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RUBBERSEED PROCESSING FOR THE PRODUCTION OF VEGETABLE OIL AND ANIMAL FEED*

US/GLO/81/103

Phase two

Collection, drying, decortication and storage of rubberseed, oil extraction, edible and technical oils, animal feeding tests on protein cakes, marketing and economic and financial evaluation

Prepared by the

Ceylon Institute of Scientific and Industrial Research**

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* This document has not been edited.

** 363, Bauddhaloka Mawatha, Colombo 7, Sri Lanka under the leadership of E. R. Jansz, Director and L. P. Mendia, Team Leader.

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FOREWORD

It is with great pleasure that we submit our sixth interim report - Draft final, on the UNIDO Global Rubber Seed Project-Phase Two (Contract No.87/34/PB). This work is a follow up of Phase One, preliminary work on Rubber Seed Processing carried out by NATEC laboratories, West Germany. In our investigations which commenced in May 1987 the emphasis was on extension of laboratory work highlighted in Phase One and pilot plant investigations to define optimum conditions to scale up for semi-commercial operations. We have been successful in obtaining parameters for efficient extraction of rubber seed oil by high pressure screw expelling and also documented commercial practice for extraction of technical rubber seed oil. Other investigations have dwelt on such topics as constraints to rubber seed processing, product markets, animal feed trials and financial/ economic analysis.

Work in Phase Two was undertaken by the following team of senior scientists and engineers of the CISIR - L P Mendis (Team Leader), Miss M J Gooneratne, T Habarakada, G S Jayatilake, A L Jayewardene, A M Mubarak, P S Peiris, Mrs K M Pieris, G Rajapakse and R C Wijesundera. They were ably supported by many other research and technical personnel of the CISIR. Animal feed tests were carried out by Dr G A P Ganegoda of the Veterinary Research Institute, Department of Animal Production and Health, Gannoruwa, Peradeniya.

CISIR is grateful to numerous organizations and individuals both within and outside Sri Lanka who helped us in our investigations, a list of these contacts is given in Appendix 4. Our Institution has endeavoured to complete the task entrusted to us to the best of our ability and we alone are responsible for any errors of omission and commission.

E R Jansz
DIRECTOR.
CEYLON INSTITUTE OF SCIENTIFIC & INDUSTRIAL RESEARCH.

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CHAPTER 1

INTRODUCTION

1.1 Background

Phase Two of the UNIDO Global Rubber Seed Project was targeted to carry out product and process research and expected to result in the final definition of the most suitable rubber seed processing technology for production of defined quality rubber seed oil and meal. Earlier in the Phase One operation (carried out by NATEC, W. Germany) a comprehensive literature survey and laboratory work was carried out to pinpoint areas needing attention for successful commercial utilization of rubber seed. The Phase Two operation involved laboratory, pilot plant and field operations covering two seasons of seed fall (1987 and 1988) in Sri Lanka and information was also obtained from commercial rubber seed processing practice in South India and Sri Lanka. In this chapter, plantation aspects and brief descriptions of work carried out in Phase Two are recorded.

1.2 Plantation Aspects of Rubber Seed

Rubber seed fall is seasonal, the harvesting season of about two months' duration depending on location. In Sri Lanka, plantations which are subject to South West monsoonal rains harvest during August-September while those subject to North East monsoonal rains harvest during the December-January period. The yield of seed is dependent on weather patterns during the flowering season which occurs six months before seed fall and also during harvesting and also such other factors as clonal variation, fertilizer selection and fungal attack *(Phytophthora palmivora* and *Oidium heveae)*. The average annual collection of seed in natural rubber producing countries has been estimated in the range 55-300kg/hectare (Phase I report), the average for Sri Lanka in the best collection years being about 100kg/hectare. Plantation practice in selection of clones and manuring (lowered N.K ratio) are not conducive to seed formation in Hevea.

In the two seasons during which we gathered information on seed fall patterns, estimates (on areas from which seed was collected) were between 20-200kg/hactare/season. Several estates and smallholders recorded no collection of seed due to bad weather conditions during the period of seed fall due to pod rot. Collection of rubber seed also presents difficulties due to pecularities in terrain and high labour costs. Some of the plantations entrusted the job of collection to tappers, paying incentives while in smallholdings collection was carried out as a family routine. An estimate of potential for annual rubber seed harvesting is given in Table 1.1 for some countries with interest in commercial production of Hevea (the minimum figure of 55kg/hectare/year has been assumed for seed collection). The total estimate of 437,855 tons/year of rubber seed is much less than conventional oil seed production (Table 1.2), nevertheless with increasing demand for vegetable oils, could play a useful complementary role in Hevea producing countries.

1.3 Laboratory Work

Experimental investigations in Phase 2 were an extension of preliminary experiments carried out in Phase I and additionally work of relevance to pilot plant and animal feeding trials. These included the following areas:-

(a) collection, characterization and preparation of rubber seed

(b) drying in relation to moisture and cyanide levels

(c) lipase activity and FFA change

(d) moisture uptake and loss during storage of rubber seed

(e) oil extraction

(f) toxic substances such as aflatoxins, gossypol and saponins

(g) polyisoprene in rubber seed oil

(i) preparation of soap, alkyd resin and vulcanized oil

(j) hydrogenation

(k) characterization of rubber seed oil and meal

1.4 Pilot Plant Trials

Investigations were carried out to determine optimum conditions for drying, decortication and storage of seed. The most significant contribution was in the area of expelling fresh rubber seed kernel where parameters using conditioning (cooking) and high pressure screw expelling were defined. Filtration studies clearly indicated that the presence of poly(isoprene) did not retard rates of filtration.

1.5 Product Market Tests and Animal Feed Trials

Product market tests highlighted the possibility of use of RSO for edible purposes, as a source of nutritionally valuable α-linolenic acid, blending with other vegetable oils or light (brush) hydrogenation being required to reduce odour and darkening on heat treatment. Frying and cooking experiments were also carried out to compare rubber seed oil with other vegetable oils. Technical oil of high FFA content is obtained commercially by expelling aged undecorticated rubber seed.

1.6 Financial/Economic Evaluation

Project evaluation/appraisal studies (using *UNIDO GUIDELINES)* carried out on rubber seed processing showed that with respect to base parameters in Sri Lanka, the Financial and Economic Internal Rates of Return (FIRR and EIRR) for production of edible quality oil are slightly less than minimum values of 20% and 13% for project acceptance in Sri Lanka. The main reasons adduced for lowered profitability of production of edible quality RSO are high costs of production due to the requirement of high pressure expelling, low capacity utilization and high costs of refining. On the other hand production of technical oil requires reduced capital investment and combined with low priced raw material in the form of aged, undecorticated rubber seed, yields high returns on investment.

Table 1.1 - Potential for Rubber Seed Collection

Country	Year of estimate	Area under cultivation ('000 Hectare)	Seed collection Tons/year
Brazil	1965	20	1,100
China	1982	453	24,915
India	1987	398	21,890
Indonesia	1986	2872	157,960
Liberia	1973	120	6,600
Malaysia	1987	1875	103,125
Nigeria	1982	185	10,175
Sri Lanka	1987	205	11,275
Thailand	1986	1718	94,490
Vietnam	1983	115	6,325

Note: Total seed collection is 437,855 tons/year

(Source : Association of Natural Rubber Producing Countries, Kuala Lumpur).

Table 1.2 - Estimate of Annual World Oil Seed Production 1987/1988.

Oil seed type	Seed production (million tons)
Soya bean	101.4
Cotton seed	30.0
Rape seed	22.2
Sunflower	20.4
Peanut	19.1
Copra	4.5
Flax	2.4

(Source : J. American Oil Chem. Soc., May 1988 issue).

CHAPTER 2

COLLECTION, DRYING, DECORTICATION AND STORAGE OF RUBBER SEED

2.1 Introduction

Rubber seed fall is seasonal and occurs at most for a period of two months. The seed is also very much prone to biological attack hence the need to establish optimum conditions for collection, drying, decortication and storage operations. In this chapter field, laboratory and pilot plant trials are described.

2.2. Collection of Rubber Seed

Field collection trials showed that best quality seeds were obtained if collected soon after seed-fall, with minimum duration of contact with ground. The possibility of lipase activity and fungal infestation increased with longer duration of seed on ground. In Table 2.1 FFA and total cyanide values of seed collected after varying periods are given. Differences in FFA and moisture levels are random but a clear pattern of increased FFA for seed collected after increased number of days frequency is noticeable. It was also noted that the ratio of kernel weight/weight of whole seed was dependent on quality, irrespective of moisture levels. Results in Table 2.2 indicate a ratio greater than 60% for good quality seed and less than 50% for poor quality seed. Thus to obtain best quality seeds, collection must be carried out as frequently as possible, preferably on a daily basis. Field collection trials carried out on a small scale on a daily basis gave FFA levels of 1-2%

whereas seed collected on a weekly basis had FFA levels in the 10-15% range. It was also noted that mechanical removal of in d seed reduced FFA levels, although when large qua es are processed, this would be not possible.

2.3 Drying of Rubber Seed

Fresh rubber seed has a moisture content of about 30% and hence it is most important to reduce moisture levels to about 5% for storage purposes (experimental proof of this requirement is given in Section 8.5) to prevent increase of FFA due to lipolytic activity. Drying also helps in reduction of cyanide levels (Section 8.3) to a large extent. The following methods of drying carried out during field trials are described:-

(a) indirect dryer
(b) smoke house
(c) copra kiln
(d) sun drying
(e) solar cabinet

2.3.1 *Indirect dryer* (Fig.2.1)

The indirect dryer constructed in the premises of the Ceylon Institute of Scientific and Industrial Research was a drying house of brickwork with flue pipes arranged as shown and could be categorised as a dryer with natural draft hot air circulation (Ref.1). The path of hot air could be regulated by a set of dampers fixed on the ceiling of the drying house, temperature of air (60-75^{o}C) being controlled by air intake and quantity of fuel used. For the latter purpose dry rubber wood was used and this was supplemented with rubber seed shell as stocks built up on decortication (one disadvantage with use of rubber seed shell was high level of carbonaceous matter which built up during use).

Whole seed or kernel was spread on the grating (drying floor) made of arecanut *(Arica catechu)* strips. It was possible to spread 200kg whole seed or 250-300kg kernel per batch. A uniform temperature was maintained in the horizontal plane after a period of stabilization of about three hours, temperature difference between drying floor and ceiling being about 10°C on the average (temperature less at ceiling level). Drying time to reduce moisture content of rubber seed from 20-25% to the 5% level was typically about 18 hours but material was kept for a further period after shutdown for cooling and reduction of cyanide levels in the air (Section 8.3).

2.3.2 *Smoke House* *(Fig.2.2)*

Since smoke houses are plentifully available in plantation areas for purposes of drying sheet rubber, field trials were carried out to evaluate smoke house drying. A typical smoke house was modified by fixing layers of wire mesh or use of metal trays for purposes of holding rubber seed. Since there was the possibility of fire due to evolution of combustible gases during drying of rubber seed, care was taken to prevent direct impinging of flame on the dyring area, especially during the initial stages. The sheet of metal normally used as an arrester in smoke houses was adequate for this purpose. Maximum temperatures attained during field trials were around 50° C. A period of 3-4 days was necessary to reduce moisture levels of fresh seed to 5%. A total of 2200kg of seed was dried in four smoke houses in batches ranging from 65-350kg.

2.3.3 *Copra Kiln (Fig. 2.3)*

Kilns for coconut drying are usually found in rubber growing areas and advantage was taken to evaluate drying of rubber seed in copra kilns. These were of the directly heated smokeless type (Ref.1) using coconut shell as fuel. Risk of fire was high especially if steps were not taken to control the burning of coconut shell by arranging these in separate rows. Fire hazards arise from evolution of flammable gases and concentration of these gases would be reduced if seeds are pre-dried e.g. by sunlight to reduce moisture levels. Investigation of a pilot plant kiln which burnt down during drying operations revealed that logs of firewood had been used instead of the normal coconut shell, resulting in flame impinging on the drying floor. Temperatures of 60°C were readily attained during trials, duration to reduce moisture levels to 5% being 2-3 days. A total of 1700kg of seed were dried in copra kilns during field trials, a typical batch being about 400kg whole seed.

2.3.4 *Sun drying*

Natural sun drying of seed would be the least expensive method of drying and if weather conditions are conducive would be the most convenient. Sun drying during field trials required a period of 4-5 days to reduce moisture levels to 5-7%, rates of drying of whole seed and kernel being about equal. About 500kg of seed were sun dried during pilot plant operations.

2.3.5 *Solar Cabinet (Fig.2.4)*

An experimental solar cabinet constructed on a pilot plant scale was used for drying of seed and kernel, temperatures around 80°C maximum being attained, so that drying to the 5% level was achieved in one day. Costs and inability to handle large quantities do not favour solar cabinet drying.

2.3.6 *Discussion of Drying Methods*

All drying methods carried out during field trials were satisfactory with respect to attainment of objective of reduction of moisture levels to 5% (being the optimum moisture level for storage) however efficiency, cost and safety factors varied. Whereas indirect drying presented no fire hazard, direct drying in smoke houses and copra kilns need to be carried out cautiously with fire arrester installation in the former and orderly combustion of coconut shell in the latter. A short period of pre-drying in the sun also greatly reduces the fire risk since the bulk of combustible products are liberated at high moisture levels. It may also be noted that rates of drying of kernel and seed are similar. Wherever possible it would be best to pre-dry seed in the sun soon after collection before subjecting to drying to attain optimum moisture levels around 5%. The practical determination of attainment of optimum moisture levels could be made by crushing the kernel between fingers and noting hardness, with some experience. A summary of drying conditions is given in Table 2.3.

2.4 Decortication of Rubber Seed

Supply of good quality oil and meal was dependent on efficient decortication of rubber seed i.e. separation of shell from kernel. During laboratory and pilot plant trials over ten tons of freshly collected seed were decorticated by the following methods:-

(a) disc grinder
(b) drum type
(c) manual.

2.4.1 *Disc Grinder Decorticator (Fig.2.5)*

Equipment consists of two metal discs, one stationary other rotating at high speed driven by a 2HP 3 Phase motor, clearance between discs being adjustable. An average output rate of about 35kg/h (total of kernel and shell fragments) was attained with fresh seed, power consumption averaging 0.4kW.

2.4.2 *Drum Decorticator(Fig.2.6.)*

Consists of a rotating drum made of hard wood (Artocarpus integra Merr.) located inside a chamber built with the same wood, clearance between drum and surface of chamber decreasing towards the outlet. The clearance itself is adjustable to accomodate different size of seed. The drum was lined symmetrically with four wooden wedges parallel to its axis and driven by a 1 HP single phase motor. Decortication with minimum damage of kernel occurred at a drum rotation of about 300 rpm. Average output rate was 60kg/h for fresh seed with a power consumption of 0.5kW.

2.4.3 *Separation of Shell from Kernel after Decortication*

The process of decortication must be followed by separation of kernel from shell fragments to ensure good quality of kernel. For this purpose a pneumatic type of separator was designed and fabricated (Fig.2.7). Crushed seed was fed from the Vortex finder end and air flow adjusted for efficient separation. An average output rate of 75kg kernel/h was possible at an air flow rate of 0.11m^3/s (linear velocity of 18 m/s).

2.4.4 *Manual Decortication and Separation*

About 1500kg of rubber seed were decorticated and separated manually, this being the preferred manner of operation in rubber producing areas. It was possible to obtain about 8kg of kernel/hr/person. It may be noted that in South India manual decortication and separation is carried out almost entirely in commercial rubber seed processing.

2.4.5 *Effect of Moisture Content on Decortication of Rubber Seed*

One important observation made during decortication operations was the fact that efficient decortication (as judged by high rate of production of kernel with reduced fragmentation) was possible in the 10-20% moisture level of seed. Above this level, removal of shell from kernel was difficult possibly due to strong adhesion while at lower moisture content fragmentation of kernel was evident to a large extent making separation difficult as shown in Table 2.4.

2.5 Storage of Rubber Seed

Rubber seed collection takes place during a two month period so that storage of dried seed or kernel is necessary for subsequent processing. Several trials on storage showed that provided seed or kernel is subjected to a heat treatment to reduce moisture levels to 5%, material kept in a satisfactory state without much increase in FFA or fungal contamination, provided steps were taken to keep material enclosed. Changes in parameters on storage are shown in Tables 2.5, 2.6, 2.7 and 2.8.

The following deductions can be drawn from the data in these tables:-

(a) keeping qualities of whole seed are better compared with kernel

(b) if kernels are well enclosed and stored they can be kept for long periods

(c) cyanide levels reduce during storage, rates being higher under ventilated conditions.

Moisture uptake and loss of seed/kernel during storage is dependent on ambient conditions. Equilibrium moisture content of seed and kernel under relative humidity and temperature ranges prevalent were 5.5-7.5%.

2.6 Summary

Analysis of laboratory and pilot plant trials clearly showed that best quality seed is obtained if collection is carried out immediately after seed-fall with minimum ground contact duration. Soon as seed is collected it is preferable to pre-dry seed in the sun to reduce moisture levels as far as possible and carry out subsequent drying to the 5% moisture level in indirect dryers, smoke houses or copra kilns. The risk of fire hazard is greatest in smoke houses and copra kilns and adequate steps must be taken to prevent impinging of flame on the drying floor. Decortication can be carried out mechanically or manually and it has been noted that decortication is most efficient in the 10-20% moisture level of seed. Storage, if carried out after reduction of moisture levels to 5% is satisfactory if steps are taken to keep material air-tight. Seed keeps better on storage compared with kernel.

2.7 References

1. Coconut Processing Technology Information Documents, Part 1 of 7, "Coconut Harvesting and Copra Production" UF/RAS/78/049 (UNIDO 1980).

Table 2.1 - Characteristics of Rubber Seed of Defined Frequency of Collection

Frequency of collection (No. of days)	Moisture content of kernel (% by mass)	FFA Of oil expelled from kernel %	Total Cyanide content of kernel mg/kg on dry basis
1	39.0	0.8	4230
2	33.5	2.0	ND
3	17.3	5.7	ND
4	27.4	3.4	1260
5	15.6	8.2	3300
7	12.2	9.4	ND
10	9.5	15.3	ND

ND - Not Determined

Table 2.2 - Grading of Quality of Rubber Seed According to Ratio of Weight of Kernel/Weight of Whole Seed

Type of Seed	Weight of Kernel / Weight of whole seed x 100%
Good quality	>60
Medium quality	50-60
Poor quality	<50

Table 2.3 - Summary of Drying Conditions

Method of drying	Initial moisture content %	Temperature range °C	Duration of operation (hrs)	Final moisture content %
Indirect	15-25	70-80	24	2-5
Solar cabinet	15-25	max.80	8-10	5-6
Smoke house	15-25	40-50	72-96	5-7
Copra kiln	15-25	40-60	48-72	5-7
Sun	15-25	30-34	96	6-8

Table 2.4 - Relation of Moisture Level of Rubber Seed to Decortication Efficiency

Moisture content %	Weight kernel (kg) obtained from 100kg of seed after decortication and pneumatic separation	Output kg kernel/hour
5.2	36	14
16.7	52	25
26.1	42	20
30.6	38	18

Table 2.5 - Effect of Storage on Heat Treated Rubber Seed Kernel

Storage time	SEALED POLY BAGS			POLYPROPYLENE WOVEN BAGS			STOCK PILE		
(Weeks)	M.C.	Pet Ether Extract	F.F A	M.C	Pet Ether Extract	F F A	M C	Pet Ether Extract	F F A
0	3.9	46.2	0.8	3.9	45.5	0.8	3.9	44.7	1.0
1	3.3	40.1	0.6	5.0	43.0	1.1	5.9	35.7	1.4
2	3.3	40.0	0.9	6.4	43.0	2.1	7.0	37.4	2.0
4	3.7	40.1	1.3	6.9	43.5	2.2	7.5	40.2	3.1
8	3.9	37.7	1.6	7.5	41.6	6.5	8.4	41.3	10.0
12	4.4	35.2	3.5	7.7	39.2	9.3	8.0	35.0	12.1

Material - Kernel heat treated at 75°C for 16 h in Mitchell drier

Storage - Ambient conditions

M C - Moisture content (Mass %), Pet Ether Extract - Mass % (on dry basis)

F F A - (as oleic acid) % on Pet Ether extracted oil

Table 2.6 - Changes in FFA of Heat Treated Rubber Seed Kernel and Whole Seed on Storage

Storage Time (Days)	WHOLE SEED		KERNELS	
	Enclosed in POLY bag	Stock piled (open)	Enclosed in POLY bag	Stock piled (open)
0	0.9	0.9	0.9	0.9
10	1.3	1.0	0.8	0.6
18	1.1	1.3	0.6	0.6
40	1.3	2.9	1.5	8.7
100	2.7	1.4	4.2	18.1

Material - Whole seed and kernel dried at 75°C for 3 days in Mitchell drier (initial moisture content less than 5%)

Storage - Ambient conditions

F F A (as oleic acid)% - on oil got by pressing

Table 2.7 - Change in FFA of Heat Treated Rubber Seed Kernel and Whole Seed on Storage

Storage Time (Days)	WHOLE SEED Enclosed in POLY bag	WHOLE SEED Stock piled (open)	KERNELS Enclosed in POLY bag	KERNELS Stock piled (open)
0	1.6	1.6	1.6	1.6
7	2.5	2.5	2.9	2.2
14	2.3	2.9	3.0	2.0
21	3.2	2.4	2.5	2.4
100	3.1	4.3	2.2	*

Material - Whole seed and kernel dried at 100°C for 2 days in Mitchell drier (initial moisture content less than 5%)

Storage - Ambient conditions

F F A (as oleic acid)% - on oil got by pressing

* - material perished

Table 2.8 - Storage of Dried Kernels under Different Conditions - Variation in Total Cyanide Levels

Storage Time (Weeks)	Condition of storage	Total cyanide mg/kg on dry weight of kernels	Total cyanide loss %
00	-	283	-
04	Ventilated	48	83
08		38	87
12		38	36
16		36	87
08	Sealed POLY bag	234	17
16		234	17
04	Polypropylene bag (closed)	99	65
08		80	72
12		79	72
16		33	88

Material - Rubber seed kernel dried at 75°C for 12 hours in oven with blower.

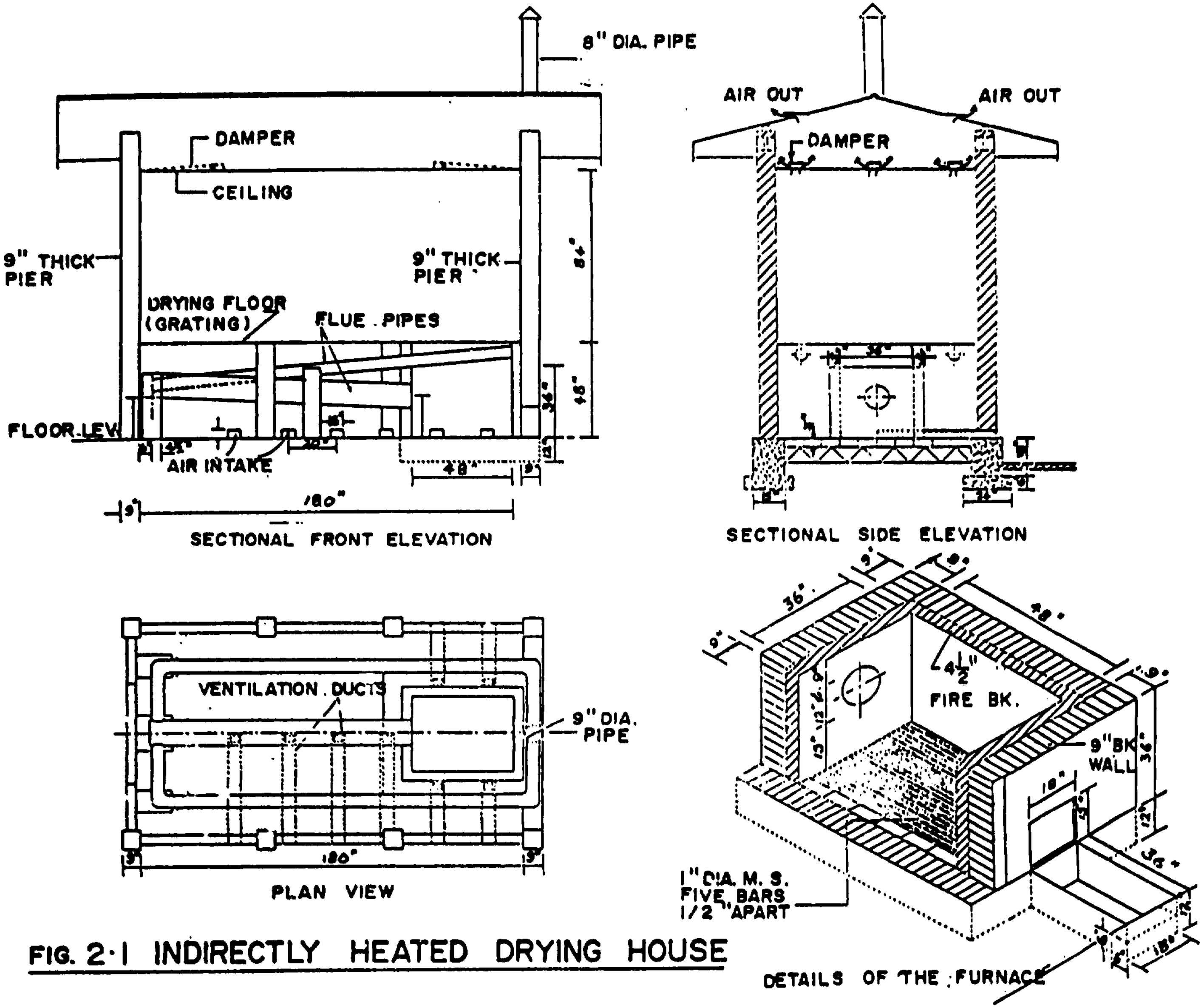


FIG. 2·1 INDIRECTLY HEATED DRYING HOUSE

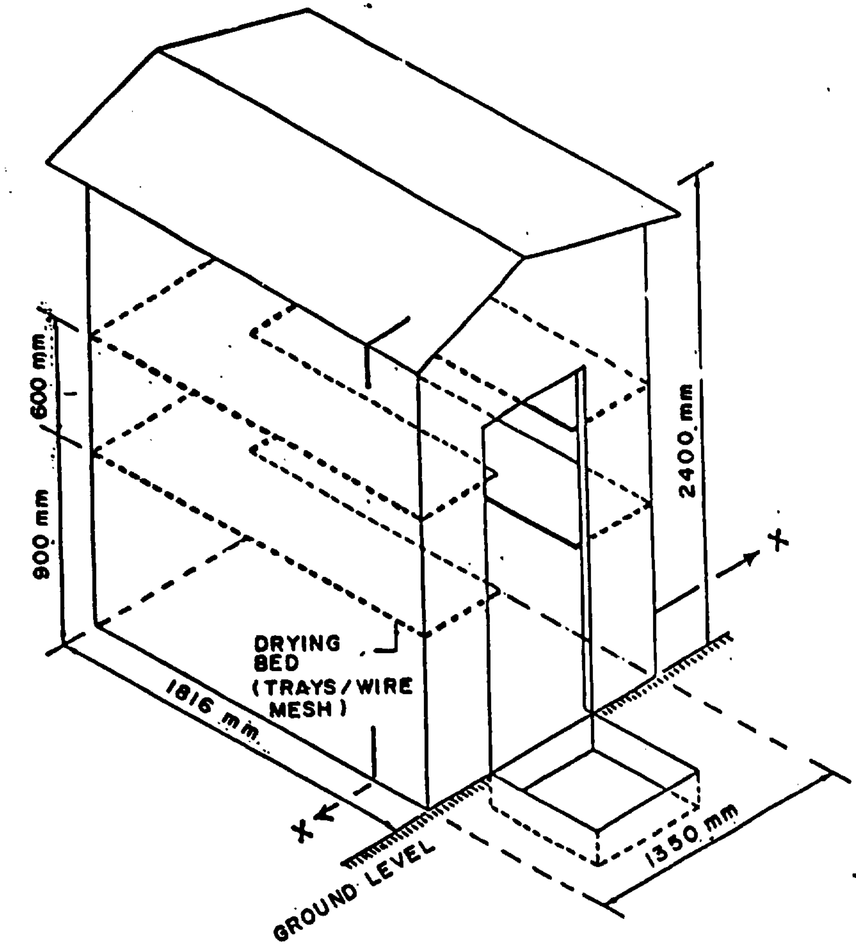
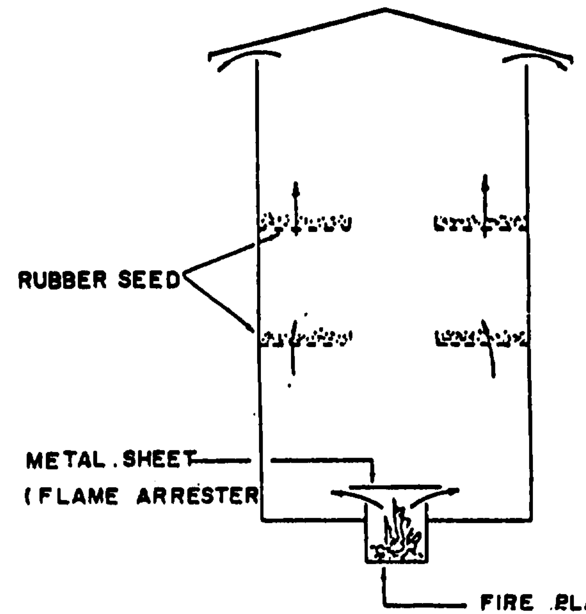
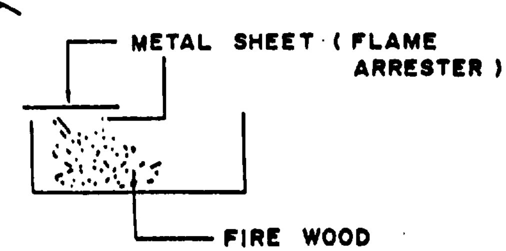


FIG. 2·2 SMOKE HOUSE



SECTIONAL VIEW THROUGH X - X



DETAILS OF THE FIRE PLACE

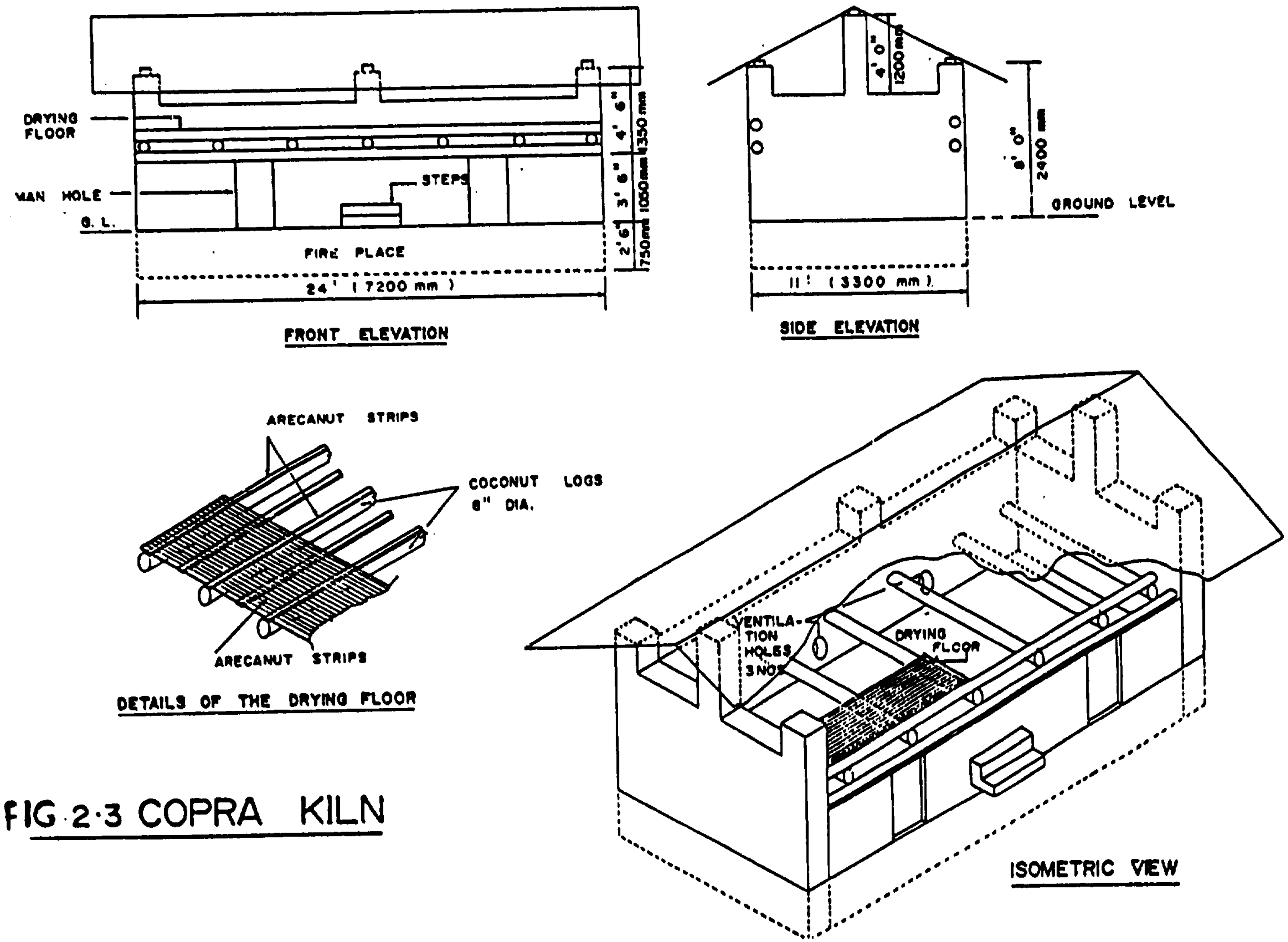


FIG 2·3 COPRA KILN

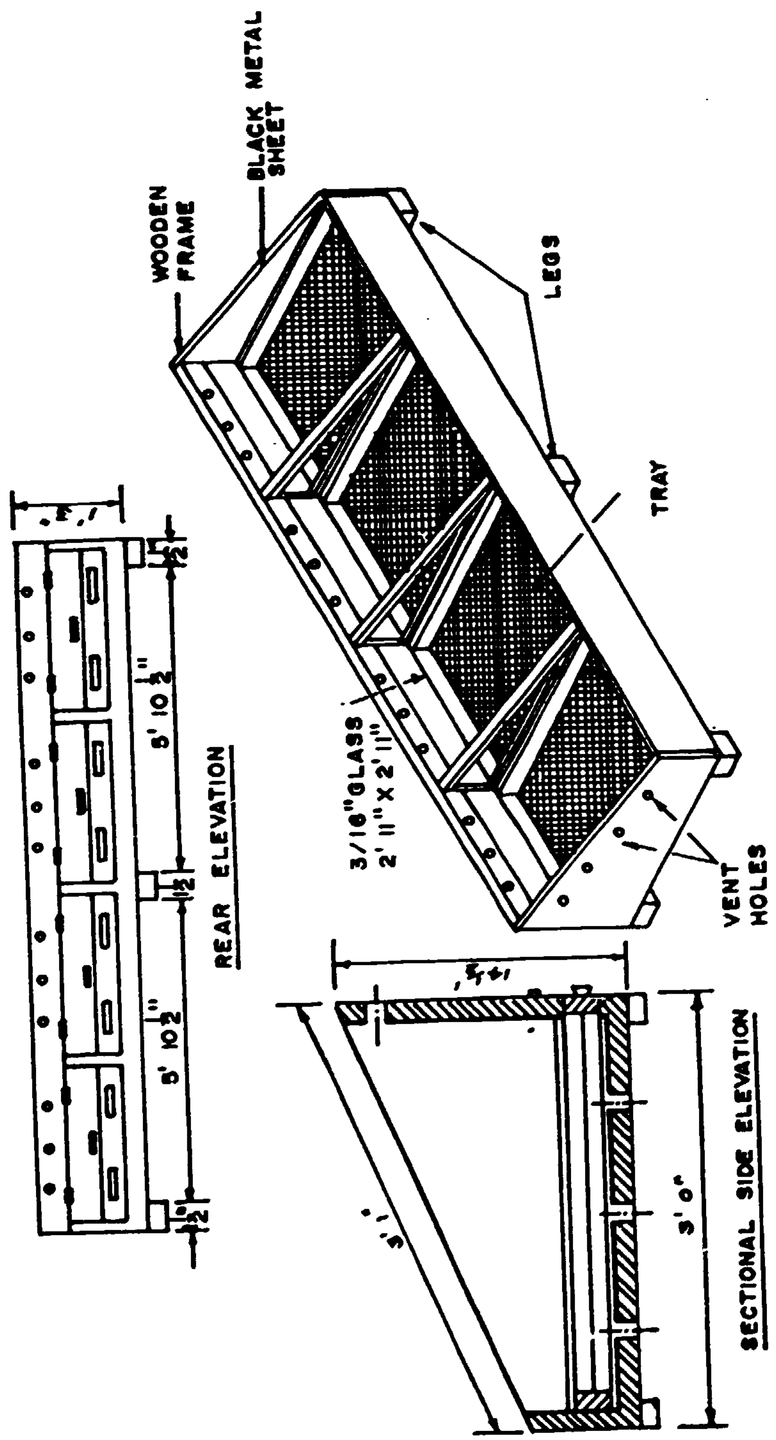


FIG. 2·4 SOLAR CABINET DRYER

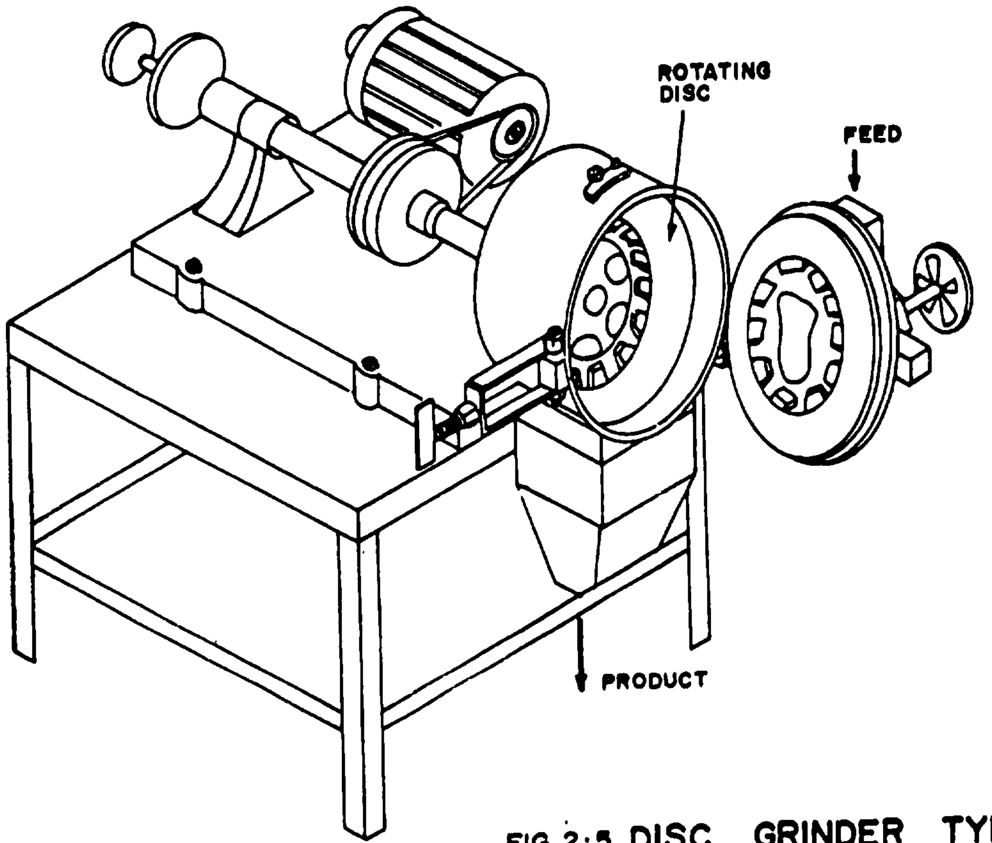


FIG. 2·5 DISC GRINDER TYPE DECORTICATOR

FIG 2·6 DRUM DECORTICATOR

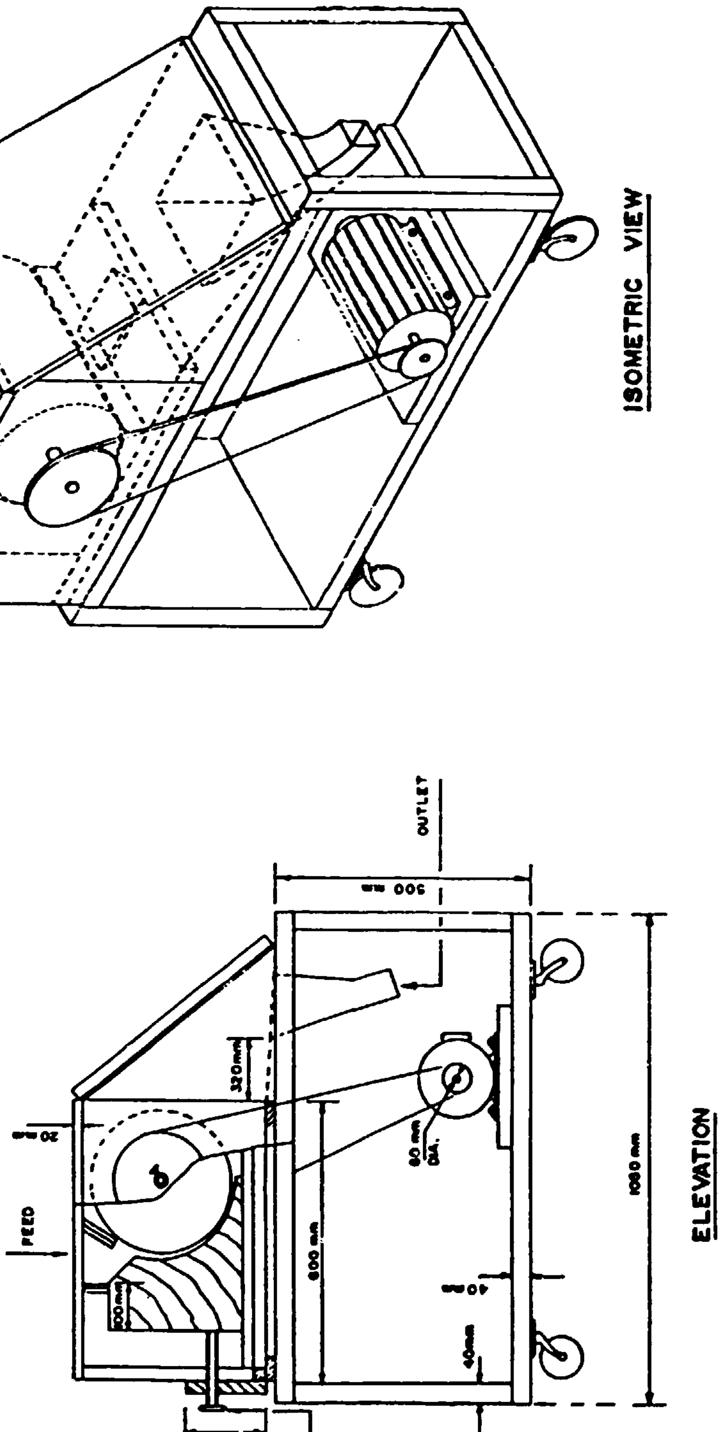
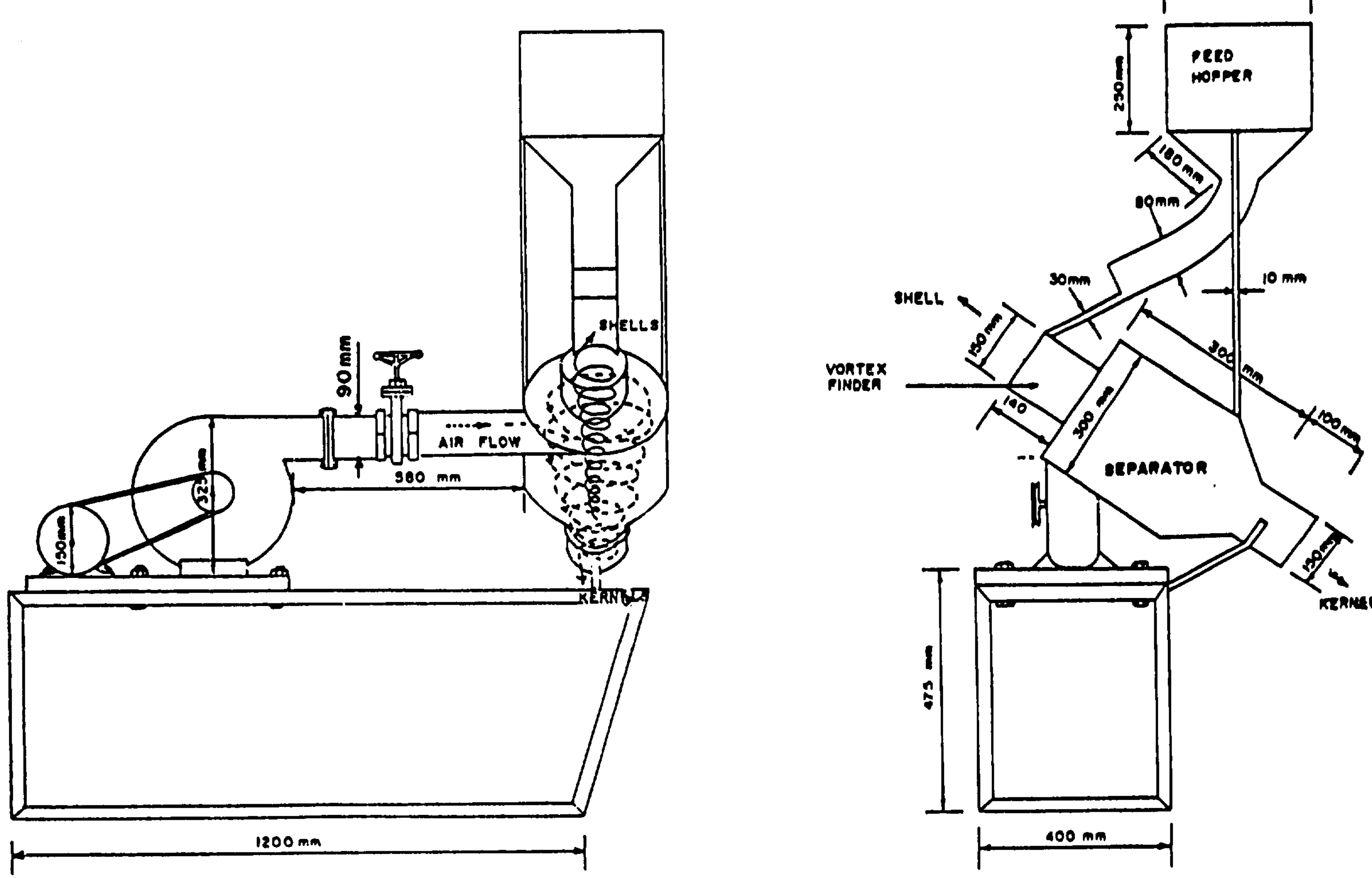


FIG 2·7 RUBBER SEED KERNEL SEPARATOR



CHAPTER 3

EXTRACTION OF OIL AND MEAL FROM RUBBER SEED

3.1 Introduction

Laboratory and pilot plant trials were carried out to determine optimum conditions for extraction of oil in rubber seed processing. Experiments conducted to expel fresh rubber seed kernel using low pressure expellers as are used for expelling copra in Sri Lanka were not successful so that high pressure expelling preceded by cooking of kernel was necessary for extraction of oil from fresh seed, throughput being increased by use of rubber seed meal itself and a small amount of coconut meal (poonac). Production of technical oil of high FFA was possible by expelling of undecorticated seed allowed to age over a period of time, low pressure expellers being used for oil extraction. Meal produced from fresh kernel was of high quality while meal obtained during production of technical oil was of low quality due to contamination with shell. Since difficulties of extraction of oil were encountered both in laboratory and pilot plant work in the use of fresh rubber seed kernel, much of the investigations was concentrated in this area.

3.2 Laboratory Trials

All laboratory work for expelling of oil by compression of kernel was carried out in a 50 Ton Hydraulic Press (Moore, UK) with heated platens. Material to be extracted for oil (about 50g) was contained in a square piece of filter cloth, wrapped over and placed in a semi-positive mould. Reproducible conditions were maintained with respect to application of pressure and duration. Expelling efficiency was judged by determination of residual oil in meal by petroleum ether extraction. Results of extraction of oil carried out at different temperatures gave a mean repeatability of 20% when outliers were included and 15% when outliers were excluded (calculation according to ISO 5725 - Precision of test methods by interlaboratory methods). Experiments were carried out to determine effect of following parameters on oil expelling efficiency (using fresh RS kernel):-

(a) pressure
(b) temperature
(c) size reduction
(d) cooking (conditioning).

It was shown that increased pressure and temperature resulted in lowered residual oil in meal. Size reduction also helped expelling efficiency. Cooking, carried out by treatment with water at 100°C resulted in improved expelling efficiency when moisture levels of 7-8% were attained, expelling efficiency being poor at lowered moisture levels. Typical results in Fig.3.1 indicate expelling efficiency dependence on moisture levels.

3.3 Pilot Plant Trials in Extraction of Oil

All pilot plant extraction trials were carried out in a HANDER EX-100 (Hander Oil Machinery Corporation, Japan) fitted with a 7.5 kW (10 HP) three phase induction motor. High pressure expelling of rubber seed kernel with the HANDER was necessary since all experiments carried out with low pressure expellers were inefficient with respect to oil yield when fresh rubber seed kernel was used. The objective of trials was to determine optimum conditions for oil extraction to scale up on a larger scale. As in laboratory work, efficiency of extraction was evaluated by residual oil in meal.

The HANDER was preheated when required to a temperature of 80-85 °C by expelling a mix of coconut poonac and rubber seed kernel (1:4 by weight) with a tight choke opening of 1-1.5mm. Input feed material was cooked (conditioned) by subjecting 10kg batches to live steam in a steam jacketed pan and allowed to attain different moisture levels by changing duration of steam entry into the feed. Cooked material was mixed with any other material and immediately expelled. Foots were filtered away with a fine wire mesh and added onto the weight of meal. Duration required to obtain respective yields (by weighing) was obtained. All experiments were at a single shaft speed of 30rpm. Results are averages of two or more determinations.

3.3.1 *Effect of Pressure*

Pressure was varied by changing the choke opening. Results (Fig. 3.2) for a typical feed clearly indicate that increase of pressure by reducing choke opening results in a low residual oil content, however throughput is also reduced.

3.3.2 *Effect of Coconut Meal (Poonac)*

It was reasoned that the higher fibre content of poonac would aid expelling of rubber seed kernel and hence rubber seed kernel/poonac feeds were expelled. Results in Fig.3.3 indicate that poonac helps in increasing throughput but the residual oil values also increase signifying inefficient expelling. It was however noted that incorporation of poonac into rubber seed kernel resulted in a smoother extrusion and less foots formation. In all subsequent experiments 5% poonac was mixed with rubber seed kernel as a processing aid.

3.3.3 *Effect of Rubber Seed Meal*

The effect of incorporation of rubber seed meal (of l[illegible] residual oil content around 12%) into a mix so that total of rubber seed kernel and rubber seed meal is 95% and the remaining 5% is poonac is shown in Fig.3.4. In this instance throughput increases, at the same time residual oil content remains around the same level. It is seen that the oil output also increases with increased incorporation of rubber seed meal (Fig.3.5).

3.3.4 *Effect of Moisture Content*

Experiments were carried out with a mix composed of 50% rubber seed meal, 45% rubber seed kernel and 5% poonac as feed material. The kernel component was cooked to different moisture levels and mixed with rubber seed kernel and poonac. Lowered moisture levels were obtained by drying cooked material in an oven. Results in Fig.3.6 and 3.7 indicate that lowest residual oil content and highest oil output are obtained at a moisture content around 7% (this value is that of cooked rubber seed kernel and since the moisture content of rubber seed meal is around 9%, the average moisture content of feed material is about 8%).

3.3.5 *Discussion on Oil Extraction*

Experiments on high pressure expelling in the HANDER clearly show that incorporation of rubber seed meal at a level of about 50% and poonac at 5% greatly improves efficiency of rubber seed kernel expelling. Optimum moisture levels for expelling are around 8% attained by cooking of rubber seed kernel and mixing with rubber seed meal. Experiments in which rubber seed kernel, rubber seed meal and poonac (45%, 50% and 5% respectively) were cooked together did not give satisfactory residual oil content after expelling, probably due to excessive absorption of moisture. Double expelling i.e. re-expelling of cake obtained from rubber seed kernel alone did not give improved overall increase in efficiency. All high pressure experimental results seem to indicate that optimum results are obtained by cooking of rubber seed kernel to a moisture content around 7% and incorporated in a mix containing 45% rubber seed kernel, 50% rubber seed meal and 5% poonac. Efficient expelling with low residual oil meal was accompanied by flake formation, whereas during production of high residual oil meal powdery material was obtained.

Results appear to fit into experience of other seed technologies. It is well known that cooking helps in extraction of oil from seed containing high protein levels e.g. cottonseed, soya, peanut (Ref.1,2) where protein is coagulated to free oil globules. Rubber seed kernel is in the high protein category and its fibre content is low so that increased fibre levels in rubber seed meal aid in throughput increase and exertion of frictional forces during expelling.

The influence of rubber seed meal and moisture content on rubber seed kernel expelling could be explained by fitting results into a simplified expression (Ref. 3,4) for flow of material in a screw extruder viz:-

$$Q' = G_1N - (G_2/\mu)P$$

[Q' = throughout, G_1 and G_2 are geometric parameters, N is rotation speed of shaft, μ is apparent viscosity of seed mass, P is pressure in barrel]

The throughput Q' increases with introduction of high fibre material (Fig.3.3 poonac, 3.4 rubber seed meal) or reduction of moisture content (Fig.3.6). This is due to increased μ caused by high fibre content and lowered moisture levels (Ref.5). The output of oil is lowered by increasing Q' (low residence time in expeller) but increased by pressure P, the maximum output of oil at about 7% moisture (Fig.3.7) representing optimum conditions relating Q' and P.

Since fresh quality kernel was used in high pressure expelling operations the resultant meal was also of high quality. Typical properties of rubber seed meal obtained by expelling good quality kernel in the HANDER are given in Table 3.1.

3.4 Production of Technical Grade Oil

Rubber seed oil of high (> 15%) FFA value is produced commercially in Sri Lanka using low pressure screw expellers normally used for extraction of coconut oil. For this purpose collection of rubber seed is carried out during the period of seed fall and although as far as possible good quality seed is collected, no attempts are made to reject any bad quality seed. The seed is transported from collecting centres in rubber growing areas in polypropylene woven bags (without inner liners) and stacked in sheltered warehouses (average temperature of 30° C and relative humidity of 70%) for a period of about two months. During this period spontaneous drying to about 10% moisture levels occur. This material is subjected to low pressure screw expelling as in the case of copra (Fig.3.8). Some millers in Sri Lanka skip the cutting and drying operation and feed the seed direct into the expeller. The oil is filtered while still warm (c.70°C), filtration rates being comparatively less compared with coconut oil. Filter cake and other solid residues are further mechanically pressed if desired to obtain a lower quality oil. Cake discharged directly from expellers has large pieces of shell rendering it unfit for animal feed but some millers carry out a grinding and sieving operation to produce a feed component suitable for cattle and pigs. Some parameters in production of oil from aged undecorticated seed in low pressure expellers is given in Table 3.2, typical properties of meal containing shell (ground and sieved) are given in Table 3.1.

3.5 Recommendations for Scaling up Pilot Plant Trials

Laboratory and pilot plant operations have conclusively shown that high pressure screw expelling is necessary for efficient extraction of low FFA oil from good quality rubber seed kernel. Conditions necessary are enumerated below:-

(1) obtain good quality RSK from seed collected soon after seed fall, drying to a moisture level around 5% for storage purposes.

(2) Cook kernel to a moisture level around 7%
e.g. in stack of high pressure expeller.

(3) Mix kernel with rubber seed meal (residual oil content and moisture content around 12% and 9% respectively) and poonac in the ratio 45/50/5 (RSK:RSM:poonac) just before entry into expeller.

(4) Maintain tight choke at expelling temperature 80-85°C.

3.6 References

1. D.K. Bredeson; Mechanical extraction, JAOCS 55 762-764 (1978).

2. Anderson International, USA;
Bulletin 359 R.

3. V.S. Vadke and F.W. Sosulski; Mechanics of oil expression from Canola,
JAOCS 65 1169-1176 (1988).

4. V.S. Vadke, F.W. Sosulski and C.A. Shook; Mathematical simulation of an oilseed press, JAOCS 65 1610-1616 (1988).

5. J.M. Harper, Extrusion of foods, Vol.1 CRC Press, USA (1981).

Table 3.1 - Typical Analyses of Rubber Seed Meal

Property	RSM from expelling kernel	RSM from expelling whole seed (aged)
Moisture (% mass)	9.5	7.1
Protein	28.3	20.9
Total carbohydrate	32.3	28.6
Oil content	18.4	11.5
Crude fibre	4.5	20.6
Total cyanide (mg/kg)	94	44

Note: All values, except moisture and total cyanide content are percent by mass on dry basis.

Table 3.2 - Parameters for Expelling Whole (Undecorticated) Seed in Low Pressure Screw Expellers

Parameter	BATCH I	BATCH 2	BATCH 3
Method of drying	Spontaneous ageing under ambient conditions		
Initial moisture content of rubber seed %	18.6	20.2	17.5
Period of storage (weeks)	10	12	12
Moisture content just before expelling %	9.6	7.4	7.7
FFA of extracted oil %	24.3	18.3	22.9
Residual oil in meal %	6.1	7.3	8.0
Colour of extracted oil, filtered (Lovibond 1" cell)	60Y+9.8R	60Y+7.1R	57Y+8.2R
Moisture content of oil %	0.1	0.1	0.1

FIG 3·1 EXPELLING EFFICIENCY DEPENDENCE ON MOISTURE LEVELS

MATERIAL COMPRESSED : DIRECT KILN DRIED
(MOISTURE LEVELS OF MATERIAL BEFORE COMPRESSION ARE INDICATED)

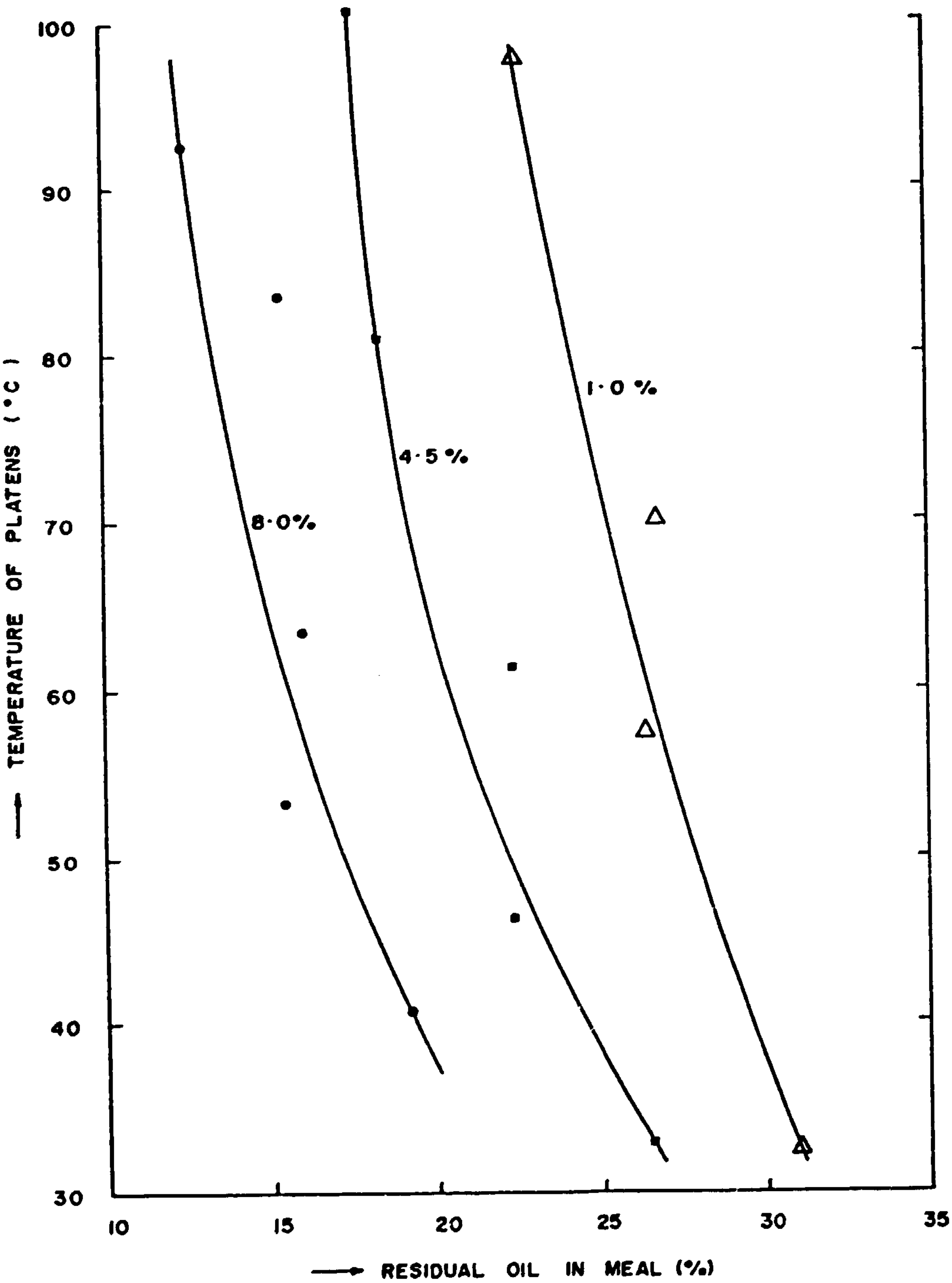


FIG. 3·2 - DEPENDENCE OF RSO EXTRACTION ON CHOKE OPENING

FEED : 95% RSK + 5% COCONUT POONAC

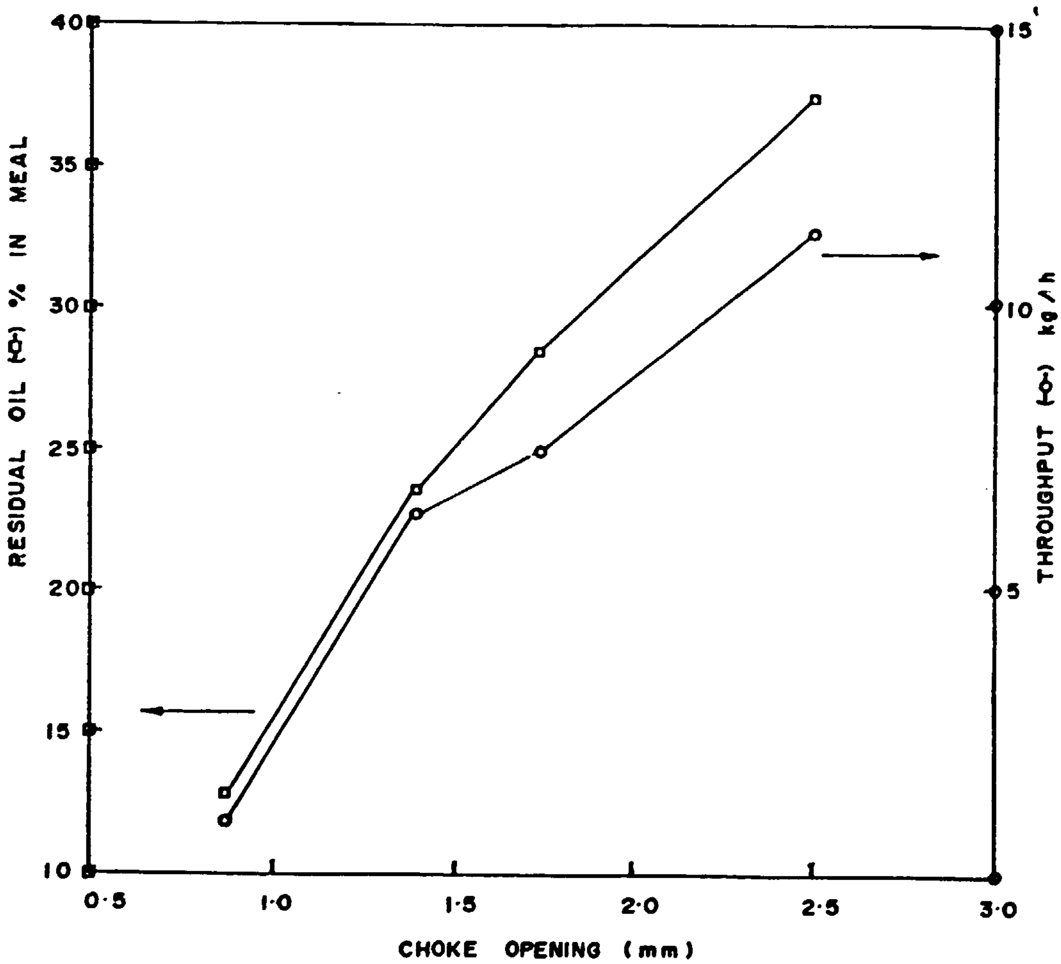


FIG. 3·3 DEPENDENCE OF RSO EXTRACTION ON COCONUT POONAC CONTENT OF FEED.

FEED : VARIABLE RSK ONLY (NO RSM) CHOKE OPENING (GAP) - 1 mm

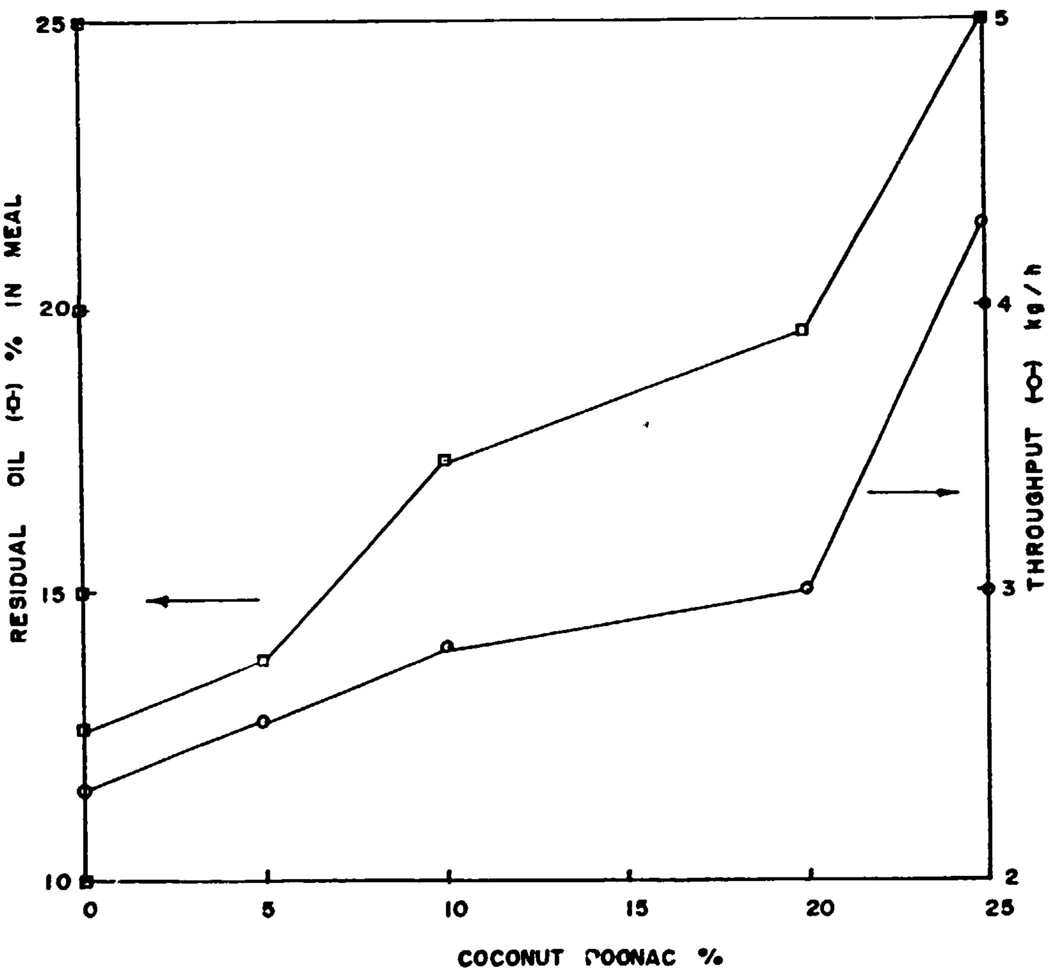
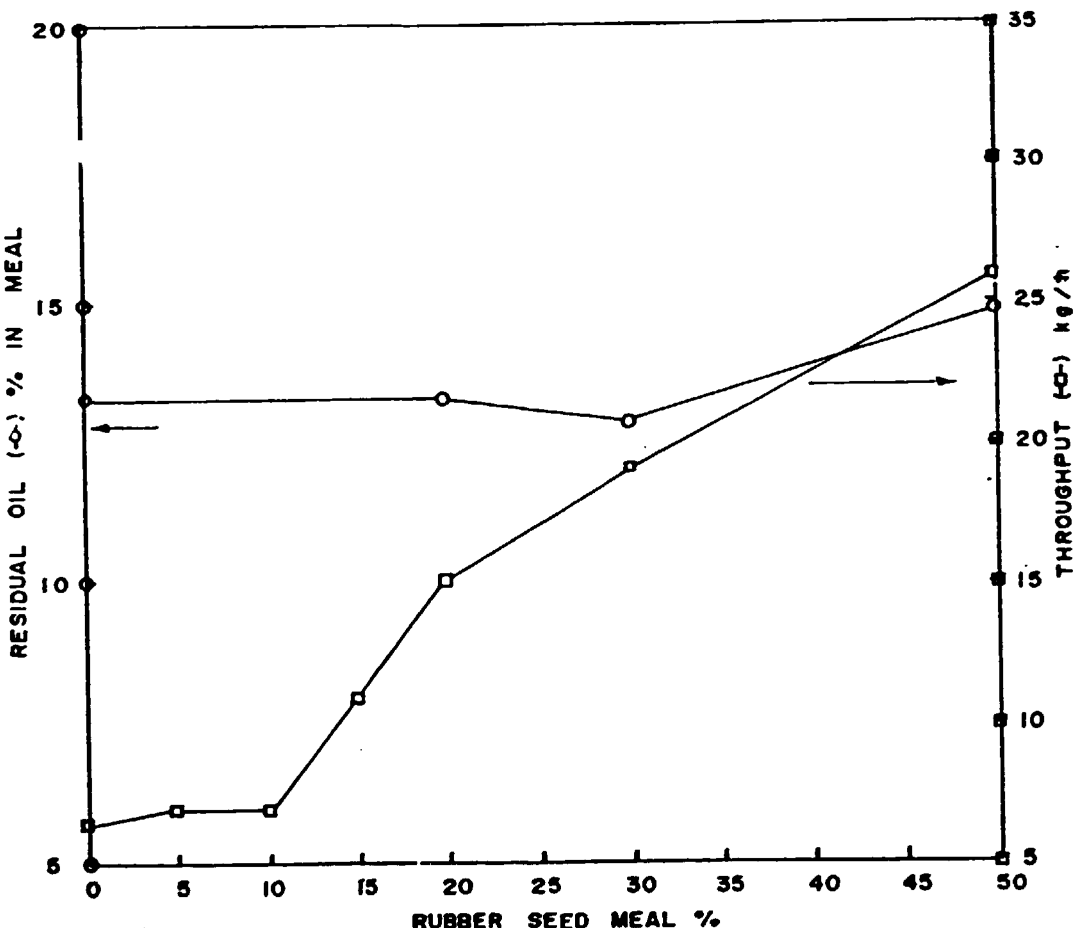


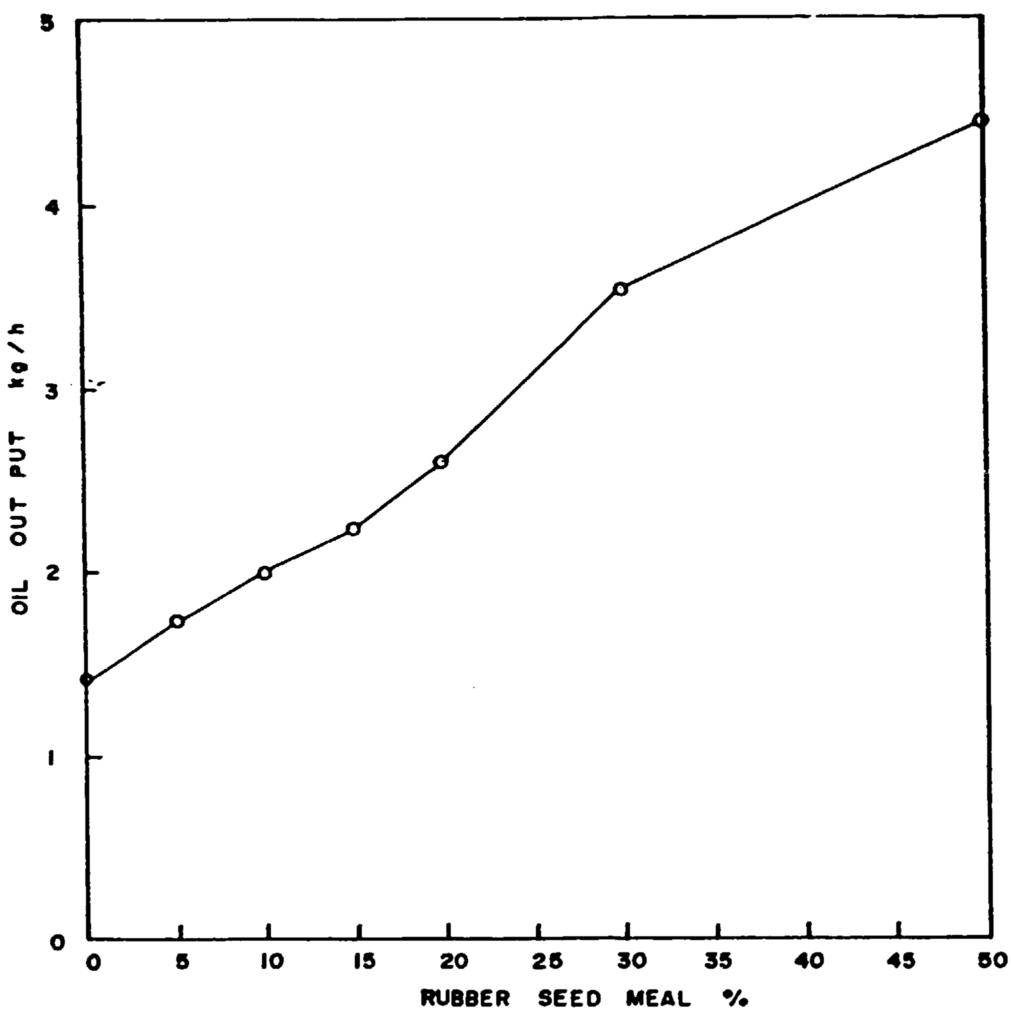
FIG. 3·4 - DEPENDENCE OF RSO EXTRACTION ON RUBBER SEED MEAL CONTENT OF FEED



FEED :- (RSK% + RSM%) TO ADD TO 95% WITH 5% POONAC

GAP :- 1mm

FIG.3-5 DEPENDENCE OF RSO OUTPUT ON RSM CONTENT



FEED :- (RSK% + RSM%) TO ADD TO 95% WITH 5% POONAC

GAP :- 1 mm

FIG. 3·6-DEPENDENCE OF RS. THROUGHPUT ON MOISTURE CONTENT

FEED : 50% RSM + 45% RSK + 5% CP , GAP 1 mm

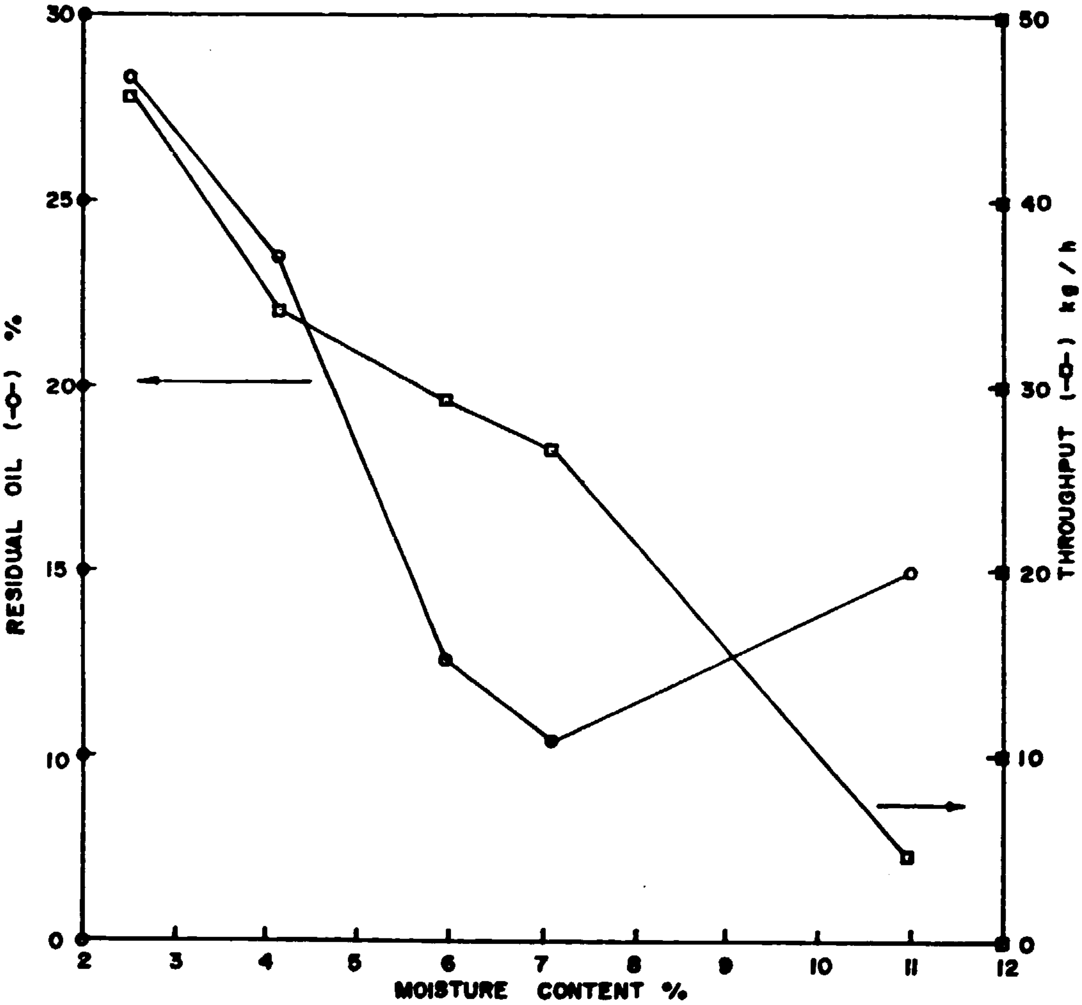


FIG.3·7-DEPENDENCE OF RSO EXTRACTION ON MOISTURE CONTENT

FEED : 50% RSM + 45 % RSK + 5 % CP
CHOKE OPENING (GAP) 1 mm

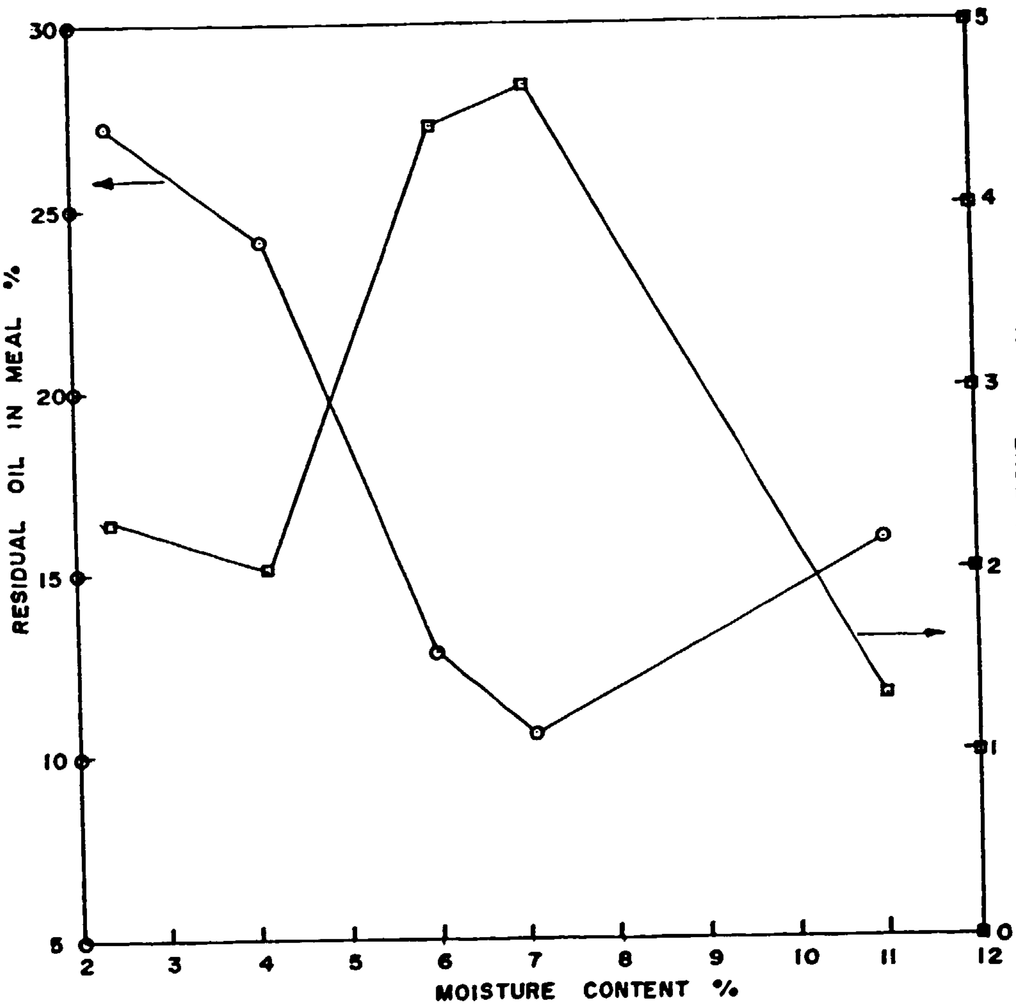
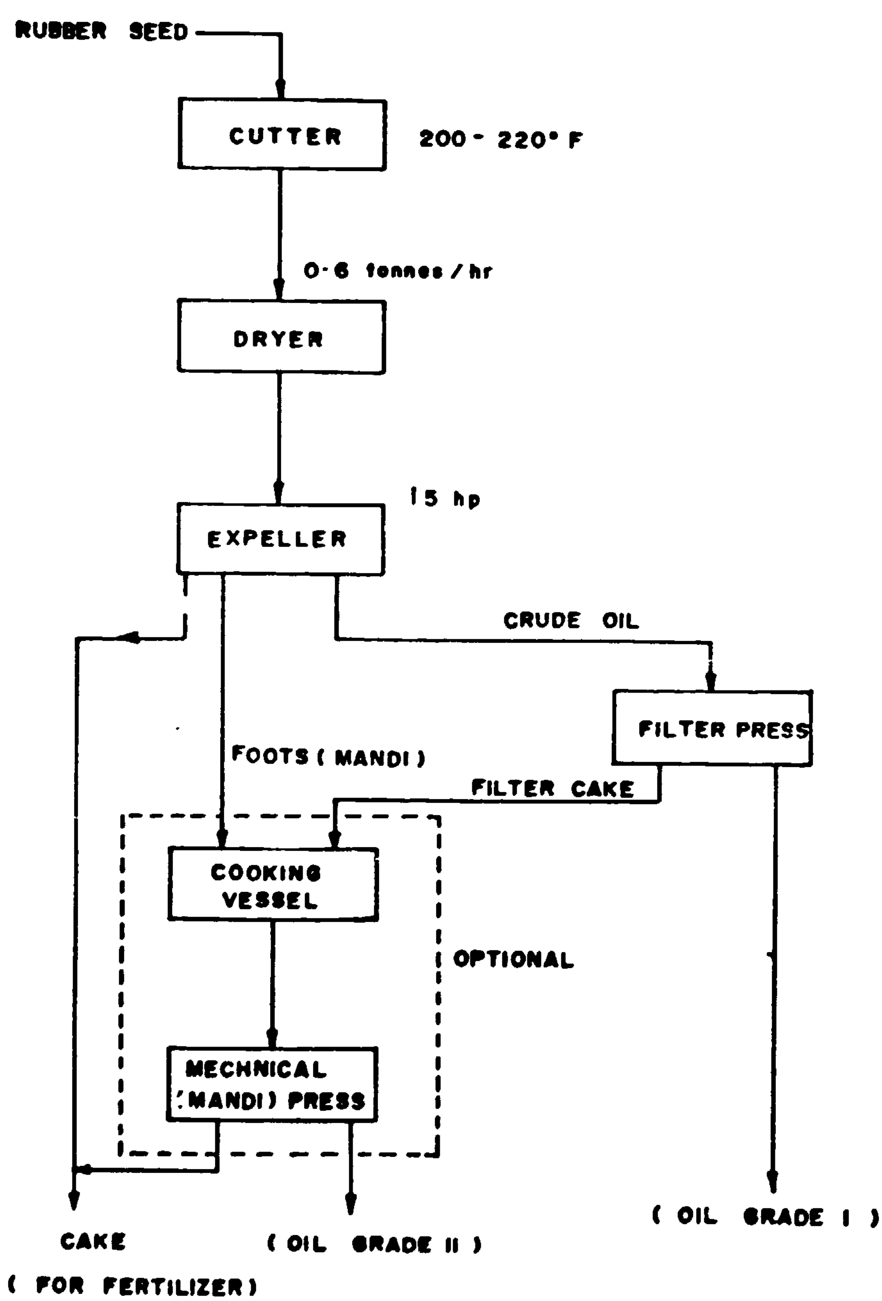


FIG. 3·8 FLOW DIAGRAM FOR LOW PRESSURE EXPELLING OF WHOLE (UNDECORTICATED) SEED



CHAPTER 4

USE OF RUBBER SEED OIL FOR EDIBLE PURPOSES

4.1 Introduction

A major objective of the UNIDO Global Rubber Seed Project is to define conditions to prepare rubber seed oil for edible purposes. The composition of the fatty acids of rubber seed oil is such that it belongs to the class of polyunsaturated vegetable oils with the added advantage of containing nutritionally valuable α-linolenic acid. Several constraints have to be overcome before rubber seed oil can be accepted as an edible oil suitable for human consumption and these are discussed below.

4.2 Constraints in the Development of Rubber Seed Oil for Edible Purposes

Several factors which have a bearing on development of rubber seed for edible purposes were investigated during Phase Two and these are reviewed as follows:-

(a) development of FFA in RSO
(b) poly(isoprene) problem
(c) refining
(d) darkening on heat
(e) odour development.
(f) hydrogenation

4.2.1 *Development of FFA in Rubber Seed Oil*

Unless steps are taken to collect rubber seed soon after seed fall with minimal contamination, FFA develops fairly rapidly due to lipolytic activity arising from exogenous lipase (Sec. 8.5). During our Phase Two laboratory and pilot plant trials, seed was purchased both from large estates and small holders instructed to collect seed with the minimum delay. An estimate of FFA values corresponding to batches of oil extracted reveals (Table 4.1) that only about 44% of the total oil obtained had FFA values below 5% even with care exercised in collection. It is evident that difficulties will be encountered for rubber seed oil to conform to specifications for crude vegetable oils (Table 4.2 gives contractual requirements for some vegetable oils). High FFA values will result in high refining losses and also poor quality meal so that unless it is possible to reduce FFA levels to the 3-5% range, rubber seed oil will be down-graded to technical oil quality.

4.2.2 *The Poly(isoprene) Problem*

The presence of poly(isoprene) to the extent of about 1% in rubber seed oil would also result in lowering of oil quality. In the present work attempts were made to remove poly(isoprene) however the only successful technique is to use a differential solvent such as acetone which dissolves the oil phase at the same time precipitating insoluble poly(isoprene). However some samples of rubber seed oil failed to respond to precipitation by acetone, this could be due to absence of poly(isoprene) or more probably due to solubilization by chemical modification of poly(isoprene) through hydroperoxide formation.

Possible chemical modification of poly(isoprene) was indicated by determination of intrinsic viscosity on samples of poly(isoprene) obtained by treatment of rubber seed oil with excess (about 3 fold) acetone. Any precipitated poly(isoprene) was dissolved in toluene reprecipitated with methanol and intrinsic viscosity determined with an Ubbelohde viscometer. Constants determined (Table 4.3) showed that poly(isoprene) obtained from fresh as well as old seed had progressively reduced intrinsic viscosities, as well as increased k' values (compared to polyisoprene in sheet rubber), both these pointing to chemical degradation and modification.

It was reasoned that the presence of poly(isoprene) could reduce filtration rates in rubber seed oil, however both flow time determinations and practical filtration trials under pressure did not reveal any difficulty in filtration (Fig. 4.1 and 4.2). Long term effects of ingestion of poly(isoprene) are at present not known so that detailed investigations would be required to clarify the situation.

4.2.3 *Refining of Rubber Seed Oil*

Experimental work in Phase I had shown that crude rubber seed oil could be refined by a conventional desliming (citric acid, water treatment), neutralization, bleaching and deodorization procedure, the overall yield being 19%, most of the losses occurring at bleaching stage. In the present studies also refining was carried out as shown in Fig.4.3, the overall yield being around 66%. The effect of refining is shown in Table 4.4.

It was not possible to remove poly(isoprene) by the refining procedure adopted. As noted in the earlier Section, the only method appears to be treatment with excess of acetone, this is however an expensive method. In commercial operation sufficient rubber seed oil quantities would not be available for physical refining so that a batch neutralization, bleaching and deodorization plant would be suitable. A few commercial refining operations carried out in Sri Lanka have shown very high refining losses, the refining factors being nearly thrice those for coconut oil.

4.2.4. *Darkening of Rubber Seed Oil on Heating*

A simple test for suitability of an oil for frying purposes is to determine the change in colour on maintaining the oil at 200 °C for 40 hours (Ref.1). Results for rubber seed oil (both crude and refined) and blends with other oils given in Table 4.5 show that rubber seed oil undergoes large changes in colour compared with other oils and blends. Rubber seed oil and rubber seed oil rich blends also showed signs of resin and carbonaceous matter formation. The lightly hydrogenated material showed a comparatively reduced change in colour as also the blends with rubber seed oil less than 5%.

4.2.5. *Odour Development*

The smell of linseed oil was characteristic in all samples of rubber seed oil obtained by mechanical expelling even immediately after expelling. This odour was less objectionable in light hydrogenated material. (Section 4.4). Odour development is largely due to autooxidation of linolenic acid (Ref. 2) ,light hydrogenation reducing the level of linolenic acid in RSO.

4.3 Practical Experiment for Edible Purposes

Experiments were carried out to compare rubber seed oil with other commonly used vegetable oils in Sri Lanka especially coconut oil to evaluate rubber seed oil for cooking purposes using samples of oil without any levels of cyanide, aflatoxin or gossypol recorded.

4.3.1 *Frying Experiments Based on Rubber Seed Oil*

Samples of rubber seed oil (both crude and refined) were used for frying purposes - stir frying in which complete absorption of oil takes place and deep frying where oil is reusable. Rice, noodles, dried fish and potatoes were used in stir frying experiments which revealed that use of 100% of rubber seed oil was unsatisfactory due to darkening and odour development, however at the 5-10% level, blends with other vegetable oils such as coconut and soya were satisfactory.

Deep frying experiments were also unsatisfactory except at the 5-10% level of rubber seed oil. Some quantitative results in Table 4.6 (using 100% RSO) indicate that it was possible to attain a relatively higher frying temperature with rubber seed oil but the oil uptake was also high and in the case of PAPADAM did not drain off readily as in the case of the other oils.

4.3.2 *Salad Oils and Dressings Based on Rubber Seed Oil*

Emulsification of rubber seed oil with egg was satisfactory but mayonnaise prepared with rubber seed oil had objectionable taste and odour. Blends at the 5-10% level rubber seed oil were satisfactory for mayonnaise, they were also suitable for salad oils and dressings provided freezing did not take place during domestic refrigeration.

4.4 Hydrogenation of RSO

All indications on frying and other experiments were that RSO would be unsatisfactory due to colour and odour development, largely a result of high linolenic content (15-20%). Some preliminary experiments were carried out (details Appendix 2) to hydrogenate RSO as to reduce linolenic levels. Lightly hydrogenated material underwent comparatively less darkening (Table 4.5) and odour development, linolenic levels reduced to around 10% (Table 4.7). Prolonged hydrogenation results in high slip MPt solids, dilatation (SFI) characteristics of these products showed them to be similar to beta-type hydrogenated oils (coconut, corn) rather than beta-prime types (palm, cotton seed) which confer better properties to margarine formulations (Ref. 3).

4.5 References

1. L. Masson; Relative nutritional value of various dietary fats and oils, JAOCS 58 249-255 (1981).

2. K. Robards, A.F. Kerr and E. Patsalides; Rancidity and its measurement in edible oils and snack foods, ANALYST 113 213-224 (1988).

3. Lars H. Wiedermann; Margarine and margarine oil, formulation and control JAOCS 55 823-829 (1978).

Table 4.1 - FFA values of Batches of Rubber Seed Oil Extracted During Phase Two

Wt. of batch of RSO (kg)	% of total of batches	FFA%
250	16	2.8
450	28	3.9
200	12	8.4
300	19	11.2
400	25	13.5

Table 4.2 - Contractual Requirements of Different Types of Crude Vegetable Oil

Type	FFA value %	Equivalent acid
Rapeseed	3.4	oleic
Sunflower	3.0	oleic
Soya	1.3	oleic
Palm kernel	5.5	lauric
Palm	5.0	palmitic
Coconut	3.0	lauric

Note: - FFA figures are maximum limits in contracts.

Source : J.R. Pritchard; Oilseed quality requirements for processing JAOCS 60 322-332 (1983).

Table 4.3 - Characterization Constants for Poly(isoprene) Obtained from Rubber Seed Oil by Precipitation with Acetone

Constant	Material		
	RSO(from fresh seed)	RSO (from old seed)	RSS*
Intrinsic viscosity $[\eta]\ g^{-1}ml$	1.30	0.96	5.15
Viscosity average molecular weight $\bar{M}_v$	116,650	92,780	326,700
Huggins' constant k'	1.31	5.71	0.53

*Sheet Rubber

Note: [η] and k' obtained from Huggins' equation

$\frac{\eta sp}{C} = [\eta] + k' [\eta]^2 C$. JACS 64 2716-18 (1942). $\bar{M}_v$ estimated from data in JApp Poly Sc. 1 245-249(1959), $[\eta] = 2.3 \times 10^{-7}\ \bar{M}_v^{\ 1.33}$

Note: FFA content of RSO from fresh seed 4.6%, from old seed 18.9%.

Table 4.4 - Comparison of Crude and Refined Rubber Seed Oil

Property	Crude RSO	Refined RSO
Colour (1" Lovibond)	10Y+4R	4Y+0.5R
FFA %	4.6	0.1
Phosphorus content (P ppm)	51	7

Table 4.5 - Colour Change after Keeping 40 hours at 200°C (Lovibond 1" Cell)

Oil	Colour before heat treatment		Colour after heat treatment		
	Red	Yellow	Red	Yellow	Blue
RSO (crude)	4.0	9.9	20.0	12.1	7.0
RSO (Refined)	0.8	6.0	20.7	12.7	6.0
Coconut (Crude)	0.1	1.5	0.2	3.0	-
Coconut (Refined)	-	0.3	0.1	0.9	-
Soya (Crude)	0.1	2.3	1.3	20.0	-
Sesame (Crude)	1.1	40	4.2	43.0	-
Crude RSO/CO (5:95)	0.2	3	1.2	12	-
Crude RSO/CO (10:90)	0.5	3	1.8	21	-
Crude RSO/CO (15:85)	0.7	4	4	20	-
Crude RSO/CO (20:80)	1.0	10	6	20	-
Refined RSO/CO (25:75)	2.2	0.2	3	22	1.0
Refined RSO/CO (50:50)	4.2	0.4	4.3	21.1	1.1
Refined RSO/CO(75:25)	5.2	0.5	5.0	20.0	1.8
Hydrogenated (IV 110 RSO)	5.5	9.4	4	8.0	7.0
Linseed	4.2	24	completely darkened		

Abbreviation - CO - Coconut oil.

Table 4.6 - Deep Frying Experiments with RSO Compared with Other Frying Oils used in Sri Lanka - Oil uptake by Fried Materials

Material Fried	Oil Used			
	RSO	COCONUT	SOYA	CORN
1. Papadam	+2.0	+3.5	+8.0	+7.5
2. Ash Plantain chips (well dried)	+36	+24	+24	+32
3. Potato chips (well dried)	+11	-4	+3	0
Frying temperature °C	175	160	190	180

Note: (a) PAPADAM is a legume based cracker type snack food popular in India and Sri Lanka.

(b) RSO and coconut oil was not refined, soya and corn oils were refined oils commercially available.

(c) Ash plantain is a starchy fruit from the plant *Musa sapientum*, used for cooking purposes.

Table 4.7 – Hydrogenation of Rubber Seed Oil: Variation of Fatty Acid Composition with Reaction Time.

	Fatty acid composition mass % Time (minutes)				
Fatty Acid type	0	15	30	45	60
12:0	0.8	0.8	0.8	0.8	0.8
14:0	0.4	0.4	0.4	0.4	0.4
16:0	9.9	10.4	9.5	9.8	9.6
18:0	10.1	11.9	15.7	20.1	27.7
18:1 Δ9t	–	2.9	5.9	10.6	14.4
18:1Δ9c + 18:1Δ12t	23.5	24.1	24.1	25.4	24.3
18:1 Δ12c	–	0.5	3.8	6.1	6.4
18:1 Δ15c	–	0.2	0.8	1.4	1.8
18:2 Δ9t, 12t	–	1.0	2.7	3.7	3.5
18:2 Δ9c, 12t	–	0.4	1.6	2.3	2.0
18:2 Δ9c, 12c + 18:2 Δ9t, 12c	37.5	30.0	22.6	13.0	6.0
18:2 Δ12c, 15c	–	1.1	2.4	2.3	1.4
18:3 c+t isomers	–	1.3	2.5	1.7	0.7
18:3 Δ9c, 12c, 15c	17.8	13.5	5.8	1.3	0.3
Slip melting point °C	-2.0	20.5	27.0	36.0	44.0
Iodine value	126	113	96	76	59
Trans fatty acid content(%)	0	5.6	12.7	18.3	20.3

c = cis t = trans

(See Appendix 2 for details of hydrogenation)

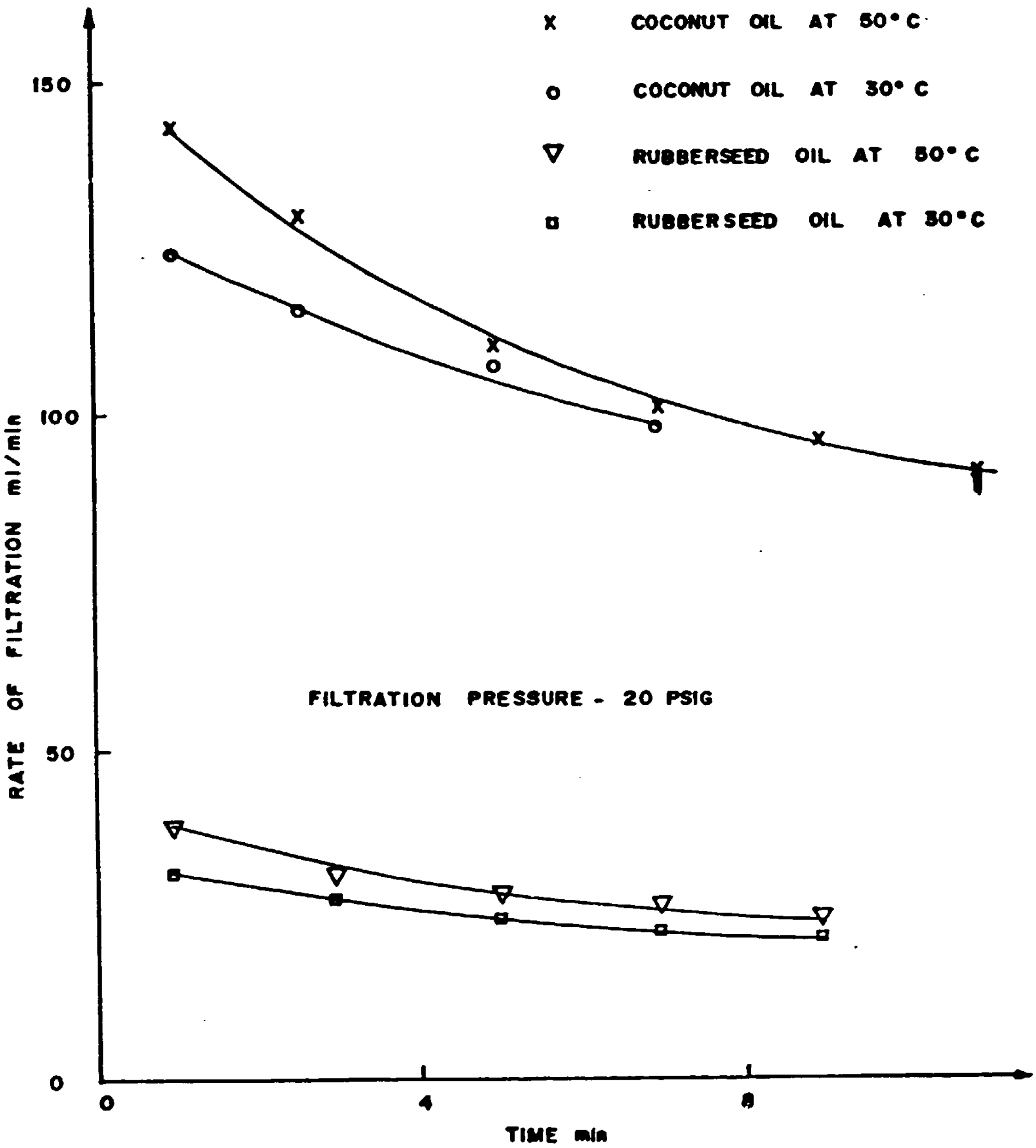


FIG. 4·1 COMPARISON OF FILTRATION OF CRUDE OIL

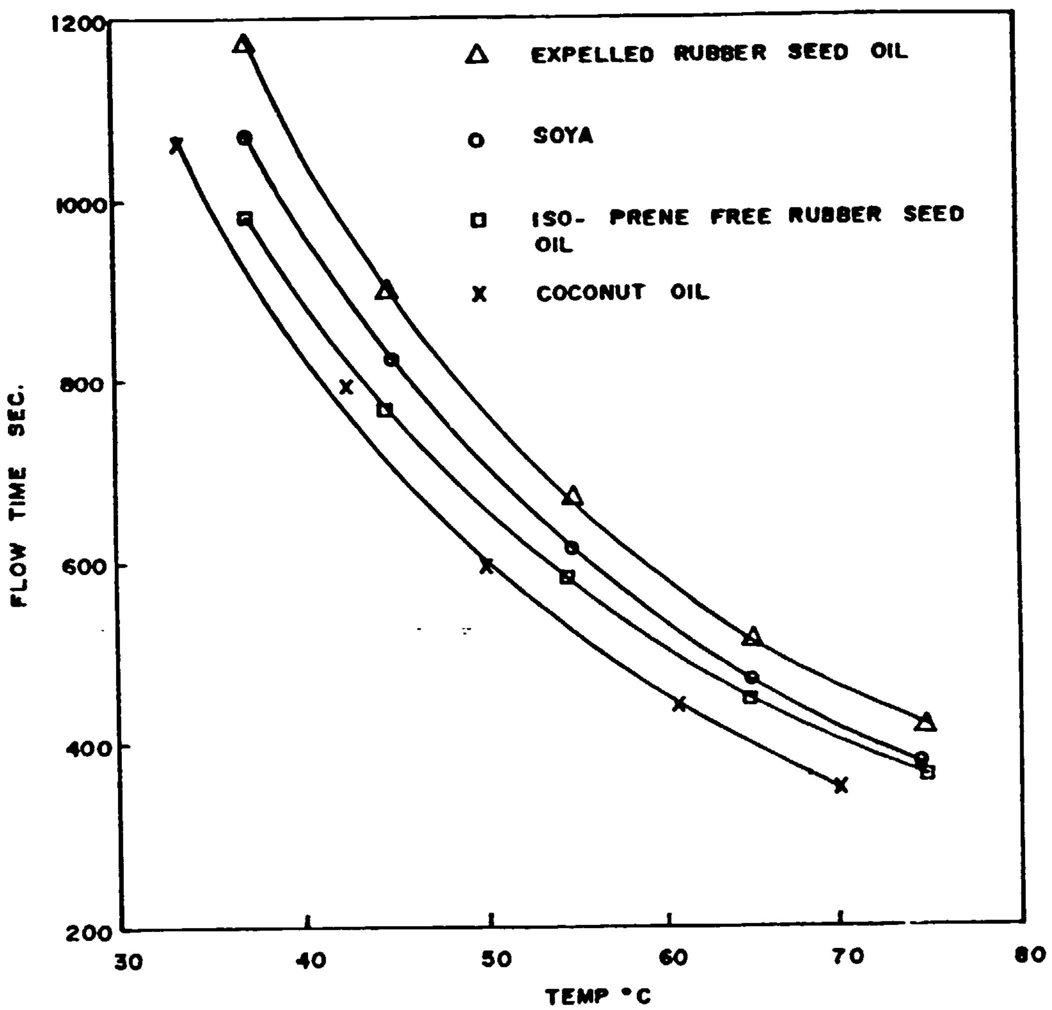


FIG. 4·2 - COMPARISON OF FLOW TIMES OF DIFFERENT OILS

Fig. 4.3

Type of oil used for experiments on RSO for edible use:-

(a) Crude RSO obtained from freshly collected seed, expelled in the HANDER EX-100 and filtered.

All samples used had FFA values in the range 3-5%. Typical colour values (LOVIBOND 1" cell) were Red 4.0 Yellow 9.9.

(b) Refined RSO obtained as follows from crude RSO.

Crude RSO (1000g)		1. Degum (add 1g of 75% H_3PO_4 at 80-90°, stirri,g 10 minutes
↓	11% loss	2. Cool to 30°C add 15g water and stir one hour. Heat to 60°C while stirring for 30 minutes, allow to cool overnight.
↓		3. Centrifuge and remove sludge.
Sludge free RSO		1. Heat to 70°C neutralise with slight excess (5%) of 0.9N NaOH. Separate off aqueous phase, wash oil with warm saturated NaCl solution and finally warm water. Dry oil in vacuum oven at 70°C.
↓	18% loss	
Alkali refined RSO		1. Treated with FULMONT PREMIERE* (activated bleaching earth) 2.5% on weight of RSO at 80°C stirring 30 minutes.
↓	10% loss	2. Filter in laboratory press (cloth supported paper).
↓		3. Vacuum dry at 70°C.

Typical properties of refined oil - Colour (LOVIBOND 1" cell)
0.3 - 0.8 Red, 2.0 - 6.0 yellow
FFA (as oleic acid) 0.1%

*Supplier - Laporte Industries Limited (UK).

CHAPTER 5

TECHNICAL PRODUCTS IN RUBBER SEED PROCESSING

5.1 Introduction

Rubber seed oil which cannot be economically processed and refined for edible purposes could be used as an intermediate in manufacture of industrial products. Following are major areas of development possible with rubber seed oil:-

(a) soap
(b) alkyd resin
(c) other chemical modifications
(d) rubber seed meal and waste products.

5.2 Soap

Low titer and saponification values and high iodine values precludes the use of rubber seed oil as a major constituent for soap manufacture (Table 5.1). In Sri Lanka, rubber seed oil has been used for laundry soap manufacture at the 5% level and when hydrogenated to an IV of 90 it has been possible to incorporate upto 20% (Ref. 1,2). In India rubber seed oil is used with blends of other non-edible vegetable oils in the manufacture of low quality soaps filled with extenders.

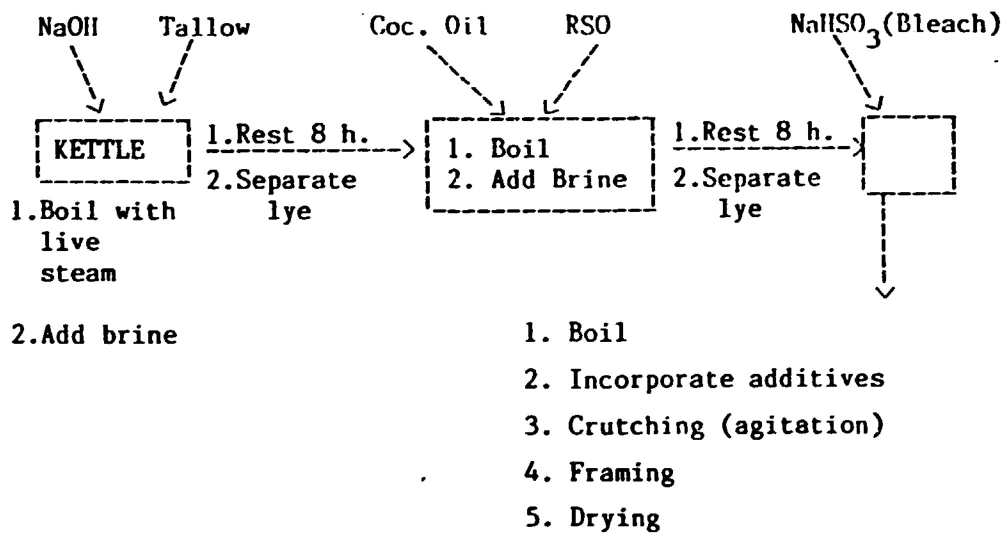
5.2.1 *Laundry Soap*

Sri Lankan manufacture of laundry soap is mainly dependent on the fully boiled process, a typical recipe using RSO being as follows:- (Ref.1).

Coconut oil	55 parts by weight
Tallow	40
RSO	5
NaOH (37^{o} Be')* added per sap value	

*specific weight 1.345

A block diagram of the manufacturing process is given below:-



Laundry soap with RSO at 5% level kept satisfactorily over a six month period without any adverse effects on retention of perfume impact, darkening or lathering. Similar results were obtained with hydrogenated RSO (IV 90) when incorporated at a 20% level, with corresponding reduction of coconut oil and tallow content (Ref. 2). The annual laundry soap requirement in Sri Lanka being about 25,000 tons, incorporation of RSO at the 5% level could use upto 1,250 tons.

5.2.2 *Cheap Quality Filled Soap*

The fully boiled process for soap manufacture is simplified in the cold process which does not involved separation of glycerine. Cheap inorganic fillers/extenders such as china clay could be incorporated in laundry soap for hardening purposes. A cheap type of filled laundry soap marketed in South India was made from a blend of 75% RSO and 25% castor oil and was analysed as follows:-

Total fatty matter	21.4%
Ash	43.1%
Unsaponified matter	0.5%
Free caustic alkali	0.06%

5.2.3 *Soft/Liquid Soap*

The semi-drying properties of RSO makes it ideally suitable in the manufacture of soft soap. The following recipe was used in the laboratory preparation of soft soap (semi-boiled process):-

RSO 800g (heated to $60^{o}C$)

NaOH 100

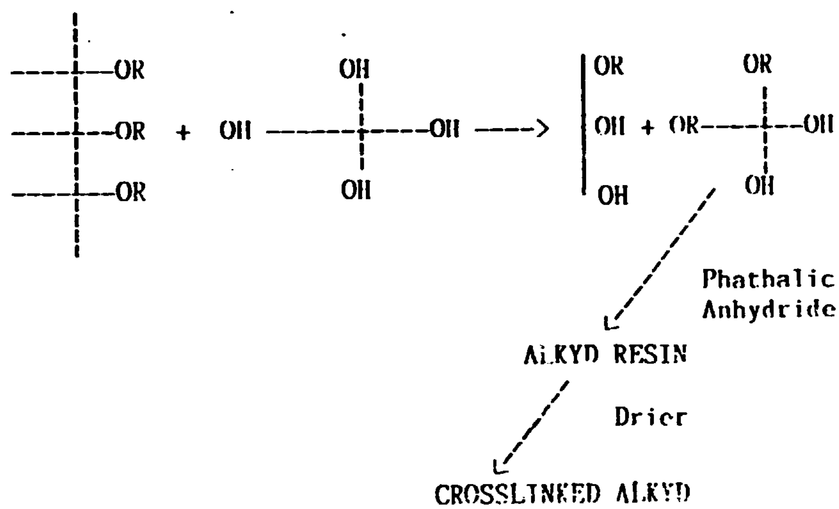
Water 480

The consistency of the soap could be altered by use of a blend of NaOH/KOH. Liquid soap was made in a similar manner by the incorporation of a larger amount of water at the soap making stage. A potential of about 600 tons exists in Sri Lanka per year for soft/liquid soap.

5.3 Alkyd Resin Manufacture from RSO

5.3.1 *Background*

An alkyd resin is synthesised from a triglyceride, polyol and phthalic anhydride as follows (Ref. 3-4).



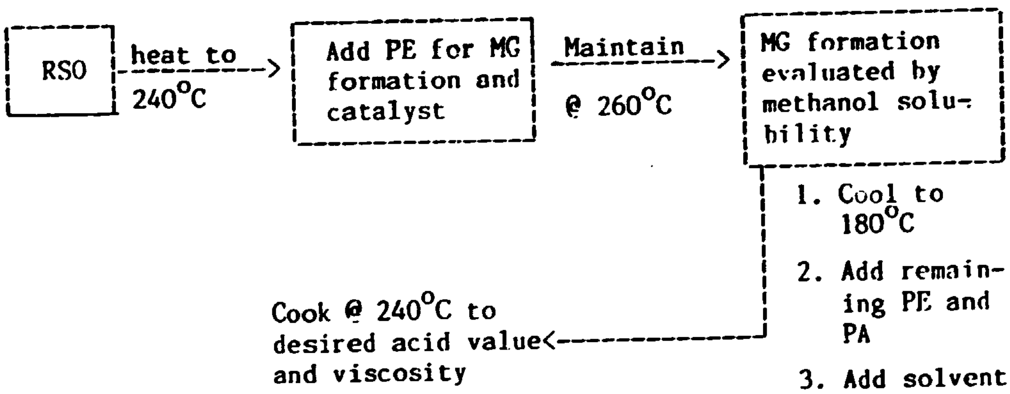
An alkyd is characterised by the oil length defined as the triglyceride proportion of an alkyd expressed as the percentage of the finished alkyd weight (sometimes this is also expressed in terms of phthalic anhydride or fatty acid content). The surface coating industry in Sri Lanka manufactures SHORT, MEDIUM and mostly LONG type of alkyd, RSO being used for the latter two types by either the FUSION OR SOLVENT process. Typical recipes for an RSO based LONG OIL ALKYD by the fusion and solvent processes are given :-

Recipe for Long Oil Alkyd (parts by weight)

	FUSION	SOLVENT
RSO	740	740
Pentaerythritol	194	194
Phthalic anhydride	325	296
Catalyst (10% NaOH)	10	10
Solvent	-	3% by weight Xylene

NOTE: RSO has FFA > 15% and treated with activated bleaching earths if a lighter coloured alkyd is required.

A block diagram for alkyd resin manufacture by the SOLVENT process is given below:-



NOTE: PE - Penta erythyritol

PA - Phthalic Anhydride

MG - Monoglyceride

In the fusion process the procedure is similar except that excess phthalic anhydride used makes allowance for sublimation and solvent is not added after the mono-glyceride formation stage. Venting is carried out at this stage if needed to accelerate the cooking reaction. A blanket of nitrogen maintained during the entire operation helps in light coloured alkyd production.

A serious drawback for RSO alkyds is its yellowing behaviour on outdoor exposure and hence is suitable only for dark colour pigmented enamel and anti-corrosive coatings. The alternative to RSO for non-yellowing alkyds is TALL OIL FATTY ACIDS and VEGETABLE OIL FATTY ACIDS with lower linolenic content (e.g. soya, sunflower fatty acids). The lowered linolenic content of Tall Oil Fatty Acids also favours reduced gelation compared to linolenic richer RSO during alkyd synthesis.

5.3.2 *Properties of RSO Alkyd Resin*

The test properties of an RSO based alkyd commercially available in Sri Lanka are compared with a TOFA based alkyd in Table 5.2. The RSO based alkyd had inferior colour and yellowing index but enamel paints formulated from the respective alkyds were satisfactory with respect to service factors such as consistency, brushability and drying properties. The total Sri Lankan market of base alkyd (60% solids in low aromatic white spirits) for formulation of dark pigmented enamel and anticorrosive coatings is about 800 tons so that potential use of RSO in this area is about 350 tons.

5.4 Chemical Modification of RSO

The high degree of unsaturation in RSO offers potential for chemical modification and two products which could be synthsised without difficulty are dark factice and sulphonated RSO. The former is obtained by reaction of RSO with sulphur (Ref. 5) and was marketed in Sri Lanka for the processing of natural rubber. Sulphonated RSO could be used in the fat liquoring of leather (Ref. 6). Both these products need to be developed to better quality levels if they are to compete with materials available in the international market. The potential for chemical modification in Sri Lanka is estimated at 300 tons RSO.

5.5 Marketing of Rubber Seed Meal

The relatively high protein and low fibre content of RSM would be helpful in its marketing. About 7000 tons of RSM are marketed annually in South India in formulations for pig, poultry and cattle feed. The Sri Lankan market has been much less amounting to only about 500 tons per year where RSM is substituted for coconut poonac in cattle feed recipes.

Animal feed trials on hen breeders and broilers were conducted by the Veterinary Research Institute, Department of Animal Production and Health, Sri Lanka and are presented in Chapter 6.

5.6 Marketing of Waste Products in Rubber Seed Processing

Rubber seed shell obtained during decortication could find potential as a fuel and as a raw material in activated carbon manufacture. Nearly 40% of the seed is shell so that large quantities of shell would be available.

Laboratory trials were carried out at HAYCARB Limited., a manufacturer of activated carbon in Sri Lanka with international marketing contacts. Results in Table 5.3 reveal that rubber seed activated charcoal was comparatively inferior to activated COCONUT SHELL charcoal and further development work is required for upgrading. The conclusions of HAYCARB were as follows:-

1. It is relatively more difficult to activate Rubber Seed shell charcoal compared to Coconut Shell charcoal.

2. In its pore size distribution RS shell activated carbon resembles Coconut Shell based activated carbon more than a macro-porous, softer coal based activated carbon.

3. RS shell activated carbon does not possess adequate strength/attrition resistance for use in most applications where coconut shell activated carbon performs satisfactorily.

4. RS shell activated carbon possesses lower bulk density thus necessitating larger bed volumes/filters for the same magnitude in end applications.

5.7 Summary and Conclusion

Technical products manufactured from RSO include soap, alkyd resin and chemical modifications. Rubber seed meal will contribute to the financial viability of RS processing due to bulk quantities produced as also RS shell as a fuel and possibilities of activated carbon production. The total potential for marketing technical products estimates use of 2500 tons RSO, 5000 tons RSM and 8,000 tons shell (Table 5.4).

5.8 References

1. Communication: BCC Lanka Ltd., Colombo, Sri Lanka.
2. Communication: Lever Brothers (Ceylon) Limited, Colombo, Sri Lanka.
3. T.C. Patton: Alkyd Resin Technology, formulating techniques and allied calculations (John Wiley, 1962).

4. D.H. Solomon: The Chemistry of Organic film formers (John Wiley, 1967).

5. M.R.N. Fernando: Manufacture of dark factice from Rubber Seed Oil, Rubber Research Institute of Ceylon, Quarterly J, 47 59-64 (1971).

6. Private communication: Leather Research Institute of Nigeria, Zaria, Nigeria.

Table 5.1 - Characteristics of Fats Used in Soap Manufacture

Fat	Titer°C	Iodine Value	Saponification Value
Coconut oil	20-24	7-11	250-264
Tallow	40-48	40-48	185-205
RSO	33	138-142	186-195
"Ideal" fat charge	36-38	38-40	215-225

(Ref: Chapter on Soap by E. Jungermann in Bailey's Industrial Oil and Fat Products Vol.1, Ed. Daniel Swern, Wiley - Interscience).

Table 5.2 - Comparison of Alkyds (Long Oil Length)
Based on RSO and TOFA

Property	RSO Based Alkyd	TOFA Based Alkyd
Total solids %	60.1	59.3
Acid value	7.8	2.6
Viscosity mPa.s (Brookfield)	13,250	11,000
Colour (Lovibond 1" cell)		
(a) from refined RSO	11.1Y, 11.2R, 1.8B	20Y + 2.4 R*
(b) from crude RSO	3.2Y, 16.4R, 3.6B	
Drying time (hours)		
(a) surface dry,	1.5	2.5
(b) hard dry	5.2	5.5
Yellowing index (ASTM D1543, D2244,E313)	28.6	10.3

*NOTE: Colour of alkyd prepared from commercial TOFA.

Results have been obtained by laboratory tests on commercial samples in Sri Lanka.

Table 5.3 - Report on Activation of Rubber Seed Shells

(a) Carbonization in limited air supply @ 550°C.

Ash (on dry basis)	0.6%
Volatile matter (on dry basis)	28%
Fixed carbon (on dry basis)	71%
Yield on carbonization (on dry basis)	28%

(b) RS Charcoal obtained as above crushed and screened to 4.75 x 2.36 mm size and activated.

	Activated RS Shell Charcoal	Activated Coconut Shell Charcoal
1. Activity (g CCl_4/100g)	46	75
2. Iodine number (measure of surface area)	950	1200

NOTE: Results made available by courtesy of

HAYCARB LIMITED,
400 Deans Road,
Colombo 10,
SRI LANKA.

Table 5.4 - Estimate of Marketing Potential for Technical RSO, RSM and Waste Products in Sri Lanka

Product	Quantity (MT)
Laundry soap	1,250
Soft/liquid soap	600
Alkyd resin	350
Factice and sulphonated RSO	300
Rubber Seed Meal	5,000
Rubber Seed Shell	8,000

CHAPTER 6

ANIMAL FEEDING TRIALS*

6.1 Review of Past Work

6.1.1 *Processing*

The material used in most of the feeding experiments reported from Sri Lanka has been an expeller-processed meal prepared on a pilot scale from kernels subjected to kiln-drying and cooking (see Nadarajah, 1979). In reports from India, Malayasia and Nigeria, the material used has been described as cake (eg. Talpada et al, 1980), hydraulic-pressed (eg. Nwokolo & Akpapunam, 1986) or mechanically pressed (eg. Toh & Chia, 1978). Some workers have used solvent-extracted material prepared from fresh kernels (eg. Nwokolo et al, 1987).

Table 6.1 - Proximate Composition of Variously Prepared Rubber Seed Meals
(Expressed in g/kg dry matter)

Processing method: Reference:	Expeller Lever Bros. (1969)	Expeller Buvanendran & Siriwardene (1970)	Hydraulic Nwokolo & Akpapunam (1986)	Extracted Nwokolo *et al* (1987)
Crude protein	338	263	290	425
Ether-extractives	128	122	206	11
Crude fibre	52	110	56	152
Ash	54	66	64	92
N-free extractives	428	439	354	320

In this Table, expeller means expeller-processed, hydraulic means hydraulic-pressed and extracted means solvent-extracted.

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*This report has been submitted by Dr G A P Ganegoda, Head of Animal Nutrition Division, Veterinary Research Institute, Department of Animal Production and Health, Gannoruwa, Peradeniya, Sri Lanka.

6.1.2 *Proximate Composition*

The proximate composition of the meal varies in relation to the extent of decortication and residual oil content. Table 1 gives representative values for expeller-processed, hydraulic-pressed and solvent-extracted materials.

6.1.3 *Essential Amino-Acid Composition*

The essential amino-acid contents of variously prepared rubber seed meals are given in Table 2. It is seen that the deviation of the smallest value from the largest value is greatest in the case of histidine (61%), followed by methionine plus cystine, (59%), methionine (58%), lysine (42%) and arginine (38%). These differences may be due to any one or combination of the following factors:-

(a) the proportions of rubber seed proteins may differ according to rubber variety;

(b) certain amino acids are destroyed (eg. cystine and methionine) or become resistant to acid hydrolysis as a result of heat treatment involved in oil extraction, the extent of the effect being dependent on the severity of the heat treatment;

(c) in addition to tryptophan, which is totally destroyed, cystine, methionine and threonine are destroyed to variable extents during ordinary acid hydrolysis for amino acid analysis;

(d) in the case of cystine and methionine, accurate values can be obtained if the analytical sample is oxidized by performic acid before acid hydrolysis.

Table 6.2 shows that the essential amino-acid composition of expeller-processed rubber seed meal resembles that of coconut meal quite closely.

Table 6.2 - Essential Amino-Acid Composition of Variously Prepared Rubber Seed Meals in Comparison with that of Coconut Meal
(Expressed in g/16 g N)

	Rubber Seed Meal				Coconut Meal
	(1)	(2)	(3)	(4)	
Arginine	9.2	7.0	11.2	9.2	12.9
Histidine	1.8		4.6	2.7	2.7
Iso-Leucine	3.1	2.5	3.6	2.8	3.1
Leucine	6.0	4.9	7.0	5.2	7.1
Lysine	2.8	2.5	4.3	3.5	3.0
Methionine	1.1	1.0	1.7	2.4*	1.4
Methionine plus Cystine	2.5	3.0*	2.6**	6.1*	2.8
Phenylalanine	3.8	2.8	4.0	3.5	4.3
Threonine	3.1	2.5	3.4	2.7	3.1
Tryptophan***					
Tyrosine	2.6	- -	3.1	2.4	7.9
Valine	6.5	5.4	6.7	6.6	4.7

(1) Expeller-processed meal (Lever Bros, 1969)
(2) Expeller-processed meal (Toh & Chia, 1978)
(3) Mechanically pressed meal (Nwokolo et al, 1987)
(4) Solvent-extracted meal (Achnewhu, 1986)
*Determined on samples oxidized with performic acid
**Cystine determined on samples oxidized with performic acid
***1.2 to 1.4 (see Rajaguru & Vohra, 1975).

6.1.4 *Fatty-Acid Composition and Properties of Oil*

Figures quoted in Table 3 show that oil extracted from rubber seed kernel is rich in unsaturated fatty acids and has a high polyunsaturated:saturated (P:S) ratio (cf coconut and soya bean oils). Another significant feature is its high content of unsaponifiable matter.

Table 6.3 - Fatty acid Composition and Physico-Chemical Properties of Rubber Seed Oil in Comparison with those of Other oils

Oil: Reference:	Rubber seed Nwokolo et al (1988)	Soya bean Nwokolo et al (1987)	Coconut CCB (1939)
Fatty acids, g/kg:			
Caproic (6:0)			3.5
Caprylic (8:0)			84.0
Lauric (12:0)			478.5
Myristic (14:0)	0.8	1.1	175.0
Palmitic (16:0)	92.7	130.7	82.5
Stearic (18:0)	106.0	55.3	20.0
Arachidic (20:0)	5.7	4.9	
Behenic (22:0)	1.5	5.1	
Lignoceric (24:0)	1.2	2.7	
Palmitoleic (16:1)	1.4	1.4	
Oleic (18:1)	273.0	281.6	66.0
Linoleic (18:2)	349.0	444.4	
Linolenic (18:3)	173.0	64.5	
Gondoic (20:1)	1.8	1.9	
Total saturated	207.9	188.8	910.0
Total unsaturated	798.2	805.1	90.0
Total EFA*	522.0	508.9	18.0
P:S** ratio	2.5	2.7	0.02
Refractive index	1.469		
Iodine value	138		8
Saponification value	192		257
Unsaponifiable matter, g/kg	4.8		

*Essential fatty acids
**Polyunsaturated:saturated

6.1.5 *Mineral Composition*

The major-element and trace-element contents of mechanically pressed material of Nigerian origin are given in Table 6.4; mean values for coconut and soya bean meals are also given for comparison. It is seen that the values are typical of oilseed meals, except for the rather high zinc content; part of the iron may be that worn off from processing machinery, as in the case of coconut meal (cf. soya bean meal).

6.1.6 *Antinutritional Factors*

The cyanogenic glucosides present in the fresh kernel decompose due to enzymic action as well as to slight acidity caused by the formation of free fatty acids on standing to yield hydrocyanic acid (HCN). The HCN content of fresh kernel could be as high as 1200 mg/kg on dry basis; however, it diminishes rapidly by as much as 80% after storage for about 1 week and much less rapidly thereafter (see George et al, 1932). Similarly, the residual HCN content of expeller-processed meal may decrease from about 25 to about 10 mg/kg on storage for about 4 weeks and very slowly thereafter (see Toh & Chia, 1978). According to Rajaguru & Wettimuny (1971), the residual HCN in the meal is unlikely to cause any toxicity problems; these workers have reported that histopathological examination of broiler chickens fed a diet containing 40% decorticated expeller-processed meal did not show any evidence of HCN toxicity.

6.1.7 *Protein Quality*

Limiting amino acid and chemical score. The percentage deviations of the essential amino-acid content of variously prepared rubber seed meal from the corresponding essential amino acid content of whole-egg protein are given in Table 5. It is seen that methionine or methionine-plus-cystine is the limiting amino acid in the case of expeller-processed or otherwise pressed meal and lysine in the case of the solvent-extracted meal. In the latter case, the processing temperature had not exceeded 60 °C, whereas in the former case, it may have exceeded 100 °C. In the case of groundnut meal too, it has been observed that lysine is the limiting amino acid in cold-extracted material and methionine plus cystine in toasted materal. The chemical score of rubber seed meal can be expected to be within 27 and 49 (see Table 6.2).

Biological evaluation. Based on estimates of protein efficiency ratio. (PER) and biological value (BV), Fetuga et al (1978) found that as a source of essential amino acids, full-fat rubber seed meal ranked well below groundnut meal (Table 6.6). Also, they found that while autoclaving did not improve and acid-washing or alkali-washing decreased the PER and BV of the material, extraction with hot water tended to improve them; estimates with supplemental amino acids indicated that lysine and methionine were the first and second limiting amino-acids, respectively. It is interesting to note that a solvent-extracted material tested by these workers failed to support rat growth at the 10-% dietary protein level used in PER assays.

Table 6.4 - Mineral Composition of Rubber Seed Meal in Comparison with that of Coconut Meal and Soya Bean Meal
(Values expressed on dry matter basis)

Meal:	Rubber seed	Coconut	Soya bean
Processing method:	Mechancial	Expeller	Extracted
Reference:	Nwokolo *et al* (1987)	NAS (1971)	Krider *et al* (1982)
Ash, g/kg	92	72	66
Major elements, g/kg:			
Calcium	2.1	2.3	3.2
Phosphorus	7.4	6.7	7.3
Potassium	15.2	16.5	22
Magnesium	3.9	3.3	3
Trace elements, mg/kg:			
Manganese	33	71	33
Zinc	113		30
Iron	249	1420	135
Copper	34	15	41

6.1.8. Use in Animal Feeding

Feeding trials reported from Vietnam by Thuoc (1968) indicate that dried rubber seed kernel can be incorporated at 10-% level in diets for finishing meat-type chickens and at 20-% level in diets for finishing pigs without adverse effect on palatability of diet, body weight gain, feed conversion efficiency or health. Anarthasubramaniam (1980) has reviewed 55 reports which appeared over a period of 40 years from 1929 to 1979 on the nutritional aspects of rubber seed kernel and meal. The reports which have been published more recently are reviewed below.

6.1.8.1 Use in poultry feeding

Rubber seed meal could be included at 25-% level in the diet of finishing broiler chickens without adversely affecting their growth rate or muscle:bone ratio (Ong & Yeong, 1978). Similarly, the meal could be included at 45-% level in broiler finisher diets supplemented with lysine and methionine (Yeong & Syed Ali, (1979). Narahari *et al* (1986c) found that broiler performance was poorer when decorticated or undecorticated rubber seed meal was substituted for an isonitrogenous level of groundnut meal in the diet (cf Fetuga et al, 1978).

According to Nwokolo *et al* (1987), the average availability (true digestibility) of amino acids in rubber seed meal (80%) is considerably less than that of soya bean meal (93%), mainly due to poor availability of histidine (60%), lysine (60%) and cystine (66%).

Table 6.5 - Percentage Deviations of Essential Amino-acid Content of Variously Prepared Rubber Seed Meals from Corresponding Content of Whole-egg Protein
(Based on vlaues given in Table 6.2)

Protein:	Whole-egg	Rubber seed meal			
Processing method:		Expeller	Expeller	Mech	Ext
Reference:	(5)	(1)	(2)	(3)	(4)
	(g/16 g N)	Percentage deviation)			
Arginine	6.4	+44	+09	+75	+43
Histidine	2.1	-14		+119	+29
Iso-Leucine	8.0	-61	-69	-55	-65
Leucine	9.2	-35	-47	-24	-43
Lysine	7.2	-61	-65	-40	-51
Methionine	4.1	-73	-76	-59	-41
Methionine+cystine	6.5	-62	-54	-60	-06
Phenylalanine	6.3	-40	-56	-37	-44
Threonine	4.9	-37	-49	-31	-45
Tryptophan*	1.5				
Tyrosine	4.5	-42		-31	-47
Valine	7.3	-11	-26	-08	-10
Limiting amino acid		MET	MET	TSA	LYS

Figures preceded by "+" sign indicate surpluses and those preceded "-" sign indicate deficits.
(1) to (4) : see Table 6.2
(5): Block & Mitchell (1946)
*See Table 6.2 for tryptophan content of rubber seed meal.

The performance of White Leghorn layers in terms of egg production, feed conversion efficiency and body weight change from 20 to 40 weeks of age was adversely affected when undecorticated rubber seed meal as such or subjected to autoclaving or fermentation was substituted mostly for groundnut meal in the diet; however, decorticated material at 10-% level did not affect the layer performance (Narahari *et al*, 1986b). Similarly, Yeong *et al* (1981) have concluded that up to 30% of maize and soya bean meal in layer diets could be substituted with rubber seed meal.

Table 6.6 - Relative Efficiency of Rubber Seed Meal as a Source of Essential Amino Acids

Source :	Protein efficiency ratio	Biological value
Casein	2.73 (2.50)	70.9
Soya bean meal	1.88 (1.72)	65.4
Groundnut meal	1.54 (1.41)	59.4
Rubber seed meal:		
(a) full-fat	0.84 (0.77)	49.9
(b) defatted	-1.29 (-1.18)	38.5

Figures in parentheses are values standardized to a PER value of 2.50 for the standard protein (casein).
Reference: Fetuga *et al* (1978).

When rubber seed meal was substituted mostly for groundnut meal in diets of White Leghorn breeders, performance in terms of age at sexual maturity, egg production, feed conversion efficiency, body weight change and fertility was not affected, but, egg weight and hatchability of eggs decreased at dietary levels of 10% or more (Narahari *et al* 1986a). These workers have concluded that the optimum level of rubber seed meal in breeder diets was 5%.

6.1.8.2 Use in pig feeding

Based on observations on a total of 40 growing-finishing pigs fed 0, 10, 20 or 30% rubber seed meal in the diet for 147 days, Ong & Radem (1981) concluded that the residual HCN content of the material was of no significance for pig feeding.

6.1.8.3 Use in ruminant feeding

Talpada *et al* (1980) found that substitution of decorticated rubber seed cake for one-half or all (30%) of cotton seed meal in concentrates fed to growing Kankrej calves did not affect the digestibility of the rice-straw-based diet or balance of nitrogen, calcium and phosphorus in the calves; the concentrates were balanced with respect to digestible crude protein and total digestible nutrients.

When four pairs of lactating cows fed chopped fodder maize to appetite were given equal daily allowances of a concentrate containing 20% cotton seed or rubber seed meal for 16 weeks, there was no within-pair difference in milk yield attributable to the dietary treatments (Kumar *et al*, 1986). Similarly, James *et al* (1980) found that rubber seed meal was a satisfactory substitute for coconut meal in concentrates for lactating cows.

6.1.8.4 Effect of residual oil

Nwokolo *et al* (1988) observed no adverse effect on the mean daily weight gain or feed intake of rats fed rubber seed oil at 5% dietary level for 28 days when compared with those fed maize oil. Similar observations were made by Nwokolo & Sim (1988) on chicks fed rubber seed oil at 8% dietary level for 28 days; lipid and total fatty-acid digestion coefficients were similar, but, liver lipid content was higher when compared with chicks fed maize oil. These observations taken in conjunction with the fact that rubber seed oil is free from toxic fatty acids (see Table 6.3) strongly suggest that residual oil in rubber seed meal at any level is harmless for animal feeding.

6.1.9 *Concluding Remarks*

From the foregoing review of past work on rubber seed meal the following conclusions can be drawn:-

(a) the contents and availability of critical amino acids in the material for simple-stomached animals may vary in relation to the degree of heat treatment involved in processing, so that due care should be taken to avoid overheating;

(b) the material can be successfully used as a protein or protein-and-energy source in diets for simple-stomached animals, depending on its residual oil content and provided that due care is taken to balance the diets with respect to the critical amino acids in relation to the animal species concerned;

(c) the material is useful as an alternative oil seed meal in feeding of growing or lactating ruminants;

(d) the residual HCN content of the material is quite low and safe for all animal species, because of the time lapse from collection and processing of seeds to feeding;

(e) the residual oil in the material is free from any toxic fatty acid and its unsaponifiable matter is unlikely to present any danger in animal feeding;

(f) some workers have observed a decreased hatchability of eggs produced by breeding hens fed diets containing the material

(g) nobody has studied the effect of feeding the material on the flavour of meat in meat-producing animals;

(h) more work should be carried out to quantify the effect of processing conditions on the protein quality and amino-acid availability, especially lysine for pigs and methionine for poultry.

6.2 Research Programme

Where several materials resulting from alternative rubber seed processing techniques are to be screened, a standard PER assay can be carried out as a first step. However, only one principal material was available for testing; this was the residue left after hydraulic pressing of decorticated and kiln-dried kernels. As such it was decided to carry out the following research programme:-

(a) determination of the chemical composition of the material;

(b) preliminary experiments relating to the metabolizable energy value of the material for poultry;

(c) experiments to re-investigate the effect of feeding rubber seed meal on hatchability of eggs;

(d) experiments to study the effect of feeding the material on the meat flavour of broiler chickens.

However, the test material supplied for (d) above was a screw-pressed meal with coconut meal added as a processing aid at 5% level.

The results of a calf experiment conducted with undecorticated expeller-processed commercial product, which have not been published, are relevant for discussion and are therefore included in this report.

It is intended to carry out more work with the test material, especially a long-term toxicity trial using rats and estimation of the available lysine content for pigs, at a later stage.

6.3 Estimation of Metabolizable Energy Value for Poultry

6.3.1 *Introduction*

At the outset, it became clear that the total quantities of test material required for the hen-breeder and broiler experiments could not be prepared in single batches, the residual oil content varied from batch to batch and that several such batches had to be blended for the purpose of each experiment. A knowledge of the ME value of the blend was a prerequisite for the formulation of the experimental diets. Biological estimation of the ME value of a poultry feeding stuff is tedious. On the other hand, chemical estimation is relatively easier and quicker, provided that the method adopted is applicable to the feeding stuff concerned.

The biological method of Hill *et al* (1960) is commonly employed for the estimation of the nitrogen-corrected (N-corrected) ME value of poultry feeding stuffs including oilseed meals (see Hill & Renner, 1960). The main objective of this experiment was to determine whether the said chemical method was as good as the biological method for estimating the N-corrected ME value of the test material.

6.3.2 *Materials and Methods*

Test materials. Two test materials of rubber seed meal were obtained in the present investigation; one was a 30 kg batch of hydraulic-pressed rubber seed meal of residual oil content in the 12-20% range and the other was a 15 kg batch of extracted rubber seed meal prepared by subjecting the first-mentioned material to extraction with petroleum ether (boiling range: 60-80 °C) for 16 h in a large Soxhlet extractor.

Table 6.7 - Biological Estimation of Metabolizable Energy of Rubber Seed Meal for Poultry: Composition of Basal Diet
(All values expressed in g/kg dry wt unless otherwise stated)

	Crude protein	Reference diet
Ingredients:		
Glucose		430
Ground whole wheat	128	163
Soya bean meal	505	175
Dried whole milk	263	95
Fish meal	575	50
Casein	890	20
Dried brewers yeast	356	25
Calcium carbonate		15
Dicalcium phosphate		12
Salt		5
Vitamin & trace-element premix*		2
Lasalocid sodium, 20% concentrate		0.5
DL-Methionine		3.5
Chromic oxide		3
Nutrients:		
Crude protein		193
Lysine**		12.5
Methionine + cystine**		8.5
Calcium**		12
Available phosphorus**		5

*Supplied per kg of dry diet, 15,000 IU vitamin A, 3,000 IU vitamin D, 30 IU vitamin E, 3 mg vitamin K, 2 mg thiamine, 6 mg riboflavin, 12 mg pantothenic acid, 30 mg niacin, 20 mcg vitamin B12, 2 mg pyridoxine, 1 mg folic acid, 100 mcg biotin, 125 mg choline, 80 mg Mn, 50 mg Zn, 40 mg Fe, 10 mg Cu, 0.5 mg Co, 1 mg I and 0.2 mg Se.
**Calculated values

Biological estimation. The N-corrected ME value of each test material was estimated by the method of Hill *et al* (1960). Glucose of known ME value for poultry (15.23 MJ/kg dry matter) was used as the reference substance in the reference diet shown in Table 6.7. Each test material was substituted for glucose at a level of 300 g/kg in the reference diet to give the two test diets. Sixty crossbred ("Dekalb XL") cockerels arranged in six groups of ten were fed the reference diet from hatching to 2 weeks of age. Thereafter, each of the three diets (reference and two test) were fed to two groups from 14 to 28 days of age. Excreta of each group collected at 24 h intervals on four successive days during the last week of the experimental period were dried in a forced-draught oven at 70° C for 24 h and placed in an airtight container before pooling and equilibrating with atmospheric moisture.

Chemical estimation. The N-corrected ME value of each test material was computed from its crude protein (CP), ether-extractive (EE), starch and sugar (expressed as sucrose) contents by the equation -

$$ME = 0.01551\ CP + 0.03431\ EE + 0.01669\ starch + 0.01301\ sugar$$

where ME is in MJ/kg and CP, EE, starch and sucrose are g/kg on dry-matter basis (see HMSO, 1988).

Analyses. The moisture contents of all materials were determined by drying in vacuum oven at 85° C and 25 mm of Hg for 5 h. Their nitrogen (N) contents were determined by the (macro) Kjeldahl procedure using copper and selenium catalysts; where necessary, crude protein was expressed as 6.25 x N. The gross energy contents of the diets and excreta were determined by a "Parr" oxygen bomb calorimeter; their chromic oxide contents were determined spectrophotometrically, after conversion to dichromate. The starch and sugar contents of the test materials were determined by the method of Clegg (1956), using anthrone for colour development and Varian Techtron 635 spectrophotometer for measurement of absorbance; their ether-extractive contents were determined by Soxhlet extraction with petroleum ether (boiling range 40-60° C). HCN was determined by the method of AOAC (1965). All analyses were carried out in triplicate.

6.3.3 Results and Discussion

The results of biological and chemical estimation of the N-corrected ME values of the two test materials are summarised in Table 6.8 and 6.9, respectively. It is seen that the chemical estimate is in close agreement with the biological estimate in the case of the hydraulic-pressed material. However, in the case of the extracted material, the chemical estimate exceeds the biological estimate by 31%.

Table 6.8 - Biological Estimation of Metabolizable Energy of Rubber Seed Meal for Poultry: Summary of Results
(All values expressed on dry matter basis)

		Reference	Rubber seed meal Hydraulic	Rubber seed meal Extracted
Gross energy, MJ/kg:				
diet	(a)	17.598*	19.694*	18.447*
excreta	(b)	14.389**	15.556**	14.841**
Chromic oxide, g/kg:				
diet	(c)	3.178*	3.186*	3.528*
excreta	(d)	18.300**	11.125***	10.200**
Nitrogen (N), g/kg:				
diet	(e)	32.077*	45.148*	50.207*
excreta	(f)	62.210**	74.344**	78.900**
Excreta energy, MJ/kg diet:				
= bc/d	(p)	2.501	4.456	5.133
N retained, g/kg diet:				
= e - fc/d	(q)	21.263	23.844	22.917
Energy in retained N, MJ:				
=q x 0.0344***	(r)	0.731	0.820	0.788
N-corrected ME of diet:				
= a - p - r		14.366	14.418	12.526
N-corrected ME of test material:				
= MEG - [(MER - MET)/0.30]			15.3	9.1

*Mean of triplicate values
**Mean of triplicate values for two groups of cockerels
***Calorific value of uric acid, MJ/kg
MEG = ME of glucose (15.23 MJ/kg); MER = ME of reference diet;
MET = ME of test diet.

The energy-yielding constituents of a poultry feedingstuff can be broadly grouped as crude protein, ether-extractives and available carbohydrates consisting of starches, dextrins, disaccharides and monosaccharides. In the method of Clegg (1956), available carbohydrates extractable with hot aqueous ethanol (monosaccharides, disaccharides and some dextrins) are determined as sugar (glucose) and the remainder as starch. The ME value of a poultry feedingstuff depends largely on the digestibility of the energy-yielding constituents of that feeding stuff and incidence of antinutritional factors in it. The chemical method of HMSO (1988) is based on the correlation of the energy-yielding constituents with the biologically estimated ME value of common poultry feeding stuffs that are readily digestible and virtually free from antinutritional constituents. The close agreement between the biological and chemical estimates of the ME value of the Hydraulic-pressed rubber seed meal strongly suggests that its energy-yielding constituents are readily digestible (cf. Nwokolo & Akpapunam, 1986; Nwokolo *et al*, 1987; Nwokolo & Sim, 1988) and that its residual HCN content is harmless (see Thuoc, 1968).

Table 6.9 - Chemical Estimation of Metabolizable Energy of Rubber Seed Meal: Summary of Results
(All values expressed per kg dry matter)

Material:	Hydraulic-pressed	Extracted
Crude protein, g	271	365
Ether extractives, g	183	9
Starch, g	243	298
Sugar, g	67	82
Sugar expressed as sucrose, g:		
= sugar x 0.95	64	78
N-corrected ME*, MJ	15.4	11.9
Residual HCN, mg	54	63

*Computed by the equation given in Section 6.3.2.

The discrepancy between the biological and chemical estimates of the ME value of the extracted material could be due to lowering of the digestibility of the energy-yielding constituents by additional processing, lowered absorption of dietary nutrients by its relatively higher crude fibre content and increased heat increment in the birds caused by its relatively higher crude protein content.

6.3.4 *Conclusion*

It was concluded that in the case of hydraulic-pressed rubber seed meal resulting from the oil extraction technique developed in the present investigation:-

(a) the energy-yielding constituents were readily digested by poultry;

(b) the residual HCN content was virtually harmless for growing poultry;

(c) the ME value for poultry could be accurately estimated by the chemical method of HMSO (1988).

6.4 Hen Breeder Experiment

6.4.1 *Introduction*

In addition to Narahari *et al*(1986a) quoted in Section 6.1.8.1. Buvanendran (1971) also observed that rubber seed meal at 20% level in the diet of breeding hens reduced the hatchability of eggs due to increased embryonic death; Rajaguru (1971) also observed that when rubber seed meal was included at levels ranging from 10 to 40% in the diet of hen breeders from the 12th week of age, higher levels delayed sexual maturity, and lowered the egg weight, hatchability of eggs and weight of chicks at hatching. The objective of this experiment was to determine whether the present test material would cause such effect in hen breeders when included in the diet at a level which is, from a practical view point, high for an oilseed meal.

6.4.2 *Materials and Methods*

Test Material. The test material was the residue resulting from the following process: rubber seed kernels separated from freshly collected seeds by a combination of manual and mechanical means were kiln-dried to reduce the moisture level, cooked in a steam-jacketed vessel and subjected to hydraulic pressing ,the residual oil content in the meal being in the 15-20% range. The required quantity, supplied in several batches, was ground in a hammer mill fitted with, 3mm screen and blended. The material was packed in plastic bins and stored in a cold room before and after blending up to the time of inclusion in the test diets; it had the composition given in Table 6.10.

Diets. The nutrient content of the ingredients are given in Table 6.10. The control and two test diets were formulated to contain the amounts of nutrients specified in Table 6.11. The two test diets differed from the control in having rubber seed meal in place of coconut meal and some of the soya bean meal, and rice bran in place of some of the maize meal. The test diets contained rubber seed meal at 250 g/kg, without or with extra DL-methionine at 0.5 and 1.0 g/kg during the grower and breeder stage, respectively. Table 6.12 gives the composition of the diets.

Table 6.10 - Hen Breeder Experiment: Composition of Ingredients (*Figures in italics are values from published data; all values are expressed in g/kg air-dry material unless otherwise stated)*

Ingredients	ME*	CP	EE	CF	LYS	TSA	Ca	AP
Maize meal	*14.1*	86	33	27	*2.4*	*3.6*	*0.2*	*1*
Rice bran	8.3	98	161	151	*4.8*	*4.2*	*0.6*	2
Rubber seed meal**	12.1	264	92	52	*7.5*	*6.5*	2.2	1.7
Coconut meal	*6.0*	210	62	118	*6.0*	*5.5*	*1.5*	*1.5*
Soya bean meal	*9.4*	446	14	68	*28*	*13*	2	2
Fish meal	*11.0*	670	68		*48*	*23*	*30*	*20*
Shell grit							332	
Dicalcium phosphate							242	171

*MJ/kg air-dry material
**Contained 58 mg/kg Residual HCN (air-dry basis)
CP = Crude protein; EE = Ether extractives; CF = Crude fibre;
LYS = lysine; TSA = total sulphur-containing amino acids;
Ca = Calcium; AP = available phosphorous

Table 6.11 - Hen Breeder Experiment: Nutrient Specifications for diets *(Values expressed on air-dry basis)*

Stage :	Grower	Breeder
Metabolizable energy, MJ/kg	10.5	11.1
Crude protein, g/kg	150	175
Lysine, g/kg	6.5	8.0
Methionine + cystine, g/kg	5.6	6.3
Calcium, g/kg	10	34
Available phosphorus, g/kg	4.5	4.5

Birds. A batch of 250 Rhode Island Red pullets procured from the Central Poultry Research Station of the Department of Animal Production & Health Sri Lanka, were raised from hatching to 8 weeks of age on a stock starter feed. At 8 weeks of age, 210 of them were divided into 15 groups of 14, assigned to the three dietary regimes and housed in deep-litter pens in a completely random design. The pullets were individually weighed before randomization at 8 weeks, at 18 weeks and at 40 weeks of age.

Management. The grower diets were fed from 8 to 20 weeks of age according to the feeding schedule given in Table 6.13. Nest boxes were introduced at the rate of four per pen when the pullets were 18 weeks old. The breeder diets were fed *ad libitum* from 20 to 40 weeks of age. Group feed intakes were recorded on a weekly basis from 32 to 36 weeks of age. Eggs were collected not less than six times daily, the first and last collections being at 08.30 and 16.30 hours. The weight of eggs collected from each pen on a day were weighed to the nearest gramme on the same day; the number of eggs was also recorded.

Hatching. Hens were artificially inseminated with semen from test RIR roosters of the same age. The eggs of hatching were collected in two weekly batches when the hens were 36 to 37 weeks old, and were set in two batches in a Zincky incubator with a capacity to set 6,000 eggs. Those eggs which were withdrawn on the basis of the 7th day and 18th day candling were broken and examined. Early-dead embryos, late-dead embryos, pipped eggs and hatchability were expressed as percentages of the fertile eggs.

Table 6.12 - Hen Breeder Experiment: Composition of Diets *(Values expressed in g/kg of air-dry diet unless otherwise stated)*

Treatment:	Control Grower	Control Breeder	RSM* Grower	RSM* Breeder
Maize meal	380	435	330	440
Rice bran	29	-	-	70
Coconut meal	140	233	-	-
Soya bean meal	102	152	23	101
Rubber seed meal	-	-	250	250
Fish meal	20	30	20	30
Soya bean oil	25	42	-	-
Shell grit	15	85	15	85
Dicalcium phosphate	16	17.2	16	17.4
Salt	2.5	2.5	2.5	2.5
Vitamin & trace-element premix**	2	2	5	2
Amproleum, 20% concentrate	0.5	-	0.5	-
Virginiamycin, 2% concentrate	0.5	0.5	0.5	0.5
L-Lysine monohydrochloride	-	-	1.5	0.8
DL-Methionine	0.5	0.8	0.6	0.8

Table 6.13 - Hen Breeder Experiment : Feeding Schedule for Growing Pullets

Age (weeks)	Daily feed allowance (g/bird)
9	50
10	54
11	57
12	61
13	64
14	67
15	70
16	73
17	76
18	78
19	80
20	82

*Test diet without extra DL-methionine; the remaining test diet (RSM + MET) contained extra DL methionine at 0.5g/kg during growing storage and 1.0g/kg during breeding stage.

**Supplied per kg of air-dry diet, the amounts and trace elements stated in Table 6.7.

Prophylaxis. The pullets were vaccinated against Marek's disease, Newcastle disease, infectious bronchitis and avian encephalomyelitis at the appropriate ages.

Chemical analyses. The ME content of the rubber seed meal was estimated by the method of HMSO (1988); its calcium content was determined by the standard volumetric method and available phosphorus content, as inorganic phosphorus, by the colorimetric method of Pons & Guthrie (1946). The crude protein, ether-extractive and crude fibre contents of the ingredients were determined by standard methods.

Statistical analyses. The observations were subjected to analysis of variance and treatment means compared with each other by Duncan's new multiple range test according to Steel & Torrie (1960a) at 5% significance level.

6.4.3 *Results and Discussion*

The results are summarised in Table 6.14 and 6.15. There were no significant differences between treatments in any of the parameters observed ($p > 0.05$). Also, the infertile egg percentage and hatchability were quite within the normal limits (see North, 1984). The coefficient of variation was very small (about 3%) except that it was 30% in the case of infertile egg percentage. As for the two test diets, inclusion of extra DL-methionine resulted in only a trivial improvement in breeder performance. It is likely that the test diet without extra DL-methionine was almost adequate with respect to methionine, inclusive of any that may be required for detoxification of HCN originating from rubber seed meal. The reproductive disturbances observed by Buvanendran (1971), Rajaguru (1971) and Narahari et al (1986a) may have been due to nutritional imbalances in the diets fed to the hens.

The performance of the hens in terms of the egg weight and egg number up to 40 weeks of age was strikingly poor irrespective of the dietary treatment and despite the fact that the pullets procured for the experiment were from selected dams. It is known that the RIR flock at the Central Poultry Research Station is degenerated.

Table 6.14 - Hen Breeder Experiment: Body-weight Changes, Egg Production and Feed Utilization
(Mean values for five replicates of 14 birds per treatment)

Treatment:	Control	RSM	RSM+MET	$S_{\bar{x}}$ *
Body weight, kg:				
at 8 weeks of age	0.57	0.58	0.58	
at 18 weeks of age	1.45[a]	1.46[a]	1.44[a]	0.01
gain from 18 to 40 weeks	0.72[a]	0.68[a]	0.69[a]	0.02
Sexual maturity:				
age at first egg, days	163[a]	162[a]	163[a]	0.9
age at 50% HDP, days	185[a]	184[a]	188[a]	2
Peak production:				
age, weeks	33.4[a]	33.8[a]	33.8[a]	0.3
HDP, %	84.3[a]	83.1[a]	84.1[a]	0.94
Performance up to 40 weeks of age:				
egg number	81.1[a]	79.1[a]	80.3[a]	0.7
egg weight, g	51.0[a]	50.4[a]	50.8[a]	0.4
Feed consumption at peak production:				
daily feed intake, g/hen	113[a]	116[a]	115[a]	1
kg feed per kg eggs	2.67[a]	2.80[a]	2.73[a]	0.03

*$S_{\bar{x}}$ = Sample standard error of a treatment mean, with 12 df. In a given row, values with the same superscript are not significantly different ($p > 0.050$).
HDP = Hen-day egg production.
See Table 6.12 for explanation of treatment designations.

Table 6.15 - Hen Breeder Experiment: Fertility and Hatchability of Eggs and Mortality of Hens *(Mean values for five replicates of 14 birds per treatment)*

Treatment:	Control	RSM	RSM+MET	$S_{\bar{x}}$*
Number of eggs set	137	134	136	
Infertile eggs, %**	6.3[a]	5.6[a]	4.5[a]	1.3
Early-dead embryos, %***	2.4	3.1	2.1	
Late-dead embroys, %***	3.0	5.0	3.5	
Pipped eggs, %***	0.9	0.6	0.8	
Hatchability, %***	93[a]	91[a]	93[a]	1.1
Mortality	nil	nil	nil	

*Sample standard error of a treatment mean, with 12 df.
**Expressed as percentage of eggs set.
***Expressed as percentage of fertile eggs.
In a given row,values with the same superscript are not significantly different ($p > 0.05$).
See Table 6.12 for explanation of treatment designations.

6.4.4 *Conclusion*

The results show that the test material of rubber seed meal is unlikely to cause infertility or reduced hatchability of eggs in hen breeders even when fed at high dietary levels as 250 g/kg, provided that the diet is nutritionally balanced.

6.5 Broiler Experiment

6.5.1 *Introduction*

In testing a new protein source for meat-type animals, it is important to assess its effect on the flavour of meat as much as on growth performance. Even though rubber seed meal cannot be regarded as a new protein source, it seems to be an unusual protein source to the the minds of many people. Review of past work on rubber seed meal revealed that no worker had investigated this aspect. The objective of this experiment was to study the effect of the test material on growth and meat flavour of broiler chickens.

6.5.2 *Materials and Methods*

Test material. The test material available for this experiment was the residue resulting from high pressure screw-pressing of a 95:5 (w/w) mixture of rubber seed kernels and expeller-processed coconut meal. The latter had been used as a processing aid; the residual oil content of the meal was in the 10-15% range, processing conditions are given in Chapter 3 of this report. The composition of the test material is given in Table 6.16.

Diets. The nutrient contents of the dietary ingredients and nutrient specifications for the diets are given in Table 6.16 and 6.17, respectively. The test diet differed from the control in that it had a high level of the test material instead of groundnut meal and some of maize meal and soya bean meal. Table 6.18 gives the composition of the diets; the assignment of the diets to the treatments are indicated in Table 6.19.

Table 6.16 - Broiler Experiment: Composition of Ingredients *(Figures in italics are values from published data; all values are expressed in g/kg air-dry material unless otherwise stated)*

Material	ME*	CP	EE	CF	LYS	TSA	Ca	AP
Rubber seed meal**	12.9	275	116	58	*7.5*	*6.5*	2	1.7
Groundnut meal	*11.0*	472	12	70	*16*	*11.5*	*1*	*1.5*
Fish meal	*13.4*	702	88		52	22.4	*30*	*20*
Calcium Carbonate							*380*	
Soya bean oil	*37.4*							

Other ingredients: Maize meal and soya bean meal had the same nutrient contents indicated in Table 6.10; the remaining ingredients are shown in Table 6.18.
*MJ/kg air-dry material
**Contained 5% coconut meal (see Section 6.5.2); available phosphorus (AP) was determined as inorganic phosphorus.

Birds. A batch of 150 1-day-old commercial broiler (Cobb 500) males were procured from the Uplands Farm, Peradeniya. Of these, 135 which were within the body weight range of 39 to 51 g were assigned to the three dietary treatments in a randomized complete block design with three replicates per treatment. The chicks were housed on wire-mesh from the start to 2 weeks of age and on a deep litter thereafter. The feed intakes during the starter and finisher stages were separately recorded. The birds were individually weighed again at 28 and 56 days of age.

Table 6.17 - Broiler Experiment: Nutrient Specifications Formulation of Diets *(Values expressed on air-dry basis)*

Stage;	Starter	Finisher
Metabolizable energy, MJ/kg	12.5	12.6
Crude protein, g/kg	230	210
Lysine, g/kg	11.9	10.4
Methionine + cystine, g/kg	9.0	8.5
Calcium, g/kg	10	10
Available phosphorus, g/kg	4.5	4.5

Processing of birds. At 56 days of age, the birds were killed by bleeding. Each carcass was immediately dressed by wet plucking, using water at 54 °C and a defeathering machine. Pectoral and leg muscles were dissected, taking care to exclude fat and tendons, sealed in polythene bags and deep-frozen for organoleptic assessment; only ten birds per replicate were taken for muscle dissection.

Organoleptic assessment. A taste panel of 14 members were selected from the staff-members of the Veterinary Research Institute. On each occasion, pectoral or leg muscles of five birds each from the control and one of the test treatments of one block were taken for tasting. Muscles were thawed on melting ice and then in running water, minced and mixed thoroughly. About 150 g of the minced muscle was placed in a glass beaker, covered in aluminium foil and steamed in a rice cooker for 35 minutes. Cooked meat and liquor were thorouhgly mixed and 10g samples were dispensed into covered 90mm petri dishes; the dishes with meat were maintained at 55 °C up to the time of tasting, which followed immediately. Half of the tasters had meat from control birds and the other half meat from birds of one of the test treatments as

Table 6.18 - Broiler Experiment: Composition of Diets *(Values expressed in g/kg of air-dry diet unless otherwise stated)*

Diet designation:	Control		RSM	
Stage:	Starter	Finisher	Starter	Finisher
Maize meal	572.5	617	395	437
Soya bean oil	17	15.5	-	-
Soya bean meal	226	202	117	95
Groundnut meal	100	100	-	-
Rubber seed meal*	-	-	400	400
Fish meal	50	30	50	30
Calcium carbonate	10	10	12	11
Dicalcium phosphate	17.4	17.7	16.2	16.4
Salt	2.5	2.5	2.5	2.5
Vitamin and trace-element Premix*	2	2	2	2
Lasalocid sodium, 15-%	0.5	0.5	0.5	0.5
Virginiamycin, 2-%	0.5	0.5	0.5	0.5
L-Lysine monohydrochloride	-	2.6	-	2.7
DL-Methionine	1.6	2.2	1.8	2.4

*Contained 5-% coconut meal (see Section 6.5.2)
**Supplied, per kg of air-dry diet, the amounts of vitamins and trace elements stated in Table 6.7.

Table 6.19 - Broiler Experiment: Assignment of Diets to Treatments

Treatment designation	Diet: Starter stage (0-28 days)	Diet: Finisher stage (28-56 days)
CON-CON	Control	Control
RSM-CON	RSM	Control
RSM-RSM	RSM	RSM

the odd sample in a triangular test. Each treatment pair was presented on two occasions so that there were 288 tastings in all. The tasters were asked to identify the odd sample in the pair on the basis of smell and taste. The results were analysed according to Steiner (1966). A score equal to the sum of the correct decisions and one-third the number of "no difference" decisions was given. A score of over 42 for breast or leg muscle in a treatment pair was considered as significant at 5% level.

Analyses. Chemical analyses of the dietary ingredients were carried out as in the hen breeder experiment. The observations on broiler performance were subjected to analysis of variance and Duncan's procedure was used to test differences among means at 5-% significance level (see Steel & Torrie, 1960b).

6.5.3 *Results and discussion*

The performance of the broiler chickens on the three dietary treatments are summarised in Table 6.20. There were no significant differences in feed intake, weight gain or feed conversion ratio attributable to the dietary treatments ($p > 0.05$), indicating that the diets containing the test material of rubber seed meal at 40-% level were palatable and that the availability of nutrients from it was satisfactory while its residual HCN content was harmless for broiler performance.

Table 6.20 - Broiler Experiment: Summary of Broiler Performance *(Mean values for three replicates of 15 birds per treatment)*

Treatment:	CON-CON	RSM-CON	RSM-RSM	S_d*
Starting weight, kg	0.044	0.044	0.044	
*Overall performance from 0 to 56 days of age**:*				
Feed intake, kg	5.94^a	5.99^a	5.70^a	0.19
Weight gain, kg	2.54^a	2.51^a	2.40^a	0.06
Feed conversion ratio	2.34^a	2.39^a	2.38^a	0.05

*Sample standard error of the difference between two treatment means, with 4 df.
**No significant differences existed among the treatment means pertaining to 0-28 or 28-56 days of age.
In a given row, values with the same superscript are not significantly different ($p > 0.05$).

The results of the organoleptic assessment of the broiler meat, summarised in Table 6.21, indicated that the meat of the birds fed the test material in the diet at 40-% level from hatching to 4 weeks of age up to the day of slaughter did not significantly differ in taste from that of the control birds fed the diets based on maize, soya bean and groundnut meals ($p > 0.05$).

6.6. Conclusion

In Sri Lanka, collection and processing of rubber seed for oil and residue on a pilot scale was started in earnest more than 20 years ago. However, the technological problems associated with dehulling and pressing of this oilseed have not been resolved, at least as far as the oil millers are concerned. It has now become customary for oil millers to crush rubber seed with the hull, using expeller mills designed for copra. The resulting oilmeal contains about 17% crude protein and all the hull that is originally present in the seed.

Table 6.21 - Broiler Experiment: Summary of Organoleptic Assessment of Cooked Muscle by Panel of 14 Members

Muscle	Block	No. of tastings	Correct decisions	No difference decisions	Score*
		*Treatment pair: CON-CON and RSM-CON***			
Breast	1	28	9	12	13
	2	28	6	17	11 2/3
	3	28	5	17	10 2/3
					35 1/3
Leg	1	28	8	11	11 2/3
	2	28	11	8	13 2/3
	3	28	7	9	10
					35 1/3
		*Treatment pair: CON-CON and RSM-RSM***			
Breast	1	28	8	9	11
	2	28	9	10	12 1/3
	3	28	10	11	13 2/3
					37
Leg	1	28	9	7	11 1/3
	2	28	9	10	12 1/3
	3	28	12	8	14 2/3
					38 1/3

*In a treatment pair for a given muscle, a total score of 42 or less is not significant ($p > 0.05$).
**See table 6.18 for treatment designations.

Information given in the Addendum shows that the crude protein content of undehulled rubber seed meal can be increased to that of coconut meal and its crude fibre content decreased to some extent by coarse grinding followed by sieving; apparently, the coarsely ground unsieved material does not adversely affect the dry matter intake or health of calves. On the basis of these findings, undecorticated rubber seed meal is currently utilized as a substitute for coconut meal in feeding of ruminants and pigs in Sri Lanka. However, from the view-point of producing vegetable oil as well as residue for animal feeding, the desirability of developing appropriate technology for rubber seed processing cannot be over emphasized.

The decorticating, drying and pressing procedure developed in the present investigation (Chapter 3) for rubber seed processing yields a meal which is virtually free from hull and contains 265 to 275 g/kg crude protein, 100 to 150 g/kg residual oil and less than 60 g/kg crude fibre. The ME content of the meal for poultry can be accurately estimated from its chemical composition, indicating that the nutrients contained in it are well utilized by poultry and that the residual HCN level in it is harmless for poultry. It can be used at high levels in diets for poultry without adversely affecting their reproductive performance, meat flavour or health.

However, more work on the usefulness of the meal in animal feeding is advocated. Since lysine is the first limiting amino acid in practical pig feeds, determination of the available lysine content of the meal for pigs is warranted.

6.7 Summary

A technique developed by the Ceylon Institute of Scientific and Industrial Research for processing of rubber seed kernel involved mechanical separation from hull, kiln-drying, cooking and hydraulic pressing; the processing did not exceed 90 °C at any stage. The resulting rubber seed meal (RSM) contained, per kg, about 270 g crude protein, 100 to 150 g residual oil and less than 60 g crude fibre and 60 mg residual hydrocyanic acid.

The nitrogen-corrected metabolizable energy (ME) content of RSM for poultry was determined by a standard biological method using chicks and glucose as the reference substance, and by a standard chemical method based on crude protein, fat, starch and sugar contents.

The two results were in close agreement with each other, indicating that the availability of the energy-yielding nutrients of RSM was satisfactory and that the chemical method was accurate enough for the estimation of its ME content for poultry.

In an experiment to re-investigate the effect of RSM on hen breeder performance, 210 eight-week-old RIR pullets were assigned to three dietary treatments in a completely random design with five replicates per treatment; the grower as well as breeder diets were balanced with respect to ME, crude protein, lysine, calcium and available phosphorus, and contained no RSM or 250 g/kg RSM without or with extra supplemental methionine. Hen breeder performance up to 40 weeks of age was judged by body weight at 18 weeks of age, body weight change during lay, age at first egg, at 50-% hen-day egg production (HDP) and at peak production, HDP at peak production, egg number, weight, fertility and hatchability and mortality. The results indicated that the inclusion of RSM in the diet at the stated level did not affect the performance of the hen breeders and that the provision of extra supplemental methionine was unnecessary ($p > 0.05$).

In an experiment to test the effect of high dietary RSM on broiler performance and meat flavour, 135 Cobb-500 males were assigned to three dietary treatments in a randomized complete block design with three replicates per treatment; the diets were balanced with respect to ME, crude protein, lysine, methionine plus cystine, calcium and available phosphorus, and the treatments provided no RSM from 0 to 56 days (CONTROL), 400 g/kg RSM from 0 to 28 days no RSM from 28 to 56 days (RSM-CONTROL) or 400 g/kg RSM from 0 to 56 days of age (RSM-RSM). For organoleptic assessment of meat, the breast as well as leg muscle of birds of each test treatment in each block was compared with the corresponding control muscle in a triangular test on two occasions by an untrained panel of 14 members. The results indicated that the high dietary level of RSM during the first half or whole of the life of the broiler chickens did not affect their weight gain or feed conversion efficiency and did not cause any difference in the flavour of their meat ($p > 0.05$).

It was concluded that the RSM was suitable for animal feeding. Determination of its available lysine content for the pig is warranted.

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6.9 ADDENDUM

UNDECORTICATED RUBBER SEED MEAL: EFFECT ON PERFORMANCE AND HEALTH OF CALVES AND PROCESSING METHOD TO IMPROVE QUALITY

1. Introduction

In Sri Lanka, copra is the major source of vegetable oil. Almost all the oil mills are of the expeller type, designed to crush and expel oil from copra. Nadarajah (1969) has described how such mills could be modified for expelling oil from rubber seed kernels. However, expeller mills are still used without modification to expel oil from undecorticated rubber seed; hull (shell) acts as a processing aid and the resulting oil meal contains all the hull originally present in the seed and only about 17% crude protein.

Several years ago, certain deaths among calves in a state farm were presumptively diagnosed as due to injuries caused to the gastro-intestinal mucosa by rubber seed hull particles in the concentrate fed to the calves. Consequently, the local use of rubber seed meal came to a virtual halt. However, the practice of expelling oil from undecorticated rubber seed still continues.

The objectives of the work reported herein were to study the effect of undecorticated rubber seed meal on the performance and health of calves, and to test whether the material could be further processed to improve its quality.

2. Materials and Methods

Test materials. A 1000-kg batch of undecorticated rubber seed meal was coarsely ground in a mill fited with 6mm screen. One half of the coarsely ground material was reground in a hammer mill fitted with 4mm screen and then sieved using 1mm wire mesh. The sieved fraction was labelled sieved rubber seed meal (SRSM) and the remaining half of the coarsely ground material was labelled unsieved rubber seed meal (URSM).

Diets. Three concentrates were formulated to contain 180 g/kg crude protein in all, 70 g/kg from rice polishings and 100 g/kg from a combination of soya bean meal and coconut meal, SRSM or URSM. Table 6.22 and 6.23 give the composition of the dietary ingredients and concentrates, respectively.

Animals and treatments. Twelve Sindhi male calves ranging from 59 to 71 kg in body weight were assigned to the three concentrates in a randomized complete block design with four calves per treatment. The daily dry matter (DM) requirement of each calf was computed in relation to its body weight at weekly intervals according to the NRC recommendations (see NRC, 1978). Each calf was fed a daily concentrate allowance equivalent to 50% of its daily DM requirement and *B.ruziziensis* hay *ad libitum*; the concentrate allowance was given in two meals. Feeding was continued for 10 weeks.

Analyses. The proximate fractions of the concentrates were calculated from those of their ingredients determined by standard methods. The metabolizable energy (ME) contents for ruminants and digestible crude protein (DCP) contents of the concentrates and hay were estimated from the proximate fractions by the methods of Zintzen & Putnam (1976) and Knight & Harris (1966), respectively. Observations on daily weight gain and intakes of total DM, DM from hay, ME and DCP of the individual calves were subjected to analysis of variance and differences between treatment means were assessed by Duncan's procedure at 5% significance level (see Steel & Torrie, 1960). The faeces of the calves fed URSM were individually collected on three successive days during the final week of the experiment: hull particles were separated from the rest of the faecal matter by washing the faeces on a 1mm sieve, dried in the oven and weighed.

Table 6.22 - Calf Experiment: Composition of Dietary Ingredients *(Expressed in g/kg of material as such unless otherwise stated)*

	SRSM	URSM	Coconut meal	Soya bean meal	Rice polishings	Hay
Moisture	78	78	101	93	88	91
Crude protein	224	151	197	466	144	73
Ether extract	96	114	102	10	120	10
Crude fibre	250	448	102	46	85	346
N-free extract	295	136	439	299	468	403
ME, MJ/kg	11.1	9.5	12.2	10.3	12.4	6.7
DCP	169	102	145	392	93	38

Table 6.23 - Calf Experiment : Composition of Concentrates
(Expressed in g/kg of material as such unless otherwise stated)

Concentrate designation:	Control	SRSM	URSM
Ingredients:			
Rice polishings	500	500	500
Soya bean meal	70	23	127
Coconut meal	392.5		
Sieved rubber seed meal		439.5	
Unsieved rubber seed meal			335.5
Shell powder	20	20	20
Salt	15	15	15
Vitamin & trace-element premix*	2.5	2.5	2.5
Nutrients:			
Metabolizable energy, MJ/kg	11.7	11.3	10.7
Crude protein	180	180	180
Digestible crude protein	134	131	131

*Zoodry VM 9006 (Roche)

3. Results and Discussion

The results are summarised in Table 6.24. The total DM intake as well as the DM intake from hay of the calves fed the concentrate containing URSM was not different from that of the other calves ($p > 0.05$), indicating that there was no accumulation of hull particles in the lumen of the gastro-intestinal tract. The mean daily weight gain of the calves fed the control concentrate was only marginally superior to that of the others, presumably due to the marginally higher intake of ME and DCP in the case of the former. The weight of the hull particles voided by the calves fed URSM concentrate over a 3-day period was more or less equal to that of the hull particles recoverable from the amount of the concentrate fed over the same period, further indicating that the hull particles did not accumulate in the gastro-intestinal lumen.

Table 6.24 - Calf Experiment: Summary of Results
(Mean values for four calves in four replicates per treatment over a 10-week period)

Concentrate designation:	Control	SRSM	URSM	S_d^*
Body weight at start, kg	66	65	64	
Total DM intake, kg/day	2.85^a	3.06^a	2.86^a	0.11
DM intake from hay, kg/day	1.61^a	1.78^a	1.70^a	0.10
ME intake, MJ/day	21.0^a	20.4^a	19.3^a	0.7
DCP intake, kg/day	0.188^a	0.181^a	0.177^a	0.005
Weight gain, kg/day	0.33^a	0.25^b	0.25^b	0.04

*Sample standard error of the difference between two treatment means, with 6 df.
In a given row, values with the same superscript are not significantly different ($p > 0.05$).

When undecorticated rubber seed meal was further processed in the manner described aobve, the fraction retained on the sieve accounted for about 54% by weight of the material and consisted mostly of hull particles; the sieved fraction contained 48% more crude protein and 44% less crude fibre than the original materal.

4. Conclusion

Where rubber seed must be crushed as such due to shortcomings in the technological facilities for dehulling and expelling, the resulting oil cake can still be included at moderately high levels in concentrates for ruminants without adverse effects. However, the quality of the material can be improved by coarse grinding and sieving to remove most of the hull particles.

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CHAPTER 7

MARKETING OF RUBBER SEED PRODUCTS

7.1 Introduction

Marketing of rubber seed products could be broadly classified into the following areas:-

(a) edible oil
(b) technical oil
(c) meal
(d) waste by products.

7.2 Marketing of Rubber Seed Oil as an Edible Oil

Vegetable oils play an increasing role in human diet and recent surveys e.g. by UNIDO (Ref. 1) have shown higher apparent consumption (sum of domestic production and net imports) of fats and oils of vegetable origin compared to those of animal origin. However, several countries have very low levels of consumption of vegetable fats and oils with annual per capita values (1982 figures) as low as 5kg, compared to maximum values of 25 to 30kg in some of the highly industrialized countries.

Recent advances in nutrition and health have advocated human consumption of a balanced diet of saturated, monounsaturated and polyunsaturated fats (Ref. 2). This has led to changes in dietary habit especially involving greater use of vegetable oils over animal fats. This is clearly shown in Table 7.1 for USA (Ref. 3). Most countries exhibit similar patterns of preferential consumption of vegetable oils. The important polyunsaturated fatty acids (PUFAs) in vegetable oils are typified by n-6 (ω-6) and n-3 (ω-3) families, linoleic being the major dietary source of the former and α-linolenic of the latter family. Rubber Seed Oil has a high proportion of both linoleic and α-linolenic acid (Table 7.2) and references in Phase I and more recent work (Ref. 4-5) have pointed the possibility of utilization of Rubber Seed Oil for edible purposes. Present investigations have shown that toxic substances present in Rubber Seed Kernel viz. cyanide, aflatoxin, gossypol and saponins do not contaminate expelled oil but two obstacles stand in the way of Rubber Seed Oil for edible purposes:-

(a) The fact that Rubber Seed Oil is a semi-drying oil with a fairly high linolenic content.

(b) The presence of poly(isoprene) to the extent of about 1% associated with the unsaponifiable matter.

The semi-drying properties of Rubber Seed Oil could be overcome by judicious blending with other vegetable oils or hydrogenation. In this connection it may be noted that linseed oil with a much higher linolenic content compared to rubber seed oil is being marketed for edible purposes (Ref. 6). In the case of poly(isoprene) the problem would be one of any long-term effect (Phase I, page 89) connected with ingestion of high molecular weight material. Although no evidence of harmful effects of intake of high molecular weight material appears to be recorded this matter needs careful investigation.

The pattern of vegetable oil consumption in the natural rubber producing countries is variable and although some of these countries account for the production of large quantities of edible oil of vegetable origin no planned policies on consumption of vegetable oils have been forthcoming. Thus, in Sri Lanka (Table 7.3) it is to be noted that coconut oil contributes to the bulk of consumption and consumption of PUFAs is very low (average per year per head values being 14.6kg for coconut oil and less than 200g PUFAs, due to low levels of domestic production and high levels of tariff/non-tariff barriers on imports. At present Sri Lanka imports about 6000 tons of unsaturate type vegetable oils mainly serving the urban-sector of the population.

7.3 Marketing Rubber Seed Oil as a Technical Oil

The marketing of rubber seed oil as a technical oil would depend mainly on the use of rubber seed oil as:-

(a) a semi-drying oil in manufacture of convertible coatings (e.g. alkyd resin);

(b) use in soap manufacture;

(c) miscellaneous chemical reactions.

Alkyd resin manufacture from rubber seed oil has been a commercial success in Sri Lanka, resins being generally satisfactory except for evidence of yellowing and hence used in solvent based coatings of dark pigmentation. High iodine values and discolouration restrict use of rubber seed oil in laundry soap to any large extent but blends with other oils and hydrogenation would make rubber seed oil a potential raw material in filled and soft soap manufacture. The high unsaturated nature of rubber seed oil makes it a useful intermediate in manufacture of processing aids for the rubber industry.

7.4 Marketing of Rubber Seed Meal

High protein and low fibre levels offer potential for rubber seed material as an animal feed material. Several publications (Ref. 7-8) have drawn the attention of use of rubber seed material in varying proportions in animals such as poultry, cattle, pig: reports of satisfactory protein digestibility, growth and palatability being available.

Rubber seed meal admixed with extraneous matter such as shell is of lower quality but still has been found to be satisfactory in feeding trials. Detailed information on rubber seed material is given in the ANIMAL FEEDING TRIALS in Chapter 6.

7.5 Waste by Products

The by-products of rubber seed processing are shell obtained during decortication and pods. Both these could be gainfully used as a fuel for domestic purposes and also as a raw material for production of activated charcoal.

7.6 Worldwide Trends in Marketing of Oil and Animal Feed from Vegetable Sources

Changing trends in supply/demand of vegetable oil and feed and governmental intervention in the form of tariff and non-tariff barriers has greatly distorted market prices of vegetable oils and feeds. Thus in the case of Sri Lanka, tariff structures are responsible for increase of prices of imported vegetable oils by as much as 75% over cif prices in certain instances while government subsidies in EEC countries e.g. in the production of rape seed oil have tended to depress world prices for this commodity. It is to be hoped that the

General Agreement on Tariffs and Trade (GATT) will succeed in negotiations aimed at trade liberalization and agricultural reform (Ref. 9-10). Recent trends in stocks/usage ratio, prices and demand growth (average of seventeen oils and fats) are given in Fig.7.1 (Ref. 11).

7.7 Summary and Conclusion

Marketing of rubber seed products would be valuable to natural rubber countries with potential for collection of rubber seed (Table 1.1 - Chapter 1). These countries use more of the saturated types of vegetable oil for dietary purposes and rubber seed oil being polyunsaturated in nature offers the advantage of having nutritionally valuable linolenic acid as a component fatty acid (Ref. 12). However, since levels of linolenic acid are high, blending with other oils or hydrogenation is needed to overcome any disadvantage due to excess linolenic acid. In addition to rubber seed oil for edible purposes potential exists for marketing of technical rubber seed oil as a raw material in the manufacture of convertible coatings, soaps and also rubber seed meal as a source of high protein, low fibre animal feed. Waste by products could be used as domestic fuel or for production of activated charcoal.

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Table 7.1 - US Food Supply; Fats and Oils Consumption per Capita (pounds)

Year	Butter	Margarine	Shortening	Lard	Edible beef fat	Vegetable oils
1950	10.7	6.1	11.0	12.6	0	8.5
1955	9.0	8.2	11.5	10.1	0	10.5
1960	7.5	9.3	12.5	7.5	0	11.4
1965	6.4	9.7	14.2	6.3	0	14.1
1970	5.3	10.9	17.3	4.6	0	17.7
1975	4.7	11.0	17.0	2.9	0	19.9
1980	4.5	11.4	18.2	2.6	1.1	22.5
1985	4.9	10.7	22.8	1.8	1.9	25.1

Source: JAOCS 65 723 (1988).

Table 7.2 - Component Fatty Acids of Some Fats and Oils

Fatty Acid	RSO	S	R	P	C	M	L	T	LI
16:0 Palmitic	9	11	5	48	11	19	24	25	6
18:0 Stearic	8	4	2	6	4	4	13	19	4
18:1 Oleic	23	23	53	38	7	16	41	36	22
18:2 Linoleic	39	51	22	9	2	2	10	4	16
18:3 Linolenic	18	7	11	-	-	1	1	1	52
20:5 Eicosapentaenoic	-	-	-	-	-	13	-	-	-
22:6 Docosahexaenoic	-	-	-	-	-	8	-	-	-

Note: Above values are representative averages

(RSO - Rubber seed; S - Soya; R - Rapeseed; P - Palm;

C - Coconut; M - Menhaden fish; L - Lard; T - Tallow;

LI - Linseed).

Table 7.3 - Consumption of Vegetable Oils in Sri Lanka

Type	Consumption in urban sector g/head/year	Consumption in rural sector g/head/year	Average g/head/year
Coconut oil			
(a) Visible	4,000	3,400	3,600
(b) Invisible	12,000	10,500	11,000
Gingelly oil	75	110	100
Soya oil	120	30	58
Margarine and hydrogenated products	1,460	500	800

Note: (1) Visible consumption of coconut oil is direct use e.g. in frying, cooking curries.

(2) Invisible consumption of coconut oil is the components of coconut milk (cream) and shredded coconut used in general purpose cooking.

(3) Margarine and hydrogenated products are largely made from coconut and palm oils.

(Figures are 1986 estimates from Central Bank of Sri Lanka and Department of Census and Statistics Sri Lanka. The urban population is estimated at 5 million and the rural population 11 million for a total population of 16 million).

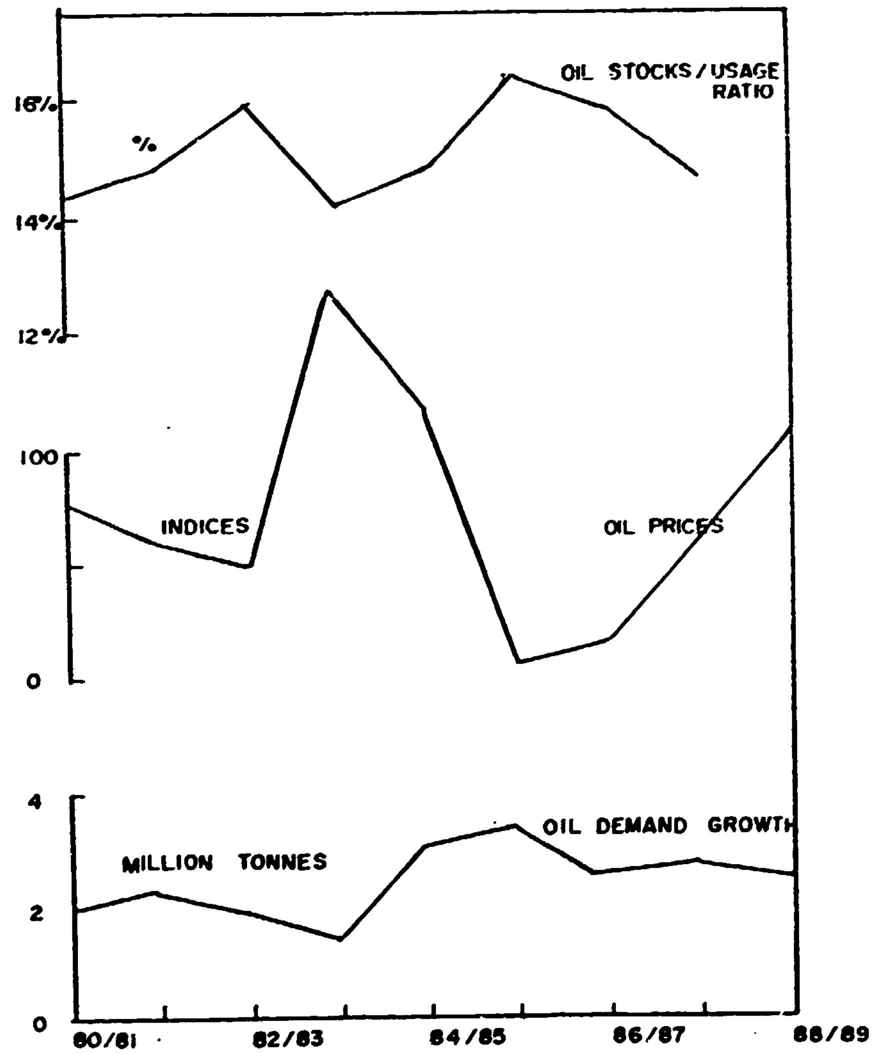


FIG 7.1 - TRENDS IN SELECTED PARAMETERS FOR INTERNATIONAL SITUATION IN VEGETABLE OILS.

SOURCE : OIL WORLD (HAMBURG) MAY 1988 ISSUE

CHAPTER 8

SPECIAL TOPICS IN RUBBER SEED PROCESSING

8.1 Introduction

In this Chapter the following topics of relevance in rubber seed processing are discussed:-

(a) aflatoxin

(b) cyanide

(c) gossypol and saponins

(d) microbial aspects of lipase activity

8.2 Aflatoxin

The possibility of aflatoxin contamination in rubber seed meal was pointed out in the Phase I Report, where analyses revealed aflatoxin concentrations in excess of safety limits in rubber seed kernel. Detailed investigations were carried out in this area. Analyses of aflatoxin (B_1, B_2, G_1, G_2) were carried out by TLC and HPLC techniques.

8.2.1 *Screening for Presence of Aflatoxin*

Fifteen Specimen of seed, kernel, meal and oil were stored in open containers in various locations of the laboratory, ambient conditions being temperature 28-32°C and relative humidity around 70%. All batches screened had visible mould growth belonging to the genera *Aspergillus*, *Penicillium* and *Mucor*. However two batches of kernel and one of meal were found to contain aflatoxins, these being infected with an *Aspergillus* sp. Aflatoxin B_1 levels as determined by visual estimation on TLC plates were 80 ppb and 1000 ppb in kernel and 8 ppb in meal. Thus obvious signs of mould contamination in rubber seed substrate is not definitely indicative of high aflatoxin levels. Other literature reports confirm the fact that profuse growth of fungi such as *A. niger* results in suppression of aflatoxin formation by aflatoxigenic fungi (Ref. 1).

8.2.2 Growth of *Aspergillus parasiticus* on Rubber Seed Meal and Production of Aflatoxins

Inoculation of rubber seed kernels and meal indicated that they are good substrates for growth of *A. parasiticus* and aflatoxin production. The fungal growth on oil was however comparatively slow. Toxin accumulation on sterlized substrates (autoclaving at 121°C for 30 minutes) was high in comparison to accumulation in non-sterilized substrates (Table 8.1). It is evident that growth of fungus is accelerated on crushed kernel compared with whole kernel. In another experiment it was noted that the proliferation of *A. parasiticus* on meal (residual oil content 25%) was only possible at moisture levels greater than 10%.

8.2.3 *Distribution of Aflatoxin in Meal and Oil*

Experiments carried out to determine partitioning behaviour of aflatoxin during rubber seed expelling conclusively showed that the bulk of the aflatoxin remained in the meal (Table 8.2).

8.2.4 *Discussion*

Results of total aflatoxin in kernel (45 samples) and meal (52 samples) taken during laboratory and pilot plant operations are given in Fig. 8.1 and 8.2. Individual aflatoxin values for RSM (Table 8.3) reveal a high scatter of results reflecting uncertainties in sampling and experimentation. Guideline levels for aflatoxin range from 10-200 μg/kg (B_1) depending on the feeding stuff (Ref. 2) so that aflatoxin levels in RSM are on the high side but dilution at a level of about 25% in animal feed (Chapter 6) could render it fit for consumption.

Out of 10 samples of rubber seed oil tested, six did not have any detectable aflatoxin, the average of the remaining being less than 10 ppb (B_1). Detoxification of aflatoxin in coconut oil by sunlight has been reported (Ref. 3) but commercial viability in terms of output and efficiency will need investigation: indications are that RSO will be more difficult to detoxify than coconut oil due to presence of a brown pigment.

It is thus seen that the aflatoxin problem could be best handled by preventive measures by collection of good quality seed and storage at reduced moisture levels around 5%, so that minimum levels of aflatoxin are produced.

8.3 The Cyanide Problem

Rubber seed kernel contains a cyanogenic glucoside (which has been claimed to be identical with the *Manihot* species - Ref. 4) linamarin, the glucoside of acetone cyanhydrin. This glucoside is hydrolysed either as a result of enzyme action or on heating in acid to yield HCN. Total cyanide is the sum of free HCN and that bound in the glucoside.

Freshly collected rubber seed has a high level of cyanide, kernel values being in the range 1500-3000 mg/kg on dry basis. During drying and storage these levels are drastically reduced (Tables 8.4, 8.5, 8.6) slow drying being preferred to fast drying to ensure high water activity for faster rates of hydrolysis. Further reduction of cyanide in RSK occurs during cooking and expelling (Chapter 3) some typical values given in Table 8.7. Soaking RSM in water (1:1) for a period in excess of one hour and drying at 105°C helped in reduction of total cyanide levels, 10mg/kg being attained after a 24 hour period.

Specifications of cyanide limits for animal feed do not differentiate between total and free cyanide which is determined by the test method. A typical limit for tapioca meal (Indian Standard 1509) being 300 ppm, RSM will not be expected to be toxic with respect to cyanide especially since a three to four fold dilution will occur on compounding.

Aerial contamination of cyanide was also determined during rubber seed processing, by collection of air through back suction and dissolving HCN in 5% sodium carbonate solution. Results in Table 8.8 are given for contamination in decorticating, drying rooms and exhaust outlet of oven used for drying and in Table 8.9 inside the indirect dryer used for large scale drying. Care must be exercised to spend minimum periods in locations where aerial cyanide values exceed safe limits (threshold value 10 mg/m^3 air, the time weighted average for a normal 8 hour work day - Guidance Note EH 15/80 from Health and Safety Executive-HMS, London).

8,4 Gossypol and Saponins

Total gossypol and saponins were determined by respective test methods using spectrophotometric and HPLC techniques (see Appendix II - Test Methods). Results given in Table 8.10 are low compared to other materials and these toxins are not expected to influence RS processing. In particular, animal feed trials (Chapter 6) did not reveal any ill-effects to poultry caused by saponins present.

8.5 Microbial Aspects of Lipase Activity

The quality of RSO and RSM will be of optimum level when lipase activity is at the lowest so that conditions for this requirement are important. Lipolytic activity could be due to exogenous or endogenous enzymes and preventive action, such as collection of seed soon after fall and heat treatment to attain low moisture levels is effective in arresting FFA increase. Some studies carried out during our investigations are described.

Three fungi *Aspergillus sp*, *Penicillium sp* and *Mucor sp* isolated from stored seed showed lipolytic activity. The particular *Aspergillus sp* and *Mucor sp* used were dominant at 30 °C and these were used for more detailed studies. The two organisms were inoculated into crushed kernel (one batch autoclaved at 121° C and other batch not autoclaved) maintained at a moisture level of 10% in a desiccator and the increase in FFA after a five day period determined. Results (Table 8.11) showed that growth of *Aspergillus* sp led to a rapid increase of FFA compared to *Mucor sp*. The increase of FFA in autoclaved material was relatively higher compared to the material which was not autoclaved primarily because autoclaving promotes the growth of saprophytic organisms.

The effect of moisture level on the development of FFA in autoclaved whole kernel inoculated with *Aspergillus sp* (4 x 10^4 spores/g of dry material) was studied over a period of 30 days. FFA levels increased with moisture levels (Fig. 8.3). At 5% moisture level FFA values remained constant but increased dramatically with storage time at increased moisture levels. Thus as in the case of aflatoxins, collection of seed with minimal ground contamination and reduction of moisture level to 5% for storage purposes would be the optimum method of arresting lipolytic activity.

8.6 References

1. J. Lacey; Factors affecting mycotoxin production - IUPAC Symposium, Pretoria (1985).

2. FAO; Developments concerning regulations and tolerance limits for aflatoxins - Intergovernmental group on oil seeds, oils and fats (1988).

3. U. Samarajeewa, C.L.V. Jayatilake, A. Ranjithan, T.V. Gamage and S.N. Aresecularatne; A pilot plant for detoxification of aflatoxin B_1 in contaminated coconut oil by solar irradiation, J. Applied Microbiology and Biotech. 1 333-343 (1985).

4. N.M. Pieris; Studies on the glucoside and glucosidases of Manihot esculenta Crantz, PhD Thesis, University of Sri Lanka (Colombo Campus 1976).

Table 8.1 - Production of Aflatoxin in Sterilized and Non-Sterilized RSK, RSM and RSO Inoculated with *Aspergillus Parasiticus*

Sample	Moisture content (mass %)	Aflatoxin µg/kg $B_1 + B_2$		$G_1 + G_2$	
		Non-Sterilized	Sterilized	Non-sterilized	Sterilized
		$x10^2$	$x10^5$	$x10^2$	$x10^5$
RSK (crushed)	11.2	0.6	5	0.6	2
RSK (whole)	11.2	7	0.09	5	.07
RSM	10.0	2	5	0.5	4
RSO	11.3	40	ND	.06	ND

ND = Not determined.

Table 8.2 - Distribution of Aflatoxin in Meal and Oil

	Dry weight distri-bution	Aflatoxin x 10^4 (μg/kg)				Aflatoxin distribution (%)
		B_1	B_2	G_1	G_2	
RSK	100	4	0.4	0.8	0.3	100
RSM	96	3	0.3	0.9	0.2	79
RSO	4	0.6	0.07	0.2	0.04	1

NOTE : 1. The total aflatoxin distribution has been calculated on the basis of yields of RSM and RSO.

2. The deviation in the last column is probably due to inherrent errors in methods of determination.

3. In a separate experiment using naturally contaminated kernel, when oil expelled was 27%, meal and oil contained approximately 900 and 100 μg/kg aflatoxin respectively.

Table 8.3 - Analysis of Aflatoxin Determination in Rubber Seed Meal

Aflatoxin type	B_1	B_2	G_1	G_2
Average ppb	77	6	128	9
Coefficient of variation %	57	71	72	83

Note : Averages of 52 samples of RSM taken during laboratory and pilot plant trials.
Test method - HPLC technique.

Table 8.4 – Loss of Total Cyanide Content on Oven (75°C) Drying of Rubber Seed Kernels

Time (h)	Moisture content of kernel (mass %)	Total cyanide mg/kg on dry weight of kernel	Loss of total cyanide %
00	14.4	768	–
02	13.2	394	49
04	10.0	341	56
06	8.2	240	69
24	1.6	208	73
28	1.5	179	77

Note : Oven used had a blower to circulate air

Table 8.5 - Loss of Total Cyanide Content on Oven (100°C) Drying of Rubber Seed Kernels

Time (h)	Moisture conent of kernel (mass %)		Total cyanide mg/kg on dry weight of kernel		Loss of total cyanide %	
	Batch 1	Batch 2	Batch 1	Batch 2	Batch 1	Batch 2
00	82.1*	14.4	3200	768	-	-
02	30.3	8.1	2400	754	25	2
06	< 1	2.2	1640	532	49	31
24	< 1	1	1630	484	49	37

*High moisture content of immature seed.

Note : Oven used had a blower to circulate air.

Table 8.6 - Loss of Total Cyanide Content on Sun Drying of Rubber Seed Kernels

Time (days)	Moisture content of kernel (mass %)	Total cyanide mg/kg on dry weight of kernel	Loss of total cyanide %
00	15.2	787	-
01	8.7	583	26
03	5.1	227	71
04	4.9	185	76

Table 8.7 - Typical Levels of Total Cyanide in Rubber Seed Processing

Material	Total Cyanide mg/kg
Kernel from fresh seed (20% moisture content)	1830
Kernel after drying to 5% moisture level in smoke house	236
Meal immediately after expelling in high pressure screw expeller at 80°C	124

Table 8.8 - Aerial Cyanide Levels at Sites of Rubber Seed Processing

Site	Total cyanide mg/m^3 Air
Decorticating room	Not detected
Room with drying of kernels progressing	5.6
Room after completion of drying	4.2
Exhaust of circulating air oven during drying of kernels	85.8

Table 8.9 - Total Cyanide Content Inside Drying Chamber of Kiln during Loading and Drying

Time (h) Interval	Temp °C	Total cyanide (mg/m^3)
Loading of kernel	30	15
Drying of kernel		
2	30-45	125
1.5	45-55	228
1.5	50-60	295
1	60	261
1	60	203
1	60	173
1	60	167
1	60	134
1	60	142
1	60	121
Kernels kept in kiln without firing for 12 hours		
1	40	22
1	40	20
During unloading	35	8
30 minutes after unloading	30	less than 1

Note : Drying of kernel time intervals follow in succession.

Table 8.10 - Total Gossypol and Saponin Content in Rubber Seed

Material	Total Gossypol ppm	Saponins %
Screw pressed RSM	7	0.6
Solvent extracted RSM	6	0.9
Rubber seed oil	not detected	not detected
Cotton seed kernel	54	ND
Soya flour	ND	1.2

ND - Not determined

Table 8.11 - Effect of *Aspergillus* sp. and *Mucor* sp. on Development of FFA in Autoclaved and Non-autoclaved samples of crushed RSK.

	FFA (as oleic acid) %			
	NOT AUTOCLAVED		AUTOCLAVED	
	Control	Inoculated	Control	Inoculated
Aspergillus sp	22.2	48.9	7.7	66.6
Mucor sp	21.5	23.8	6.4	33.2

Initial FFA:- 1.7%

Period of storage at 10% moisture content:- 5 days

Note : Table refers to particular *Aspergillus* sp and *Mucor* sp isolated.

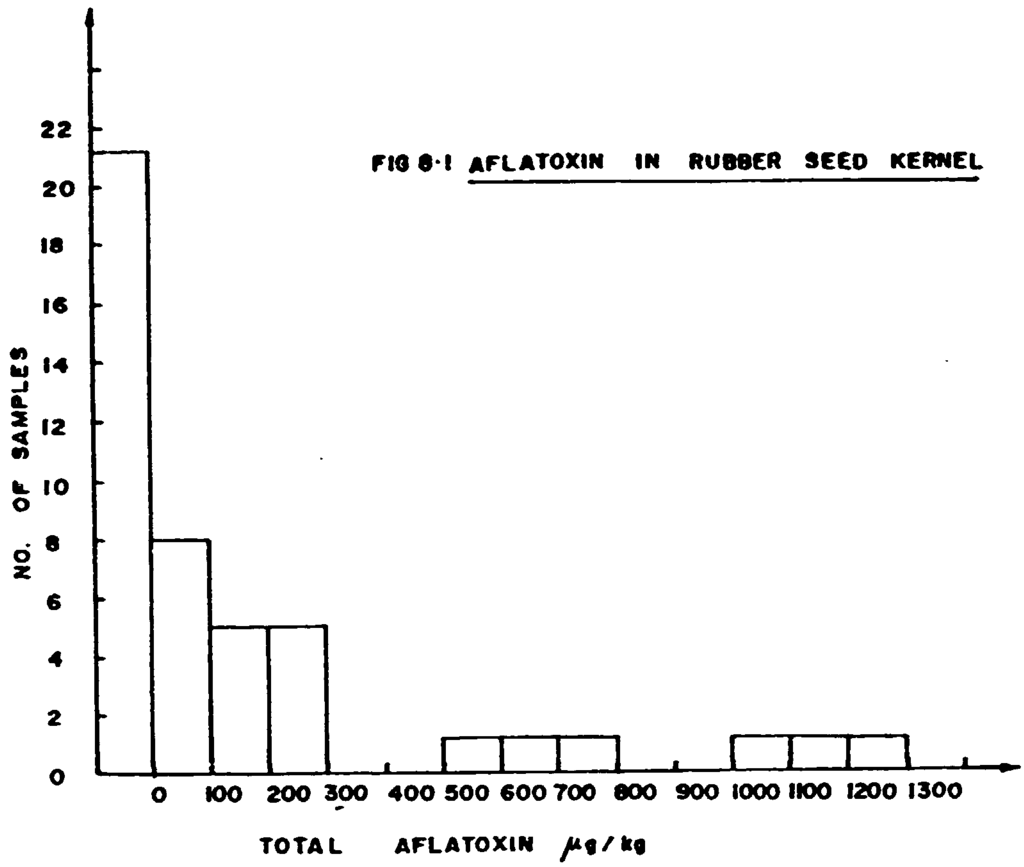


FIG 8·1 AFLATOXIN IN RUBBER SEED KERNEL
NO. OF SAMPLES
0
2
4
6
8
10
12
14
16
18
20
22
0 100 200 300 400 500 600 700 800 900 1000 1100 1200 1300
TOTAL AFLATOXIN µg/kg

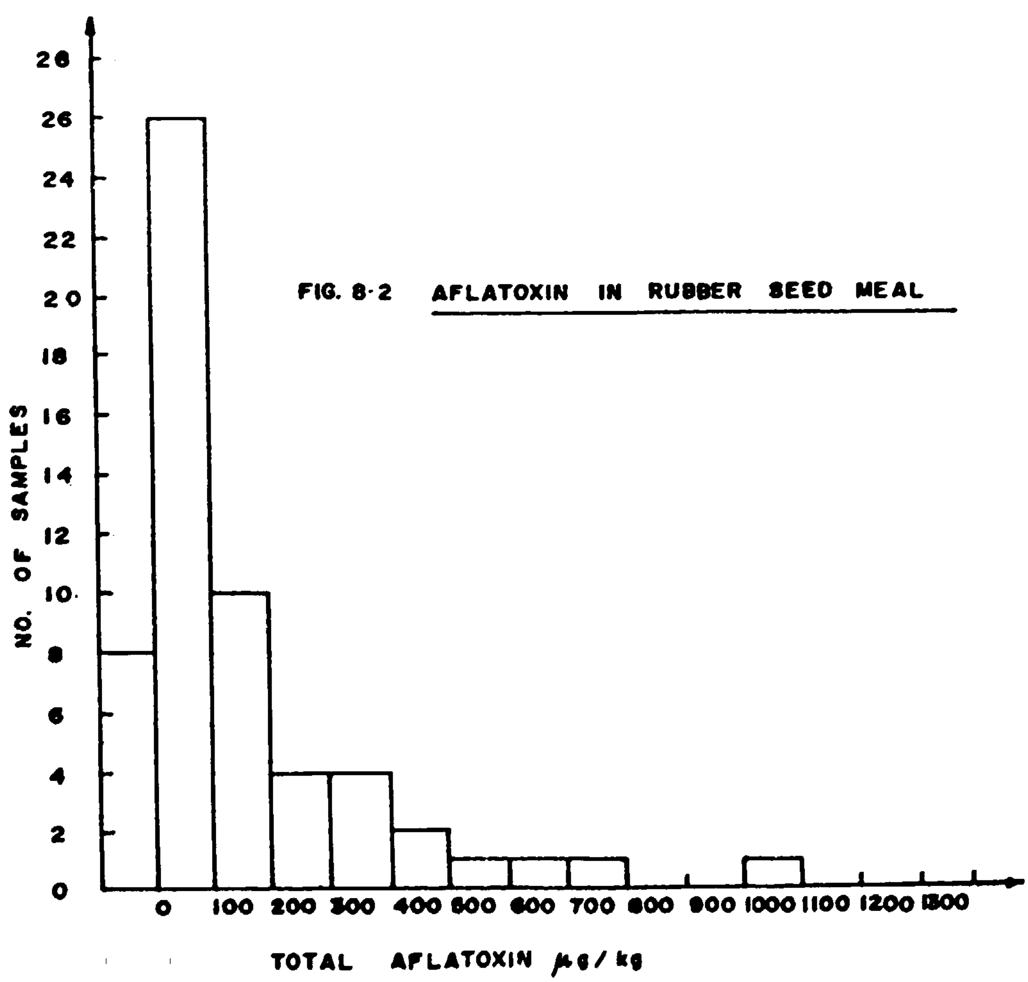
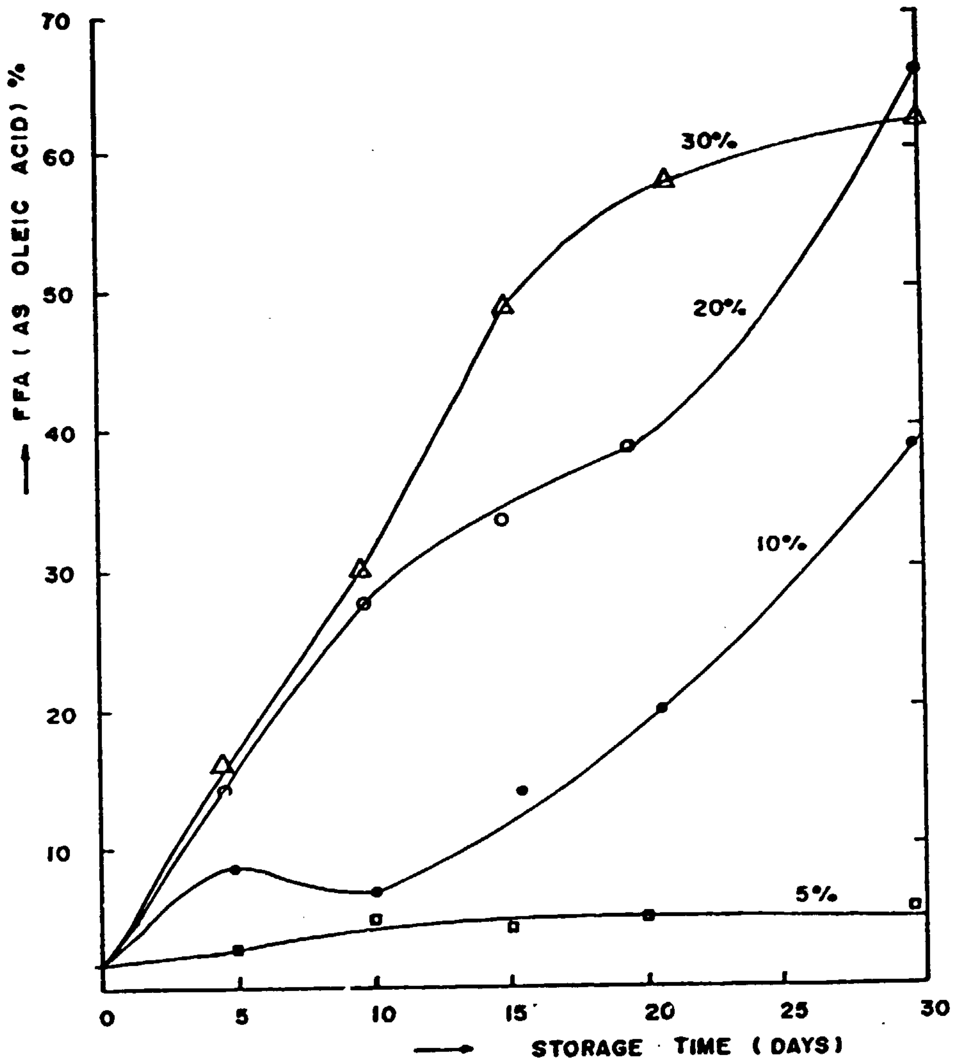


FIG. 8·2 AFLATOXIN IN RUBBER SEED MEAL
NO. OF SAMPLES
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
0 100 200 300 400 500 600 700 800 900 1000 1100 1200 1300
TOTAL AFLATOXIN µg/kg

FIG. 8·3 LIPASE ACTIVITY OF ASPERGILLUS SP ON RUBBER SEED KERNEL AT VARYING MOISTURE LEVELS.

(NOTE : MOISTURE LEVELS INDICATED)



CHAPTER 9

ECONOMIC/FINANCIAL EVALUATION OF RUBBER SEED PROCESSING

9.1 Introduction

The economic/financial evaluation of rubber seed processing was carried out with respect to base parameters in Sri Lanka. Financial evaluation has been carried out to test efficiency of resource use of rubber seed processing at current market prices while economic analysis has been used to judge efficiency of resource use when market prices are adjusted to shadow prices using concepts of opportunity costs/ benefits. The concepts and methodology are based on the well known UNIDO publications, *Guidelines* and *Guide* on project appraisal/evaluation, supplemented with other useful texts in this area (Ref. 1-10). In both financial and economic analyses the emphasis is more on sensitivity and alternatives rather than absolute profitability, the Financial Internal Rate of Return (FIRR) taking note of cost of capital at market prices prevalent in Sri Lanka (about 20%) and Economic Internal Rate of Return (EIRR) taking note of adjustment of market prices to shadow (accounting) prices to indicate contribution to the real national income of Sri Lanka (about 13% at present).

9.1.1 *Financial Evaluation - Edible Oil and Meal*

9.1.1.1 Background

The analytical framework of the UNIDO Guide (Ref. 1) has been used to prepare a financial evaluation of RS processing. A financial income statement (FIS) and cash flow statement (CFS) obtained from supporting information form the core of financial evaluation. The CFS is divided (a deviation from standard financial tables) into two parts one, NET CASH FLOW - REAL dealing with operating cash flows related to sale or purchase of physical items and other NET CASH FLOW - FINANCIAL dealing in cash flows for financing operations. Working capital is divided between Net CF Real and Net CF Financial, inventories (stocks) included in former while cash in hand, receivables and payables are included in latter. Constant prices are used in all statements unless otherwise stated so that no allowance has been made for inflation, foreign exchange losses etc. Market prices relate to Sri Lanka rupees. Calculation of financial Internal Rate of Return (FIRR) based on net present values have formed the basis of project comparison.

9.1.1.2 Rubber Seed Raw Material Cost

It is necessary to prepare rubber seed kernel of good quality to produce edible quality rubber seed oil and meal. This involves stages of collection of seed, drying, decortication and separation of shell from kernel. Costs are worked out on the basis of collection of 1000 tons of fresh rubber seed(20% moisture content), drying to 5% moisture, storage, decortication and production of 450 tons quality kernel. An estimate of market price for good quality RSK dried to a moisture content around 5% was made as follows:-

(a) Collection - Average cost of collection and transport upto a distance of 25 miles was estimated at Rs.2.50 per kg of fresh seed inclusive of packing in used polypropylene woven bags. Taking note of loss of drying from 20% moisture to 5% and kernel content

(60% of whole seed - see Section 2.2), cost of material content in dried RSK (excluding drying charges) is estimated at Rs.5.00 per kg.

(b) <u>Drying Costs</u> - Drying can be carried out on a large scale in smoke houses, copra kilns or indirect dryers (Section 2.3). In Table 9.1 respective costs of drying by these methods have been estimated. The smoke house and copra kiln drying involves hiring charges whereas the indirect dryer has to be specially constructed for drying rubber seed. Depreciation is estimated at 10% of construction cost of indirect dryer over a 270 day period and reduced to a six day period (ie. $\frac{5200}{270} \times 6 = 115$). Overheads are similarly estimated on a total of Rs.13,400 representing 20% of construction cost and maintenance charges ($\frac{13400}{270} \times 6 = 297$). Considering the availability of the different methods of drying a practical solution to the distribution of drying methods (1000 tons of fresh seed of 20% moisture content to give 450 tons of kernel of 5% moisture content) is given in Table 9.2. It is seen that the average cost of drying is estimated at Rs.1.40/kg dry kernel. It must be noted that this is a maximum value since in practice pre drying with sunlight could considerably reduce drying cost.

(c) <u>Decortication Costs</u> - Disc Grinder, Drum Decorticator or manual methods of decortication are possible (Section 2.4) respective costs being estimated in Table 9.3. Depreciation is 10% of cost over a 180 day period (540 eight hour shifts) and reduced to a single shift. Overheads are estimated similarly on a total of Rs.12,000 for disc grinder ($\frac{12,000}{540}$ = 22.2) and Rs.4000 for drum decorticator $\frac{4000}{540}$ = 7.4). Considering individual running costs of decortication, the disc grinder method is the most expensive while manual decortication is least expensive. Assuming a 10% share each in use of disc grinder and drum decorticator and 80% manual decortication, an average decortication cost of Rs.1.38/kg dry kernel has been estimated.

(d) Separation Costs - It is possible to carry out separation of shell from kernel after decortication either with a pneumatic separator or manually (Section 2.4.3) respective costs being estimated in Table 9.4. Depreciation is 10% of cost over a 180 day period (540 eight hour shifts) reduced to a single shift ($\frac{950}{540}$ = 1.76). Overheads are estimated similarly on a total of Rs.2400 ($\frac{2400}{540}$ = 4.44). Assuming 25% utilization for separation with drum decorticator and 75% manual separation an average of Rs.1.40 per kg dry kernel is estimated as separation costs.

The total costs for production of good quality rubber seed kernel are estimated as follows (SL Rupees/kg dry kernel):-

Material cost	5.00
Drying cost	1.40
Decortication cost	1.38
Separation cost	1.40
Total	9.18

This estimate could be greatly reduced if sun drying and manual operations are given greater weightage.

9.1.1.3 <u>Project Cost for Establishment of a Unit for Rubber Seed Processing</u>

Practical considerations mainly due to difficulties of collection of plentiful supplies of rubber seed will limit a high turnover in operations and an estimate of 1000 tons of freshly collected rubber seed (moisture content 20%) has been considered optimal for a processing unit. Drying and decortication will reduce 1000 tons to 450 tons of kernel. It is necessary to equip a processing unit with suitable equipment for production of high quality (low FFA) rubber seed oil as follows (Chapter 3):-

(a) High pressure screw expelling

(b) Cooking (conditioning) of kernel to a moisture level around 7%

(c) Mixing RSK with rubber seed meal and poonac in ratio RSK/RSM/poonac - 45/50/5.

(d) High levels of FFA and other associated unsaponifiable matter (Section 4.2) necessitates a high degree of refining, however due to comparatively small quantities of crude oil, batch chemical (alkali) refining is preferred to physical refining.

Parameters for a practical processing unit utilizing high pressure screw expelling for oil extraction are given in Table 9.5. It is seen that an input of 3 tons of rubber seed kernel admixed with 3.66 tons rubber seed meal and poonac is the recommendation.

Raw material availability restricts rubber seed processing to 150 days and the remaining period is utilised for copra expelling. The total output of refined RSO is estimated at 185 tons and coconut oil 412 tons.

The project cost has been estimated from the total of Initial Capital Investment Costs (Table 9.6) and Working Capital calculation (Table 9.7).

9.1.1.4 Initial Capital Investment Costs

These include purchase of land, site preparation, building construction and other infra structural facilities. The extraction equipment consists of a high pressure type screw expeller with capacity to process 7 tons material per 24 hour day, fitted with a 30 H.P. motor, and facilities for cooking, filtering and settling. The refining plant fitted for alkali neutralization, bleaching and deodorization has a capacity to handle 15 tons crude oil per day, supporting equipment mainly consisting of a boiler. Total initial capital investment is estimated at Rs.22.81 million, 73% being foreign costs.

9.1.1.5 Calculation of Working Capital

The calculation of working capital is shown in Table 9.7. This has ben simplified taking account of general accounting principles. The total production cost has been estimated first to include overheads, depreciation and interest payment (see Table 9.8). Requirements of current assets and liabilities have been calculated from factory costs and overheads on the basis of indicated periods of coverage. The working capital is estimated at current assets less current liabilities to be Rs.3.97 million.

9.1.1.6 Total Project Cost

The total project cost for establishment of a unit for rubber seed processing is estimated as follows:-

Initial Capital Investment Costs		22.81 million
Working Capital		3.97
	Total	26.78 million

It is expected that an organisation which has vested interests in the rubber plantation sector (e.g. the state run Janatha Estates Development Board in Sri Lanka) will raise the necessary capital in the form of equity contribution of Rs.11.78 million and a long term development loan of Rs.15 million at concessionary interest rates.

9.1.1.7 Pricing of Inputs and Outputs

The prices of major raw material inputs viz. rubber seed kernel and copra and outputs, the corresponding oil and meal would be expected to register much variation due to fluctuations in international and domestic prices peculiar to the crushing industry. International prices are often quoted for unrefined oil, however refined oil e.g. coconut oil packed in drums from Sri Lanka commands a premium in world markets (Table 9.9). The increased demand for vegetable oils in Sri Lanka is such that domestic prices exceed international prices, effective rates of protection* by way of tariff and non-tariff barriers being in excess of 50%. Information on oil seed product prices is also given in Tables 9.10 and 9.11. Considering

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$$\text{*Effective Rate of Protection} = \frac{\text{Value added @ domestic} - \text{Value added @ world prices}}{\text{Value added @ world prices.}}$$

market wholesale and retail prices in relation to value addition and averaging over the period during which the information was gathered (January-July 1989) the following pricing has been adopted for financial evaluation (prices Sri Lanka Rupees per kg) as base.

OUTPUTS

Rubber Seed Oil (refined)	-	54.00
Rubber Seed Meal (without shell, 10% residual oil)	-	3.50
Coconut Oil (refined)	-	43.50
Coconut Meal (poonac, 5% residual oil)	-	5.00

INPUTS

Rubber Seed Kernel (5% moisture)	-	9.18 (see Section 9.1.1.2)
Copra (milling superior)	-	17.00

9.1.2 *Financial Internal Rate of Return in Rubber Seed Processing (UNIDO Guide Stage I)*

9.1.2.1 Financial Income Statement

This statement is compiled according to the format of the UNIDO Guide. The following simplified assumptions have been made:-

(a) The project is operational at full capacity in the first year and is continued for a period of ten years with no changes in inventory.

(b) No additional capital equipment purchases are envisaged during the life time of the project. Sale prices, inputs, utilities, operational expenses and other financial transactions remain constant at first year prices over the time horizon of the project, (based on initial investment price levels).

(c) Interest payment has been averaged over the period of the project (Table 9.8). Depreciation costs have also been averaged at 10% of initial capital investment for equipment (Table 9.6), although in practice accelerated depreciation would be permitted on capital equipment for development projects.

(d) Provision has been made for inclusion of additional revenue e.g. by way of making available excess refining capacity.

Using annual sales projections (Table 9.12) and other information in relevant tables on operational expenses (Table 9.7) and initial capital costs (Table 9.6) the financial income statement has been compiled (Table 9.13). Values for each item over the ten year period have been discounted to net present values (facilitated by the computer programme used). This income statement has been used to construct a financial cash flow statement in two parts - Real (Table 9.14) and Financial (Table 9.15).

9.1.2.2 Financial Cash Flow Statement

This statement is compiled according to the UNIDO Guide format in Tables 9.14 and 9.15. The following assumptions and features of this format are to be noted:-

(a) Net present values are obtained from the Net Cash flow - Real part (Table 9.14), the Net Cash Flow - Financial (Table 9.15) being complementary in dealing with cash flows involved in financing operations.

(b) Inventories are included in Net CF Real, remainder of working capital (cash in hand, receivables and payables) being separated into the Net CF financial part.

(c) Depreciation is added to operating profit before interest and tax as required for calculation of Internal Rate of Return.

(d) Fixed assets and inventories are used in year 0 and salvaged at termination as follows:-

Inventory	- full value
Land and Building	- an appreciated value (150% increase)
Equipment	- 10% of initial value

The financial IRR (FIRR) of rubber seed processing has been estimated at 17.5% taking note of a base unit operational for 150 days of the year to process rubber seed kernel and 150 days to process copra, the inputs and outputs (Table 9.12) being based on current market prices. The FIRR is somewhat on the low side when comparison is made with nominal commercial interest rates and cut-off rates for FIRR, the minimum acceptable value being about 20% at present in Sri Lanka.

9.1.3 *Rubber Seed Processing Alternatives and Sensitivity Analysis*

The computer programme used in calculation of FIRR has facilitated other calculations in alternatives and sensitivity analysis.

9.1.3.1 Alternatives

The financial IRR was estimated at 17.5% on the basis of operations half the year with rubber seed and remainder with copra. The alternatives were estimated on the basis of working throughout the year with rubber seed or copra, assuming that other costs are not altered. The estimated FIRR are as follows:-

300 day rubber seed processing - 22.1%
300 day copra processing - 13.2%

Thus, if the above processing operations are considered independently (i.e. not mutually exclusive projects) rubber seed processing by itself offers the best returns. However practical difficulties concerned with seed availability will not permit such an operation. Another alternative would be to utilise excess refining capacity. Running costs for refining operations (alkali neutralization, bleaching, deodorization) are given in Table 9.16, estimated at Rs.1599 per ton of crude oil input. Excess capacity for the refining unit under consideration is estimated at 3000 tons per year and additional income will accrue by levy of a margin over running costs, the corresponding FIRR values given in Table 9.17. It is noted, that a margin of 15-20% over refining costs (which is quite reasonable) will help in increase of FIRR to acceptable values for the project in its entirety.

9.1.3.2 Sensitivity Analysis

The sensitivity of rubber seed processing to the major variables viz. market prices estimated for sales, raw material and capital costs was determined. Values of financial IRR are shown in Fig.9.1 giving the following variations upto ± 10%, for both rubber seed and copra processing.

(a) Sales (revenue change)

(b) Raw material

(c) Both sales and raw material (interpolated values)

(d) Capital costs

Fig. 9.1 shows that an increase in sales price by 5% raises the FIRR to an acceptable value (greater than 20%), even the interpolated curve showing an FIRR of 23.2% at a 5% increase in sales. The gradients in Fig.9.1 show that the FIRR is more sensitive to changes in sales than changes in raw material costs or capital cost.

We felt that our estimate of raw material cost for rubber seed has been over estimated (Section 9.1.1.2), this being confirmed by small holders. Variation of FIRR in relation to reduction of rubber seed kernel costs (without changes in copra costs and other costs) are given in Table 9.18. It is seen that a reduction of rubber seed kernel price in the 15-20% range from the base value of Rs.9.18/kg increases FIRR to acceptable values over 20%.

9.1.4 *Summary and Conclusions on Financial Profitability of Rubber Seed Processing (Edible Oil & Meal)*

The financial profitability of rubber seed processing has been evaluated on the basis of inputs and outputs estimated at average market prices in Sri Lanka. A base financial internal rate of return (FIRR) for rubber seed processing has been estimated for a practical operational unit processing half the year rubber seed kernel and the remainder copra processing to yield oil and meal of high grade quality. The estimated FIRR of 17.5% is somewhat less than nominal commercial interest rates and the financial cost of capital (market cost) estimated around 20%, this being regarded as the minimum FIRR cut-off value for project acceptance in Sri Lanka. The comparatively low value of FIRR is due to high initial investment costs coupled with under utilization of refining capacity (Section 9.1.3.1). Utilization of refining capacity with a margin of 15-20% over refining costs results in an acceptable FIRR. The other alternative of processing rubber seed all the year round also results in acceptable values of FIRR greater than 20%. However this alternative is not practicable due to difficulties in seed collection and storage.

The financial internal rate of return appears to be most sensitive to sales revenue, a 5% increase elevating the base FIRR to an acceptable level. On the other hand a reduction of rubber seed kernel raw material price by 15-20% (from the base market price of Rs.9.18 per kg) is necessary to increase FIRR over 20% (Table 9.18).

Reduction of capital investment costs at the 10% level (Fig. 9.1) also leads to acceptable values of FIRR. Thus it appears that the FIRR could attain acceptable levels by adjustments of variables which are within limits of permissible error.

9.2 Economic Evaluation of Rubber Seed Processing - Edible Oil and Meal and Overall Project Feasibility

In the last Section the financial evaluation of rubber seed processing (i.e. whether a practical unit will be profitable enough to cover average cost of capital of lenders and sponsors) was determined and in this Section economic evaluation will be analysed from the view point of efficient allocation of resources. The approach and methodology will be based on the UNDIO *GUIDELINES* AND *GUIDE* relying on the use of shadow (accounting) prices obtained by adjusting market prices to provide a measure of social benefits and costs involved. The deviation of shadow prices from market prices will be determined by the adjustment factor AF defined as :-

$$AF = \left(\frac{\text{Shadow Price}}{\text{Market Price}} - 1\right) \text{ per cent.}$$

Due to difficulties in obtaining reliable information, economic analysis will be confined only to Stage 2 dealing with measurement of contribution of rubber seed processing to the real national income in Sri Lanka and Stage 3, the net effect of the project on total savings (assumed equal to investment). It is to be noted that the common unit of account (numéraire) originally used in the Guidelines has been modified in the Guide as "net present consumption benefits in the hands of people at the base level of consumption in the private sector in terms of constant price domestic accounting rupees" the advantage of modification being discussed in the *GUIDE*.

9.2.1 *Economic Analysis - Determination of Economic Internal Rate of Return (EIRR)*

Estimation of EIRR is carried out according to the following sequence:-

(a) determination of adjustment factors for components of sources and uses in the financial cash flow - Net cash flow (Real) statement Table 9.14 by shadow pricing;

(b) adjustment of net present values in Table 9.14 by use of AFs determined above to preliminary economic values;

(c) adjustment of preliminary economic values thus obtained by the foreign exchange premium factor.

9.2.2 *Detemination of Adjustment Factors for Inputs/Outputs in Rubber Seed Processing*

The determination of opportunity costs (benefits forgone by use of scarce resources for a project instead of for their next best alternative use) for inputs/outputs in rubber seed or for that matter any other project is an involved process and simplification has been achieved by following principles in the *UNIDO GUIDE* and other texts (see References).

(a) the following items have been classified as FULLY TRADED, shadow prices being average border prices converted to Sri Lankan currency at market exchange rates (Sri Lankan Rs. 33 = 1 US $) -

Rubber seed oil, coconut oil, copra, poonac (Table 9.19). Rubber seed oil is not an article of international trade and shadow pricing is based on prices of vegetable oil imported into Sri Lanka.

(b) a list of non-traded items is given in Table 9.20. It has been assumed that market prices reflect opportunity costs and hence adjustment factors are zero for each of these items. Skilled labour is in this category.

(c) a list of partially traded items is given in Table 9.21. Rubber seed kernel has low demand for alternate use and the shadow price is that commanded by rubber seed in manufacture of technical, low quality oil of high FFA. Inventories have been shadow priced on basis of raw material (RSK, copra),land and buildings and equipment on the basis of other similar projects in Sri Lanka. Unskilled labour is shadow priced at 50% market wages to give an AF of-50%.

(d) foreign exchange has been shadow priced using the simplified formula in the *GUIDE* viz.

$$S\,E\,R = O\,E\,R \frac{(M + T_i) + (X + S_x)}{M + X}$$

S E R = Shadow Exchange Rate

O E R = Official (Market) Exchange Rate

M, X imports (cif value), Exports (FOB vlaue)

T_i Import tax Revenue, S_x Export Subsidies

The current adjustment factor for Sri Lanka is calculated to be 10%, ($\frac{S\,E\,R}{O\,E\,R}$ = 1.1) i.e. foreign exchange enjoys a premium of 10% over the market rate.

9.2.3 *Adjustment of Net Present Values (Financial) to Preliminary Economic Values*

The Net Present Values (NPVs) from Table 9.14 (which are domestic market prices) are converted to shadow prices by means of adjustment factors to give preliminary economic values (Table 9.22). Adjustments have been made to production outputs (RSO, RSM, coconut oil, poonac), raw material (copra, RSK) and labour (unskilled) and also inventories, land and building and equipment. The preliminary economic internal rate of return is estimated at 4.3%.

9.2.4 *Adjustment of Preliminary Economic Values*

The preliminary economic values represent a mix of *numéraires*; these are converted by multiplication with the weighted premium on foreign exchange to a common *numéraire* in the form of domestic (Sri Lankan) accounting rupees (Table 9.23). The UNIDO Stage Two present values thus reflect the combined effect of shadow pricing and effect of foreign exchange on the project and are used for calculation of the ECONOMIC INTERNAL RATE OF RETURN for the base case with inputs/outputs in Tables 9.22 and 9.23, the EIRR is estimated at 8.5%. This estimate is lower than the value of 13% taken as the cut off for project acceptance in economic terms - the economic cost of capital (opportunity cost) in Sri Lanka. Hence rubber seed processing appears to be unsatisfactory based on the adjustment factors in Table 9.22. The main reason for economic unacceptability is the fact that domestic market prices of vegetable oils in Sri Lanka are much higher than world prices due to a high tariff structure on imported oils.

9.3 Alternatives and Sensitivity Analysis

The computer programme has facilitated calculation of several project alternatives and sensitivity analysis to variables.

9.3.1 *Alternatives*

Comparison of alternatives shows that processing of copra for 300 days leads to a negative EIRR whereas processing of RSK alone for 300 days results in an EIRR of 23.6% which is higher than the base value of 13% for economic acceptance of projects in Sri Lanka. However, as pointed in Section 9.1.3.1. it is not practical to process rubber seed throughout the year due to unavailability of raw material, although processing of rubber seed is a better project alternative contributing to real national income. The economic returns of utilization of additional refining capacity (Section 9.1.3.1) were not evaluated due to difficulties in estimation of shadow prices.

9.3.2 *Sensitivity Analysis*

Considering the rubber seed part of processing (ignoring the coconut input/output part) EIRR values were determined for variation in changes of adjustment factor for RSO and premium on foreign exchange (Fig. 9.2). Changes in EIRR are more sensitive to variation in AFs for RSO than the premium on foreign exchange, it is possible to attain the cut off value of 13% taken as a measure of the opportunity cost of investment in Sri Lanka, with an increase of AF for rubber seed oil by 20% (shadow CIF price for RSO increased from Rs. 30.40 to Rs.35.10 - see Table 9.19).

9.3.3 *Economic Internal Rate of Return*

The preliminary economic IRR for rubber seed processing (Section 9.2.3) which reflects market price distortion when shadow prices are used has been estimated at 4.3% while adjustment of this value by the premium attached to foreign exchange in Sri Lanka results in the true Economic Internal Rate of Return of 8.5% (Section 9.2.4). Both these are below the value of 13% accepted as the cut off for EIRR for acceptance/ rejection of additional investment in Sri Lanka (the financial IRR is taken as 20%).

Reasons for lowered EIRR in rubber seed processing can be enumerated as follows -

(a) comparatively low world prices of vegetable oils relative to domestic market prices in Sri Lanka (Tables 9.9, 9.19). This is mainly due to low production of oil seed so that comparative advantages of economies of mass production are not prevalent in countries such as Sri Lanka. Low world prices have the effect of decreasing AFs (Table 9.22) resulting in higher adjustment to cash flow and reduced preliminary adjusted present values.

(b) the premium on foreign exchange (Section 9.2.2) does not adequately compensate for reduced benefits of domestic production. This is due to the fact that the premium which is a rough measure of protection in the economy of Sri Lanka indicating average price differentials between market and border prices is much less than the level of protection afforded to the vegetable oil sector. Sensitivity analysis (Fig. 9.2) has also shown that EIRR variation to premium on foreign exchange is comparatively lower relative to change of adjustment factors.

9.4 Income Flow Analysis and Economic Value of Savings (UNIDO Guide Stage 3)

An attempt has been made to analyse rubber seed processing, examining the impact on savings and consumption. Steps taken are those in Stage 3 of the UNIDO *GUIDE*. The groups which lose and gain income due to investment in rubber seed processing are categorised thus :-

Group	Marginal Propensity to save (MPS)
Project (Rubber Seed Processing)	0.5
Government	0.5
Estate sector	0.2
Consumers	0.2
Workers	0.1

As detailed in the *Guide*, adjustments were carried out with economic and financial and foreign exchange adjustments. The Net Distribution Impact Values are given in Table 9.24, as are also the adjustment value to savings (assumed equal to investment) - see also Addendum.

The adjustment value to savings is a result of income being taken away from consumers and distributed to government (by way of taxes) and the estate sector (for services), the former having a higher MPS. Savings would be higher if world vegetable oil prices fall (without change of domestic prices) leading to a greater income flow to the rubber seed project with a higher MPS value. The adjustment value to savings amounts to about 15% relative to the net present value (economic) in rubber seed processing. The ECONOMIC IRR for this stage (UNIDO Stage 3) is estimated at 10.4%.

9.5 Overall Feasibility of Rubber Seed Processing (Edible Oil and Meal)

The feasibility of rubber seed processing is discussed from the analysis of financial and economic data obtained. Basic parameters relevant to rubber seed processing and evaluation in terms of Internal Rate of Return are given in Table 9.25.

As discussed in Section 9.1.4 the financial IRR could be made to attain acceptable levels of 20% by minor adjustments in sales, rubber seed kernel costs and capital costs. The low value of 8.5% for economic IRR could be also stepped up to greater than 13% (the minimum level of opportunity cost of capital in Sri Lanka) by slight changes of adjustment factors and premium on foreign exchange (Section 9.3.2). It has also been shown that rubber seed processing results in additional savings to the Sri Lankan economy by way of income flows to government and estate sector (both of which sectors have comparatively higher marginal propensity to save -Section 9.4).

Some of the changes necessary for acceptance from the basic parameters of Table 9.25 are summarised in Table 9.26. These changes are thought to be well within the errors involved in estimation of basic parameters and may be combined together for overall feasibility of rubber seed processing.

9.6 Rubber Seed Processing - Production of Technical Oil and Miscellaneous Factors

9.6.1 *Introduction*

The preceding Sections have described the financial/economic evaluation of rubber seed processing for production of oil and feed for edible purposes. Conditions for production of technical oil are quite different and base parameters have to be changed by large values to accomodate variations. Earlier reports have dealt with production of technical oil and low quality animal feed and some of the distinctive features are enumerated:-

(a) Technical oil is produced from aged seed either in the undecorticated form as in Sri Lanka or from kernel as in South India. Processing of kernel gives purer products but conditions are more demanding than use of undecorticated seed necessitating use of external "roughage", most commonly molasses, in South India.

(b) Extraction of oil from aged seed is comparatively easier than when fresh seed is used, low pressure screw expellers or oil chucks being sufficient for the purpose.

(c) Elaborate refining is not required in production of technical oil, treatment with activated bleaching earth and filtration is sufficient if necessary.

(d) Since special drying or treatment of seed is not necessary cost of raw material is reduced.

(e) Wearing out and damage of extraction equipment components is a serious problem in use of undecorticated seed.

9.6.2 *Production of Technical Oil and Meal*

It is not intended to give a detailed analysis in terms of financial/economic variables rather a general idea of base parameters. These have been obtained from actual commercial operations in Sri Lanka and relevant information to commence a project for rubber seed processing is given in Table 9.27. The type of screw expeller used generates pressures on the low side (compared to high pressure expellers needed for fresh quality kernel) powered by a 15 HP motor with a throughput of 2-3 tons of material per 24 hour operation. Undecorticated whole rubber seed is used after a period of storage (about 3 months) during which ageing occurs. Operations with two expellers facilitate oil extraction, filtration being carried out at the same time. The filtration rate is slower than in the case of coconut oil but is fast enough for routine operation. A processing unit could handle about 350 tons during a season and as in the good quality rubber seed oil case it is necessary to carry out expelling alternatives during the off-season period. The practical processing unit detailed in Table 9.27 has a capacity of handling 2.27 T whole rubber seed and one ton of copra yielding 0.5 tons rubber seed oil and 1.77 tons meal per day operation. The input material is estimated at a unit cost of Rs. 1 per kg, output rubber seed oil at Rs.15 per kg and rubber seed meal at Rs.1 per kg. The rubber seed oil and rubber seed meal are of low quality the former used for production of alkyd resin while rubber seed meal after powdering and sieving could be used as a component of low quality animal feed.

Cash flows and financial internal rates of return worked out as in earlier Sections result in a FIRR of 57.3% and Return on Capital Employed (ROCE) of 47.6% compared with 17.5% and 11.9% for the good quality oil processing operations. The high rates of return are a result of lowered capital costs due to use of low pressure screw expellers and cheap raw material which does not require any pre-processing.

In comparison of alternatives it is readily seen that rubber seed processing throughout the year gives higher returns than copra processing throughout the year. However practical difficulties in the way of collection and storage of sufficient quantities of rubber seed for an year round operation preclude such a profitable alternative. Enquiries in Sri Lanka have confirmed these findings - that it is comparatively profitable to extract rubber seed oil in copra mills, even with attendant higher costs of maintenance and breakdown of machinery when undecorticated rubber seed processing is performed.

9.6.3 *Economics of Use of Technical Rubber Seed Oil and Rubber Seed Meal*

Current market price for rubber seed oil and rubber seed meal in Sri Lanka are around Rs.15 and Rs.1 respectively. Treated rubber seed Oil (with activated bleaching earth) of lighter colour and powdered, sieved rubber seed meal command higher prices dependent on import duties and demand for alternatives.

As pointed out in the PRODUCT MARKETS (Ch.5), alkyd resin manufactured from rubber seed oil is inferior due to the problem of yellowing. The use of Tall Oil Fatty acids or other vegetable oil fatty acids (e.g. soya, sunflower) gives a superior alkyd. Current market prices of tall oil fatty acids in Sri Lanka (inclusive of a concessionary import duty of 5%, TOFA being classified as an industrial raw material) are around Rs.27 per kg compared with Rs.19 per kg for the best grades of technical rubber seed oil. The latter is presently used in manufacture of alkyd resin for formulating dark pigmented solvent based surface coatings. Tariff controlling bodies in Sri Lanka have looked into the possibility of increasing import duties on tall oil fatty acids, but unavailability of sufficient quantities of rubber seed oil has prevented imposition of high levels of protection for the rubber seed oil industry in Sri Lanka.

Rubber seed meal obtained during low grade oil production has a high shell content and hence is of low quality. The present price paid for this type of meal after grinding and sieving to remove coarse particles is about Rs.1/- per kg compared to Rs.5/- for high quality animal feeding material.

9.7 Conclusions on Financial/Economic Evaluation of Rubber Seed Processing (Technical/Edible Oil and Meal)

The preceding sections have described the details of financial/economic evaluation of rubber seed processing according to the UNIDO GUIDE both for production of high quality oil/meal production (for edible use) and for technical oil, as a raw material for industry. Findings in terms of estimation of Internal Rates of Return (financial/economic) and Return on Capital Employed are summarised in Table 9.28 (no economic analysis has been carried out for technical RSO production due to uncertainties in base parameters).

A practical unit for rubber seed processing both for high grade and low grade rubber seed production needs to be combined with copra milling due to difficulty of obtaining sufficient kernel/seed for an year-round operation. The base evaluations have thus been carried out on an assumption of 150 days processing for rubber seed oil and 150 days for copra.

It is seen from Table 9.28 that the base operation for High Quality rubber seed production gives FIRR and EIRR values below the respective limits of 20% and 13% taken for project acceptance in Sri Lanka. These shortcomings are attributed to high capital costs of production (financial) and low shadow prices for rubber seed products (economic) in Sri Lanka due to low world market prices for substitute vegetable oils. It has also been shown that the premium on foreign exchange in Sri Lanka (Section 9.2.2) does not adequately compensate for reduced opportunity costs, leading to a low EIRR (Section 9.3.3).

Alternatives in the form of additional income gained by utilization of extra refining capacity (Section 9.1.3.1) and Sensitivity Analysis (Sections 9.1.3.2 and 9.3.2) help increase of FIRR and EIRR to acceptable levels in Sri Lanka (Table 9.26). An analysis of Income Flow and Economic Value of Savings (Section 9.4) reveals income distribution to government and the estate sector with a net savings impact of 15%.

Production of technical oil from aged undecorticated rubber seed (Section 9.6) is shown to be relatively profitable compared to high quality products due to reduced capital costs and low cost raw material.

This exercise in rubber seed processing appears to pinpoint one of the key problems in oil seed technology worldwide - that viable vegetable oil production needs large quantities of seed input with efficient, capacity utilization operation to benefit from increasing returns to scale or if seed quantities are limited there must be a drastic reduction of capital costs with appropriate type of technology albeit comparatively inefficient (e.g. high residual oil in meal or low level of refining).

9.8 References

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9.9 Addendum

CLARIFICATIONS ON UNIDO GUIDE FOR FINANCIAL/ECONOMIC EVALUATION

The financial income statement FIS (Table 9.13) and financial cash flow statements FCF (real - Table 9.14 and financial Table 9.15) form the core of the financial/economic evaluations. The FIS itself is obtained from information given in supporting tables on capital investment (Table 9.6), working capital (Table 9.7), loan payment (Table 9.8) and sales/inputs (Table 9.12). The utilities and services item 8.1 in the FIS is Total Production Cost less the total of raw material, depreciation and interest (Table 9.7).

The FCF statement is divided into two parts REAL and Financial (Tables 9.14 and 9.15) as elaborated in the Guide. The REAL part is sufficient for calculation of FIRR while the financial part dealing with money flows for financing operations is used for later use in Stage 3 - Savings impact analysis.

For the economic analysis, market price distortion values and adjustment for foreign exchange serve the purpose of adjusting market prices to shadow prices (Table 9.22) and converting these shadow prices to a common numéraire (Table 9.23).

In the income Flow Analysis and Economic Value of Savings determination (UNIDO Stage 3), the Net distribution impact values have been obtained from the sum of market price distortion (Table 9.22), foreign exchange adjustment (Table 9.23) and cash flow (financial) components. The latter is made up of debt service (interest payment), taxes and dividends (Table 9.13). The adjustment factor AF for interest payment* is zero (interest payment on project is 13% - see Table 9.8 and opportunity cost of capital in Sri Lanka is 13%) while AF for taxes and dividends is taken to be - 100%. The Net Impact values (Table 9.24) are obtained from Net distribution impact values by use of MPS factors for the different groups (Section 9.4). These are in the form of savings values and are converted to consumption values (on which the UNIDO Guide numéraire is based) by multiplication by the adjustment factor for savings AFs defined as :-

$$AFs = \frac{MPC\ (MP^{cap})}{CRI - MP^{cap}MPS} - 1$$

MPC - marginal propensity to consume (85%)

MPS - marginal propensity to save (15%)

MP^{cap} - marginal productivity of capital (23%)

CRI - consumption rate of interest (13%).

Values given in parentheses are those taken as representative in Sri Lanka.

$$*\frac{\text{Interest payment - opportunity cost of capital}}{\text{Opportunity cost of capital}} \times 100 \text{ per cent}$$

TABLE 9.1

CALCULATION OF RUNNING COST IN DRYING OF RUBBER SEED

	Smoke House	Copra Kiln	Indirect Dryer
Construction cost	Hired	Hired	52,000
Average duration of drying (days)	3	2	1
Material dried over 6 day period (kg)			
(a) Seed	750	1500	3270
(b) Kernel	450	900	1960
Running cost for 6 day period			
Firewood	100	450	750
Hire charge	350	1500	-
Labour	-	-	1150
Depreciation	-	-	115
Overheads	-	-	297
Total	450	1950	2312
Cost of drying/kg dry kernel:-	1.00	2.17	1.18

(Note : Costs in Sri Lanka Rupees)

TABLE 9.2

PRACTICAL DISTRIBUTION OF DRYING RUBBER SEED BY DIFFERENT METHODS

Type of drier	No. of Units	Capacity over 90 day period per unit (Tons dry kernel)	Total dried (Tons dry kernel)	Unit cost of drying Rs/kg	Drying cost Rs.
Smoke House	30	6.75	202	1.00	202,000
Copra Kiln	10	13.50	135	2.17	292,950
Indirect Dryer	4	29.40	117	1.18	136,880

(Average cost of drying - Rs.1.40/kg dry kernel).

TABLE 9.3

CALCULATION OF RUNNING COST FOR DECORTICATION OF RUBBER SEED

	Disc Grinder	Drum Decorticator	Manual
Construction cost	55,000	15,000	--
Throughput kg dry kernel/hour	20	30	8
Running cost per eight hour shift			
Labour	300	300	83
Electricity	6.4	8.0	-
Depreciation	10.1	2.8	-
Overheads	22.2	7.4	-
Total	338.7	318.2	83
Running cost of decortication per kg dry kernel	2.12	1.32	1.30

(Note: Costs in Sri Lanka Rupees)

Table 9.4 - Calculation of Running Cost for Separation of Kernel from Shell Fragments

	Pneumatic Separator	Manual
Construction cost (Rs)	9500	-
Electrical power kW	0.5	-
Throughput (kg dry kernel/hour)	60	6
Running cost per eight hour shift		
Labour	167	84
Electricity	8.0	-
Depreciation	1.76	-
Overheads	4.44	-
TOTAL	181.20	84
Running cost of separation/kg dry kernel	0.38	1.75

(Note: Costs in Sri Lanka Rupees).

TABLE 9.5

PARAMETERS FOR A PRACTICAL PROCESSING UNIT USING SCREW EXPELLING

	Rubber Seed	Copra (Coconut)
Input rubber seed kernel/ copra per day (tons)	3.0	4.5
Other material used per day (tons)	3.33 RSM 0.33 Poonac	Double expelling necessary
Operating period (days)	150	150
Input of extractable material (tons)	450	675
Total crude oil output (tons)	200	420
Total meal output (tons)	252	250
Average residual oil content in meal (%)	10.0	5.0
Refining loss (%)	7.0	2.0
Total output of refined oil (tons)	185	412

TABLE 9.6

INITIAL CAPITAL INVESTMENT COSTS

		Foreign Cost US $ converted into SL Rs.	Local Cost SL Rs.	Total SL Rs.
1.	Land 3 acres (12,000m^2)	-	0.4	0.4
2.	Site preparation and development	-	0.6	0.6
3.	Structures & civil works			
	(a) building	0.4	1.4	1.8
	(b) services	1.2	1.0	2.2
4.	Extraction equipment (to process 7 tons material per 24 hour day)			
	(a) high pressure screw expeller	2.21	0.22	2.43
	(b) cooking/conditioning equipment	0.31	0.03	0.34
	(c) filter press	0.36	0.04	0.40
	(d) other (compressor, screening tank, pumps, grinder, spares etc.)	2.62	0.26	2.88
5.	Refining, bleaching & deodorizing plant (carbon steel construction) capacity 15 tons per 24 hour day			
	(a) equipment	5.91	0.59	6.50
	(b) spares, accessories	1.22	0.12	1.34
6.	Supporting equipment			
	(a) boiler, capacity 600kg/h steam @ 10 bar	0.30	0.56	0.86
	(b) laboratory, capital	0.32	0.28	0.60
7.	Office equipment and vehicles	0.46	0.38	0.84
8.	Contingencies (10% items 4-7)	1.37	0.25	1.62
9.	Total	16.68	6.13	22.81

(Note: Costs include installation. Figures rounded in million rupees).

TABLE 9.7

CALCULATION OF WORKING CAPITAL (Rs. Million)

1. Annual Total Production Cost Estimate at full Capacity.			
A. FACTORY COST			
(a) Raw Material			
Rubber seed kernel 450 T @9.18		4.13	
Copra 675T @ 17.00		11.48	
Other		0.50	16.11
(b) Labour			
Skilled - 12		0.58	
Unskilled- 25		0.75	1.33
(c) Utilities			
Furnace oil	0.50		
Electricity	1.00		1.50
(d) Repairs & Maintenance	3% Capital Investment costs		0.68
(e) Factory overheads	10% (a)....(d)		1.96
	FACTORY COST (a)..... (e)		21.58
B. ADMINISTRATIVE OVERHEADS	5% Factory cost		1.08
C. SELLING & DISTRIBUTION OVERHEADS	2% Factory cost		0.43
D. OPERATING COST	A + B + C		23.09
E. DEPRECIATION	10% Capital Investment Cost (Table 9.6)		2.24
D. INTEREST PAYMENT (Table 9.8)			1.07
	TOTAL PRODUCTION COST		26.40
2. Requirements of Current Assets & Liabilities (360 days basis)			
A. CURRENT ASSETS			
(i) Accounts receivable:	30 days @ operating cost		1.92
(ii) Inventory (stocks)			
RS kernel	20 days stock		0.23
Copra	30 days stock		0.96
Spares	one year		0.57
Work in progress	9 days @ factory cost		0.54
Finished products	15 days @(factory cost + administrative OH)		0.94
(iii) Cash in Hand:	Total production costs less (raw material + utilities + depreciation) 15 days		0.27
TOTAL CURRENT ASSETS (i)+(ii)+(iii)			5.44
B. CURRENT LIBILITIES			
Accounts payable:	30 days for (raw material + utilities)		1.47
WORKING CAPITAL			
Current assets - Current liabilities			3.97

TABLE 2.8

LOAN REPAYMENT PLAN

(Long term development loan of Rs.15 Million @ 13%)

Year	Loan	Payment	Interest	
0	15.0	-	-	
1	13.5	1.5	1.95	
2	12.0	1.5	1.76	
3	10.5	1.5	1.56	
4	9.0	1.5	1.37	
5	7.5	1.5	1.17	
6	6.0	1.5	0.98	
7	4.5	1.5	0.78	
8	3.0	1.5	0.59	
9	1.5	1.5	0.39	
10	0	1.5	0.20	Total Innterest 10.75

Repayment plan equal annual instalments of Rs.1.5 Million principal and Rs.1.07 Million interest.

(figures in Rs. Million)

TABLE 9.9

INTERNATIONAL PRICES OF VEGETABLE OILS

Period	Soyabean Dutch FOB Ex-Mill	Sunflower Ex Tank Rotterdam	Coconut Philippines CIF Europe	Coconut (Bulk) FOB Colombo	Coconut (Drums) FOB Colombo
1986	342	366	297	293	333
1987	337	372	450	375	605
1988 (Jan-June)	438	437	545	NE	1018
1989 (Jan-Feb)	420	440	538	NE	1057

NE - No exports.

Note: Prices are in US$/MT.

Source : Coconut Developing Authority, Sri Lanka.

TABLE 8.10

COPRA AND POONAC (COCONUT MEAL)

PRICES

Period	International Copra Prices (US$/MT)		Domestic prices - Sri Lanka Wholesale (Rs./kg)	
	Philippine (CIF Europe)	Sri Lanka (FOB Colombo)	Copra	Poonac
1986	197	319	6.56	2.57
1987	303	427	14.06	4.06
1988 (Jan-Feb)	391	284	22.82	5.02
1989 (Jan-Feb)	361	646	NA	4.00

NA - Not available

Source : Coconut Development Authority, Sri Lanka.

TABLE 9.11

DOMESTIC BULK PRICES OF VEGETABLE OILS IN SRI LANKA

Type of Oil	Market Price Rs./kg
COCONUT	
(a) crude (unrefined)	33
(b) partially refined	39
(c) fully refined (bleached and deodorised)	43
SOYA	
(a) crude (unrefined)	49
(b) imported (refined)	74
SESAME - crude	86
CORN - refined	89
SUNFLOWER - refined	88
PALM - refined	56

Note: Coconut, soya(crude) and sesame oils are domestically produced, others are imported. The degree of refining is not known.

Imported oils are higher priced due to a high duty structure.

TABLE 9.12

ANNUAL SALES AND INPUTS OF RAW MATERIAL

Sales at Market Prices

Material	Quantity (Tons)	Unit Price Rs./kg.	Value Rs.Million
Rubber Seed Oil	185	54.00	9.96
Rubber Seed Meal	252	3.50	0.88
Coconut Oil	412	43.50	17.91
Coconut Meal	250	5.00	1.25

Inputs of Raw Material

Material	No. of days Processing	Quantity per day (Tons)	Unit Price Rs./kg.	Value Rs.Million
Rubber seed kernel	150	3.0	9.18	4.13
Copra	150	4.5	17.00	11.48
Other				0.50

Note: Processing carried out for 300 days, half the time for rubber seed remainder for copra.

TABLE 9.13

FINANCIAL INCOME STATEMENT

Item	Net Present Values				Year 1	Year 2-10
	0%	10%	15%	20%		
1. Sales @ market prices	300.05	184.37	150.59	125.79	30.00	270.00
2. Taxes (turnover)@ 5%	(15.00)	(9.22)	(7.53)	(6.29)	(1.50)	(13.50)
3. Sales @ factor cost	285.05	175.15	143.06	119.50	28.50	256.50
4. Inventory change	-	-	-	-	-	-
5. Production	285.05	175.15	143.06	119.50	28.50	256.50
6. Material Inputs	161.06	98.96	80.83	67.52	16.11	144.99
6.1 Rubber Seed Kernel	41.31	25.38	20.73	17.32	4.13	37.17
6.2 Copra	114.75	70.51	57.59	48.11	11.48	103.32
6.3 Other	5.00	3.07	2.51	2.10	0.50	4.50
7. Value added	123.99	76.18	62.23	51.98	12.40	111.60
8. Operating Expenses	92.23	56.67	46.29	38.67	9.22	82.98
8.1 Utilities and Services	69.82	42.90	35.04	29.27	6.98	62.82
8.2 Depreciation	22.41	13.77	11.25	9.40	2.24	20.16
9. Operating Profit before interest and Tax	31.75	19.51	15.94	13.31	3.18	28.62
10. Interest Payment	10.73	6.59	5.38	4.50	1.07	9.63
11. Net Operating Profit before Tax	21.03	12.92	10.55	8.82	2.10	18.90
12. Other net income	-	-	-	-	-	-
13. Net firm Profit before Tax	21.03	12.92	10.55	8.82	2.10	18.90
14. Income Tax @ 50%	10.51	6.46	5.28	4.41	1.05	9.45
15. Profit after Tax	10.51	6.46	5.28	4.41	1.05	9.45
16. Dividends 75% PAYEE	7.89	4.85	3.96	2.31	0.79	7.11
17. Retained Earnings	2.63	1.62	1.32	1.10	0.26	2.34

Note: Values in Sri Lanka Rupees (Million) rounded. Discount rates are 0, 10, 15, 20%. Other Net Income (row 12) e.g. additional refining is added when required.

Utilities and Services (item 8.1):

Total production cost - (Raw material cost+ interest payment+ depreciation) see Table 9.7.

TABLE 9.14

FINANCIAL CASH FLOW - NET CASH FLOW (Real)

	Net Present Value				Year 0	Year 1...10	Year 10 (Terminal)
	0	10%	15%	20%			
NET CF - REAL	34.59	9.73	2.74	(2.30)	(26.05)	54.2	6.48
1. SOURCES	54.16	33.28	27.18	22.71	-	54.2	-
Operating profit BIT	31.75	19.51	15.94	13.31	-	31.8	-
Depreciation	22.41	13.77	11.25	9.40	-	22.4	-
Other	-	-	-	-	-	-	-
2. USES	19.57	23.55	24.45	25.00	26.05	-	(6.48)
Current Assets [Inventory]	-	1.99	2.44	2.72	3.24	-	(3.24)
Fixed Assets	19.57	21.56	22.01	22.29	22.81	-	(3.24)
[land & Building]	(0.60)	0.01	0.15	0.24	0.40	-	(1.00)
[Equipment]	20.17	21.55	21.86	22.05	22.41	-	(2.24)
Other capitalised Investment	-	-	-	-	-	-	-

BIT - Before Interest and Tax

Note: Values in Sri Lanka Rupees (Million) rounded. Discount rates of 0, 10, 15, 20%.

Year 10 (Terminal)column records liquidation of project at end of Year 10.

Values in parentheses are negative.

Values in square brackets are components.

TABLE 9.15

FINANCIAL CASH FLOW - NET CASH FLOW (Financial)

	Net Present Value				Year 0	Year 1......	Year 10	Year 10 (Terminal)
	0	10%	15%	20%				
NET CF - FINANCIAL	(34.59)	(9.73)	(2.74)	2.30	26.05	(5.42)	(5.42)	(6.48)
1. SOURCES	26.78	26.78	26.78	26.78	26.78	-	-	-
New Borrowings	15.00	15.00	15.00	15.00	15.00	-	-	-
New Equity	11.78	11.78	11.78	11.78	11.78	-	-	-
2. USES	61.37	36.51	29.52	24.48	0.73	5.42	5.42	6.48
Working Capital	0	0.40	0.48	0.52	0.27	0.45	-	(0.72)
[Cash in Hand]	0	0.17	0.19	0.23	0.27	-	-	(0.27)
[Receivables]	0	1.18	1.45	1.61	-	1.92	-	(1.92)
[Payables]	0	(0.95)	(1.16)	(1.32)	-	(1.47)	-	1.47
Debt Service	25.70	15.79	12.90	10.77	-	2.57	2.57	-
[Interest]	10.70	6.57	5.37	4.48	-	1.07	1.07	-
[Principal]	15.00	9.22	7.53	6.29	-	1.50	1.50	-
Taxes	10.50	6.46	5.27	4.40	-	1.05	1.05	-
Dividends	7.90	4.85	3.96	3.31	-	0.79	0.79	-
Other	17.27	9.01	6.91	5.48	0.46	0.60	1.05	7.20

Note: Values in Sri Lanka Rupees (Million) rounded. Discount rates of 0, 10, 15, 20%.
Y10 (Terminal) column records liquidation of project at end of year 10.
Values in Year 2 to Year 10 columns are identical.
Values in parentheses are negative.
Values in square brackets are components.
Other values (last row) are short term investments/realisations.

TABLE 9.16

RUNNING COSTS FOR REFINING OPERATIONS

Inputs : 15 tons crude oil per day

(a) Neutralization

Dry saturated steam @ 10 bar	- 1000 kg
Electrical energy	- 30kWh
Sodium Hydroxide	- 200 kg

(b) Bleaching

Dry saturated steam @ 10 bar	- 1500 kg
Electrical energy	- 30kWh
Bleaching earth	- 200 kg

(c) Deodorization

Dry saturated steam @ 10 bar	- 2500 kg
Electrical energy	- 30kWh

CALCULATION OF RUNNING COSTS (for 15 Tons crude oil input)

Labour	- 2050
Electricity and furnace oil	- 3100
Bleaching earth and sodium hydroxide	-11,000
Depreciation of machinery @ 10%	- 2613
Overheads @ 20%	- 5226
TOTAL	23,989 (SL Rs.1599 per ton)

Note: All prices in Sri Lanka Rupees.

TABLE 9.17

UTILIZATION OF EXCESS REFINING CAPACITY

Margin over refining Cost %	Additional Net annual income (Rs.Million)	Financial IRR %
0	0	17.5
5	0.24	18.6
10	0.48	19.7
15	0.72	20.8
20	0.96	21.8

TABLE 9.18

REDUCTION OF PRICE OF RUBBER SEED KERNEL

Price of Rubber Seed Kernel Rs./kg.	Reduction from base value %	Financial IRR
9.18	0	17.5
8.72	5	18.9
8.26	10	19.8
7.80	15	20.9
7.34	20	22.0
6.88	25	23.1

TABLE 9.19

SHADOW PRICING OF FULLY TRADED INPUTS/OUTPUTS

Item	Type	Market price SL Rs./kg	FOB Price SL Rs/kg	CIF Price SL Rs/kg	Adjustment Factor %
Rubber Seed Oil	Importable	54.00	-	30.40	- 44
Coconut oil	Exportable	43.50	34.65	-	- 20
Copra	Exportable	17.00	16.50	-	- 3
Poonac	Importable	5.00	-	6.50	+ 30

Note - Importables are CIF prices and Exportables FOB (Colombo) prices

$$\text{Adjustment Factor} = \left(\frac{\text{Shadow price}}{\text{Market price}} - 1\right) \text{ per cent}$$

TABLE 9.20

NON-TRADED ITEMS IN RUBBER SEED PROCESSING

Rubber Seed Meal

Furnace oil and electricity

Administration, selling, distribution overheads

Transport

Skilled labour

Note - Market prices are assumed equal to shadow prices for these items, hence adjustment factors are zero.

TABLE 9.21

PARTIALLY TRADED ITEMS IN RUBBER SEED PROCESSING

Item	Market Price SL Rs/kg	Shadow Price SL Rs/kg	Adjustment Factor %
Rubber Seed Kernel	9.18	1.50	- 84
Land and Building	-	-	- 5
Equipment	-	-	- 10
Inventories	-	-	- 20
Labour (unskilled)	-	-	- 50

Note - Adjustment Factors are estimates

ECONOMIC ANALYSIS OF RUBBER SEED PROJECT

Table 9.22

ADJUSTMENT TO CASH FLOW: MARKET PRICE DISTORTION

ITEM		FINANCIAL N P V				ADJUSTMEN	ADJUSTMENT TO CASH FLOW				PRELIMINARY ADJUSTED PRESENT VALUE			
		0%	10%	15%	20%	FACTOR	0%	10%	15%	20%	0%	10%	15%	20%
NET CASH FLOW REAL		34.59	9.73	2.74	(2.30)		(28.24)	(16.02)	(12.47)	(9.93)	6.35	(6.29)	(9.73)	(12.23)
OPERATING SOURCES		54.16	33.28	27.16	22.71		(30.22)	(18.50)	(15.15)	(12.69)	23.94	14.78	12.03	10.01
PRODUCTION VALUE		285.05	175.15	143.64	119.50		(72.12)	(44.31)	(36.19)	(30.24)	212.93	130.84	106.86	89.27
	R.S.O	94.65	58.16	47.50	39.68	-44.00%	(41.65)	(25.59)	(20.90)	(17.46)	53.00	32.57	26.60	22.22
	R.S.M.	0.30	5.15	4.21	3.51	0.00%	0.00	0.00	0.00	0.00	0.30	5.15	4.21	3.51
	COC.OIL	170.16	104.55	85.40	71.34	-20.00%	(34.03)	(20.91)	(17.08)	(14.27)	136.12	83.64	68.32	57.07
	POONAC	11.86	7.29	5.95	4.97	30.00%	3.56	2.19	1.79	1.49	15.42	9.48	7.74	6.47
COSTS							(41.89)	(25.74)	(21.04)	(17.54)				
COPRA		114.75	70.51	57.59	48.11	-3.00%	(3.44)	(2.12)	(1.73)	(1.44)	111.31	68.39	55.86	46.67
RSK		41.31	25.38	20.73	17.32	-84.00%	(34.70)	(21.32)	(17.42)	(14.55)	6.61	4.06	3.32	2.77
UNSKILLED LABOUR		7.50	4.60	3.80	3.10	-50.00%	(3.75)	(2.30)	(1.90)	(1.55)	3.75	2.30	1.90	1.55
USES		19.57	23.55	24.45	25.00		(1.99)	(2.55)	(2.68)	(2.76)	17.58	21.00	21.77	22.24
INVENTORY		0.00	1.99	2.44	2.72	-20.00%	0.00	(0.40)	(0.49)	(0.54)	0.00	1.59	1.95	2.17
LAND & BUILDINGS		(0.60)	0.01	0.15	0.24	-5.00%	0.03	(0.00)	(0.01)	(0.01)	(0.57)	0.01	0.15	0.23
EQUIPMENT		20.17	21.55	21.86	22.05	-10.00%	(2.02)	(2.15)	(2.19)	(2.20)	18.15	19.39	19.67	19.84

NOTE: SOURCES OBTAINED FROM PRODUCTION VALUE LESS COSTS.
SOME ITEMS WITH ZERO ADJUSTMENT FACTOR NOT INDICATED.

$$\text{ADJUSTMENT FACTOR (A.F.)} = \left(\frac{\text{SHADOW PRICE}}{\text{MARKET PRICE}} - 1 \right) \text{PER CENT.}$$

(UNIDO RSP/AW)

Table 9.23

ADJUSTMENT TO CASH FLOW: FORIGN EXCHANGE

	PRELIMINARY ADJUSTED PRESENT VALUE				FOREIGN EXCHANGE ADJUSTMENT							STAGE TWO PRESENT VALUE			
	0%	10%	15%	20%	CONTENT	PREMIUM	WEIGHTED PREMIUM	0%	10%	15%	20%	0%	10%	15%	20%
NET C.F.REAL	6.35	(6.29)	(9.73)	(12.23)				8.53	4.48	3.31	2.45	14.88	(1.81)	(6.42)	(9.78)
SOURCES	23.94	14.70	12.03	10.01				10.16	6.24	5.10	4.26	34.10	20.95	17.13	14.27
OPERATING PROFIT (BIT)															
1. PROD. VALUE	212.93	130.84	106.86	89.27				21.29	13.08	10.69	8.93	234.22	143.92	117.55	98.20
R.S.O	53.08	32.57	26.60	22.22	100.00%	10.00%	10.00%	5.30	3.26	2.66	2.22	58.30	35.82	29.26	24.44
R.S.M.	8.38	5.15	4.21	3.51	100.00%	10.00%	10.00%	0.84	0.51	0.42	0.35	9.22	5.66	4.63	3.86
COC.OIL	136.12	83.64	68.32	57.07	100.00%	10.00%	10.00%	13.61	8.36	6.83	5.71	149.74	92.01	75.15	62.78
POONAC	15.42	9.48	7.74	6.47	100.00%	10.00%	10.00%	1.54	0.95	0.77	0.65	16.96	10.42	8.51	7.11
2. COSTS	121.67	74.75	61.08	50.99				11.13	6.84	5.59	4.67	132.80	81.59	66.67	55.65
MATERIALS															
COPRA	111.31	68.39	55.86	46.67	100.00%	10.00%	10.00%	11.13	6.84	5.59	4.67	122.44	75.23	61.45	51.33
R.S.K	6.61	4.06	3.32	2.77	0.00%	10.00%	0.00%	0.00	0.00	0.00	0.00	6.61	4.06	3.32	2.77
LABOUR	3.75	2.30	1.90	1.55	0.00%	10.00%	0.00%	0.00	0.00	0.00	0.00	3.75	2.30	1.90	1.55
USES	17.58	21.00	21.77	22.24				1.63	1.76	1.79	1.81	19.22	22.76	23.56	24.05
INVENTORY	0.08	1.59	1.95	2.17	10.00%	10.00%	1.00%	0.00	0.02	0.02	0.02	0.00	1.61	1.97	2.19
LAND/BLD.	(0.57)	0.01	0.15	0.23								(0.57)	0.01	0.15	0.23
EQUIPMENT	18.15	19.39	19.67	19.84	90.00%	10.00%	9.00%	1.63	1.75	1.77	1.79	19.79	21.14	21.44	21.63

(CRIDO RSP/AW)

TABLE 9.24

INCOME FLOW ANALYSIS AND ECONOMIC VALUE OF SAVINGS

Group	Net Distribution impact			Net Impact			Adjustment value to savings		
	0%	10%	20%	0%	10%	20%	0%	10%	20%
Project	(6.0)	(3.9)	(2.7)						
Government	14.2	11.1	7.5						
Estate-sector	38.8	21.6	14.9						
Consumers	(50.8)	(31.2)	(21.3)						
Workers	3.8	2.4	1.6						
				2.1	2.0	1.4	2.1	2.0	1.4

Note - Discounted (0, 10, 20%) values are Sri Lankan rupees (million) values in parentheses are negative.

(see Addendum Section 9.9)

Table 9.25 - Basic Inputs/Outputs in Rubber Seed Processing

1. Initial Capital Investment (Table 9.6) : Rs.22.81 M

2. Working Capital (Table 9.7) : Rs. 3.97 M

3. Raw Material Input (Table 9.12)

Material	Quantity/day (Tons)	No. of days	Total (Tons)	Unit Prices (Rs/kg)
Rubber seed kernel	3.00	150	450	9.18
Copra	4.50	150	675	17.00

4. Capital costs (Table 9.6) : Rs. 22.41 M

5. Production Output (Table 9.12)

Item	Total Quantity (Tons)	Unit Price (Rs/kg)
Rubber seed oil	185	54.00
Rubber seed meal	252	3.50
Coconut oil	412	43.50
Poonac	250	5.00

6. Adjustment Factors (Table 9.19 - 9.21)

   Rubber seed oil - 44% Rubber seed meal 0

   Rubber seed kernel - 84% Equipment - 10%

   Inventories - 20% Labour (unskilled) - 50%

7. Premium on foreign exchange (Section 9.2.2) : 10%

8. (Financial) Internal Rate of Return : 17.5%

9. (Preliminary) Economic Internal Rate of Return : 4.3%

10. (Economic) Internal Rate of Return : 8.5%

11. (Savings Impact) Economic Internal Rate of Return : 10.4%

Note : Terminology is based on the UNIDO GUIDE

TABLE 9.26

OVERALL FEASIBILITY OF RUBBER SEED PROCESSING
(Edible Quality Oil from Fresh RSK)

	CASE							
Variable	1	2	3	4	5	6	7	8
1. Sale price RSO (change %)	0	+5	+5	+5	+5	+5	+5	+5
2. Cost of RSK (change %)	0	(5)	(5)	(5)	(5)	(5)	(5)	(5)
3. Capital cost (change %)	0	0	0	0	0	0	(5)	(10)
4. AF for RSO (%)	(44)	(40)	(35)	(35)	(40)	(40)	(40)	(40)
5. AF for RSK (%)	(84)	(84)	(84)	(84)	(90)	(90)	(90)	(90)
6. Foreign Ex. Premium (%)	10	10	10	20	12	10	10	10
7. Financial IRR (%)	17.5	20.8	20.8	20.8	20.8	20.8	22.2	23.8
8. Preliminary EIRR (%)	4.3	8.3	11.0	11.0	9.6	9.6	10.9	12.3
9. Economic IRR (%)	8.5	12.6	15.2	16.2	14.3	13.8	15.1	16.4

Note – RSO Rubber Seed Oil

RSK Rubber Seed Kernel

AF Adjustment Factor

Foreign Ex. Prem. Foreign Exchange Premium

Values in parentheses are negative

TABLE 9.27

BASE REQUIREMENTS AND PARAMETERS FOR TECHNICAL RUBBER SEED PROCESSING

1. Initial capital investment:-

   Equipment

(a) Two low pressure screw expellers (2-3 tons feed per day, 15 HP motor)	270,000	
(b) One cutter	20,000	
(c) One hot air blower	100,000	
(d) One filter press	85,000	
Total (inclusive land & building and other items)		Rs.0.88 M

2. Working Capital : Rs.0.56 M.

3. Inputs:

	No.days	Throughput/day (tons)	Unit price Rs/kg
Rubber seed	150	2.27	1.00
Copra	150	1.00	9.00

   Output

   A total of 75 tons rubber seed oil and 265 tons rubber seed meal for 150 days at unit prices of Rs.15.00 and Rs.1.00 per kg.

4. Labour : Skilled (2), Semi-skilled (4), unskilled (4)

5. Factory costs (per year): Rs.2.32 M

6. Total Production costs (per year) inclusive overheads, depreciation, interest : Rs. 2.64M

7. Returns :

Type of operation	Financial IRR %	ROCE %
150 days RS, 150 days copra	57.3	47.6
300 days Rubber seed	87.8	76.8
300 days Copra	28.3	21.3

NOTE: ROCE - Return on Capital Employed.

TABLE 9.28

SUMMARY OF FINANCIAL/ECONOMIC EVALUATION IN RUBBER SEED PROCESSING

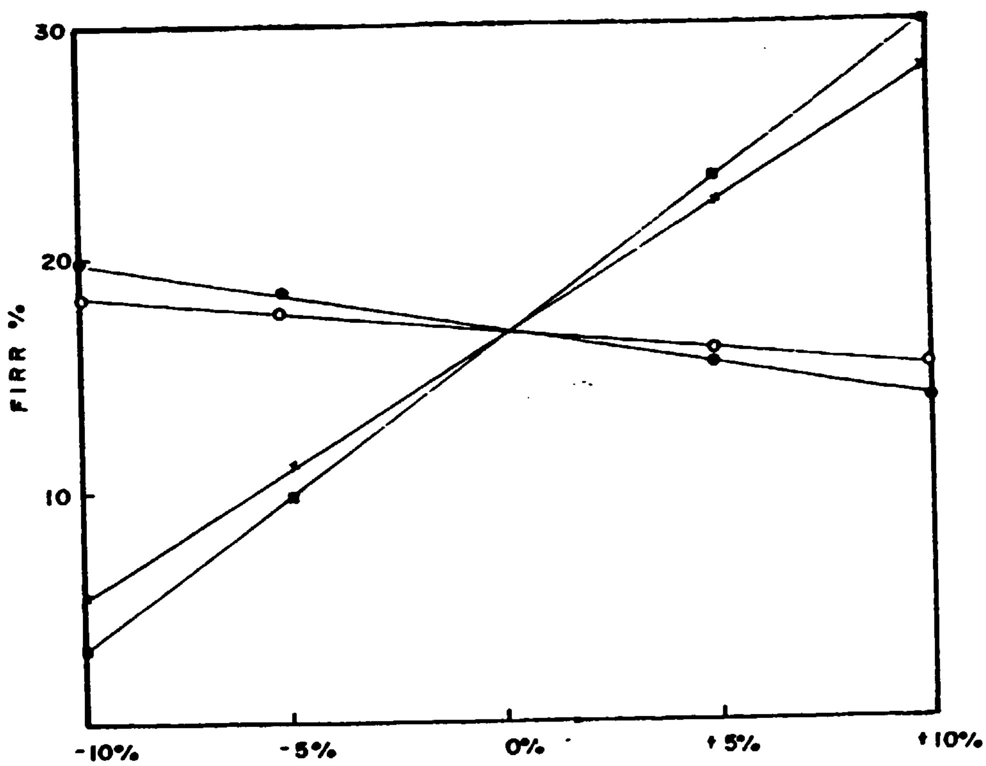
		High Quality Products	Low Quality Products
1.	Financial IRR (150 days rubber seed processing, 150 days copra)	17.5	57.3
2.	ROCE (150 days each rubber seed and copra)	11.9	47.6
3.	FIRR (300 days rubber seed)	22.1	87.8
4.	FIRR (300 days copra)	13.2	28.3
5.	ROCE (300 days rubber seed)	15.5	76.8
6.	ROCE (300 days copra)	8.6	21.3
7.	Economic IRR - preliminary (150 days each)	4.3	-
8.	Economic IRR (150 days each)	8.5	-
9.	Economic IRR (300 days rubber seed)	23.6	-
10.	Economic IRR - savings impact (150 days each)	10.4	-

Note: All values are per cent.

Inputs/outputs are base values.

Minimum values for project acceptance in Sri Lanka - FIRR 20% EIRR 13%.

FIG 9·1 SENSITIVITY ANALYSIS FOR FINANCIAL IRR



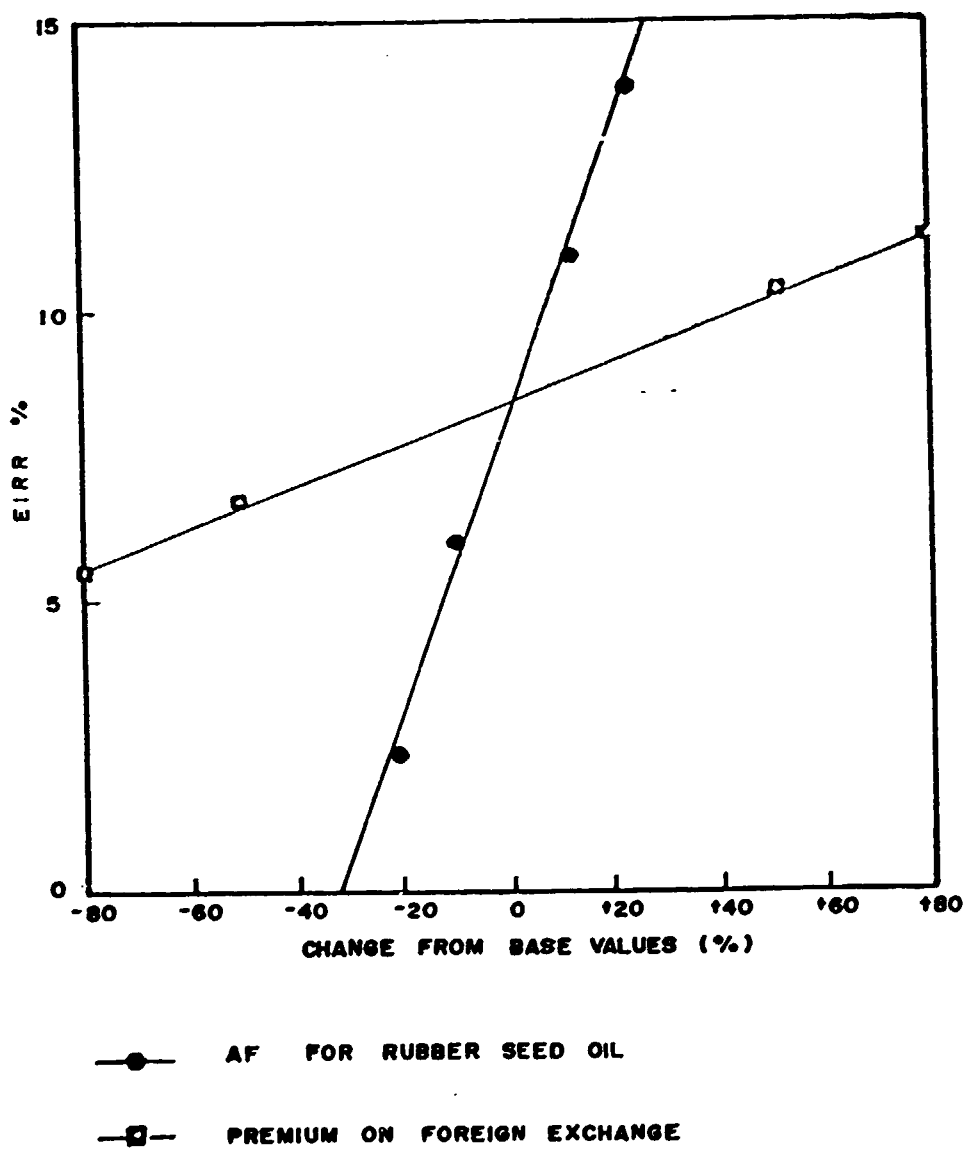
■ SALES

o RAW MATERIAL

x INTERPOLATION (SALES , RAW MATERIAL)

● CAPITAL COSTS

FIG 9·2 SENSITIVITY ANALYSIS FOR ECONOMIC IRR



CHAPTER 10

SUMMARY AND CONCLUSIONS

10.1 Introduction

The summary and conclusions pinpoint the following priority areas in rubber seed processing:-

(a) edible and technical oil manufacture

(b) collection, drying and storage of seed

(c) extraction of oil

(d) financial/economic viability

(e) scaling up of operations.

10.2 Edible and Technical Oil Manufacture

Our work has clearly shown a wide diversity in conditions for edible and technical rubber seed processing. Edible oil manufacture requires good quality seed which must be collected soon after seed fall, decorticated and dried to a moisture content of 5% for storage purposes (Chapter 2). Extraction of the fresh kernel needs high pressure expelling and preparation by cooking (conditioning) and admixture with rubber seed meal and coconut poonac for high throughput rates (Chapter 3). Development of fairly high levels of FFA (Section 4.2.1) and the presence of poly(isoprene) of high molecular weight in the unsaponifiable fraction (Section 4.2.2) are barriers which need elimination for successful acceptance of rubber seed oil. The presence of α-linolenic acid in RSO is advantageous as a source of η-3 (ω-3) polyunsaturated fatty acid but high levels need to be reduced by light hydrogenation (Section 4.4) or blending with other vegetable oils (Section 4.3.1) to prevent deleterious effects causing odour and darkening.

Conditions for production of techncial oil (Section 3.4) are not so stringent and can be carried out with low pressure expelling. The feed material consisting of kernel or whole seed is aged under ambient conditions so that oil obtained is of high FFA (> 15%). If kernel is used, roughage in the form of molasses (10-20%) is required while whole seed does not require any other process aid, the shell aiding extraction of oil.

10.3 Collection, Drying, Decortication and Storage of Seed

The importance of collection of seed soon as seed fall occurs, preferably on a daily basis has been stressed (Chapter 2). Ground contamination results in fungal infestation responsible for lipase activity and aflatoxin production. Drying of seeds soon after collection to a level of about 5% is needed for storage, higher levels of moisture favouring lipase activity (Section 8.5), with increase of FFA content. Decortication can be carried out mechanically or manually (Section 2.4) efficiency dependent on moisture content (Section 2.4.5). For storage over long periods it is preferable to use seed rather than kernel.

10.4 Extraction of Oil from Good Quality Kernel

The use of good quality kernel for extraction of RSO presents problems due to the soft nature of kernel, high protein and low fibre content. Use of high pressures was shown to be necessary, coupled with other factors such as cooking (conditioning), maintenance of high temperature and incorporation of RSM and poonac as process aids to increase throughput. The following optimum conditions were worked out for efficient extraction:-

(a) maintain high pressure expelling around 80°C

(b) subject kernel to cooking at 100°C with live steam to a moisture content around 7%

(c) ensure admixture of cooked kernel with RSM and coconut meal (poonac) in the ratio RSK/RSM/poonac, 45/50/5.

10.5 Financial/Economic Viability

Base parameters for RS processing estimated during Phase 2 operations have been used for financial/economic appraisal, *UNIDO GUIDELINES/GUIDE* used for this purpose (Chapter 9). It has been shown that the respective financial and economic internal rates of return for production of good quality oil are slightly less than the cut off values for project acceptance in Sri Lanka (20% and 13% for financial and economic IRR respectively). The main reason for reduced profitability in the production of good quality (edible) oil is the requirement of high capital costs and availability of substitutes at lower prices in the world market.

On the other hand, RS processing for technical oil requires less of capital investment and combined with cheaper raw material in the form of aged undecorticated seed, leads to high returns on investment.

10.6 Scaling up of Operations

Information given by suppliers of processing equipment is summarised for possible use in scaling up of pilot plant operations. However this does not imply endorsement of the suppliers by either UNIDO or the Ceylon Institute of Scientific and Industrial Research.

High Pressure Screw Expellers

1. Anderson International Corp, Ohio, USA

Type	:	Delta 30V
Capacity	:	7 tons per day
Motor rating	:	25kW
Price	:	US $ 76,300 (inclusive cooking equipment)

2. De Smet Rosedowns, Humberside, England.

Type	:	Mark 3 Screw press
Capacity	:	20 tons per day
Motor rating	:	55kW
Price	:	£ 130,000 (inclusive cooker)

Batch Refining Equipment

1. EMI Corporation, Illinois, USA

Type	:	EMI edible oil processing system
Capacity	:	5 tons per day
Price	:	US $ 285,600

2. G. Mazzoni S.p.A., Italy.

Type	:	RC
Capacity	:	15 tons per day
Price	:	US $ 207,000 (carbon steel construction) US $ 266,000 (stainless steel construction).

Batch Hydrogenation System

1. EMI Corporation, Illinois, USA.

Type	:	EMI edible oil hydrogenation process
Capacity	:	2.5 tons per batch 4 batches per day
Price	:	US $ 121,000

Low Pressure Screw Expellers

1. Nugaduwa Ceylon Engineering Corporation, Galle, Sri Lanka.

Type	:	Medium
Capacity	:	3 tons per day
Motor rating	:	11 kW
Price	:	SL Rs.200,000.

CHAPTER 11

RECOMMENDATIONS FOR FUTURE WORK

11.1 Introduction

Some recommendations for future work are described in the following areas:-

(a) scaling up pilot plant and laboratory trials

(b) the polyisoprene problem

(c) animal feed trials

(d) hydrogenation.

11.2 Scaling up

It is most important to carry out high pressure expelling on a large scale with commercial screw expellers. Pilot plant conditions of optimum procedure for extraction of RSO (low FFA) from good quality kernel have been described in Chapter 3 but these conditions may need refinement on the large scale. Batch refining and deodorization also needs to be performed on a large scale.

11.3 The Polyisoprene Problem

Laboratory investigations showed that one method of removal of polyisoprene was the addition of acetone to RSO, the polyisoprene separating out due to differential solubility (Section 4.2.2). However the separation did not occur in some samples tested so that this method may not be reliable. Further, use of acetone would increase refining costs. Long term effects of ingestion of high molecular weight polyisoprene also needs clarification before any firm decisions on recommendation of RSO for edible use can be taken.

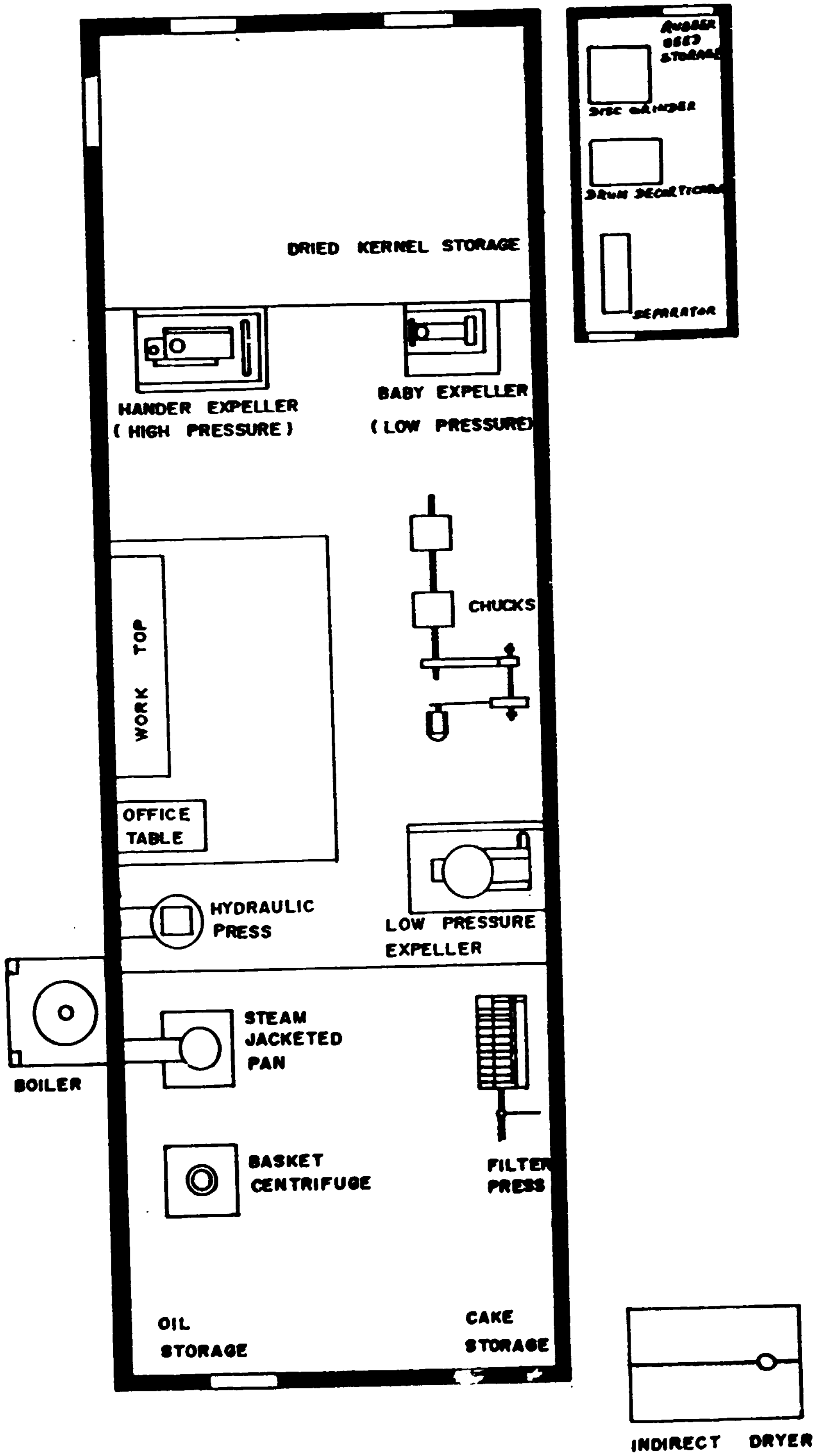
11.4 Animal Feed Trials

Present animal feeding investigations were carried out on breeding hens and broiler chickens. The trials showed that no significant differences in results were observed when rubber seed meal upto a level of 25% was incorporated in the diet of hens and 40% in chickens. Additional feeding trials on rats and other animals are desirable as also a survey of commercial usage of RSM as animal feed.

Another aspect which needs investigation is the possibility of toxic material in RSM e.g. aflatoxin and cyanide undergoing chemical modification and contaminating fluids (e.g. milk) and meat used for human consumption.

11.5 Hydrogenation

Only some preliminary work was carried out on hydrogenation in the present investigation. Comprehensive trials are necessary to evaluate hydrogenated material both for edible and technical purposes.



APPENDIX I PILOT PLANT LAYOUT

APPENDIX 2

TEST METHODS

1. Moisture and volatile matter - AOCS Ba 2 - 38

About 5g material dried at 105°C in air circulating oven to constant weight.

2. Free fatty acid (FFA) - AOCS Ca 5a - 40

Warm neutralized ethyl alcohol (95%) used for extraction of fatty acids from oil, titrate with standardized NaOH, phenolphthalein indicator.

FFA (as oleic acid) % =

$$= \frac{2.82 \times \text{ml } 0.1N \text{ NaOH}}{\text{weight of oil (g)}}$$

To convert FFA values to acid values multiply by 1.99.

3. Oil - AOCS Ba 3 - 38

10 to 20g of dried material contained in a Whatman pure cellulose thimble was extracted with petroleum ether (60° - 80°C) using a Soxhlet apparatus (4h). The extract was concentrated in a Büchi Rotavapor evaporator.

4. Colour Lovibond Tintometer used with 1/2 or 1" cells.

5. Total cyanide - *J. Sci. Food Agric.* 16, 300-305 (1965)

Approximately 10g of material was homogenized with ice and incubated in 200ml water for 24h at room temperature. At the end of the incubation period material was steam distilled and the liberated hydrogen cyanide collected in a solution of 50ml of 5% sodium carbonate. Approximately 200ml of the distillate was collected and the cyanide content in the distillate was estimated by the colorimetric picric acid method as follows:-

To 1 to 10ml of the distillate in a test tube, 4ml of 1% picric acid was added. After 2 minutes water was added to make the total volume approximately 20ml and the contents heated for 12 minutes at 100°C in a water bath. The solution was cooled, transferred quantitatively into a 25ml volumetric flask and contents made up to the mark with water. The absorbance of this solution was determined at 530nm relative to a blank solution of 5% sodium carbonate. Total cyanide was estimated with a standard curve.

6. Spot test for cyanide

A spot test for the presence of total cyanide in rubber seed kernel and/or meal was carried out as follows:-

Introduce less than 5g crushed rubber seed material into a 250ml round bottom flask with two necks, one of which could be stoppered with a stopper with a hook (a Schöniger stopper can be used). Attach picrate paper (1cm x 5cm) - prepared by soaking filter paper in 1% picric acid solution, drying and then soaking in 5% sodium carbonate solution and then drying again - to the hook and stopper flask. Add 100ml water into flask, stopper securely and allow to stand at room temperature. An orange red colour in the picrate paper indicates presence of cyanide.

The limit of detection of the spot test is 10 µg cyanide. In the experimental conditions in the present investigations, this corresponded to a total cyanide concentration of 2mg/kg (2 ppm) when 5g material was used.

7. Aflatoxin analysis *(AOAC, Official Methods of Analysis, 13th Edition)*

7.1 *TLC Method*

Reference Roberts et al: J. Assoc. Off. Anal Chem. 64 961-963 (No.4, 1981).

7.2 *HPLC Method*

Reference Hutchins & Hagler: J. Assoc. Off. Anal. Chem. 66 1458-1465 (No.6, 1983).

8. Microbial experiments

8.1 *Preparation of Inoculum of Aspergillus parasiticus*

A. parasiticus NRRL 2999 was grown in potato dextrose agar (DIFCO) at 25°C. After 7 days the slants were surface-washed with sterile distilled water containing 0.1% Tween 80 solution. This spore suspension was counted and adjusted to 10^6 spores/ml.

8.2 *Aflatoxin Production*

About 25g of substrate material in a 250ml conical flask was inoculated with 1ml of spore suspension (10^6 spores) of *A. parasiticus*. The flask was plugged with cotton wool and incubated at 35°C for 7 days.

9. Polyisoprene

9.1 *Qualitative Identification*

Pyrolysis IR spectroscopy ASTM D 297.

9.2 *Determination of Molecular Weight*

Drop times carried out in an Ubbelohde Viscometer at 25°C. Analysis of intrinsic viscosity, molecular weight and constant k' according to :-

Huggins JACS 64 2716-18 (1942)
Mullins and Watson J App Poly Sc 1 245-249 (1959).

10. Gossypol

10.1 *Spectrophotometric method AOCS Ba 8-55*

10.2 *HPLC method*

Nomeir and Abou-Donia JAOCS 59 546-549 (1982).

11. Saponins

Spectrophotometric method

Gestetner, PHYTOCHEMISTRY 5 803-806 (1966).

12. Hydrogenation

12.1 *Equipment used*

Pressure vessel (Model 4563, PARR INSTRUMENT COMPANY, Illinois, U.S.A.). Hydrogenation was carried out at 180°C and initial hydrogen pressure 200psig. Nickel catalyst (HARCAT - Harshaw Chemie BV, Holland) used at 1% by weight of oil.

12.2 *Fatty acid composition* (GLC)

SHIMADZU Model 9A instrument equipped with a flame ionization detector and using a fused silica capillary column, 30m x 0.32 mm id. (SP-2330, SUPELCO INC, U.S.A.).

Trans fatty acid content computed using GLC data excluding 18:1Δ 12t and 18:2 Δ9t, 12c which coincide with 18:1Δ 9c and 18:2 Δ 9c, 12c.

13. *Peroxide value*

A.O.C.S. official method Cd 8.53.

14. *Solid fat index*

A.O.C.S. official method Cd 10-57.

15 *Calorific value*

ASTM D 240.

APPENDIX 3

Comparison of some characteristics of RSO with other vegetables oils.

	TYPE OF VEGETABLE OIL				
CHARACTERISTIC	RSO	SOYA	COCONUT	PALM	CANOLA
Iodine value	138	130	7	55	90
Saponification value	189	192	255	200	180
Melting pt^{o}C	-2	-14	23	30	8
Fatty acid composition %					
Lauric	1	-	48	-	-
Palmitic	10	10	10	45	4
Oleic	23	22	7	38	55
Linoleic	37	50	2	10	26
Linolenic	18	8	-	-	10
Peroxide value meq/kg	14				
Calorific value MJ/kg	39.5				

NOTE : CANOLA is low erucic acid rape seed oil

RSO values are averages determined on oil of low FFA extracted from fresh kernel. Other values are typical averages from the literature.

APPENDIX 4

CONTACT ORGANIZATIONS

During Phase 2 investigations several organizations and individuals both in Sri Lanka and outside helped by way of providing information, arranging visits and other services. We sincerely wish to thank them,especially the following:-

Outside Sri Lanka

Anderson International Corp, Cleveland Ohio (USA)	Screw expellers
Arista Industries, Connecticut (USA)	Edible linseed oil
Cureopore, Industries, Petaling Jaya (Malaysia)	Technical rubber seed oil
De Smet Rosedowns Limited Humberside (England)	Screw expellers
EMI Corporation Illinois (USA)	Refining and hydrogenation
G Mazzoni S.p.A. Viale Trentino (Italy)	Refining equipment
Rubber Research Institute, Kerala State, India	Natural rubber research
Rubber Research Institute Kuala Lumpur, Malaysia	Natural rubber research
Rubber Research Institute Bangkok, Thailand	Natural rubber research
The French Oil Mill Machinery Co. Ohio, (USA)	Vegetable oil extraction

Sri Lanka

Ameresekere & Co., Colombo	Chartered Accountants
BCC Lanka Ltd., Colombo	Oil expellers
Ceylon Oils & Fats Corp, Seeduwa	Oil and animal feed suppliers
Dias & Dias Engineering Ltd, Wattala.	Engineers
A. Hilmi, Malwana	Oil seed merchant
Jaela Mills Ltd, Jaela	Oil expellers
Janatha Estates Development Board	Rubber plantations
Lever Brothers (Ceylon) Ltd, Colombo.	Soap and margarine manufacturers
Mason's Mixture Limited, Colombo	Alkyd resins
Mawaramandiya Mills, Sapugaskande	Oil expellers
Mawathagama Mills, Dankotuwa	Oil expellers
Nugaduwa Ceylon Engineering Ltd, Galle	Engineers
Paints & General Industries Ltd, Colombo.	Alkyd resins
People's Merchant Bank Ltd, Colombo.	Financial Consultants
Polycoat Resins Ltd, Malabe	Alkyd resins
Resinoplastics Ltd, Colombo	Alkyd resins
Rubber Research Institute of Sri Lanka, Agalawatta.	Natural rubber research
Sri Lanka State Plantation Corp.	Rubber plantations
Vijaya Oil Mills Ltd, Wattala	Oil expellers

APPENDIX 5

ABBREVIATIONS USED:-

AF - Adjustment factor

ANRPC - Association of Natural Rubber Producing Countries

AOCS - Americal Oil Chemists' Society

ARI - Accounting Rate of Interest

CRI - Consumption Rate of Interest

EIRR - Economic Internal Rate of Return

FIRR - Financial Internal Rate of Return

FFA - Free fatty acid

RSK, RSM, RSO, - Rubber seed kernel, meal, oil

ROCE - Return on Capital Employed