VIRGIN COCONUT OIL HOT AND FERMENTATION PROCESS

Centenary publication -43

ICAR - CENTRAL PLANTATION CROPS RESEARCH INSTITUTE & AICRP ON PHET
KASARAGOD – 671 124, KERALA.

Techical bulletin No. 108

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ICAR

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Content

1. INTRODUCTION

Coconut is an important and versatile crop, which provides all required amenities for human life. Nearly one third of the world's population depend on coconut for food and economic needs. Widely acclaimed as 'Kalpavriksha' or 'Tree of Heaven', coconut provides food security and livelihood opportunities to 10 million people in India through cultivation, processing, marketing and trade related activities and thus it exerts profound influence in rural economy. Coconut processing sector in India is largely confined to copra production, oil extraction, desiccated coconut and manufacture of coir & its products. One third of the annual production is used by processing industry for coconut oil production, while rest is processed into desiccated coconut and other products. In the recent past, the coconut oil has been used as a food ingredient in functional foods, besides being used in pharmaceuticals, nutraceuticals, cosmetics and industrial uses including biofuel. Coconut oil is a rich source of medium-chain-triglycerides (MCT) which are beneficial for human health and nutrition. Sixty three percent of coconut oil is composed of antimicrobial medium-chain fatty acids and therefore can assist the immune system in fighting against microscopic invade. Coconut oil is rich in fatty acids viz., lauric acid, capric acid, caprylic acid and caproic acid which makes up triglyceride molecule and forms antimicrobial properties of the coconut oil. MCT's found in coconut oil have been shown in laboratory experiments to be effective in destroying viruses, bacteria, yeasts and parasites.

Even though India is the third largest coconut growing country in the world, its contribution to the processing, value addition and export market is significantly less as compared to other coconut cultivating countries. The problems of fluctuation in the prices of coconut and its products due to local as well as international competition, global awareness and demand on nutraceutical and functional value added products, acute shortage of skilled manpower necessitated the need for development of broad based entrepreneurship driven processing technologies for the sustainable growth of coconut based industries. The recent high value coconut product, which is becoming globally popular, is Virgin Coconut Oil (VCO).

Virgin coconut oil is the oil obtained from fresh, mature endosperm (kernel/ meat) of the coconut by mechanical or natural means, with or without use of heat, no chemical refining, bleaching or deodorizing and maintains the natural aroma and nutrients. It is called "virgin" because the oil obtained is pure, raw and pristine. Virgin coconut oil is suitable for human consumption in its natural form immediately after extraction and filtration. It is the purest form of coconut oil, crystal clear, contains natural vitamin E and with very low free fatty acid content (0.1 %). It has a fresh coconut aroma ranging from mild to intense depending on extraction process. Virgin coconut oil greatly differs from the traditionally produced coconut oil from copra in terms of quality attributes. Refined, bleached and deodorized coconut oil does not contain natural Vitamin E since this is degraded when the oil is subjected to high temperature and various chemical processes. The fast developing and high value niche market for virgin coconut oil offers a good prospect for the improvement of the income of coconut farmers.

2. HEALTH BENEFITS OF VCO

VCO has many advantages, which include the health benefits from the retained vitamins and antioxidants, the antimicrobial and antiviral activity from the lauric acid components and its easy digestibility due to the presence of medium chain fatty acids (MCFA). VCO and coconut oil have been traditionally used to enhance the beauty and the growth of our hair, refine and moisturizes our skin in addition to being used as an "ethnomedicine" for minor illnesses such as diarrhoea and skin inflammations. Studies have proved that the topical application of VCO increased the wound healing rate of rat skin. Lauric acid, a medium chain fatty acid component in VCO, showed potential use in anti-obesity treatment as it increases energy expenditure, gets directly absorbed and burnt as energy in the liver, resulting in early satiety and thus leading to weight loss.

3. USES OF VCO

Coconut oil has several industrial applications. But VCO is unique among all the other vegetable oils because of its high lauric acid content. The lauric acid present in VCO is converted to monolaurin which provides disease fighting ability to body and keeps infants away from getting viral or bacterial or protozoal infections. Since mother's milk also contains monolaurin, VCO can be considered as equivalent to mother's milk. It is also used as

1. Hair and skin conditioner
2. Oil base for various cosmetic and skin care products
3. Carrier oil for aroma therapy and massage oils
4. Nutraceutical and functional food

4. PROCESSING OF VIRGIN COCONUT OIL

Virgin coconut oil can be extracted directly from the fresh coconut meat or from coconut milk. The different processes involved in VCO production are hot-processing method, natural fermentation method, centrifugation process and extraction from dried grating (EDG) method. The choice of the technology to be adopted depends to a great extent on the scale of operation, the degree of mechanization, the amount of investment available and the market demand. For decades, people in coconut producing countries like India and the Philippines boiled coconut milk extracted from freshly grated or comminuted (grated, chopped, granulated) coconut meat with or without the addition of water, to produce coconut oil for hair and body massaging applications.

The modified hot process method for producing VCO also follows the same principle except for controlled heating to prevent the oil from turning yellow and maintain the moisture content less than 0.2 % to prolong its shelf life. Hot process comprises of two stages: extraction/preparation of coconut milk and cooking the milk to get VCO.

In fermentation method, the VCO can be produced in a home-scale operation using ordinary kitchen utensils after extracting the coconut milk. The oil produced in this method is water-clear in colour. The VCO produced could turn sour if the fermentation period is prolonged and the fermentation process conditions are not controlled properly. Fermentation method comprises of two stages: extraction/preparation of coconut milk and fermentation of the milk for VCO production.

4.1. Process Technology for VCO

CPCRI has developed processing technologies for production of VCO by hot and fermentation method. In hot process, coconut milk is cooked in specially designed cooker whereas in fermentation process, coconut milk is allowed to ferment in a specially designed fermentation tank for specified period to get VCO. The process protocol is described below:

11-12 months old fully matured coconut is selected for VCO production. The husk is removed from coconut by using manual or mechanical dehusker. The shell is removed by using chisel type tool or shell removing machine. Testa, the brown outer layer of coconut kernel, is removed by using a manual peeler or coconut testa remover. Testa removed coconut is washed in clean water and cut into 3-4 pieces followed by blanching in 50°C hot water for 5 minutes to arrest enzyme activity. Blanched coconut pieces are pulverised using pulverizer. The pulverized coconut is fed to either manual or mechanical milk extractor to produce coconut milk. Second and third milk extraction is also carried out by mixing warm water (250 ml/ kg of residue) to the residue of the first and second milk extractions, respectively. Third milk extraction is recommended for fermentation method and it will not be economical for hot processing method. First, second and third milk extracts are mixed together vigorously for few minutes.

In fermentation process, the extracted milk is allowed to stand for 20-24 hours in a food grade plastic or stainless steel container with a conical bottom with outlet tap and a sight glass to see the different layers as the oil separates during fermentation. Under favourable conditions of 35-40°C temperature and 75% relative humidity, fermentation process results in fine quality VCO yield which is about 16-18% of the coconut kernel weight. To fasten the fermentation process, skim milk at the rate of 30 mL per litre of coconut milk is added to the mixture before the start of fermentation process. If proper operating conditions and sanitary precautions are strictly followed, four distinct layers can be seen in the fermentation container after allowing it to settle for 16 hours. The bottom layer is made up of a gummy sediment. The next layer is watery and contains fermented skim milk that is no longer fit for human consumption. The next layer is the separated oil for recovery as VCO. The top layer has floating fermented curd. The fermented curd also contains a considerable amount of trapped oil. By carefully removing the distinct layers, the oil can be separated. After VCO separation, the fermented curd is heated at 90°C to recover the residual oil which can be used for making skin care products and soap.

In hot process, the extracted coconut milk is allowed to stand for maximum 3 hours under refrigerated condition in order to separate coconut cream from coconut skim milk. Coconut cream is separated and placed in a double walled boiler known as VCO cooker developed at ICAR-CPCRI to coagulate the protein and release the oil. After slow heating for about 2 to 2.5 hours, coconut cream will begin to coagulate and separate out the pure oil. In the first hour of heating, temperature can be allowed to reach 120°C. Thereafter, the temperature is brought down to 90°C for the protein to coagulate and when the temperature is reduced to 60°C, oil starts to separate. The heating source may be LPG, biogas or steam or agricultural waste. The VCO is separated from the protein rich residue (VCO cake / 'kalkam') by straining the mixture through a muslin cloth or stainless steel mesh. VCO cake is pressed in hydraulic press to yield more oil. The remaining residue or cake can also be further slow heated to recover more oil. However, this type of oil is yellow in colour and is suitable for skin care or massage products. The oil recovery from hot process is about 20-22% of fresh weight of the coconut kernel.

The oil is filtered through sterilized cotton wool, filter paper or filter cloth and dried in a double walled boiler at 50°C for 15 minutes or until the turbid oil becomes crystal clear. VCO can be stored in stainless steel containers and poly-lined drums. However, for long-term storage, the recommended packaging material for VCO is glass containers and should be kept away from light. Polyethylene terephthalate (PET) bottles can be used for day-to-day use. The packaging material should be free from moisture before filling the oil in it.

Important steps involved in the production of virgin coconut oil are given in Fig. 1 as process flow chart and each process involved in VCO production are discussed in detail.

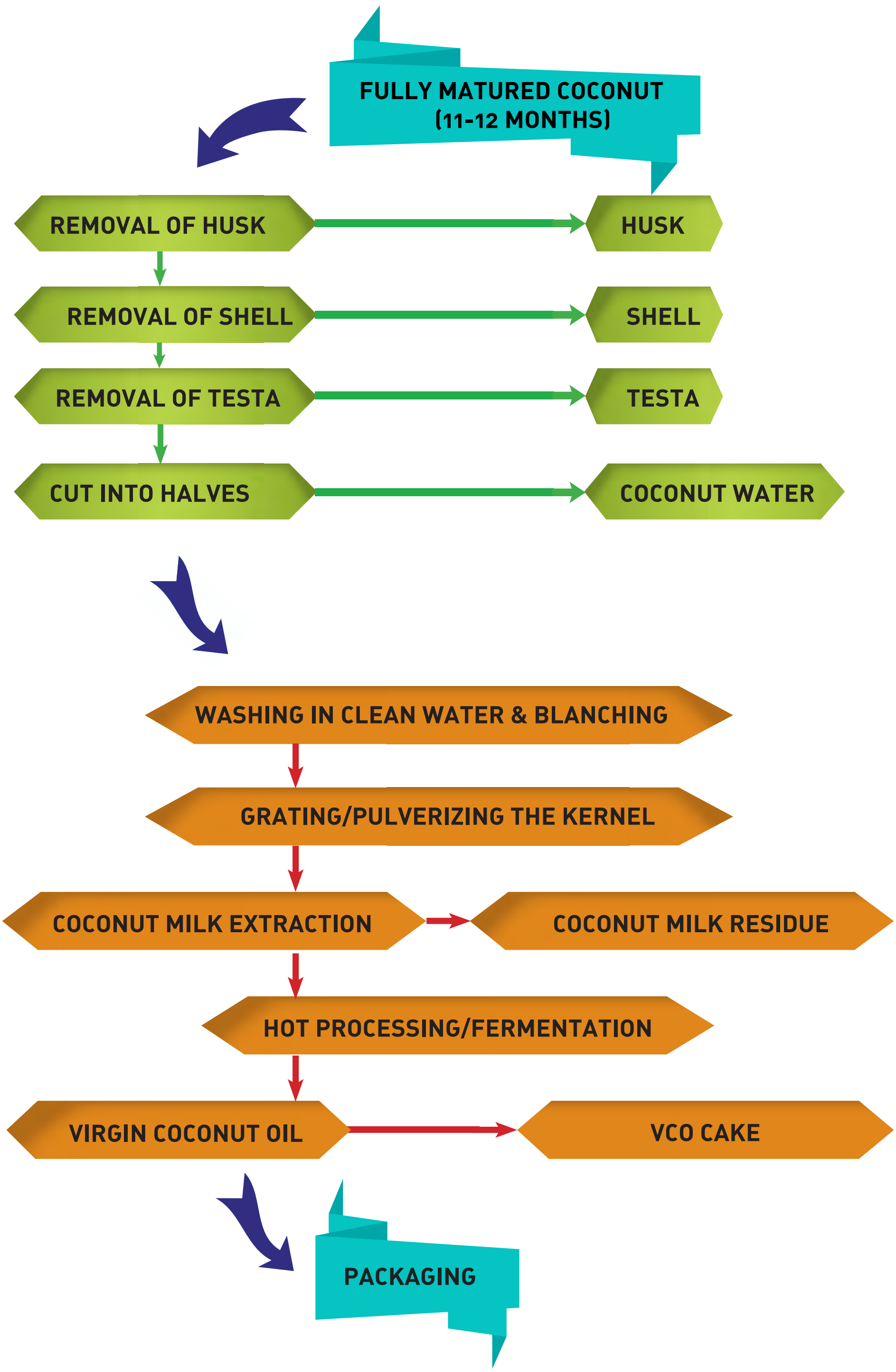

Fig. 1 Process flow chart for the production of virgin coconut oil

5. PROCESS FOR THE EXTRACTION AND PREPARATION OF COCONUT MILK

5.1. Selection of nuts

Fully mature 11-12 month olds nuts are selected for VCO production. As an indicator of maturity of the nut, the husk will be yellowish to brown in colour and makes a sloshing sound when shaken.

5.2. Removal of husk

After the harvest, the coconuts have to be dehusked using a tool called manual coconut dehusker (Fig. 2) and stored without husk in shade place for 3-4 days. This will help in easy removal of the shell.

Fig. 2 Manual coconut dehusker

The husk can also be removed by ICAR-CPCRI modified power operated coconut dehusker (Fig. 3). The capacity of the dehusker is 350 coconuts/h. The power requirement is 2 HP. The dehusker contains two sets of rollers for dehusking and tail fibre removing. For dehusking, there are two rollers with pins on their surface. For tail fibre removing, two blade type rollers and one helical type roller is provided. The dehusking roller speed is maintained at 40 rpm and tail fibre removing roller speed is 60 rpm. The machine can automatically adjust clearance between rollers and input to accommodate the coconuts of different size.

Fig. 3 Power operated coconut dehusker

5.3. Removal of shell

By using ICAR-CPCRI developed coconut deshelling machine (Fig. 4), the shell is removed without breaking the coconut kernel, which helps for easy removal of the testa. The shell can also be removed after breaking the coconut

Fig. 4 Coconut deshelling machine

Fig. 5 Manual deshelling of coconut

into halves and then scoop out the kernel pieces by knife (Fig. 5). But it will increase the time required for removing the testa.

Coconut deshelling machine is intended to reduce both time and drudgery involved in the manual deshelling process. Two concentrically rotating circular blades and a stationary shaft on which coconut is placed firmly are the major components of the deshelling machine. Coconut to be processed is pressed towards the rotating blades by firmly placing on the stationary shaft. Shell gets detached from the kernel due to the impact force of the rotating blades.

5.4. Removal of testa

The testa of the coconut kernel has to be removed for getting colorless virgin coconut oil. For the purpose, a peeler can be used and the testa can be removed manually (Fig. 6). Care should be taken to peel the testa only, without affecting the white kernel.

Fig. 6 Manual removal of testa

The testa can also be removed using the testa removing machine (Fig. 7) developed at ICAR-CPCRI, Kasaragod. The machine consists of a circular wheel covered with an emery cloth or water paper. This friction wheel is rotated using an electric motor. Coconut kernel is pressed to the surface of the rotating friction wheel either by hand or using a fork. Removed testa is collected at the bottom. The emery cloth/ water paper needs to be replaced periodically when the surface gets smoothened. One person can remove testa of about 75-100 coconuts per hour.

Fig. 7 Testa removing machine

5.5. Kernel grating/pulverizing

The coconut meat, free from testa, is fed to a mechanical grating/pulverizing machine (Fig. 8). The coconut pulverizer consists of power operated rotary blade. The coconut kernel pieces are fed into the hopper manually. Due to the impact of the rotary blade and the rubbing on the stationary blade, the coconut kernel turns into fine powder. The machine has a capacity of 250 nuts per hour. Alternatively, coconut may also be grated manually using a coconut grating machine (Fig. 9). Here the coconut cups, after splitting coconut into two halves, are pressed manually to the rotating blade of the machine for

Fig. 8 Coconut pulverizer

Fig. 9 Manual coconut grating machine

grating. The coconut grating machine scrapes off the coconut flesh into fine gratings with the help of a specially designed stainless steel blade. Care should be taken to grate the meat without adhering testa. The capacity of the grating machine is 60 nuts per hour.

5.6. Coconut milk expelling

Coconut milk expelling is an important process in the production of high value products like virgin coconut oil, coconut milk powder, cream etc. ICAR-CPCRI has developed different types of milk expeller viz., manual, manual with hydraulic jack, single screw, double screw and hydro pneumatic milk expellers.

Two manually operated coconut milk expelling machines are available to extract milk from coconut gratings. Both the machines are similar to a hand operated vertical screw press. The grated coconuts are kept in a perforated cylinder and by rotating the handle provided at the top of the screw, the gratings are pressed. An outer cover to the perforated cylinder is provided to avoid possible milk splash during the process. In the first machine (Fig. 10a) the whole pressing process is done manually by rotating the handle. In the second machine (Fig. 10b) an additional hydraulic jack is provided at the bottom. After exerting maximum pressure using the handle, the bottom hydraulic jack is

Fig. 10a Manual coconut milk expeller

Fig. 10b Manual coconut milk expeller with hydraulic jack

operated again manually. By doing this, the platform holding the cylinder moves up thereby pressing the gratings. Using this hydraulic jack, a pressure of eight ton could be easily applied enhancing the extraction efficiency considerably.

Among the expellers, screw type expellers are the preferred ones, since they have high milk extraction efficiency. However, it may be noticed that while compressing the coconut kernel gets heated up, especially near the outlet. In order to dissipate the heat generated during the extraction process, prototype of a coconut milk expeller has been fabricated with an in built cooling mechanism.

The expeller is basically a single screw type expeller (Fig. 11a). The cooling is done by providing a cavity at the outlet side of the screw because maximum pressure is exerted and hence heat is generated towards the outlet side of the screw. Provision is made to circulate water through this cavity. Heat energy generated due to compression of coconut is dissipated by circulating

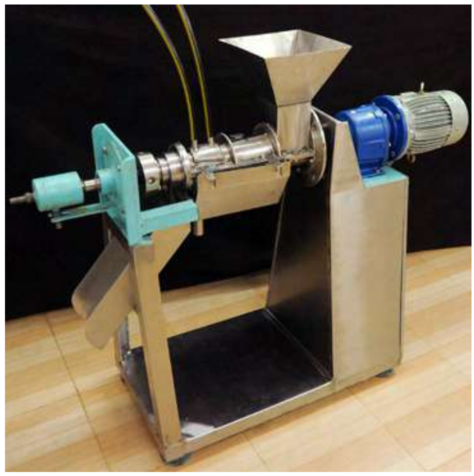

Fig. 11a Single screw milk expeller with cooling arrangement

cold water. By controlling the water circulation rate, temperature could be maintained within the safe/ required limit.

Prototype of a double screw coconut milk expeller (Fig. 11b) has been designed and fabricated to expel milk from coconut kernel. Prime mover of the expeller is an induction motor having a power rating of 1.1 kW and run at 1415 rpm. Power from the motor is

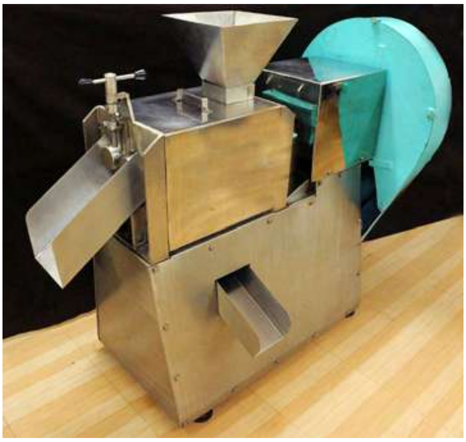

Fig. 11b Double screw milk expeller

transmitted to the screws first through a belt driven pulley and then through a reduction gear. The screws rotate at 14 rpm. Screws of the expeller are custom made in stainless steel to get maximum extraction efficiency. Clearances in the strainers are so designed that each one expands outward. This reduces the chance of these apertures getting clogged to a very minimum. All the contact parts of the machine are fabricated using food grade stainless steel. The expeller has a capacity to extract milk from 1000 coconuts in one hour. Maximum milk could be extracted in two runs itself. Milk extraction efficiency remains same when the coconut kernel is fed with or without pulverization. The machine would be of great help to all processing units involved in coconut milk extraction.

Two hydro pneumatic coconut milk expellers of different capacities (Fig. 12.) were also developed for large scale production of coconut milk. The operation of both the machines is completely automated using a programmable logical controller. The user can programme the operation of these machines, i.e. extraction pressure, frequency and duration of pressing etc. using the programmable logical controller as per the requirement. They are useful for large scale production of coconut milk in coconut milk processing industries and virgin coconut oil production centres. The smaller machine is having a capacity of handling 250 nuts/hour, where as the bigger machine can handle 500nuts/h.

Fig. 12 Hydro pneumatic milk expellers

5.7. Coconut milk expelling process

Coconut milk is expelled from the grated/pulverized coconut meat using ICAR-CPCRI developed manual or mechanical milk expellers of various capacities. The coconut milk obtained from the first expelling is collected separately and the residue is utilized for second expelling. Similarly, second and third milk expelling is carried out by mixing warm water (250 ml / kg of residue) to the residue and the rest of the process is same as above. Third milk extraction is recommended for fermentation method and it will not be economical for hot processing method. Then, the milk is stirred vigorously for few minutes.

6. HOT PROCESS FOR PROCESSING OF COCONUT MILK TO PRODUCE VCO

6.1. Settling of the coconut milk

Coconut milk is an emulsion of oil and water that is stabilized by protein. To recover the oil from coconut milk, the protein bond has to be broken either by heat or by enzymes or some other mechanical means. The extracted coconut milk is allowed to stand for maximum three hours. If the settling is done in the refrigerator or in ice box, coco skim milk, a very nutritious beverage containing protein and other nutrients like calcium, potassium, phosphorus, niacin, thiamine and riboflavin, can be recovered for human consumption. Settling the coconut milk at ambient temperature turns the skim milk sour and unsuitable for human consumption.

6.2. Cream separation

The cream (oily part) is separated from the coco skim milk (aqueous part) by scooping the cream from the top. Coco skim milk can be preserved for processing further into beverage.

6.3. Slow heating of the coconut cream

If the coconut milk is directly used in slow heating process, it will take a much longer heating time to recover oil. Coco cream is placed in a double walled boiler known as VCO cooker developed at ICAR-CPCRI under slow heat to coagulate the protein and release the oil. After slow heating for about 2 to 2.5 hours, coconut cream will start to coagulate and separate out the oil. For the first hour of heating, temperature can be allowed to reach 120°C. Further the temperature is brought down to 90°C until the protein begins to coagulate and the temperature is reduced to 60°C when the oil starts to separate.

The hot processing of coconut milk in VCO cooker designed and developed at ICAR-CPCRI, Kasaragod is shown in Fig. 13 a & b. It consists of a double jacketed vessel filled with thermic fluid. The thermic fluid ensures efficient and uniform heat transfer to coconut milk kept in the cooker. Four Teflon tipped stirrers are provided to stir coconut milk. This helps the cooker to distribute heat energy uniformly

Fig. 13a Hot processing of VCO in VCO cooker (Biofuel based)

Fig. 13b LPG based VCO cooker

within the coconut milk kept in the cooker. The stirrers are powered by an electric motor with a reduction gear. An outlet with a door attached to a lever is provided at the bottom of the cooker to take out the extracted oil. The cooker is supported by three legs with sufficient clearance from ground for easy collection of extracted oil. A thermometer is provided to measure the temperature of the thermic fluid so that it can be kept from 100-120°C. A safety valve is also provided for releasing the pressure developed, if any, in the thermic fluid chamber. The cooker is heated by two burners provided at the bottom of the heating chamber. Biogas or LPG could be used as fuel. Virgin coconut oil cookers of any capacity could be fabricated.

6.4. Oil separation

The oil is separated from the protein rich residue, VCO cake by straining the mixture through a muslin cloth or stainless steel mesh. Part of the remaining oil in the VCO cake is expelled by using manually operated milk expeller with hydraulic jack. The VCO cake can be further slow heated to recover more oil. However, this type of oil is yellow in colour and is suitable for skin care or massage products.

6.5. Drying

Drying is required to ensure that all residual moisture is removed to prolong the shelf life of the VCO. Drying of the oil can be achieved by placing the extracted oil in a double walled boiler at 50°C for fifteen minutes or until the turbid oil become crystal clear.

6.6. Filtration

Oil is again filtered to remove the adhering fine particles of VCO cake, if any, that has passed through the muslin cloth. Under small scale, the oil is filtered through sterilized cotton wool and for large-scale operation, a fabricated pressure filter with filter cloth is recommended to increase the filtration rate.

7. FERMENTATION PROCESS FOR PROCESSING OF COCONUT MILK TO PRODUCE VCO

Coconut milk extracted from the grating as explained above is allowed to stand for 20-24 hours. Under favourable conditions, the oil naturally separates from the water and the protein. The air borne lactic acid bacteria, which has the capability to break the protein bonds, act on the coconut milk mixture, is causing the VCO separation.

7.1. Settling of the coconut milk in fermentation tank

After the coconut milk is placed in the settling/fermentation container, it must be covered with a loose fitting cloth to prevent aerial contamination by yeast, moulds or bacteria. A fermentation temperature of around 35-40°C is to be maintained in the area where the fermenting container is placed. Relative humidity within the area should also be maintained at a maximum of 75%. A small electric heater with built-in thermostat control can also be installed in the fermentation cabinet. Under these conditions, a fermentation time of 20-24 hours results in a relatively high yield (16-18%) of fine quality VCO.

To fasten the fermentation process, skim milk at the rate of 30 ml per litre of coconut milk is added to the coconut milk mixture before the start of the fermentation process. This will not only fasten the fermentation process (16-18 hours), but also results in comparatively high recovery (16-18%) of VCO. This technique will also reduce the quantity of floating fermented curd which is normally found in the top layer after the fermentation process.

7.2. Separation

The fermenting container should be made up of food-grade, transparent plastic. It should be wide-mouthed for easy removal of fermented curd. The fermenting container can also be a food grade stainless steel cylindrical tank with a conical bottom with outlet tap specified and a sight glass to see the different layers as the oil separates. Oil can be withdrawn from the outlet tap based on the levels shown in the sight glass. The fermentation container with VCO and skim milk is shown in Fig. 14.

Fig. 14 Fermentation tank

If proper operating conditions and sanitary precautions are strictly followed, four distinct layers can be seen in the fermenting container after settling for 16 hours. The bottom layer is made up of gummy sediment. The next layer is the watery, fermented skim milk that is no longer fit for human consumption. The next layer is separated for recovery as VCO. The top layer is floating fermented curd. The fermented curd also contains a considerable amount of trapped oil. By carefully separating the distinct layers, the oil can be separated.

7.3. Filtration

The separated oil contains some adhering particles of fermented curd and it needs to be filtered before drying and packing. Under small scale, the oil is filtered through sterilized cotton wool or filter paper or filter cloth placed in the hole of a big funnel and allowing it to trickle down and for large-scale operation, a pressure filter with filter cloth is recommended to increase the filtration rate.

7.4. Drying

Drying is required to ensure that all residual moisture is removed to prolong the shelf life of the VCO. Drying of the oil can be achieved by placing the extracted oil in a double walled boiler at 50°C for fifteen minutes or until the turbid oil become crystal clear. Oil drying temperatures should not exceed 65°C otherwise that will result in slight yellow colour oil which is classified as class B oil. Apart from removing the residual oil, heating the VCO will ensure that fermentation is stopped. It will also remove the fermented sour smell from the oil to some extent.

7.5. Heating of fermented curd

After VCO separation, the fermented curd is heated to recover the residual class B oil which can be used for making skin care products and soap. The temperatures are not as strictly controlled but should not exceed 90°C as the oil will become dark yellow.

8. PACKAGING AND STORAGE OF VCO

Virgin coconut oil can be stored in stainless steel containers and poly-lined drums. However, for long-term storage, the recommended packaging material for VCO is glass. PET bottles can be used for day-to-day use. The packaging material should be very dry before filling the oil in it. Fig. 15a & b show the virgin coconut oil prepared by ICAR-CPCRI developed methods and packed in PET bottle respectively.

9. UTILIZATION OF BY-PRODUCTS

Husk, shell, testa, water, coconut milk residue and VCO cake are the by-products of the VCO production process based on whole coconut. The products of importance derived from coconut

Fig. 15a VCO produced by different methods

Fig. 15b VCO packed in PET bottle

husk are coir fibre and coir pith. The husk usually forms 35 to 45 per cent of the weight of the whole nut, when ripe. The major use of shell is as a fuel. To a lesser extent, it is used as a raw material for the manufacture of hookah shells, various domestic utensils, curious, fancy items etc. The commercial utilization of coconut shell for the production of shell charcoal, activated carbon, shell flour etc is now gaining importance in the producing countries with an expanding market demand. Testa, rich in dietary fibre and protein, is an excellent compound for bakery, extrudate and animal feed. Coconut water has been recommended for the production of Nata de coco, soft drink/ squash, vinegar, etc. which could be developed on a cottage industry basis, for augmenting the income of coconut growers. Coconut milk residue and VCO cake are the by-products of the VCO process based on coconut milk. The milk residue and VCO cake represents approximately 35-50% and 5-10% of the weight of freshly grated meat on a wet basis, respectively, depending on the coconut milk extraction process used. Coconut milk residue usually retains about 35-40% of the original oil content of the fresh coconut meat and is very rich in dietary fibre. VCO cake is rich in protein. They can be utilized in various ways and the different uses are listed below:

1. They can be used for preparing fortified wheat flour. Adding coconut milk residue and VCO cake to wheat flour fortifies the food product with dietary fibre, protein and fat essential for good nutrition.

2. As an ingredients, they can be used for making many value added products namely laddu, biscuits, halwa, porridge, extrudate etc. When using coconut milk residue for biscuits, by partially substituting wheat flour, the cost is reduced and the nutritional value of the product is enhanced by way of dietary fat and fibre.

3. If VCO processing is carried out under strict hygienic conditions, the coconut milk residue can also be used as high quality animal feed ingredient.

   Another by-product of this process is coconut skim milk which is a nutritious beverage with protein and other nutrients.

10. RESEARCH FINDINGS

In order to improve the recovery, the effect of milk expelling methods (manual and mechanical) and pre-treatments (slicing, pulverizing and blanching) on milk and hot process VCO recovery with respect to fresh coconut kernel weight was studied. The blanching and pulverizing yielded more milk and VCO recovery in both manual and mechanical expelling methods. The recovery of coconut milk and VCO ranged from 34.04 - 51.57 per cent and 14.18 - 22.37 per cent respectively. Among the different treatment combinations, pulverized, blanched and double screw pressed coconut kernel yielded the highest milk and VCO recovery. The per cent recovery of the two important co-products namely coconut milk residue and VCO cake ranged from 38.48 – 55.60 and 6.26 – 8.76 respectively.

The ideal quality characteristics of VCO are given table 1. The quality characteristics of VCO prepared by ICAR-CPCRI developed hot and

Table 1. Ideal quality characteristics of VCO

Properties	Specification
Colour	Water-clear
Free fatty acid (as lauric acid)	< 0.1 %
Moisture (matter volatile at 105°C)	< 0.1 %
Peroxide value	< 3
Lauric acid content	47-55 %
Aroma	Fresh coconut, mild to strong

Table 2: Comparative quality characteristics of VCO by hot and fermentation processes with commercial coconut oil and *APCC standard for VCO

Chemical parameters	Hot process VCO	Fermentation process VCO	Commercial Coconut Oil	*APCC standard
Tocopherol (µg/g)	15-20	20-30	2-6	-
Polyphenols (µg/g)	500-700	350-500	150-250	-
Antioxidant activity (%)	80-90	65-75	35-45	-
Monoglycerides (%)	1.5-2.0	2.0-3.0	0.5-1.5	-
Phytosterol (µg/g)	2.5-3.0	2-2.5	0.5-1.0	-
Color (Lovibond)	0.1R+0.5Y	0.1R+0.1Y	0.1R+0.5Y	Water clean
Refractive Index at 40°C	1.4480-1.4490	1.4480-1.4490	1.4480-1.4490	1.4480-1.4492
Saponification value	250-260	250-260	250-260	250-260
Iodine value	7-8.6	7.5-8.4	7.4-8.1	4.1-11.00
Specific gravity at 30°C	0.915-0.920	0.915-0.920	0.915-0.920	0.915-0.920
Moisture (%)	0.09-0.1	0.08-0.1	0.08-0.1	0.1-0.5

*APCC – Asian & Pacific Coconut Community, Jakarta, Indonesia

fermentation processes are compared with that of commercial coconut oil in the following Table 2.

Coconut testa is one of the by-products of VCO production process. Phenolic compounds in these have been considered to be the potential and important contributors in reducing oxidative stress due to their antioxidant activity, which are of great importance, predominantly in human diets. An attempt was made to extract the phenolics present in the defatted cake of testa using different solvent systems. Ethanol extract of testa contained 0.9 to 2.3 g phenolics (Gallic acid equivalent) per 100 g dry weight. The ethanol extract showed better antioxidant activity as compared to other solvent extracts.

An attempt was made to recover the oil from the dried coconut milk residue and VCO cake at 8% moisture content in commercial oil expeller. The oil recovery from milk residue and VCO cake flour was 41.24±1.08 per cent and 25.72±0.96 per cent respectively.

In order to utilize the coconut milk residue and VCO cake in oil extraction and extrudate production, the biochemical constituents of dried powders of coconut milk residue and VCO cake were analyzed and presented in Table 3

Coconut milk residue and VCO cake flour can be incorporated up to 20 per cent with broken rice, maize and pearl millet in producing extrudates (Fig. 16.) with comparative extrusion characteristics and good acceptability. The utilization of broken rice, pearl millet, maize, coconut milk residue and VCO cake based extrudates and sweet snacks (Fig. 17.) would be beneficial for consumers, snack processors and

Table 3. Properties of coconut flours

Parameters	Milk residue flour Mean±s.D.	Cake flour Mean±S.D.
Crude protein(% N x 6.30)	5.29±0.065	20.12±0.081
Moisture (%)	2.86±0.186	3.12±0.096
Crude fat (%)	49.24±0.651	35.57±0.191
Crude fiber (%)	25.51±0.647	3.80±1.742
Ash (%)	0.93±0.012	6.08±0.084
Total fietary fiber (%)	46.50±0.353	12.75±0.309
Free fatty acids (%)	1.20±0.021	1.79±0.057
Peroxide value (mEq/kg)	0.25±0.012	0.57±0.055
Particle size distribution (μm)	524.77±10.680	594.56±5.640

S.D. - Standard deviation at ±=0.05 level

Fig. 16 Coconut flour based extrudates

the most important is to add value to broken rice, maize, pearl millet and co-products of coconut milk and virgin coconut oil.

Fig. 17 Coconut flour based sweet snacks

11. CRITICAL CONTROL MEASURES

Coconut milk contains protein and other nutrients and has high moisture content making it more susceptible to microbial contamination and rapid spoilage. Because of these characteristics, grating or milling of fresh coconut meat and subsequent extraction of the milk should be done in a clean environment and under strict sanitary conditions. The following critical control measures are to be followed while preparing VCO.

- Wash hands with soap and water before doing any preparation work and wear the necessary protective clothing with hair cover.
- Ensure that all materials, utensils or equipment used in extracting and holding coconut meat and milk are thoroughly cleaned and rinsed with hot water. Utensils should be free from any soap or chemical residue.
- Always ensure that grating or scraping of coconut meat and subsequent milk extraction is done under clean conditions by observing good personal hygiene.
- High quality clean water should be used for second milk extraction.
- Virgin coconut oil should not be heated in a pan on direct heat as this will cause the oil to turn yellow.
- Precise controls for the maturity of coconuts and the ambient conditions for the fermentation room are necessary to obtain good and high quality VCO recovery.

- Fermentation method is very sensitive to the maturity and freshness of the nuts. Immature nuts contain a high percentage of protein which makes the protein bonding in coconut milk much more difficult to break and release the oil. Likewise, if the coconuts are stored for longer period, the risk of spoilage and contamination will be higher.
- In fermentation method, occasionally the coconut milk mixture that is left for 16 to 24 hours will generate big bubbles and no oil will be separated. The major cause of the bubbling problem is contamination, either through soap residues in the fermenting container or invasion of micro-organisms. If this occurs, immediately transfer the creamy layer to the evaporating pan and heat the contents so that oil can be still recovered. However, this oil will be considered as Class B oil and should only be used for making some skin care products and soap. It is not suitable for human consumption.

12. COST ANALYSIS OF THE VCO PROJECT BY HOT PROCESS METHOD

12.1. Land and building

The VCO making unit shall be located in the vicinity of the coconut growing area to ensure the continuous supply of raw material "coconut". As the plot area of about five cents is required for the project, it can be purchased at the appropriate rate.

The investment on land @ Rs.1 lakh per Cent	: Rs. 5,00,000
Built up area of 1000 sq.ft will be required for housing as well as facilities	
Hence investment on building @ Rs. 1000/sq.ft	: Rs. 10,00,000
Total investment on land & building	: Rs. 15,00,000

12.2. Raw material

The raw material will be matured coconut. The coconut is dehusked and deshelled prior to be used as a raw material for VCO extraction. Five hundred coconuts yield about 125 kg kernel/gratings and 25 litres of VCO. The proposed processing unit will be having the capacity of processing 500 nuts daily which costs about Rs. 5000/- and for working 300 days in a year, the cost of the raw material comes to Rs. 15,00,000/-.

12.3. Miscellaneous expenses

Assets such as office furniture	: Rs. 50,000
Pre operative expenses such as Registration, documentation, legal expenses, deposits such as for electricity, water, consultancy etc.,	: Rs. 1,50,000
Administrative expenses like stationary and traveling	: Rs. 50,000
Utility bills like electricity and water charges per year	: Rs. 50,000
Total miscellaneous expenses	**: Rs. 3,00,000**

12.4. Manpower required

Sl.No	Staff	No. of posi-tion	Salary / month	Salary/ annum (Rs.)
1	Manager-cum-product supervisor	01	20,000	2,40,000
2	Unskilled labour	03	10,000	3,60,000
			Total	**6,00,000**

12.5. Working capital

S.No.	Item	Quantity	Rate per unit	Amount (Rs)
1	Coconut	1,50,000	Rs.10 / coconut	15,00,000
2	Packaging material	7,500	Rs.10 / bottle	75,000
3	Miscellaneous items			25,000
			Total	**16,00,000**

12.6. Equipment and machinery required for processing 500 coconuts per day					
Sl. No	**Name of the material**	**Specifica-tion**	**Quan-tity**	**Unit price (Rs)**	**Total cost (Rs)**
1	Coconut dehusker	Power operated	1	2,05,000	2,05,000
2	Coconut desheller	Power operated	1	75,000	75,000
3	Coconut testa removing machine	Power operated	1	75,000	75,000
4	Coconut pulverizer	Power operated	1	1,00,000	1,00,000
5	Milk expeller	Power operated	1	3,25,000	3,25,000
6	VCO cooker	LPG/Elec-trical	1	3,25,000	3,25,000
7	Vacuum dryer	Power operated	1	1,50,000	1,50,000
8	Packaging system	Power operated	1	1,00,000	1,00,000
9	Weighing Balance	Power operated	1	25,000	25,000
10	Miscellaneous items such as stainless steel containers, SS containers with trolley attached and other vessels, electrical fittings, electrical water heaters			1,20,000	1,20,000
				Total	**15,00,000**

12.7. Capital Investment		
a.	Investment on land for 5 cents @ Rs.1 lakh per Cent	Rs. 5,00,000
b.	Investment on building for 1000 sq.ft @ Rs. 1000/sq.ft	Rs. 10,00,000
c.	Machinery and equipment	Rs. 10,00,000
d.	Miscellaneous assets	Rs. 3,00,000
	Total	**33,00,000**

12.8. Source of finance		
a.	The entrepreneur (One third)	Rs. 11,00,000
b.	Loan from bank (Two third)	Rs. 22,00,000
	Total	**33,00,000**

12.9. Fixed cost		
a.	Depreciation on plant, machinery and equipment @ 10 %	Rs.1,50,000
b.	Depreciation on building @ 5%	Rs. 50,000
c.	Interest on term loan @ 12.5 %	Rs. 2,75,000
d.	Interest on working capital @ 11%	Rs.1,76,000
e.	Repair and maintenance of machinery @ 5%	Rs. 75,000
f.	Salary	Rs. 6,00,000
g.	Administrative overheads	Rs. 60,000
h.	Insurance	Rs. 24,000
i.	Sales promotion and advertisement expenses	Rs. 60,000
	Total	**14,70,000**

12.10. Variable cost		
a.	Working capital including raw materials	Rs. 16,00,000
b.	Other variable costs like electricity, watch and ward and other factory overheads	Rs. 1,00,000
	Total	**17,00,000**

12.11. Profitability projections

Total cost of production (Fixed cost + variable cost) : Rs. 31,70,000

Cost of production (31,70,000 / 7,500)

: Rs. 423 per litre

Total cost of selling (7500 litres at Rs.800 / litre) : Rs. 60,00,000

Profit : Rs. 28,30,000

Break even point = Fixed cost / [selling cost – (variable cost / No. of units)]

= 14,70,000 / [800 – (17,00,000 / 7500)]

= 14,70,000/ [800 –227]

= 14,70,000/ 573

= **2,565 litres of virgin coconut oil**

Break even sales = 2,565 x 800

= **Rs. 20,52,000**

Break even period = 2, 565 / 25

= **102 days**

12.12. Benefit cost analysis

Capital productivity analysis is the most important tool for evaluating the financial feasibility of any project. The *ex-ante* concept of cost benefit analysis is adopted to evaluate the present project. The study was confined to the direct costs and benefits, the social cost-benefit aspects are not accounted.

Feasibility analysis of the project on commercial production of virgin coconut oil revealed a benefit cost ratio of 1.79 and an internal rate of return of 157.21 per cent. General theory as well as empirical studies on project feasibility analysis indicates that, a project with BCR value above 1 is always feasible. As far as IRR is concerned, it is advisable to compare the value with the prevailing returns we may obtain, had we invested the amount in other ventures. In the present study, the IRR is found to be 157.21 percent, which is well above that of any other prevailing market rate of return. Thus, we may conclude that the commercial production of VCO by hot process method could turn out to be a highly profitable venture.

During hot process VCO production from 1,50,000 nuts/year, 60,000 kg husk, 20,000 kg shell, 15,000 litres water, 7,500 litres VCO, 7,500 kg milk residue flour, 1,500 kg VCO cake flour and 1,000 kg testa are obtained. The additional benefit of selling these co-products is not accounted in this analysis. Hence, by selling the co-products like coconut husk, shell, testa, water, milk residue, VCO cake, entrepreneur can earn more income.

Since land is an appreciating asset, in the present capital productivity analysis the value of land has been excluded. Similarly, since we are accounting for the depreciation of building we are excluding that as well, instead we are imputing the leased/rental value of land and building. The rental value of land and building are imputed in terms of the annual interest rate we would have paid, had we purchased the land and building by taking a bank loan.

It is concluded that after producing 2,565 litres of virgin coconut oil, the no profit no loss point will occur which will correspond to a sales volume of Rs. 20,52,000 and this stage will arrive after 102 days of functioning of the unit. Therefore, the VCO making unit will start earning profit during fourth month of production.

Discounted cash flow of virgin coconut oil production by hot process method

Year (n)	fixed cost(Rs)	variable cost(Rs)	Total cost	Total returns	Dis-counting factor	Dis-counted cost	Dis-counted benefits
0	1800000		1800000		1		-1800000
1	1470000	1700000	3170000	6000000	0.889	2817778	5333333
2	1470000	1700000	3170000	6000000	0.790	2504692	4740741
3	1470000	1700000	3170000	6000000	0.702	2226392	4213992
4	1470000	1700000	3170000	6000000	0.624	1979015	3745770
5	1470000	1700000	3170000	6000000	0.555	1759125	3329574
6	1470000	1700000	3170000	6000000	0.493	1563666	2959621
7	1470000	1700000	3170000	6000000	0.438	1389926	2630774
8	1470000	1700000	3170000	6000000	0.390	1235490	2338466
9	1470000	1700000	3170000	6000000	0.346	1098213	2078636
10	1470000	1700000	3170000	6000000	0.308	976189	1847677
Benefit Cost Ratio (BCR)= 1.79							
Internal Rate of Return (IRR)= 157.21%							

13. COST ANALYSIS OF THE VCO PROJECT BY FERMENTATION METHOD

The cost of land and building, raw material and miscellaneous expenses are same as mentioned in section 12.1, 12.2 and 12.3.

13.1. Equipment and machinery required for processing 500 coconuts per day					
Sl. No.	**Name of the material**	**Specification**	**Quantity (Rs.)**	**Unit price (Rs.)**	**Total cost (Rs.)**
1	Coconut dehusker	Power operated	1	2,05,000	2,05,000
2	Coconut desheller	Power operated	1	75,000	75,000
3	Coconut testa removing machine	Power operated	1	75,000	75,000
4	Coconut pulverizer	Power operated	1	1,00,000	1,00,000
5	Milk expeller	Power operated	1	3,25,000	3,25,000
6	Fermentation tank		1	25,000	25,000
7	Vacuum dryer	Power operated	1	1,50,000	1,50,000
8	Packaging system	Power operated	1	1,00,000	1,00,000
9	Weighing Balance	Power operated	1	25,000	25,000
10	Miscellaneous items such as stainless steel containers, SS containers with trolley attached and other vessels, electrical fittings, electrical water heaters	-	-	1,20,000	1,20,000
				Total	**12,00,000**

13.2 Manpower required				
Sl.No	Staff	No. of position (Rs.)	Salary / month(Rs.)	Salary/ annum(Rs.)
1	Manager-cum- product supervisor	01	20,000	2,40,000
2	Unskilled labour	03	10,000	3,60,000
			Total	**6,00,000**

13.3. Working capital

S.No.	Item	Quantity	Rate per unit	Amount (Rs)
1.	Coconut	1,50,000	Rs.10 / coconut	15,00,000
2.	Packaging material	6,750	Rs.10 / bottle	67,500
3.	Miscellaneous items	-	-	32,500
			Total cost	**Rs. 16,00,000**

13.4. Capital investment

a.	Investment on land for 5 cents @ Rs.1 lakh per Cent	: **Rs. 5,00,000**
b.	Investment on building for 1000 sq.ft @ Rs. 1000/sq.ft	: **Rs. 10,00,000**
c.	Machinery and equipment	: Rs. 12,00,000
d.	Miscellaneous assets	: Rs. 3,00,000
	Total	**Rs. 30,00,000**

13.5. Source of finance

The fixed working capital is worked out to be Rs. 30,00,000. The amount shall be raised as given below.

a.	The entrepreneur	(One third)	: Rs. 10,00,000
b.	Loan from bank	(Two third)	: Rs. 20,00,000
		Total	**Rs. 30,00,000**

13.6. Fixed cost

a.	Depreciation on plant, machinery and equipment @ 10 %	: Rs. 1,20,000
b.	Depreciation on building @ 5%	: Rs. 50,000
c.	Interest on term loan @ 12.5 %	: Rs. 2,50,000
d.	Interest on working capital @ 11%	: Rs. 1,76,000
e.	Repair and maintenance of machinery @ 5%	: Rs. 60,000

f.	Salary	: Rs. 6,00,000
g.	Administrative overheads	: Rs. 60,000
h.	Insurance	: Rs. 24,000
i.	Sales promotion and advertisement expenses	: Rs. 60,000
	Total	**Rs. 14,00,000**

13.7. Variable cost

a.	Working capital including raw materials	: Rs. 16,00,000
b.	Other variable costs like electricity, watch and ward and other factory overheads	: Rs. 1,00,000
	Total	**Rs. 17,00,000**

13.8. Profitability projections

Total cost of production (Fixed cost + variable cost) : Rs. 31,00,000

Cost of production (31,00,000 / 6,750) : Rs. 460 per litre

Total cost of selling (6750 litres at Rs.800 / litre) : Rs. 54,00,000

Profit : Rs. 23,00,000

Break even point = Fixed cost / [selling cost – (variable cost / No. of units)]

= 14,00,000/ [800 – (17,00,000 / 6750)]

= 14,00,000/ [800 –252]

= 14,00,000/ 548

= **2,555 litres of virgin coconut oil**

Break even sales = 2,555 x 800

= **Rs. 20,44,000**

Break even period = 2,555 / 22.5

= **114 days**

13.9. Benefit cost analysis

Capital productivity analysis is the most important tool for evaluating the financial feasibility of any project. The *ex-ante* concept of cost benefit analysis is adopted to evaluate the present project. The study was confined to the direct costs and benefits, the social cost-benefit aspects are not accounted.

Feasibility analysis of the project on commercial production of virgin coconut oil revealed a benefit cost ratio of 1.65 and an internal rate of return of 143.73 per cent. General theory as well as empirical studies on project feasibility analysis indicates that, a project with BCR value above 1 is always feasible. As far as IRR is concerned, it is advisable to compare the value with the prevailing returns we may obtain, had we invested the amount in other ventures. In the present study, the IRR is found to be 143.73 percent, which is well above

Discounted cash flow of Virgin coconut oil production by fermentation method							
Year (n)	fixed cost(Rs)	variable cost(Rs)	Total cost	Total returns	Dis-counting factor	Discounted cost	Discounted benefits
0	1500000		1500000		1		-1500000
1	1400000	1700000	3100000	5400000	0.889	2755556	4800000
2	1400000	1700000	3100000	5400000	0.790	2449383	4266667
3	1400000	1700000	3100000	5400000	0.702	2177229	3792593
4	1400000	1700000	3100000	5400000	0.624	1935315	3371193
5	1400000	1700000	3100000	5400000	0.555	1720280	2996616
6	1400000	1700000	3100000	5400000	0.493	1529138	2663659
7	1400000	1700000	3100000	5400000	0.438	1359233	2367697
8	1400000	1700000	3100000	5400000	0.390	1208207	2104619
9	1400000	1700000	3100000	5400000	0.346	1073962	1870773
10	1400000	1700000	3100000	5400000	0.308	954633.1	1662909
Benefit Cost Ratio (BCR)= 1.65							
Internal Rate of Return (IRR)= 143.73%							

that of any other prevailing market rate of return. Thus, we may conclude that the commercial production of VCO by fermentation method could turn out to be a highly profitable venture.

During fermentation process, VCO production from 1,50,000 nuts/year, 60,000 kg husk, 20,000 kg shell, 15,000 litres water, 6,750 litres VCO, 7,500 kg milk residue flour and 1,000 kg testa are obtained. The additional benefit of selling these co-products is not accounted in this analysis. Hence, by selling the co-products like coconut husk, shell, testa, water, milk residue, entrepreneur can earn more income.

Since land is an appreciating asset, in the present capital productivity analysis the value of land has been excluded. Similarly, since we are accounting for the depreciation of building we are excluding that as well, instead we are imputing the leased/rental value of land and building. The rental value of land and building are imputed in terms of the annual interest rate we would have paid, had we purchased the land and building by taking a bank loan.

It is concluded that after producing 2,555 litres of virgin coconut oil, the no profit no loss point will occur which will correspond to a sales volume of Rs. 20,44,000 and this stage will arrive after 114 days of functioning of the unit. Therefore, the VCO making unit will start earning profit from fourth month of production.

Thus, VCO based venture can contribute a modest increase in the income and livelihood of the coconut growers and entrepreneur.