugars, etc. These changes reduce the bitterness and astringency and give chocolate flavour.

Based on the degree of fermentation the quality of product depends. The International Cocoa Standard guidelines for assessing the degee of fermentation as follow: (i) Fully fermented: Should include all fully fermented beans, eventhough the colour cannot properly be described as brown. (ii) Partly brown and partly purple: Should include all beans showing any blue, purple or voilet colour on the exposed surface, whether suffused or as a patch. (iii) Fully purple: all beans showing a complete blue, purple or violet colour over the whole exposed surface. (iv) Slaty: irrespective of colour, any beans which are slaty but not predominantly so (not > 50%).

The fully fermented beans are dried to a moisture content between 6 and 7% for safer storage. Fully dried cocoa beans contain moisture (6-8%), fat (55-58%) with a pH of 5.8. Apart from these, the cocoa products also contain minerals like Ca, Na, K, Mg, Fe, Cu, P, S and Cl.

COFFEE

Caffeine is the major alkaloid present

in coffee. The content of caffeine varies depending on the species and type of coffee. *Coffea arabica* contains 1% caffeine whereas *C. robusta* contains 2%. However it varies from 2.8 to 4% in instant coffee. Coffee also contains trigonelline (1%) apart from proteins, carbohydrates, fats and minerals.

Coffee attains its aroma and taste on roasting, during which the pyrolytic reactions take place. Upon roasting, trigonelline yields nicotinic acid, and chlogenic acid and other organic acids reduce to 90%. These acids give astringent taste. Roasted arabica has proteins (10-15%), carbohydrates, free amino acids, and citric (0.5%), malic (0.2%), lactic (0.1%), qunic (1%), pyruvic (0.1%) and acetic (0.3%) acids. Lipids (14-17% in arabica and 7-11% in robusta) are not affected by roasting. About 800 flavour and volatile compounds are identified in coffee.

TEA

Tea has polyphenolic compounds such as thea flavins and thea rubigins. Tea wastes contain 1.7% caffeine.

With the storage period moisture content of tea increases from 4.9 to about 9 %. Thea flavins increase during storage upto 150 days then decrease, whereas thea rubigins increase during first 50 days of storage and then decrease. The valuation score of tea decreases beyond 150 days of storage.

REFERENCES

Chadha KL and Retinam P (1994). Plantation and Spice Crops (part 2, Vol 10). Advances in Horticulture (ed. KL Chadha). Malhotra Pub. House, New Delhi, India.

Chempakam B and Rajagopal V (1994). Coconut industry - challenges ahead. Paper presented at the National Seminar on Newer Challenges in Agriculture, Horticulture and Industry: Role of Palnt Physiologists and Biochemists, at UAS, Bangalore. Jan 11-13.

Enig MG (1995). Health and nutritional benefits from coconut oil and its advantages over competing oils. Coconut Development Board Pub. No. 44. Kochi, Kerala.

George KV (1980). Processing technology and marketing . Proceedings of the third annual symposium on plantation crops. ISPC Pub. CPCRI, Kasaragod.

Gopalan C, Ramasastri BV, Balasubramanian SC, Narasinga Rao BS, Deosthale YG and Pant KC (1995). Nutritive Value of Indian Foods. National Institute of Nutrition Pub. Hyderabad, AP.

Luckwill LC and Cutting CV (1970). Physiology of Tree Crops. Academic Press. London.

Nair MK and Nampoothiri KUK (1992). Oil palm - production technology. CPCRI Pub. Kasaragod.

Peter KV, Sarma YR, Rajagopal V, Ramana KV, Devasahayam S and Krishnamurthy KS (1996). Proccedings of International Symposium on Plantation Crops (PLACROSYM XI) Nov 30-Dec. 3, 1994 at Calicut. ISPC Pub. CPCRI, Kasaragod

Sethuraj MR and Raghavendra AS (1987). Tree Crop Physiology .No.18 Developments in Agricultural and Managed Forest Ecology series, Elsevier Sci. Pub. BV., Amsterdam, Netherlands.

Wood GAR (1975). Cocoa, Tropical Agricultural Series (III edn.) Longman Group Ltd., London.

Table 1 : Fatty acid composition of coconut oil

Fatty acids	% of total fatty acids	Type	C chain length and unsaturation
Lauric acid	47.3	Sat	12-C
Myristic acid	17.0	Sat	14-C
Palmitic acid	8.8	Sat	16-C
Caprylic acid	8.7	Sat	10-C
Capric acid	7.2	Sat	8-C
Stearic acid	2.3	Sat	18-C
Caproic acid	0.5	Sat	6-C
Arachidic acid	0.1	Sat	20-C
Linoleic acid	1.9	Unsat	18-C:2
Palmitoleic	1.0	Unsat	16-C:2
Oleic acid	6.3	Unsat	18-C:1

Table 2 : Biochemical composition of coconut water

Components	Tender nut water	Mature nut water
Values in mg %		
Total solids	6.5	5.4
Total sugars	5.7	2.0
Reducing sugars	4.4	0.2
Minerals	0.6	0.5
Protein	0.01	0.1
Fat	0.01	0.1
pH	4.5	5.2
Vit B	rich	
Values in mg %		
Acidity	120.0	60.0
K	290	247
Na	42	48
Mg	10	15
P	9.2	6.3
Fe (µg)	104	79
Cu	26	26

Table 3 : Biochemical composition of chocolates and cocoa powder

Components	Chacolates		Powder
	4 plain	2 milk	
Fat (%)	35.3	37.6	25.6
Protein (%)	5.6	8.7	20.4
Available carbohydrates (%)	52.5	54.5	35
Energy (cal/100g)	544	588	452

Table 4 : Polyphenolic pigments in black tea

Components	%
Thea flavins	0.808
Thea rubigins	7.72
High polymerised substances	8.76
Pheophytin index	0.724
Relative blackners	100

Table 5 : The fatty acid composition and chemical characteristics of mesocarp and kernel oil

Fatty acids and chemical characteristics	C chain length and unsaturation	Mesocarp Oil (%)	Kernel oil (%)
Lauric acid	12-C:0	0.1-0.4	40.0-52.0
Myristic acid	14-C:0	0.6-1.7	14.0-17.0
Palmitic acid	16-C:0	41.1-47	7.0-9.0
Stearic acid	18-C:0	3.7-5.6	1.0-3.0
Caprylic acid	8-C:0	-	3.0-5.0
Capric acid	10-C:0	-	3.0-7.0
Caproic acid	6-C:0	-	0.3
Arachidic acid	20-C:0	0.1-0.8	0.1
Oleic acid	18.-C:1	28.2-43.5	13.0-19.0
Linolenic acid	18.-C:2	10	0.5-2.0
Linolenic acid	18.-C:3	0.1-0.5	-
Palmitoleic acid	16-C:.1	0-0.6	-
Iodine value		52	
Refractive index		1.4553	
Vitamin E		rich (-600ppm)	

DESIGN OF EXPERIMENTS

K.Vijaya Kumar

The variability in experimental material is common in any field of research. It may vary in size from experiment to experiment but its presence cannot be disputed. When the variability is small as compared to the group or class differences and if it is not expensive to take more observations, a detailed experimental set up is not needed. But when there is lot of variation from observation to observation and if it is not economical to take large number of observations it is necessary to adopt an experimental design which allows to estimate true treatment differences in an unbiased way with a specified degree of precision.

While conducting an experiment, a researcher would be having different objects of comparison called 'treatments'. For example, In an agricultural field trial there may be different varieties, cultivation practices or different doses of fertilizer to be compared. In Post Harvest Technology (PHT) there may be different doses of a chemical to preserve a product for longer shelf life. Through a simple trial it may be possible to see a particular treatment doing better than others. But, the better/poor performance of the particular treatment may be due to other reasons rather than the real superiority of a particular treatment. In a field trial it may be because the plots allotted for the particular treatment might have been more fertile or might have been located under better environmental conditions. In the PHT problem mentioned earlier, some of the treatments might have poorly performed because the samples used for the study might have been contaminated earlier. So, it is necessary that all treatments are tried under identical conditions and without any bias. Statistical designs for an experiment will help us to determine the intrinsic worth of a treatment in an unbiased manner.

The basic requirement of a statistical design consists of three principals viz., randomisation, replication and local control. **Randomisation:** This consists of allocation of treatments to various plots without any bias of the experimenter. By randomisation, we can ensure that various treatments in long run, by repetition of the experiment, will be subjected to equal environmental effects. **Replication:** By replication we mean that the repetition of the treatment under study. Since the inherent variation in the experimental material cannot be allowed directly because of unpredictable nature, the experimenter wishes to average out its influence over the different treatments by replication. If we repeat a treatment 'r' times, the mean of these repetitions will be subject to a standard error (SE) of $\sigma/\sqrt{r}$, where σ is the standard deviation (SD) of individual plots which is estimated from the experiment. The percentage SE to which this mean will be subject equal to $C/\sqrt{r}$ where C is coefficient of Variation (%). We will be able to estimate the number of replications required for inferring the difference between two treatments (given as % of general mean say d%) as significant at a given level of significance (say at 5%) when observed difference exceeds a given per cent of mean. Therefore,

$$\frac{\text{difference}}{\text{S.E of difference}} \geq 1.96.$$

Solving 'r' from this gives the minimum number of replications required. However, since the CV is an estimated value only and not true value, this will give only an approximate idea of the minimum number of replications required for the study.

Local Control: The variation in the experimental material existing which cannot be controlled by the experimenter is termed as experimental error. Therefore,the observed differences between two treatments may be due to i) Real treatment differences ii) Experimental error which influences the yield irrespective of the real treatment differences.

Thus it is required to find out the magnitude of experimental error and compare it with the treatment variations to see if there is any real difference between treatments. It is possible to reduce the experimental error by suitable arrangement of experimental units within homogeneous blocks. This is known as the principle of **Local control.**

Different ways of arrangements of experimental plots to investigate the treatments is known as **Experimental designs. Completely Randomized Block Design(CRD):** This is the simplest of all the designs. Here, all the experimental units available for the experiment are assumed to be homogeneous. The treatments are allotted at random to different units(plots). CRD is a flexible design as there is no restriction of equal number of replication for each treatment. However,the principle of 'local control' is overlooked since randomization is carried out throughout the field. This has its own disadvantages and advantages. If the experimental area/material is homogeneous as it is assumed, the design is most efficient as compared to other designs. If it is not, this design is to be avoided. The following example illustrates the layout of a CRD.

Example 1: A trial is to be conducted to find out a treatment schedule for preserving coconut wood for timber purpose. Six treatments(coded as A,B,C,D, E and F) are to be compared. Forty six logs of equal size and which are homogeneous with regard to their initial physical property are available for the study. For treatment F chemical which is enough for only 6 logs is available. Design an experiment which will help to decide the best treatment schedule.

The experiment.can be laid out in a CRD as the experimental material is given to be homogeneous. Since chemicals for maximum of 6 logs only is available, for treatment F we can have 6 replications and 8 replications each for treatments A to E. For this purpose, first all the 46 logs are serially numbered from 1 to 46. With the use of random number tables the numbers 1 to 46 are arranged randomly. The first 8 numbers are allotted to treatment A and the next 8 to treatment B and so on till treatment E. The remaining 6 numbers are allotted to treatment F. The analysis of variance consists of finding out sum of squares due to the only source of variation viz., treatments. The sum of square for unknown causes(error) is found out by subtracting treatment sum of square from total sum of square. When the ratio of treatment mean square to error mean square exceeds table value of F for corresponding degrees of freedom, the null hypothesis of equality of treatment means is rejected at 5% or 1% level.

Randomized Block Design:

This is the most commonly used design. Since the principle of local control is utilized for reducing the experimental error by restricting the treatments within homogeneous blocks, this is an improvement over CRD.

In the case of a field trial a block can be contiguous area of land and in industrial experiments, the block can be materials prepared in one single batch so that within a block homogeneity is maintained. In a RBD, each block is a complete replication and there is a reduction in error variance as replication differences is eliminated from the error variation thereby making treatment comparisons more precise. The following example will illustrate the procedure of layout of an RBD.

Example 2: In the example 1 given above it is known that the 46 logs of wood belong to palms of 6 different age groups viz.., below 40,41-50,51-60,61-70,71-80 and above 80 years and in each group a minimum of 7 logs of wood are available. Design an experiment to find out the best treatment schedule.

Since it is known that the logs belong to 6 age groups, it is better to allot treatments within each group separately as logs within a particular age group are expected to be more homogeneous than logs belonging to different age groups. So, each treatment is allotted randomly to a log within each age group so that each age group forms a complete replication. Since the variation due to age group is removed from the error variation, there will be reduction in error. In RBD there are two known sources of variation viz., replication and treatments. The variation (Sum of squares) due to experimental error is found out again by subtraction of variation (Sum of squares) due to known sources of error from the total sum of squares and test for treatments is carried out like in CRD.

Latin Square Design(LSD): In this design the heterogeneity is controlled in two directions so that variation from two sources are eliminated from error variation with a result that the treatment comparisons are generally more precise than RBD. So, in case of a Field trial, if it is known that the fertility gradient is in two directions perpendicular to each other,there can be two sets of blocks made one set called Rows horizontally and other set of blocks called Columns vertically over the previous set. The area formed by the intersection of these sets of blocks is a plot. In LSD , each treatment occurs exactly once in each Row and Column. This design lacks the flexibility of RBD or CRD as there should be equal number of replication as that of treatments. This is a major limitation of this design. The sum of square due to error is found out by subtraction of sum of squares due to rows, columns and treatments from the total sum of squares.

The following example illustrates the layout of an LSD

Example 3: In the examples 1 and 2 given above, it is further known that the 46 logs belong to 6 varieties of coconut such that a minimum of 1 log is available in each variety in each age group. Lay out the experiment in a suitable design to find out the best treatment schedule.

It is now known that the experimental materials have two known sources of variation viz., age differences and varietal differences which if not eliminated, will increase the error variation. The logs are first arranged age wise in 6 groups. Within each age group, the logs are arranged again variety wise. A 6X6 Latin square arrangement is then chosen after usual randomization procedure for the LSD. Since there is atleast one log satisfying both the classifications, different treatments are imposed on each log as per Latin square arrangement.

The Latin square arrangement for the experiment may look as below after randomization of rows, columns and treatments.

F	D	B	E	A	C
E	B	F	C	D	A
C	A	E	D	F	B
A	F	D	B	C	E
D	E	C	A	B	F
B	C	A	F	E	D

Here 6 rows represent 6 age groups and 6 columns represent 6 varieties so that each treatment is tested on one log belonging to a particular age group and the variety.

Factorial Experiment: During some occasions, the experimenter may have to investigate simultaneous variation in more than one factor. For example, he may be interested in finding out the optimum dose combination of Irrigation and fertilizer for a crop. One way of doing is to experiment first with Irrigation and arrive at an optimum dose and then conducting another experiment using the optimum dose of irrigation already found with different doses fertilizer. But this method is not only time consuming but also erroneous; because if the two factors are interacting, the dose of irrigation which is found optimum earlier may not be really optimum at lower/higher dose of fertilizer. So, in such situations, only way is to take all possible combinations of the two or more factors in one and the same experiment and try to find the optimum combination. The factorial experiment can be laid out in a CRD or RBD depending on the experimental material.

Confounding: When there are more than two factors and more levels for each factor, there will be too many treatment combinations. In a field trial it is difficult to get large uniform area to accommodate all these combinations. Since a smaller area is expected to be more homogeneous than a larger area, a portion of the treatment combinations can be tried in these homogeneous blocks; thus a replication wherein all the treatment combination appear once consists of more than one block. This procedure of dividing the replication into two or more homogeneous compact blocks is called as **confounding.** Such a subdivision of a replication disturbs the precision of treatment comparisons and some effects will be mixed up with block differences. However, with judicious allocation of treatment combinations in different blocks, it is possible to retain all the important comparisons intact.

The following example of a 2^4 experiment will illustrate method of confounding. In a 2^4 factorial experiment 4 factors(say a,b,c,d) each at two levels (say absence and presence) are tried so that there will be a total of 16 treatment combinations. These can be listed as below.

(1),a,b,ab,c,ac,bc,abc,d,ad,bd,abd,cd,acd,bcd,abcd

Here, (1) represents the absence of all the factors and 'a' the presence of factor 'a' and the absence of all other factors.

The following blocking system with treatment combinations in the respective blocks in one replication is an arrangement which confounds the highest order interaction ABCD. Here the effect ABCD is mixed up with block differences.

Block 1 a, b, c, d, abc, abd, acd, bcd
Block 2 (1), ab, ac, bc, ad, bd, cd, abcd

If there are 2 or more replications in the experiment,and same treatment combinations as above are tried in the two blocks of the other replications also,then ABCD cannot be estimated at all and it is the case of **Complete confounding** the effect ABCD. **Partial confounding** is an arrangement so that the effect confounded in one replication can be estimated from other replication(s).

Split Plot design:

In Factorial experiments, when we consider two dissimilar factors (ex: Irrigation and Spacing) first factor(Irrigation) usually shows larger differences than the second(Spacing). With a factorial layout, both the above factors will be tested with equal precision. So it is possible that the differences between Spacings may go unnoticed as the other factor produces larger differences and both are tested with the same error which will generally be large because of the first factor. One way of reducing the error is to restrict the randomization of the factors producing smaller differences within compact blocks instead of scattering them throughout the replication. So, a replication is divided into as many blocks as there are levels of first factor and the levels of first factor are allotted randomly to these blocks(Main Plots). Within each of these Main Plots, the levels of the 2nd factor are allotted at random. Similar procedure is followed in other replications also. The resulting layout is called **Split Plot Design.** Since two types of plots are involved, one larger plots for the main plot treatments and the other smaller plots for sub plot treatments, two error variations are involved one for the main plots and the other for sub plots and the interaction. The comparison of subplots thus becomes more precise as the main plot comparisons are done with the separate error.

Split Plot Design has several practical advantages and is found to be very useful in agricultural field experiments. In this design greater precision is obtained for the Sub plot treatments and Interaction - of course at the cost of Main plot treatments. Therefore we have to be careful in choosing the factors for the Main plot treatment.

Strip Plot Design:

This is analogous to Split Plot design. When two factors can be tried on larger plots, one set of factors is superposed over the other at right angles. So, a replication is first divided into as many strips as there are levels of first factor horizontally and then into as many strips as there are levels of 2nd factor vertically. Both the sets of treatments are allotted at random within a replication. Such an arrangement is called Strip Plot design. Since there will be three types of plots in this layout, three different error mean squares are involved. The test of significance for interaction is more sensitive by virtue of large number of error degrees of freedom available for the corresponding error.

Incomplete Block Designs:

When there are 10 - 15 treatments for comparison, the experiment can be laid in a simple RBD. But when there are a large number of treatments especially in Plant Breeding where number of varieties or strains to be compared, it will not be possible to accommodate all of them in a block because of soil heterogeneity. The situation here is somewhat similar to that of factorial experiments where replicates are divided into homogeneous blocks. So, the same solution of spreading replication to more than one homogeneous block is applied here also. Designs of this type are called Incomplete Block designs. In the case of confounded factorial designs the idea is to estimate the main effects and first order interactions at the cost of estimating higher order interaction. In Incomplete block design, there is nothing like interaction and we are interested in having the comparison between all the treatments. Therefore something like a partial confounding is adopted so that the treatment comparison which are confounded in one replication can be estimated from other replications. Thus comparison between all the pairs of varieties are available. So, though some information is lost by this type of confounding, ultimately because of smaller size of the blocks, the comparisons are generally more precise than what we would have obtained by adopting a simple RBD by taking all the treatments in one single block.

Simple lattice or Double lattice designs: This is the simplest case of an Incomplete Block design. In this case, the number of varieties is 'V' where V is a perfect square(q^2). The designs are available for 16,25,36,49 etc. This layout requires a minimum of 2 replications in blocks of q plots each. So,if there are 36 varieties, first the varieties/ treatments are numbered 1-36 serially and the numbers are arranged in a square array of 6X6. First replication which may be called the X group is formed by taking the row sections as blocks; so, 6 blocks are formed this way in a replication. Second replication called the Y group will have 6 more blocks consisting in each block the varieties/treatments occurring in the columns of the array. The two groups together constitute the simple or double lattice design.

The following 6X6 array shows the layout of a simple/Double lattice design.

1	2	3	4	5	6
7	8	9	10	11	12
13	14	15	16	17	18
19	20	21	22	23	24
25	26	27	28	29	30
31	32	33	34	35	36

Here, the first replication(X group) consists of 6 blocks, each consisting of treatments mentioned in the 6 rows of the array. The second replication(Y group) consists of another set of 6 blocks consisting of treatments mentioned in the 6 columns. These two sets of blocks constitute the simple lattice design for 36 treatments.

Factorial experiment in Fractional replication: In a factorial experiment, if the factors are in large number a single replication itself will have unmanageable number of treatment combinations. For example, even in comparatively small experiment like 2^6 factorial experiment. there will be 64 combinations. For estimation of main effects or two factor interactions even half this number of combinations will be enough without much loss of precision. So, it is a great saving if we can reduce the number of treatment combinations to a manageable level and still get all the main effects and important interactions. Such factorial experiments where only a fraction of the treatment combinations are tried in a replication is known as factorial experiments in fractional replications. These types of experiments are very useful in industrial experiments where sometimes the combinations are in thousands for a single replication and it will be physically impossible to carry out the complete trial. However, by using half or one fourth of a replication, we will be mixing up certain effects with some other effects called 'aliases'. So, for example while estimating the effect of say A, the alias of the component A (which is normally a higher order interaction) also is included in that. Mostly these 'aliases' are so chosen in the layout such that effects of them can be neglected. This means that it is necessary that we know few basic things about the experimental material before laying out the experiment so that an effect which is an alias of another effect will not be simply ignored. The following example illustrates laying out a 2^5 factorial experiment in fractional replication by using a 'half' replicate.

In the above example there are 32 treatment combinations. The highest interaction is ABCDE. So, the treatment combinations can be divided into two sets such that from one of these all the main effects and 2 factor interactions can be estimated. The 3 factor and 4 factor interactions which can be assumed as negligible go as 'aliases' of these 2 and 3 factor interactions. The 5 factor interaction ABCDE is taken as Defining contrast which cannot be estimated. The combinations which come under the 2 sets with ABCDE as the defining contrast are:

1st set a, b, c, d, e, abcde, abc, abd, abe - acd, ace, ade, bcd, bce, bde, cde

2nd set abcd, abce, abde, acde, bcde, ab, ac, ad, ae, bc, bd, be, cd, ce, de, (1) +

Taking the first set only in the experiment i.e half replication, we can estimate the following main effects and interactions and the corresponding alices are also given.

Main effect	Alices	Interaction	Alices
A	BCDE	AB	CDE
B	ACDE	AC	BDE
C	ABDE	AD	BCE
D	ABCE	AE	BCD
E	ABCD	BC	ADE
		BD	ACE
		BE	ACD
		CD	ABE
		CE	ABD
		DE	ABC

STATISTICAL AND GRAPHICS SOFTWARE FOR DATA ANALYSIS

K.Muralidharan

INTRODUCTION

Statistics is a rapidly growing subject which came into existence as a branch of science only in the twentieth century. The availability of cheap computing facilities and software have revolutionized the application of statistics in every aspects of modern living. Statistical planning and evaluation has been routinely used by industries to make advances in processing and statistical quality control of products makes them reliable.

There are several definitions for statistics - collation of data in primitive sense to, as a branch of science (pure and applied) of creating, devęloping and applying techniques such that the uncertainty of inducting inferences may be evaluated. Generally, statistical application involves formation of a hypothesis, collection/ generation of data and finally, based on an appropriate test a decision to reject or not to reject the hypothesis.

The hypothesis may be concerned with comparison of groups (treatments), the value of a population, association/relation between two or many characters (variables)/ individuals etc. The relevant data for testing the hypothesis may either be collected from a 'sample' of observations or generated from an 'experimental design' as what the case may be. To test hypothesis related with time, often secondary data is used.

A number of statistical procedures are used in the field of harvest and post harvest technology. However, some of the most useful techniques are seem to be overlooked. The purpose of this note is to generate a discussion on the appropriateness of certain advanced statistical techniques as a research aid of harvest and post harvest technology of plantation crops.

DATA COLLECTION

As mentioned earlier, data is obtained mainly from a sample or from an experimental design. A 'sample' is a part of a population; all possible values of the variable comprise the population. The 'experimental design' deals with planned inquiry to obtain new facts, or to confirm or deny the results of previous experiments. Broadly, the purpose of an experimental design is either for comparison of treatments or for describing a response function whereas in a sample survey one is interested in estimation of population values (parameters).

As in experimental designs, a number aspects are to be considered while choosing a 'sample design'. Ways in which the sample units is drawn termed as 'sample designs'. Defining the sampling units and population is fundamental to any sample survey. This process should enable one to locate and identify the units in the population if required. Based on the nature of sampling units, the sample design is decided. The most simple and commonly used sample designs are (1) simple random sampling, (2) stratified sampling, and (3) multi stage (cluster) sampling. Systematic sampling is also popular. Cochran (1984) may be rèferred for a detailed account on these and related topics. Sampling is also employed in experimental design to collect data from a fraction of a plot.

SOFTWARE FOR DATA ANALYSIS

Many statistical application software are in use. Some of them are very simple and users friendly as well. It is not possible to make a comparison among all the commercially available software. Neither the author is experienced enough to comment on the same. Interested readers may consult the product reviews published by computer magazines. The Indian Agricultural Statistical Research Institute, Library Avenue, New Delhi-12 had released two statistical software - one for data analysis (SPAR1) and another for selection of block designs (SPBD). At CPCRI, we use SPSS for data analysis and AXUM for graphics.

STATISTICAL PROCEDURES

Preliminaries:

The initial steps in data analysis include, summarization of data, checking for unusual values (outliers or wrongly entered values) and identifying the pattern if any. The SPSS procedure EXAMINE offers a variety of ways for a detailed examination of the data. Before the actual trial of a hypothesis, there is much evidence to be gathered and sifted. If necessary the hypothesis and/or the methods of testing may have to be changed.

With regard to a quantitative data, we may first obtain the frequency distribution. Most of the frequency distributions are characterized by its mean and variance. Since the data we come across is often a sample from an infinite or a finite population, there exists an amount of uncertainty on our inference. To measure the uncertainty we utilize the concept of probability. A simple definition of probability is the relative frequency. The frequency distribution of values of a variable in a 'population' is called the probability distribution of that variable. A large number of quantitative variables are found to follow the normal distribution; a great many may follow after appropriate transformation. Important discrete distributions are binomial, multinomial, and Poisson.

The values of an estimator will vary from sample to sample. On knowing the distribution of the estimator, the upper and lower bounds within which the values are expected to fall with a preassigned confidence (say 95%) can also be constructed - the confidence interval. The frequency distribution of values of an estimator (statistic) is referred as the 'sampling distribution' (e.g., F, t, Chi-square). We utilize these distributions to express our confidence on the estimates obtained from a sample. We also utilize the fact that the sum of the observations of a sample often follows a normal distribution irrespective of the parent distribution (the central limit theorem).

The estimated values of a parameter may have to be tested for its agreement with the value proposed by the experimenter (the null hypothesis). The null hypothesis is tested against an alternative hypothesis. There are two types of errors in this process: The Type I error - rejecting the null hypothesis when it is true and the Type II error - accepting the null hypothesis when it is false. The probability of Type I error is called the level of significance (generally fixed as 5% or 1%). The complement probability of the Type II error (the probability of a correct decision) is termed as the power of the test. The most frequently used tests are the t-test, paired t-test, F-test and Chi-square test.

Regression analysis:

An important use of statistics is in the exploration of relationship between the response variable(s) and causative variables: The linear relationships in particular. A measure of (linear) association between two variables is the coefficient of correlation. The explanatory model relating the dependent variable and the predictor variable is termed as the regression model. Regression analysis is one of the most versatile data analysis procedures. The coefficients of a linear regression model is estimated by using the least square method. It is assumed in a regression analysis that the observations are independent and normally distributed with equal variance. By looking on residuals the validity of these assumptions may be assertained. SPSS offers a number of options for the 'residual analysis'. These include different scatter plots, the Durbin-Watson statistic etc. If the assumptions of linearity and homogeneity of variance are met, there should be no relationship between predicted and residual values. If the value of Durbin-Watson statistic is not close to 2, one may suspect that the observations are not independent. When building a regression model, it is important to identify points that are influential. The important influence measures is the 'leverage'. Another aspect to be looked into is the possible high correlation among few predictor variables.

Linear equations are the simplest to fit an observed relationship. But in many situation, it may be necessary to fit nonlinear models. There are different algorithms for the estimation of nonlinear models and explained in Draper and Smith (1981).

When the dependent variable can have only discrete values (say, present or absent), the 'logistic regression model' will be used. In this case, the parameters are estimated using the 'maximum likelihood method'. That is the estimates that make our observed results most 'likely' are selected.

Loglinear models:

Analysis of contingency tables is one of the most debated topics in statistics. When more variables are included in a cross classification table, the number of cells rapidly increases and make it difficult to analyze the association among the variables by examining only the cell frequencies. The loglinear models are formulated for this kind of situation. Log linear models are similar to multiple regression models - the classification variables are the independent variables and cell frequency is the dependent variable. Interested reader may consult McCullagh and Nelder (1989) for more details.

Analysis of repeated measurements:

In many experimental situation, measurements of the same variable are taken at several occasions (time) for each subject (experimental units). The observations are then cannot be considered as independent. A number of procedures of analysis are proposed to deal with such situations of which the univariate (split-block) analysis of variance and repeated measurements multivariate analysis of variance are easy to use. In split-block ANOVA, the error is partitioned as variance among experimental units with regard to averages (or sums) over time and variance among observations within experimental units. This ANOVA is different from that of a split-plot for one additional source of variation viz., replication X time.

Since the 'sub-plot classification' (time) is not randomized, it become necessary to test the assumption of equal variances (at each time) and equal covariances (between pairs of time) to justify the use of split-block analysis. The chi-square test due to Box may be used to test this assumption of symmetry. The Repeated measurements MANOVA is identical with the usual multivariate analysis of variance (MANOVA) and the treatment x time interaction effects are tested based on an appropriate 'sets of contrasts'. The SPSS procedure for MANOVA for repeated measurements will perform both these analyses. More details on analysis of repeated measures may be obtained from Crowder and Hand (1990).

Survivorship analysis:

The statistical analysis of life time of products, storage time etc. are often come across in Engineering and Food Science. Mathematically, the life time or survival time is a non-negative valued variable. The probability of an individual survive till a specified time is termed as survival function or reliability function. The instantaneous rate of death or failure at any time is defined as the hazard function. A problem one could encountered in survivorship studies is that the experiment might have completed before determining the life time of some of the individuals. Data of this kind are called 'censored data'. Special statistical techniques are needed for the analysis of censored data. Kaplan-Meier estimation of survival rates and the Mantel-Haenszel (logrank) test for the comparison of estimated survival curves (for different levels of the predictor variable) are the most widely used devices in survivorship analysis (Haris and Albert, 1991). When the predictor variable is continuous, special type of regression model, 'Cox's proportional hazards model' is used. The parametric approach to deal with censored data is to employ parametric families of lifetime distributions and extends models such as the exponential, Weibull, and lognormal models to include regressor variables (Lawless, 1982).

Nonparametric methods:

When the assumptions (on the distribution from where the sample is drawn or regarding the population parameters of two or more population) of test is expected to be violated, one may use nonparametric tests; a majority of non-parametric tests are based on ranks of the sample observations.

REFERENCES

Cochran WG (1977). Sampling Techniques (3rd Edn.). Wiley, New York.

Draper N and Smith H (1981). Applied Regression Analysis (2nd Edn.). Wiley, New York.

Haris EK and Albert A (1991). Survivorship Analysis for Clinical Studies. Marcel Dekker Inc., New York.

Lawless JF (1982). Statistical Models and Methods for Lifetime Data. Wiley, New York

McCullagh P and Nelder JA (1989). Generalized Linear Models. Chapman & Hall, London.

PRODUCT DIVERSIFICATION IN PLANTATION CROPS - A SWOT ANALYSIS

C.V. Sairam

INTRODUCTION

Plantation crops occupy nearly 2.3 per cent of the gross cropped area in India. During 1996-97, out of the total exports of US $ 7054 from agricultural commodities, the share of spices and plantation crops alone accounted for about 20 per cent (Economic Survey, 1997-98). Since independence, the area and production of these crops is on the increasing trend. However, the changes in area or production are neither uniform among the crops nor over the periods as both were very much influenced by the agro-climatic and biotic factors and these crops are prone for high degree of price risks both in domestic and international markets (George, 1997). At present, India leads the world in the production of arecanut, cashew, ginger, turmeric and tea and ranks second in the production of coconut (in terms of copra equivalent), small cardamom and black pepper. In the present era of liberalized international trade, in which the market forces play a vital role, the concept of product diversification attains major importance. The following pages explain the scope of product diversification in plantation crops by examining the Strength - Weakness - Opportunities and the Threats (SWOT).

COCONUT

Coconut is an important small holder's plantation crop which has many end uses such as raw nuts, copra, copra meal, coconut oil, desiccated coconut, shell charcoal etc... The forecasted annual production of coconut in India for 1998 is about 22 lakh tonnes accounting for about 26 per cent of the global coconut production. The country stands first in the world in terms of productivity which is 7779 nuts/ha. Out of the total production, about 51 % is used as matured nuts for the household culinary purposes, 6.0 % as edible copra, 36.5 % as milling copra, 1.5 % as desiccated copra and 5 % for tender nut purposes. India is the largest producer and exporter of coir products and the industry is regaining its past glory. Coir fibre, coir yarn, coir mats, coir rugs and carpets, coir rope, curled coir, rubberized coir, coir geotextiles, coir pith are the some of the major coir products which are being exported from India. Except for copra making and oil making and desiccated coconut, at present there is no major industry in the country on coconut products. Hence the present level of exports is very meager in case of coconut based products. Moreover, the cost of production of copra and coconut oil in India is higher as compared to the international level. The ratio of domestic and world prices would indicate the degree of export competitiveness of a commodity. This ratio for coconut oil is 2.99 and hence India is in disadvantageous position in the international trade of coconut oil. Countries like Philippines, Indonesia and Sri Lanka in which excellent processing facilities are available and where the cost of production of copra and oil are comparatively low, are the leading exporters of not only that of oil but also other processed items of coconut like Nata de coco, coconut shell, coconut cream etc...

Particulars	Strength	Weakness	Opportunities	Threats
Area	-	Predominance of small/marginal farms	Scope for expansion	-
Production	-	-	Adoption of production technology	-
Productivity	Highest	Predominance of local varieties	-	Diseases
Cost of production	-	High as compared to international level	Competitiveness through higher productivity	-
Consumption pattern	Vast domestic market	56 per cent consumed as raw nut	Growing urban markets	-
Marketing	-	Co-operatives often non-viable Predominance of middle men	-	High degree of price risk
Processing	Vast production	Mostly diverted for oil production. Less attention to other coconut producing States like TN, AP and Karnataka	Product diversification in States other than Kerala	-
International Trade	Production	Established countries	Liberalized Trade/ Technology perfection	High cost of production/ price instability

ARECANUT

India is the largest producer of arecanut in the world. During 1995-96, the country produced 0.27 million tonnes of arecanut from an area of 0.23 million ha and the average productivity was about 1156 kg/ha. In spite of the Government policies which discourage area expansion, attractive prices prevailing during the past few years is mainly responsible for the annual increase of about two percent in area. Between 1983-84 to 1994-95, the Compound Growth Rate values (%) for area, production and productivity were 2.36, 2.87 and 0.56 respectively. Although at present there is no scope for exporting arecanut products, in future it could be possible to produce some of the value added products like arecanut husk fibre, leaf based products, areca tannins etc., on a commercial scale and export the same in international markets.

Particulars	Strength	Weakness	Opportunities	Threats
Area	-	Predominance of small/marginal farms	-	-
Production	-	-	Adoption of production technology	-
Productivity	-	Predominance of local varieties	-	Diseases like Mahali
Cost of production	-	-	Competitiveness through higher productivity	-
Consumption pattern	Vast domestic market	-	Growing urban markets	Proposed ban on its products
Marketing	Co-operatives are viable	Middle men also play a major role	-	-
	Better price stability	Lack of knowledge of marketing channel	-	-
Processing	Vast production	Not much scope at present	Product diversification in textile industry	-
International Trade	Production	-	Liberalized Trade/ Vast market in Gulf countries	-

COCOA

Cocoa is one of the major beverage crop of the world cultivated in Africa, Latin America and Asia. Cote-D-Ivoire is the largest producer of cocoa in the world and the global cocoa production had marginally decreased from 24.1 lakh tons during 1989-90 to 23.9 lakh tons during 1994-95. India is one among the Asian countries cultivating cocoa on a small scale with an annual production of 6760 t. The crop is mainly grown as a mixed crop in arecanut and coconut gardens of Kerala and Karnataka.

The area under cocoa in India had decreased from 22720 ha during 1983-84 to 11230 ha during 1993-94 (by -50.6 %), however during the same period production has increased from 5700 t to 6760 t (by 18.6 %). The productivity which was only 251 kg/ha during 1983-84 had increased to 602 kg/ha during 1993-94 (by 139.8 %). It is estimated that during 2000 AD the domestic demand for cocoa beans in the country would be about 12,000 t. Given the incentive price to the Indian grower there are prospects for increasing the indigenous production for meeting the domestic demand. However at present, the crop does not have scope for international trade as the country is in disadvantageous position in terms of cost of production as compared to other countries like Cote-D-Ivoire, Ghana , Brazil, Ecuador, Indonesia and Malaysia. Hence careful import polices may be designed for cocoa since the domestic demand has been increasing slowly, liberal imports would lead to severe price crash.

Particulars	Strength	Weakness	Opportunities	Threats
Area	Economies of Scale of production	Often grown as mixed crop	Inter-linked with the area expansion of coconut & arecanut	Decreasing trend
Production	-	-	Adoption of production technology	-
Productivity	-	Predominance of local varieties	-	Diseases like Black pod & rodents like squirrel
Cost of production	-	High as compared to international level	Competitiveness through higher productivity	-
Consumption pattern	-	Unable to meet domestic demand	Growing urban markets	-
Marketing	Co-operatives are viable	Monopoly purchase	-	High degree of price instability
Processing	Less production	-	Product diversification in beverage/ confectioneries	Liberalized trade
International Trade	-	Production unable to meet domestic demand	-	-

CASHEW

India is the largest producer of cashewnut in the world. The annual production of cashew in the country is about 3.8 lakh tonnes from an area of about 5.96 lakh ha. However, the average productivity of cashew in the country (698 kg/ha) is one of the lowest in the world. There are more than 670 cashew processing factories in the country with a processing capacity of 5.5 to 6.0 lakh tonnes of raw nuts annually. The domestic production is sustaining these industries only to the extent of 50 per cent of the their full capacity. Hence, to meet the domestic demand, India imports raw nuts from other countries. Based on the present trends of area expansion, it is expected that by the turn of the century, the area under cashew will be about seven lakh ha with a targeted production of around seven lakh tonnes. Even with the current level of domestic consumption of 50 per cent, India would contribute about 70 per cent of the world market.

Particulars	Strength	Weakness	Opportunities	Threats
Area	-	Predominance of small/ marginal farms Neglected gardens	Scope for expansion	-
Production	-	-	Adoption of production technology	Pests like Neem Mosquito bug
Productivity	-	Predominance of seed propagation	Scope for increase through vegetative propagation	-
Cost of production	-	Very low due to non adoption of technology	Competitiveness through higher productivity	-
Consumption pattern	-	50 per cent consumed in domestic market	-	-
Processing	Established factories Abundance of labour	Less production Lack of quality consciousness	New methods	-
International Trade	-	Established countries	Liberalized Trade/ Technology perfection	-

ESTATE CROPS

Tea, coffee and rubber are the three major estate crops. India is the largest producer of tea in the world. The country ranks fifth and tenth respectively in global rubber and coffee production. The annual export from these crops is worth about Rs.14000 million. The scope for product diversification is much limited as compared to that of small-holder's plantation crops. However, in case of rubber processing factories, it is observed that the capacity utilization is less than 50 per cent.

SPICES

Pepper, cardamom, turmeric, chillies are the major spices cultivated in India. The country leads the world in the production of black pepper (0.053 million tonnes from an area of 0.195 million ha). These spices is also utilized by industrial units for the production of Oleoresins, masala products, oil extraction, confectioneries and bakeries.

CONCLUSION

The scope for product diversification is more in case of small holder's plantation crops and spices. A sustained growth in production and productivity coupled with technology perfection would equip the country to face the challenges both in the domestic and international markets.

REFERENCES

George MV (1997). Status of Plantation Crops in India, J. Platn. Crops, 25(1), pp.1-14

Economic Survey 1997-98, Government of India

INTEGRATED PROCESSING OF COCONUT

C. Arumughan

INTRODUCTION:

With a total production of 14,000 million nuts/year (1997), India is the largest producer of Coconut in the world. Needless to say, coconut culture and processing play a dominant role in the agricultural economy of southern India which contributes more than 90% of the coconut production in the country. Coconut industry, by and large, depends on the volatile market of coconut oil. Dependence of coconut mainly on coconut oil therefore is not in the interest of coconut and coconut growers. Unlike other oil seeds, the potential for processing raw coconut for diverse food products is very high.

POTENTIAL AND SCOPE OF PROCESSING FRESH COCONUT:

Fresh mature dehusked nut yields on an average 50% kernel, 20% water and 30% shell. Wet kernel containing 40% fat, 3% sugars, 4% protein, 1% minerals and 50% moisture. Besides, mid and pleasing aroma of the kernel is a major subjective attributes for the universal appeal of coconut products. Wet processing of coconut preserve the natural aroma in the end products. Several commercially viable processing methods have been developed to produce value added products from the wet kernel. The important products are; virgin oil, coconut milk/coconut cream, coconut milk powder, desiccated coconut.

PROCESS FOR SHELF STABLE COCONUT MILK/CREAM:

Raw material: Well matured fresh coconuts after dehusking are the starting raw material for the process.

Deshelling and Paring: Deshelling is done manually with specialized tools and technique so as to obtain kernel in the form of ball. Next step is the removal of the brown testa over the ball, keeping the water inside, again manually and this step is known as Paring. In the process of removing the testa a small portion of the kernel is also removed resulting in a weight loss about 10-15% dry weight. The water is released by splitting the white ball.

Blanching: The white wet kernel is then subjected to blanching by soaking in hot water at 80°C for about 10. The objectives of blanching is to reduce the microbial content and to inactivate lipolytic enzymes that would affect the quality of the end product while passing through the subsequent steps.

Comminution: The wet kernel after blanching is subjected to size reduction through milling operation. There are several standard size reduction equipments available. Comparative evaluation of the available equipments indicate that hammer mill is the most appropriate for the purpose. Particle size is also crucial for the subsequent milk extraction. Sieve of appropriate size is used to control the particle size.

Milk extraction: Most crucial operation of this process is the wet pressing of the wet powder after hammer milling in terms of milk yield. The wet powder is passed through a specially designed screw press with high compression ratio. The press is designed in such a way that the powder is subjected to progressively increasing pressure as it is conveyed by the screw worms from the feeding end to the discharge end. The milk is expelled through the perforation of the cage and collected in the receiving chamber and subsequently discharged through pipe. The residue is discharged through the other end of the cage. To obtain economic level of yield it is necessary to repeat the pressing of the residue with addition of appropriate quantity of water. About 70-75% of the solids (including oil) of the wet kernel can be extracted by this method. The milk from all the pressing is pooled for the next operation.

Emulsification: Fresh coconut milk is a weak oil-in-water emulsion and therefore separates into water and oil within few hours after extraction. Separation is a poor quality attribute and it is important that the weak emulsion is stabilized using appropriate additives like emulsifiers, stabilizers etc. It may be necessary to use combinations of different emulsifiers and stabilizers at particular ratio to impart maximum stability to the emulsion. Stability of emulsion is also a function of size of the oil globules and their distribution. Emulsification and homogenization are terms used for preparation of stable emulsions. Emulsification is done to mix the emulsifiers and stabilizers with the milk to make a crude emulsion using high speed mixers designed specially and for the purpose. Oil globules of size 1-2m and uniform distribution is essential to longer stability and quality. High pressure homogenization is employed for this purpose. Homogenization is a process by which the crude emulsion is passed through a small orifice of few microns under high pressure and velocity and subsequently scattering that facilities creation of micro globules of uniform size. Coconut milk/ cream emulsion made by this technique will be stable for few months with minimum phase separation.

Pasteurization/Preheating: Preheating the coconut milk/cream is essential to reduce the microbial load as the first step of heat treatment to prevent spoilage of the finished product. A specially designed heating system employing a plate heat exchanger coupled with a holding tank is used for this purpose. The product is subjected to heating cycle at 90°C for 15 min.

Can filling: Filling the hot milk/cream cans is the next operation which consists of a storage tank and filling heads. In the case of aseptic packing paper laminates are used as containers following the method of pre-packing in which the products and packaging materials are sterilized separately and filled and sealed under aseptic environment.

Can exhausting: Exhausting is a process by which the cans filled with the product is conveyed through a tunnel filled with live steam. This facilities the displacement of air in the head-space with steam which on condensation creates partial vacuum thereby improving the shelf life of the canned product.

Can sealing: After the exhaust operation the cans are sealed using automatic can sealer.

Can sterilization: Finally, the canned coconut milk/cream is sterilized with a temperature-time combination to ensure commercial sterility of the product that enables the product stay without spoilage. Since the coconut milk is highly sensitive to heat a judicial use of heat is preferred in combination with high standard of plant hygiene and specially designed sterilizers to reduce the impact of heat. Rotary retort designed for this purpose is employed where the cans in retort are kept in very low rotary motion and ensure intimate mixing of the product which facilitates faster heat penetration and uniform distribution. Normally a steam pressure of 15 psi (pounds per inch square) or 1 atmosphere equivalent to 120°C for 20 minutes is the requirement for the canned coconut cream. After the sterilization, the cans are cooled in running water and subsequently labelled.

COCONUT MILK POWDER

Processed coconut milk/cream either in can or in tetra pack is shelf stable and an important value added product from fresh coconut produced and marketed commercially in major coconut growing countries. Coconut milk/cream is a base product used in culinary, confectionery, bakery, soft drinks with appropriate dilution. Coconut milk/cream powder is a derived product from milk made by dehydrating it under controlled conditions. Production of coconut milk/cream and mild powder have a common flow sheet upto the pasteurization stage. Composition of the milk requires to be adjusted with fat percentage in the range 50-60% of the total solids. This is done by separating the cream from milk employing a cream separator and reconstituting the milk. Emulsifiers and stabilizers are also added to the formulation. An important additive for making powder is an encapsulating material that contain fat. Formulation is followed by emulsification and homogenization as in the case of coconut milk/cream production. Most crucial step is the dehydration stage for which spray dryer is employed. A controlled stream of the homogenized milk is admitted through a rotary sprayer into the drying chamber of the spray dryer kept under vacuum and at high temperature (around 180°C). Instant dehydration takes place converting each time drop entering the drying chamber into micro capsules with fine droplet of the oil inside. Anticaking agent facilitate formation of free flowing powder. Coconut milk is a high fat product (50-60% fat) and highly hydroscopic requiring good quality packaging material with moisture barrier properties. The milk/cream powder can be reconstituted with additional water to obtain milk/cream.

DESICCATED COCONUT

Desiccated coconut (DC) is dry coconut powder made from fresh mature coconut and can be used in place of fresh coconut. Process steps for DC are similar to those of coconut milk processing upto Hammer milling stage. The wet powder is dried in a dryer using hot air at 60°C by counter current method. DC is high fat product with 62-67% fat and it is mostly consumed in bulk in the bakery sector. Promotion of DC in consumer packs has not been attempted seriously. Exploitation of consumer/retail market for DC would encourage wide spread usage of coconut even in non-traditional areas.

PROCESS FOR VIRGIN OIL

Coconut oil extracted from fresh coconut without heat treatment is known as virgin oil. Virgin coconut oil possesses the natural coconut aroma and water white in appearance. Since it is made from coconut milk, the processing method is common upto extraction of coconut milk as described before. The pooled milk without any additives is treated for demulsification through addition of salt, pH adjusted and slight warming. This facilitate precipitation of proteins and other emulsifying agents naturally present in coconut milk. Coconut milk thus will have three phases; oil, water and solids. The sludge is separated first by gravity in settling tanks. The supernatant containing oil and water is subjected to continuous centrifugation in a disc type liquid -liquid separator. The oil is subjected to vacuum drying to adjust moisture below 0.15%.

Quality of the virgin oil is superior as compared to that of expeller or rotary origin in terms of natural aróma, colour, free fatty acid content etc. However, cost of production of virgin oil is substantially high and therefore it should be sold at premium price in order to make this process commercially viable.

PROCESS AND PRODUCTS INTEGRATION THROUGH BY-PRODUCTS UTILIZATION

Wet processing of coconut whether it is for coconut milk or virgin oil involve a series of unit operations requiring specially designed equipments and therefore it is capital and technology intensive. Needless to say that the end products need to face marked resistance due to higher price and being non-traditional. Commercial viability of wet processing can be enhanced only through processing by-products and marketing. Major by-products in coconut milk/cream processing are the residue after milk extraction, coconut water and coconut shell. Residue contain 45-50% fat, 8% protein, 4% sugars and 1% minerals on dry weight and therefore is comparable with DC except for its lower oil and higher fibre content. Either it can be promoted as health product due to low fat and high fibre content as compared to DC or it can be formulated and sold as ready to use curry powder. Coconut water contains about 2-3% sugars and 0.5% minerals. After fortification with sugars and subsequent fermentation the water can be profitably utilize for Coco Vinegar with the pleasing aroma of coconut and therefore it can be sold as premium quality as compared to synthetic vinegar now available in the market. Shell is yet another by-product to be exploited for value added products. Conversion of shell into charcoal and in that process the waste heat generated can be utilized to dry the wet residue after milk extraction. Thus product and process integration as described here and marketing of the by-products need to be built in features of the wet processing technology for its commercial viability.

CPCRI -KSD
G3230