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Studies on the Extraction and Evaluation of Raw Palm Oil for Edible Use

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Pilot plant trials were conducted to optimise unit operations for the extraction of edible raw palm oil. The raw palm oil thus produced had less than 1% free fatty acids, 0.2% moisture and impurities. Detailed analytical data supported the high quality of the oil. The raw palm oil contained 700 ppm carotenes and hence forms a good source of vitamin A. The acceptability trials conducted in the laboratory indicated the possibility for direct edible use. Based on the data, equipments for various unit operations were designed for fabrication. A demonstration plant based on this technology has been established at Palode, Trivandrum as a joint venture between Regional Research Laboratory (CSIR) and Central Plantation Crops Research Institute (ICAR). The plant with a capacity to process 0.7 tonnes fresh fruit bunches per hr is in operation to demonstrate the technology to produce edible raw palm oil.

India has imported 1.9 million tonnes of edible oil during 1987-88 out of which palm oil accounted for 1.1 million tonnes. In the Indian context, oil palm holds great promise to ease the acute edible oil shortage due to its incredible productivity[1] (4 to 5 tonnes/ha/yr). Currently, oil palm is cultivated in Kerala (3,700 ha) and in Andaman and Nicobar Islands (1,6000 ha). For further expansion, the working group has identified about 0.5 million ha in Southern India and North Eastern Region[2].

The palm fruit is a drupe with a fleshy outer mesocarp that encloses a hard nut. Two distinct types of oils are obtained from oil palm fruit. Palm oil is derived from the mesocarp which comprises 90 per cent of the oil yield. The nut yields the remaining 10 per cent called palm kernel oil which is chemically identical to coconut oil. The palm fruit contains an extremely active lipolytic enzyme which under favourable conditions releases free fatty acids (FFA) very rapidly[3]. If the fruit is bruised, the FFA in the damaged part of the fruit increases to 60 per cent within an hour[4]. The increase in FFA is also dependent on the time lapsed between harvesting and sterilization[5]. Production of edible quality palm oil, therefore demands strict process controls from harvesting onwards.

Our attempt has been to evolve a technology to produce edible raw palm oil to suit the local requirements, and to match the size of plantations particularly in the small sector. Raw palm oil assumes greater significance, being the richest natural source of β-carotenes, and can provide vitamin A, 430 to 760 I.U/g and vitamin E, 210 to 460 I.U/g[6]. Detailed reviews on different aspects of processing have been published[7,8]. The objectives of the present studies are (a) to collect design data for the fabrication of palm oil extraction equipments for the small scale sector and (b) to produce edible grade raw palm oil with a view to promoting the same as a nutritional oil.

Materials and Methods

Harvesting: The fresh fruit bunches (FFB) were harvested from Central Plantation Crops Research Institute (CPCRI) Research Centre at Palode. The harvesting was carried out under two sets of conditions (a) by following the pollination records of the Research Centre thereby ensuring actual maturity of the fruit bunch (180 ± 5 days) and (b) by following field practice i.e. a few loosened fruits from the apex of fruit bunch. The harvested bunches were transported to the pilot plant of Regional Research Laboratory (RRL). The time taken between harvesting and sterilization of FFB varied from 5 to 15 hr.

Bunch sterilization: Sterilization was carried out using steam and boiled water. For steam sterilization, a vertical autoclave of 0.25 cu.m. fitted with steam inlet, condensate and pressure release valves and pressure gauge was used. The autoclave had a capacity to hold 100 kg FFB. After charging FFB, steam was admitted. On reaching the desired working pressure, steam was vented off to remove air and recharged to the same pressure. Peak of pressures of 2 kg/sq.cm and

3 kg/sq.cm were maintained for 40 min. Steam was released slowly at the end. Total time taken for the process of sterilization was 60 min. Sterilizer condensate was collected and the quantity was recorded.

Sterilization using boiling water was also carried out in jacketted kettle of 100 litre capacity. FFB was steeped in boiling water for 60 minutes.

Bunch stripping: After sterilization the fruits were separated manually from the bunches.

Fruit digestion: Planetary mixer was employed for the purpose. The mixer consisted of a mixing vessel of 15 litre capacity, a sigma blade driven by motor of 0.5 HP at 25 r.p.m. The loose fruits were conditioned with boiling water and about 10 kg was transferred to the vessel. The fruits were agitated for 5 min at about 60 to 70°C and 70 to 80°C. About 20 per cent by weight of boiling water was added to facilitate digestion and to maintain the temperature.

Oil extraction: Separation of oil-water mixture from the digested mash was effected by hydraulic pressing. A 60 tonne capacity down-stroke hydraulic press was used for the purpose. The digested mash at about 60 to 75°C was charged into a perforated stainless steel cage of 30 cm diameter and 35 cm height with 0.6 cm wall thickness. The cage had 0.6 cm perforations at 1 cm triangular pitch. The pressure of 50 and 70 kg/sq.cm was applied from the top for 1 min. Oil-water mixture was expelled through the perforations leaving the press cake in the cage.

Clarification: Hundred litre capacity steam jacketted stainless steel kettle with tilting arrangement and with operating steam pressure of 3 kg/sq.cm was used for separating crude oil from the aqueous phase. The oil-water mixture obtained by hydraulic pressing was transferred to the kettle. The temperature was raised to 95°C to effect phase separation. The oil phase at the top was separated by decantation. Different oil-water ratio (1.:1.5, 1:2.0; 1:2.5; 1:3.5, 1:4.5) was tried to obtain maximum recovery of oil.

Purification: The crude palm oil containing sludge impurities, moisture etc was subjected to high speed centrifugation in Westfalia Separator (Model TA 05-00-105). The centrifugation was carried out using a chamber type bowl of 300 ml capacity at 6,000; 8,000 and 10,000 r.p.m. The temperature of the oil was maintained at 80°C and the feed was adjusted between 100 and 200 litre per hr depending upon the bowl speed.

Analytical methods: Colour, moisture, free fatty point (MP) and carotenes were determined following PORIM test methods[9]. For tocopherol estimation, the unsaponifiable matter was first subjected to thin layer chromatographic separation. The bands corresponding to tocopherols were scraped off and estimated using Emmerie-Engel reagent[10]. Anisidine value was determined by the modified method of Jirousova[11]. Absorbance at 233 and 269 nm were recorded as measure of diene and triene values respectively[9]. Iron and copper were also estimated[9].

Fibre oil content was determined using soxhlet apparatus[12]. Sterilizer condensate and sludge oil were extracted with chloroform-methanol and estimated by gravimetry. Fatty acid methyl esters were prepared by using methanol-sulphuric acid reagent and the fatty acid composition was determined by gas liquid chromatography[12]. A Hewlett Packard 5840A model gas chromatograph with flame ionisation detector was used for the purpose. The methyl esters were separated on 10 per cent EGSS-X on chromosorb (WHP, 100-120) packed in stainless steel column (6 ft length and 1/8 inch I.D.). Injection and detector temperatures were 250°C and 300°C respectively. The column temperature was programmed from 160 to 190°C at the rate of 5°C/min. Nitrogen (20 ml/min) was used as carrier gas. Methyl esters were identified by using fatty acid standards (Sigma Chemical Co.) and the peaks were quantified by digital integration.

Development of free fatty acids: To follow the release of free fatty acids by the endogenous lipase, fresh and sound oil palm fruits were crushed using pestle and mortar. Samples from the crushed mash were taken at 5 min interval for 1 hr period for free fatty acid estimation.

To understand the stability of fruit bunches with respect to free fatty acid development on storage, the fruit bunches were stored after different treatments i.e. (a) FFB without sterilization (b) FFB sterilized in boiling water for 45 min and (c) FFB sterilized under 1 kg/sq.cm steam pressure.

The bunches after treatments were stored at ambient conditions for 15 days. Fruit samples were drawn at one day's interval and fat was extracted for FFA estimation.

Studies on fruit maturation: Three oil palm trees were selected for the purpose. One bunch from each tree was identified after consulting the pollination record of the Research Centre. The study was started from the 100th day after pollination. The fruits were extracted from these bunches separately at an interval of 10 days until 180th day of maturation. The mesocarp was separated and moisture and fat contents were

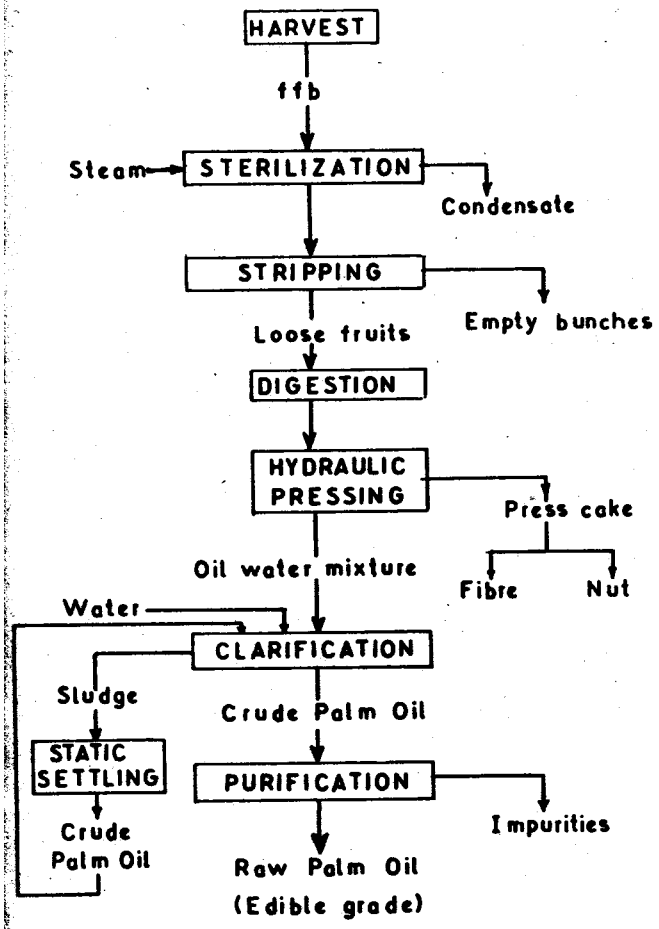

Fig. 1. Flow sheet for the production of edible grade raw palm oil.

Results and Discussion

pilot scale experiments conducted in the laboratory is presented in Fig.1. Production of raw palm oil comprises of two main stages: (1) harvesting and transport of FFB (field practices); and (2) extraction of raw palm oil (mill practices).

Harvesting: The oil palm produces fruit bunches throughout the year, although there are peak and lean periods. Harvesting can be broken down into a number of separate activities that can be broadly classified as under (i) finding and cutting ripe bunches, (ii) collection of bunches and loose fruit to the collection point, and (ii) loading into vehicle and transport to the mill.

The pattern of oil accumulation in the oil palm fruit mesocarp at different physiological maturity stages is presented in Fig.2. The results were obtained for 10 yr old oil palms of 'tenera' variety in the CPCRI Research Centre at Palode, Trivandrum. It is obvious from the results that nearly 70 per cent of the oil in the mesocarp was synthesised during 130 to 150 days after anthesis. The data further indicated that the oil content of mesocarp continued to increase till abscission though at slower rate following a sigmoidal curve pattern. Detachment of fruits from the bunches for the three palms studied here occurred around 180 days. Moisture content of the mesocarp exhibited a negative correlation with the oil content as expected. The quality of the oil in terms of FFA content at various stages of maturation varied only in narrow range from 0.2 to 0.5 per cent.

Various authors reported that the period of oil accumulation in the mesocarp ranged from 100 to 160 days depending on the variety, agro-climatic conditions and geographic location[13-15]. All these studies indicate that there is an active period of oil synthesis towards end of bunch maturation, corresponding to about 20 days and the rate of oil accumulation continues, though at a slower rate, till abscission. In the present study, the pattern of oil accumulation was found to be at a later period which is comparable with the results of Bafor and Osagie[15] reported for the 'Dura' variety. Considering the yield and the quality of the oil with respect to bunch maturation, a compromise may have to be worked out to determine the harvesting time to obtain the optimum yield without sacrificing the oil quality.

Sterilization: The primary objectives of this step are to inactivate the fruit enzyme, lipase and to loosen fruits from the bunch. The other functions of sterilization are softening the fruit tissue, coagulation of proteins and partial dehydration of nuts.

Development of FFA under different conditions is presented in Fig.3 when the fruits are crushed without sterilization, the FFA rose to 40 per cent within 10 min demonstrating the instant activity of the enzyme with the disintegration of the cell structure. This would explain the high FFA content of the palm oil extracted from damaged, over-ripened and stored fruits.

The results underscore the importance of sterilization of FFB after harvest preferably on the same day. Though the FFA release could be arrested using boiling water, the other functions i.e. loosening of fruits and softening of tissue could be achieved only when steam sterilization was adopted. In the present study, it was observed that sterilization of FFB under a steam pressure of 2 and 3 kg/sq.cm for 40 min facilitated the complete stripping of fruits from the bunches provided the bunches were well ripened.

The steam was admitted slowly to a pressure of 2 kg/sq.cm to expel air (venting) and subsequently maintained the desired pressure for 40 min. The recomended sterilization conditions of 3 kg/sq.cm for 60 to 75 min though seems to be on the higher side, it is necessary considering the non-uniformity of bunch ripening under field conditions of large plantations.

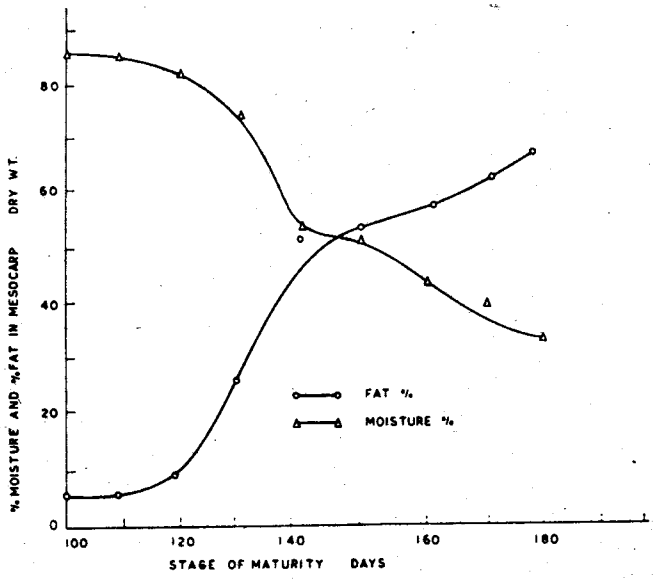

Fig. 2. Changes in fat and moisture contents of mesocarp during maturation

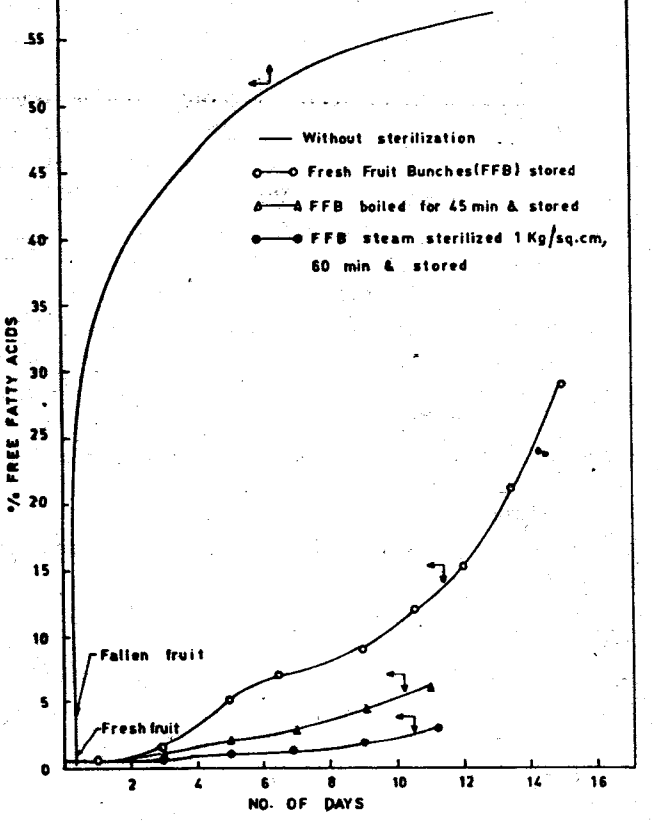

Fig. 3. Development of Free Fatty Acids (FFA)

Sterilization is a complex experimental situation which can be studied properly in a processing factory. The independent variables in sterilization technique which can be controlled within certain limits are steam pressure, the rate of increase of pressure, venting cycle time and air release. The dependent variables (oil loss, stripping efficiency, oil quality) will depend on age and type of fruit.

Stripping: The process involves the separation of the fruits and the calyx leaves from the bunch stalk. Bunch stripping was carried out manually for the pilot plant trials reported here. Bunch stripping is usually an efficient operation when standard mechanical strippers are employed. Rotary drum type is most commonly used in large mills.

Digestion: The purpose of digestion is to disrupt the mesocarp and to break up the oil bearing cells to facilitate oil release. The efficiency of digestion could be assessed only by monitoring the residual oil content of the press fibre. In the present study, the digestion seemed less efficient as revealed by the high residual oil content of the press fibre as the mash could be maintained only in the range of 70 to 80°C, unlike in the industry where it is kept at around 90°C.

Oil extraction: Hydraulic pressing, as described before was adopted here and the results obtained there from are presented in Table 1. Pressure and temperature of the mash were the major factors that affected pressing efficiency as indicated by the residual oil content. At 60°C, the pressure applied (50 and 70 kg/sq.cm) did not make appreciable difference in the residual oil content necessitating second stage pressing to bring down to 20 per cent oil in the press fibre. However, when the temperature of the mash was increased to 70 to 75°C, the residual oil content could be brought down to about 20 per cent, without further increasing the pressure. Increasing the pressure beyond 70 kg/sq.cm resulted in kernel breakage. Though further increase in the pressing efficiency could be attained by increasing the temperature of the mash, it could not be achieved due to the limitation of the digestion system adopted here. The other factors that favoured hydraulic press performance were ratio of nuts to mesocarp and presence of calyx leaves. Under ideal conditions of temperature and pressure, the efficiency could be enhanced to 98 per cent with 9 per cent residual oil content of press fibre.

TABLE 1. EFFECT OF PRESSURE AND TEMPERATURE ON OIL RECOVERY DURING HYDRAULIC PRESSING

No.	Mash temp. (°C)	Hydraulic pressure (Kg/sq.cm)	% Oil in fibre	
			Ist Press	IInd Press
1	60	50	38	20
2	60	70	35	20
3	70	70	22	-
4	75	70	20	-

Average of two trials

Clarification: The objective of this unit operation is to separate crude oil from the water, non-oily solubles and fibrous residues by taking advantage of the density gradient of oil and water at higher temperature.

The efficiency of clarification is determined by the residual oil content of the water phase, which depends on the oil-water ratio and temperature. Of the various oil-water ratios tried here, 1:2 was found to be the minimum dilution factor to achieve maximum recovery of the oil. The clarifier design based on simple over flow technique is employed for industrial purpose.

Purification: A final purification step was adopted using high speed centrifugation to remove the residual impurities (0.2 to 0.4 per cent) and excess moisture from the crude oil. In the present study, when the crude oil was fed at 80°C at a bowl speed of 8000 rpm, the impurities could be completely eliminated and moisture could be brought down to 0.2 to 0.25 per cent.

Material balance and oil recovery: The composition of FFB and yield of various constituents and palm oil recovery of selected trials are presented in Tables 2 and 3. Excepting the variation in the average bunch weight, the yield of loose fruits, empty bunches and weight loss during sterilisation are comparable to those earlier reported. The yield of palm oil around 15 per cent is significantly lower that could be attributed to higher oil loss through waste streams, variety and agro-climatic conditions. With appropriate equipments and process conditions, the recovery of palm oil could be enhanced to 90 to 95 per cent corresponding to 18 to 20 per cent on FFB. On the plant breeding side, improvement of the seed material would further enhance the oil yield.

Physico-chemical characteristics of raw palm oil: Data presented in Table 4 demonstrate the quality aspects of palm oil obtained during pilot plant trials as compared to the quality parameters prescribed by the Bureau of Indian Standards. Very low content of FFA indicates the high quality of the oil. Data for other quality parameters such as peroxide value, anisidine value, diene and triene values, iron and copper contents also reflect the soundness of raw palm oil. Of the quality parameters of palm oil, FFA is the most important one, the other parameters being consequence of initial FFA content. The palm oil extracted by the traditional African method is reported to contain as high as 50 per cent FFA and commonly around 10 to 20 per cent and possess very firm consistency[16]. However palm oil produced in the plantations of Malaysia contains FFA is the range of 2 to 5 percent[17,18]. The results reported here demonstrate the feasibility of palm oil production with very low level of FFA and other quality attributes conforming to standard specifications.

Raw palm oil owes its deep red colour to the presence of carotenoids. The raw palm oil produced in the pilot plant contained 700 p.p.m. carotenoids, of which 90 per cent was comprised of α-and β-carotenes and thus

TABLE 2. MATERIAL BALANCE OF PALM OIL EXTRACTION

Trial No.	FFB (kg)	Average bunch wt (kg)	Loose fruit wt (kg)	Empty bunch wt (kg)	Wt. loss in sterilization (kg)	% Fruit on FFA	% Raw palm oil on FFB	% Fibre (dry) on FFB	% Nut (dry) on FFB
1	100.0	12.5	60.0	26.5	13.5	60.0	14.0	4.1	8.4
2	120.0	11.0	83.0	25.3	11.7	68.0	15.0	6.9	13.5
3	90.0	18.2	56.5	23.5	10.0	57.0	14.5	6.6	13.1
4	290.0	16.5	180.0	68.0	40.0	62.0	14.7	9.0	12.5
5	280.0	28.0	176.0	60.0	42.0	62.0	15.3	8.2	14.0
6	290.0	9.0	190.0	60.0	38.0	65.0	15.0	7.0	14.5

TABLE 3. ANALYTICAL DATA ON OIL LOSS AND RECOVERY

Trial No.	Sterilizer condensate			Sludge			Fibre			Raw palm oil				
	Qnty. (kg)	% oil		Qnty. (kg)	% oil		Qnty. (kg)	% oil		Qnty. (kg)	% yield on FFB	% oil recovery	% FFB	% moisture & impurities
		On Condensate	On FFB		On sludge	On cond-FFB	Fibre	On fibre	On FFB					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	25.0	1.5	0.30	85.0	3.2	2.2	8.3	28.0	2.0	17.5	15.0	80.0	1.0	0.30
2	18.0	1.2	0.23	30.0	3.6	1.0	6.2	20.0	1.3	13.5	14.5	83.0	0.6	0.20
3	40.0	2.0	0.30	152.0	4.0	2.0	27.0	30.0	2.8	40.0	14.7	73.0	0.7	0.15
4	32.0	2.6	0.30	100.0	7.0	2.5	25.5	23.0	2.0	43.0	15.3	77.0	0.8	0.24
5	150.0	1.2	0.60	123.0	3.3	1.4	20.3	21.6	1.5	43.2	15.0	81.0	0.9	0.23

$$\% \text{ oil recovery (12)} = \frac{\text{Column 11}}{\text{Columns 3+6+9+11}} \times 100$$

TABLE 4. CHEMICAL CHARACTERISTICS* OF EDIBLE GRADE RAW PALM OIL

Chemical characteristics	Raw palm oil RRL (T)+	Crude palm oil B.I.S@
Colour (lovibond unit 1")	28 R + 10 Y	
Free fatty acids (%)	0.9	5.0 (max)
Moisture & impurities (%)	0.22	0.25
Iodine value	52	45 to 56
Saponification value	195	195 to 205
Unsaponificable matter (%)	0.56	1.2 (max)
Carotenes (ppm)	700	-
Tocopherols (ppm)	800	-
Peroxide value	Nil	-
Anisidine value (O.D. at 400 nm)	0.14	-
Diene value (E_{233} 1%)	0.17	-
Triene value (E_{269} 1%)	0.15	-
Iron (ppm)	4.0	-
Copper (ppm)	0.5	-
Melting point (°C)	36	-

* Average of four trials
\+ Regional Research Laboratory, Trivandrum
@ Bureau of Indian Standards

qualifying raw palm oil as the richest natural source of carotenes. Raw palm oil is also rich source of tocopherols (800 ppm) with α- and γ-tocopherols predominating

In the modern processing as adopted in Malaysia and elsewhere, raw or the red palm oil is subjected to refining and fractionation to suit the requirements of international market. Nearly all carotenes and considerable amount of tocopherols are removed by refining. The fact that one gram of raw palm oil is equivalent to about 500 I.U. of vitamin A and about 300 I.U. of vitamin E, this oil can make valuable contributions from the nutritional angle, when consumed in the raw form[6]. Though palm oil is considered as a saturated fat, the fatty acid profile obtained here for the raw palm oil indicated that it has considerable amounts of unsaturated fatty acids (14.0, 1.22; 16:0, 42.44; 18:0, 5.17; 18:1. 37.01; 18:2, 11.71).

Limited trials with respect to the acceptability of raw palm oil conducted in the laboratory showed encouraging results. Detailed nutritional evaluation and consumer acceptability of raw palm oil produced in the laboratory are in progress with National Institute of Nutrition, Hyderabad. An expert panel has also been constituted by Indian Council of Medical Research for the purpose.

Data collected from the pilot plant trials were used to design appropriate equipments for the production of edible quality raw palm oil. A demonstration plant with an installed capacity of 0.7 tonnes FFB/hr that can meet the requirement of 200 ha. Oil palm plantation has been established at Central Plantation Crops Research Institute (CPCRI) Research Centre at Palode, Trivandrum as a collaborative venture between Council of Scientific & Industrial Research (CSIR) and Indian Council of Agricultural Research (ICAR) to demonstrate the technology and train personnel.

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