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Entrepreneurship Oriented Processing and Value Addition Technologies of Coconut

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Introduction

Coconut palm (*Cocos nucifera* L.), a perennial horticultural crop, is a symbol of national and international integration involving more than 93 producing countries and more than 140 consuming countries. It is eulogised as 'Kalpavriksha'- the '*tree of heaven*' as each and every part of the palm is useful to mankind in one way or other. There are countless uses of this coconut palm. It is bestowed with multiple benefits like health, wealth and shelter to mankind. It is also denoted as "heavenly tree", "tree of abundance" and "nature's supermarket". India is the largest producer of coconut followed by Indonesia and Philippines. In India, Tamil Nadu ranks first in production followed by Karnataka, Kerala and Andhra Pradesh. These states account for more than 90 per cent of the area and production of coconut in India. However, it is also cultivated with varying success in other states like Assam, Goa, Gujarat, Maharashtra, Nagaland, Orissa, Tripura, West Bengal, Andaman and Nicobar Islands, Lakshadweep and Puducherry.

Health benefits of coconut

People of coconut growing regions of the world have been relied on coconut for health and nourishment since time immemorial. In India, coconut in its many forms is used to treat a variety of health problems and to nourish the body.

Coconut water

Coconut water is the liquid endosperm of the nut. The tender coconut water is consumed as refreshing drink. It is a rich source of B- group vitamins, minerals, sugars etc. It is effective against gastroenteritis, diarrhoea, vomiting and to

prevent dehydration of body tissues (Rajagopal and Ramdasan, 1999). Coconut water contains major electrolytes such as potassium, sodium, magnesium, phosphorous and calcium required for the body. In the Indian ayurvedic medicine, it is described as "unctuous, sweet, increasing semen, promoting digestion and clearing the urinary path" (Rethinam and Kumar, 2001). Coconut water is traditionally prescribed for burning pain during urination, gastritis, burning pain of eyes, indigestion and hiccups or even expelling of retained placenta. Presence of L-arginine in coconut water has a cardio protective effect through its production of nitric oxide, which favours vasorelaxation (Anurag *et al.*, 2007). Concerning nutraceutical effects, coconut water reduce histopathological changes in the brain induced by hormonal imbalance in menopausal women (Rundorn *et al.*, 2009). Coconut water contains major phyto hormones such as auxin, various cytokinins, and gibberellins (Fonseca *et al.*, 2009) which can minimize the aging of skin cells, balance pH levels, and keep the connective tissues strong and hydrated. It is an excellent oral rehydration sports beverage - replaces electrolytes lost from exercise, heat stress and illness and aids in exercise performance. Natural isotonic beverage contains the same level of electrolytes found in human blood and has 15 times more potassium (264 mg/ 100 ml) than most sports and energy drinks (12.5 mg /100 ml) (Reddy and Lekshmi, 2014).

Coconut oil

Diversified utilities of coconut oil are hair care, skin care, healing, aromatherapy, weight loss, digestion, protection against heart diseases and infections. Coconut oil acts as effective moisturizer on all types of skin. It is effective in preventing dryness and flaking of skin and delays the appearance of wrinkles and sagging of skin which normally accompany aging. It is also effective against psoriasis, dermatitis, eczema and other skin infections (Vala and Kapadiya, 2014).

Lim-Sylianco (1987) studied the anticarcinogenic effects of dietary coconut oil. Antimicrobial activity of the monoglyceride of lauric acid (monolaurin) of coconut oil has been reported since 1966. Coconut oil is useful for slowing down the degenerative process by improving mineral absorption. Coconut oil also helps to supply energy to cells (because it is easily absorbed without the need of enzymes) as well as improve insulin secretion and utilisation of blood glucose (Garfinkel *et al.*, 1992).

Coconut milk

The medium chain saturated fatty acid (MCFA) of coconut milk is converted in the body into a highly beneficial compound called monolaurin, an antiviral and antibacterial agent that destroys a wide variety of disease causing organisms. According to the National Center for Biotechnology Information, lauric acid

has many germ fighting, antifungal and antiviral properties that are very effective at ridding the body of viruses, bacteria and countless illnesses (Baldioli *et al.*, 1996).

Coconut inflorescence sap

Coconut sap, normally called as neera, is a natural health drink, which is traditionally collected from coconut spadix. It is the phloem sap, rich in sugars, proteins, minerals, antioxidants, and vitamins. It is also a rich source of phenolics, ascorbic acid and essential elements viz. N, P, K, Mg and micronutrients viz. Zn, Fe and Cu. (Hebbar *et al.*, 2015). It is considered as a nutritious drink for cure of anaemia, tuberculosis, bronchial suffocation and piles. Because of the glycemic index, it is considered good for weight maintenance, preventing over weight and obesity and good for diabetic people (Maier *et al.*, 2003). It also has antihypertensive effect. Bhagya and Soumya (2016) revealed the significant effect of supplementing coconut neera in reducing systolic blood pressure among hypertensive adult women.

Scope of entrepreneurship development in coconut processing sector

Majority of the farmers engaged in coconut cultivation mainly have small and marginal scattered holdings. This hampers the prospects of processing and value addition in coconut. Presently, coconut growers are more exposed to economic risk and uncertainties owing to high degree of price fluctuations. Further, the mindset of traditional coconut grower is attuned to processing for copra and coconut oil. Coconut-based economy can expect a revival only when the profitability of coconut farming is delinked from the price behaviour of coconut oil. This is possible through efficient utilization of land under coconut cultivation and post harvest value addition activities.

India has not made tangible progress in product diversification and by-product utilization of coconut except for the traditional activities such as oil milling and coir processing. As a result, coconut oil continues to be the only major coconut product having influence on farm level price of coconut. Present level of value addition is 8% which needs to be increased to at least 25%. This situation can be transformed only when coconut based both edible and non-edible products gets priority over coconut oil. As compared to tardy growth recorded by the country in processing sector, most of the coconut growing countries are making profit from production and export of diverse coconut products. Philippines, Indonesia and Thailand realizes more than 50% value addition level, export over 40 non-traditional products of which coco chemicals, coconut milk products, coconut water based products, and shell and coir products are important.

Product diversification and value addition play a crucial role in the stabilization of coconut oil driven market and is essential for reorienting and energizing the coconut industry cost effective and globally competitive. Hence, there exists a huge scope for coconut based agri-business in India. Processing and related activities can mitigate the seasonal price variation and generate income and employment opportunities for over two million people in India.

Entrepreneurship development through coconut value addition

Coconut is mainly consumed as fresh nuts, tender coconuts, coconut oil and copra meal. Around 50 per cent of the world production is consumed in the form of fresh nuts and tender nuts. Close to fifty per cent of the nut production is converted into copra and consumed as coconut oil and copra meal. Around 2.52 per cent of the production is consumed as desiccated coconut. In India, annual consumption of tender coconut is about 200 million. Coconut palm also provides a series of by-products such as fiber, charcoal, handicrafts, vinegar, alcohol, sugar, furniture, roofing, fuel, etc. and it has more than 200 diversified local uses. Products and by-products of the crop form vital inputs for many of the industries and support the livelihood of many millions. They contribute a significant amount to the national revenue and country's exports by way of excise and export earnings. They also provide direct and indirect employment to a large number of people in the country. Potential of converting coconut into different emerging value added products such as desiccated coconut powder, virgin coconut oil, coconut chips, coconut milk, preserved tender nut water & coconut inflorescence sap into coconut sugar is realized in view of globalization over the traditional processed products of copra and coconut oil.

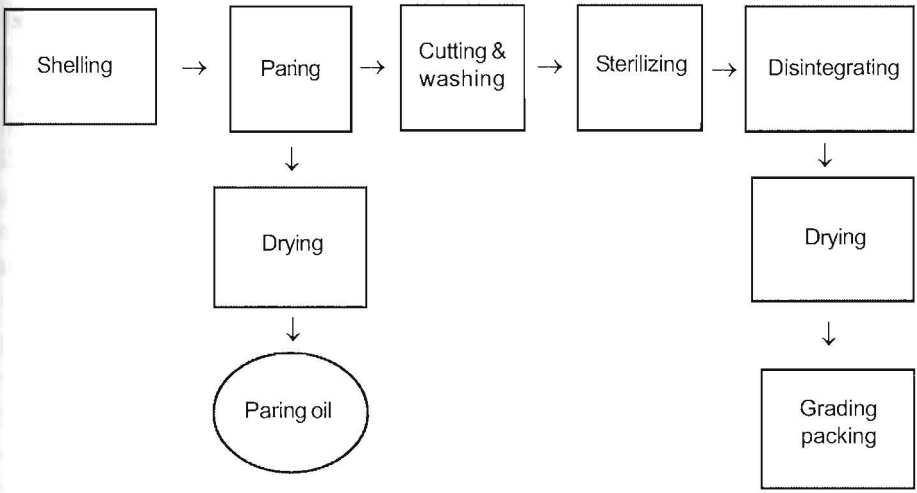
Value added food products from coconut can be broadly categorized as, those derived from mature coconut kernel, mature coconut water, tender coconut water, tender coconut kernel and coconut inflorescence sap.

Products derived from mature coconut kernel

Coconut reaches full maturity in about 12 to 13 months time after the opening of inflorescence. Mature raw coconut are used for culinary uses, religious purposes, making copra and manufacturing convenience products such as desiccated coconut, coconut milk, spray dried coconut milk powder, etc. About 40% of the Indian annual coconut production goes to culinary and religious purpose, 35% for copra production, 17% for tender nut purpose, 2% for seed purpose and only 6% is the share of value addition which comprises of desiccated coconut powder (4%), virgin coconut oil and coconut milk/ cream (1% each). Process technology for major value added mature coconut based products is described below.

Desiccated coconut

Shredded and dried white kernel or endosperm is marketed as desiccated coconut. The steps involved in processing of desiccated coconut involves selection, sorting and husking of coconut, shelling, paring, washing, sterilizing, grinding, drying, sieving, packing, and storage (Fig.1). The main uses of desiccated coconut are for the confectionary industry, as a filling for chocolates and candies; bakery industry for biscuits, cake and nut filling products; direct usage to decorate cakes, biscuits and ice cream and preparation of various snacks. During the year 2015-16, India exported 4261 MT desiccated coconut worth Rs. 52.60 crores. In comparison with the export figure of previous year, India achieved an increase to the tune of 60%, which indeed is a remarkable achievement. The flow chart of desiccated coconut powder preparation is described below.



Techno economic details

Machineries required	Coconut dehusker, desheller, testa remover, washing unit, inspection conveyor, blanching unit, pulverizer, fluidized bed dryer, desiccated powder cooler, lump breaker, vibro siever, packaging unit.
Capital investment	Rs.130 lakhs for processing 15,000 nuts per day
Yield	1 ton from 10,000 coconuts

(*Source:* Coconut Development Board)

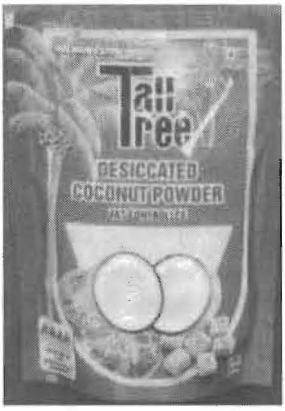


Fig. 1: Desiccated coconut powder

Virgin coconut oil (VCO)

It is the oil obtained from fresh, mature kernel by mechanical or natural means, with or without use of heat and absence of chemical refining, bleaching or de odourizing. It is called "virgin" because the oil obtained is pure, raw and pristine. It has a fresh coconut aroma ranging from mild to intense depending on extraction process. It is extracted directly from fresh coconut meat or from coconut milk. Different methods involved are hot-processing, natural fermentation, centrifugation and direct micro expelling. 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 market demand.

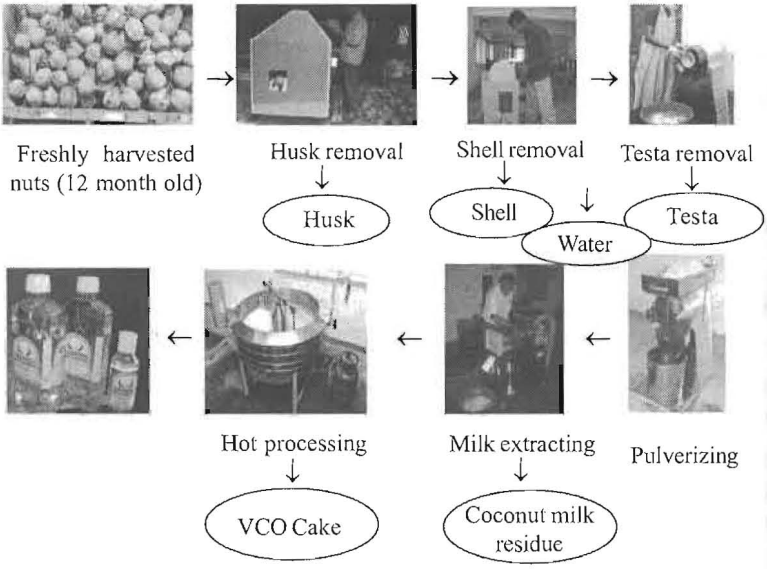


Fig. 2: Flow chart of VCO processing

ICAR-CPCRI has developed processing technologies for production of VCO by hot and fermentation methods. In hot process, coconut milk is cooked in specially designed cooker whereas in fermentation process, coconut milk is allowed to ferment in specially designed fermentation tank for specified period to get VCO. The process protocol is given in Fig.2.

Techno economic details

Machineries required	Coconut dehusker, Coconut desheller, Coconut testa removing machine, Coconut pulverizer, Milk expeller, VCO cooker, Vacuum dryer, Packaging system, Weighing balance, Miscellaneous items such as stainless steel containers, stainless steel containers with trolley attached and other vessels, electrical fittings, electrical water heaters etc
Total investment on machines for processing 500 nuts /day	Rs.15 lakhs (Hot process)Rs.12 lakhs (Fermentation process)
Unit production cost	Rs.420 per litre
Breakeven period	103 days
Net profit percentage	47.17%
Production details per year	VCO – 7500 litres (20% of kernel weight)Milk residue – 7500 kg VCO Cake – 1500 kgTesta – 1000 kg Husk – 60000 kg Shell – 20000 kg Water – 15000 litres

i.VCO based margarine

Technology for preparation of virgin coconut oil based margarine to be operated at small and micro level industries is reported to be patented by Indonesia. The process involves mixing of emulsifiers, stearine, antioxidants, β-carotene, water & salt with VCO, blending at 60°C for 10 minutes, filling, packing and cooling at 16°C (Fig.3). Product can be used as bread spread. It contains high lauric acid and no trans-fats.

Fig. 3: VCO based margarine

ii. VCO based mayonnaise

Mayonnaise is prepared by mixing coconut oil, vinegar or citric acid or emulsifiers. Carbohydrates, spices and flavour enhancers are added to modify the flavour and to avoid crystallization (Fig.4). Final formulation consist of 70% VCO, 6% natural vinegar, 7% fresh yolk and 1% emulsifiers and cooled boiled water.

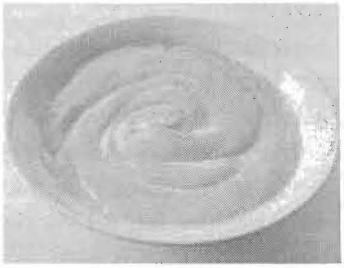


Fig. 4: VCO based mayonnaise

Mayonnaise production units can be commercially operated at home or micro level to enhance the income of farmer families.

Coconut oil

Coconut oil is one of the major edible products of coconut. This is referred as lauric oil in the world market because of its high lauric acid content. It is very heat-stable, and suitable for cooking at high temperature. It is slow to oxidize and resistant to rancidity for up to two years due to its high saturated fat content. Coconut oil is used in India for culinary/edible, toiletry, soap making and as an illuminant and lubricant.

The fresh kernel is dried to less than 6% moisture (copra) which is then expelled to get coconut oil. Copra is cut into small chips in a copra cutter. Chips are fed into steam jacketed kettles and cooked mildly at a temperature of 70°C for 30 minutes. After proper cooking, cooked material is fed into the expeller continuously and pressed twice. Combined oil from the first and the second pressing is collected in a tank. This oil is filtered by means of a filter press and stored in MS tanks and then bulk packaging is done in tin containers. HDPE containers and polymeric nylon barrier pouches are used for consumer packaging.

Techno economic details

Machineries required	Copra cutter, bucket elevator, steam jacketed kettle, oil expeller, screw conveyor, crude coconut oil storage tanks, filter press, micro filter, filtered oil storage tank, baby boiler, packaging unit.
Capacity	5 tons copra/day
Yield	3 tons oil
Total project cost	Rs.72 lakhs for 3 ton/d capacity
Plant & machinery cost	Rs.25 lakhs
Annual sales turnover	Rs. 315 lakhs
Net profit	Rs. 12 lakhs
Return on investment	28%

(*Source:* Coconut Development Board)

Coconut chips

Coconut chips are ready-to-eat, snowy white crisp and healthy non fried snack prepared from fresh kernel through osmotic dehydration in a forced hot air electrical dryer at 70-80°C for 5-6h to less than 3% moisture content. The kernels undergo paring, blanching, slicing and osmotic dehydration to prepare ready to eat chips (Fig 5&6). It contains 46% carbohydrate, 1.24% protein, 48% healthy fat, 6.13% fibre and 1.36% minerals. Method of drying on the basis of osmosis is used, in which partial dehydration in sliced form is brought about by dipping fresh kernel in sugar solution followed by hot air drying. This

is claimed to result in product with better flavour than freeze drying method at comparatively lesser cost. Hence, the resultant coconut chips give health promoting substances and do not pose any health hazard. Nutraceutical and medicated coconut chips can also be made by incorporating juice of beet root, carrot, ginger and pepper.

Fresh kernel of 8-9 months old coconut is to be used for making chips. Here, the index for selection of the nut is that the nut should be matured enough to be sliced. If it is too tender, slicing and testa removal is not possible. Important steps involved in the production of coconut chips are given below.

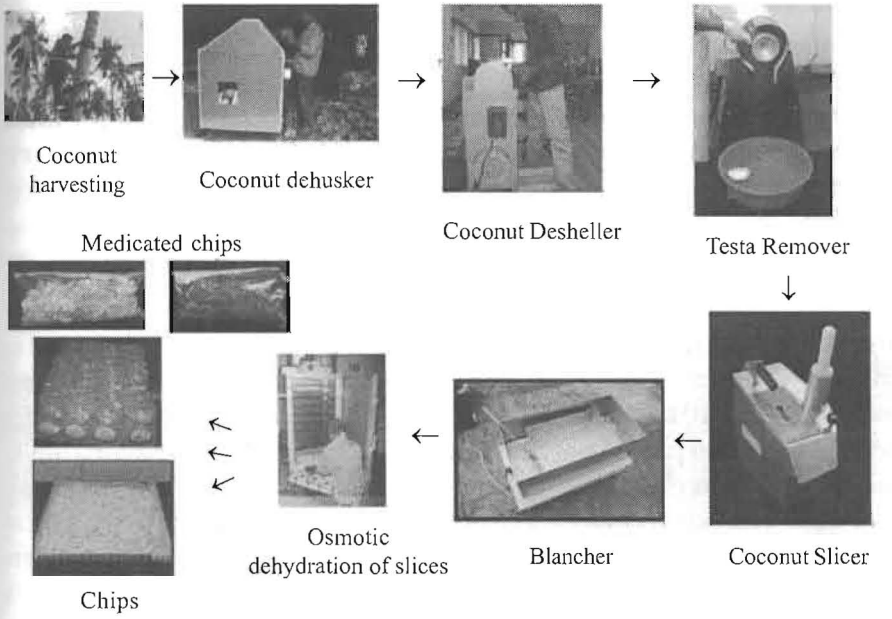


Fig. 5: Process protocol developed for the production of coconut chips

Techno economic details

Machineries required	Coconut dehusker, coconut desheller, coconut testa removing machine, multi commodity coconut slicer, blanching unit, plastic basin, filter, muslin cloth, vessel, gas stove, stirrer, solar dryer, electric dryer, heat sealing machine etc.
Capacity	250 coconuts per day
Total investment on machines	Rs.6 Lakhs
Unit production cost	Rs.8.45 / packet of 25 g
Breakeven period	56 days
Net profit percentage	57.71
Production details per year	Chips – 11250 kg Husk – 30000 kg Shell – 10000 kg Testa – 500 kgWater – 7500 litres

(Manikantan *et al.*, 2015)

Fig. 6: Coconut chips

Coconut milk

Coconut milk is an oil-in-water emulsion, stabilized by naturally occurring proteins (globulins and albumins) and phospholipids (lecithin and cephalin). In comparison with dairy milk, coconut milk is richer in fat, poorer in protein and sugar. Coconut milk can be used in curry preparation, confectionaries etc. It is utilised as a substitute of dairy cream in beverage type milk, and in evaporated and sweet condensed milk and in the preparation of white soft cheese, yoghurt and many other food stuffs (Sanchez and Rasco, 1983). Coconut milk contains 5.8% protein, 38 to 40% fat, 6.2% minerals and 9 to 11% carbohydrates.

First step is breaking the dehusked nuts into halves. Split nuts are deshelled to separate the kernel. Kernel is washed and then blanched by immersing in hot water at 80°C for 10 minutes. It is then pulverized after cutting into small pieces and is subjected to pressing using continuous screw press to extract the milk. Coconut milk thus obtained is filtered by passing through a vibratory screen. Food additives such as emulsifiers and stabilizers are to be added to the milk to obtain a stable consistency and texture. For this purpose, permitted emulsifiers and stabilizers are mixed with hot water separately and mixed thoroughly. This is added to the coconut milk and then subjected to emulsification using a mechanical impeller emulsifier. Emulsified milk assumes a creamy consistency. Coconut cream is then pasteurized at 95°C for 10 minutes in a plate heat exchanger. Pasteurized coconut cream is hot filled in cans using a mechanical volumetric filling machine followed by steam exhausting. Cans are seamed using an automatic can seamer. Seamed cans are sterilized in a rotary retort at 15 psi for 20 minutes. Cans are then cooled in running water (Fig. 7).

Techno economic detail

Machineries required	Hammer mill, elevator, screw press, coconut milk storage tanks, vibrating sieving machine, coconut residue mixer, additive mixing tank, emulsifier, homogenizer, pasteurizer, volumetric filling machine, exhaust box, can seaming machine, horizontal rotary retort, hot air drier, agro waste vertical boiler, sterilization tank, coconut residue storage bins.
Capacity	10,000 mature coconuts/day
Land	1 acre (cost variable)
Building - 6000 sq.ft @ Rs.1000 per sq.ft.	Rs.60 lakhs
Plant & machinery (does not include DG set, weigh bridge, effluent treatment equipment and other items not directly connected with process operation)	Rs.75 lakhs
Electrification	Rs.25 lakhs
Preliminary and pre-operative expenses	Rs.15 lakhs
Margin money for working capital	Rs.40 lakhs
Yield	2,500 kg coconut milk/500 kg coconut cream residue

(Source: Coconut Development Board)

Fig. 7: Packaged coconut milk

Spray dried coconut milk powder

Spray drying method is used for the commercial production of coconut milk powder. The product is packed in laminated foil bags and contains 62 per cent fat, 14 per cent protein and 2 per cent moisture which can be used in place of fresh coconut milk for food preparation/ beverages in household and food industries. Additives such as maltodextrin, casein or skim milk or corn syrup are added to the extracted milk and the mixture is pasteurized and homogenized before spray drying (Gonzalez, 1986). Such additives aid the spray drying process and help to convert a high fat coconut milk into flowable, but cohesive powders

through encapsulation of fatty substances (Seow & Leong, 1988). It can be reconstituted into coconut milk by diluting with water. It offers additional advantages like less storage space, enhanced shelf life and reduced packaging cost. Central Food Technological Research Institute, Mysore with the financial assistance of the Board has developed the technology for spray dried coconut milk powder.

Techno economic analysis

Machineries required	Hammer mill, coconut milk extractor/ screw press, coconut milk storage tanks, additive mixing tank, pasteurizer, homogenizer, spray drier, elevator, vibrating sieving machine, volumetric filling machine, horizontal rotary retort, sterilization tank, can seaming machine, agro waste vertical boiler, coconut residue mixer etc.
Capacity	20,000 coconuts per day
Land	60 cents
Building - 6000 sq ft.	Rs.45 lakhs
Plant & machinery	Rs.200 lakhs
Contingencies	Rs.10 lakhs
Preliminary & pre-operative expenses	Rs.15 lakhs
Working capital (margin money)	Rs.25 lakhs
Yield	1 ton of coconut milk powder

(*Source:* Coconut Development Board)

Coconut flavoured milk

Coconut milk is vegan alternative to dairy milk. Coconut milk does not contain lactose and is lower in carbohydrates than dairy milk, which can be consumed by people who are lactose intolerant or just don't enjoy the taste of dairy milk. Milk is extracted from freshly grated coconut of 9-10 months old. Extracted milk is clarified to remove suspended solids which are present in the milk. Coconut milk is then mixed with coconut water and diluted by adding purified drinking water until it is appropriate for flavoured coconut milk production. It is then mixed with 10-12% sugar, 2% stabilizers, emulsifiers and flavours. The flavoured coconut milk is then UHT sterilized at 138-140°C for about 15 seconds, which is then packed in sterilized polypropylene bottles (Fig 8).

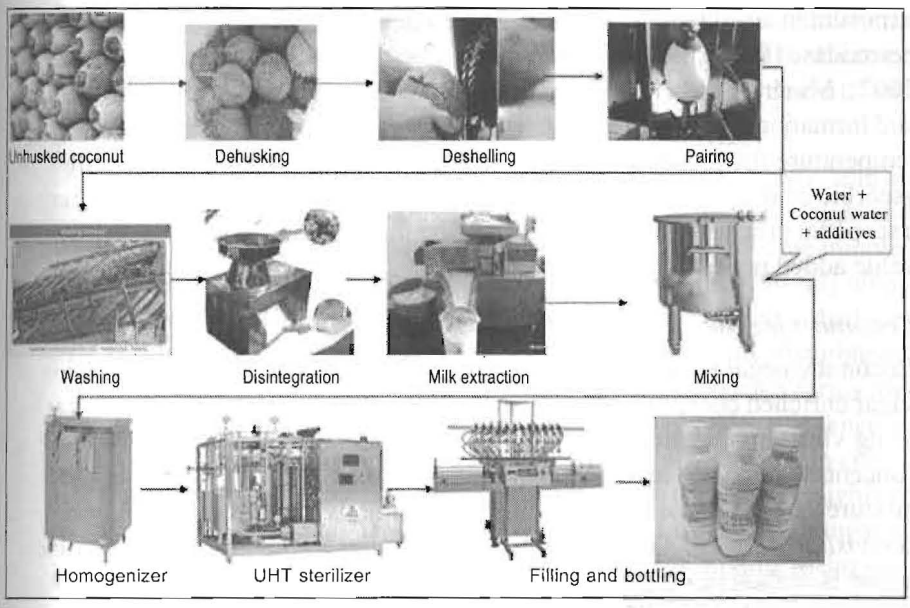


Fig. 8: Flow chart of flavoured coconut milk processing
(*Source:* http://coconutboard.nic.in/process.htm)

Techno economic details

Machineries required	Dehusking, deshelling, testa removing, blanching, pulverizing, milk expelling, filtration, mixing, agitation, homogenization, UHT sterilization.
Capacity	5,000 coconuts/ day
Yield	4000 litres flavoured milk
Cost of plant and machinery	Rs.132 lakhs
Total project cost	Rs.2.23 crores
Pay back period	4.5 years
Internal rate of returns	19%
Breakeven point	49%

(*Source:* Coconut Development Board)

Products derived from mature coconut water

Water obtained from mature coconut is usually disposed after dehusking, while kernel is used for production of coconut oil or coconut milk. Until recently, mature coconut water has been considered as waste, especially in coconut processing plants.

Water when taken out from the nut spoils within a day because of external contamination by microorganisms. Minerals catalyze lipid oxidation and results in free fatty acid (FFA) formation that affects aroma and quality of either fresh or processed coconut water. Even if coconut water is extracted aseptically, its

exposure to air initiates oxidation promoted by polyphenol oxidase (PPO) and peroxidase (POD), which are naturally present in coconut water (Duarte *et al.*, 2002). Minerals and electrolytes in coconut water also catalyze lipid oxidation and formation of volatile compounds. Hence, it is recommended that the storage temperature for processed coconut water should not exceed 4°C. Addition of ascorbic acid inhibits the activity of PPO and POD in coconut water. There is a scope for processing mature coconut water into different commercially feasible value added products.

Coconut vinegar

Coconut vinegar is the resultant product of alcoholic and acetic fermentation of sugar enriched coconut water. Coconut water can be converted into vinegar by using vinegar generators. Matured coconut water consisting of 1-3% sugar is concentrated to 15% level by fortifying with sugar after filtration. Pasteurized mixture is then cooled and inoculated with active dry yeast *Sacharomyces cerevisiae* (1.5g/L). After alcoholic fermentation for about 5 to 7 days, clear liquid is siphoned off and inoculated with mother vinegar or starter culture containing *Aceteobactor* bacteria. This acetified vinegar is then aged before bottling. Vinegar generator assembly comprises a feed vat, an acidifier and a receiving vat for collection of vinegar. Vinegar has extensive uses as a preservative in pickle industry and flavouring agent in food processing sector.

Techno economic details

Machineries required	Feed trough, vinegar acetifier, receiving trough, wooden storage drums
Capacity	100 litres coconut water/ day
Yield	100 litres vinegar
Land	25 cents
Total project cost	Rs. 6 lakhs
Building (Area - 750 sq. ft.)	Rs.3.0 lakhs
Plant & machinery	Rs.2.5 lakhs
Preliminary & pre-operative expenses	Rs.0.25 lakhs
Contingencies	Rs.0.20 lakhs
Margin money for working capital	Rs.0.25 lakhs
Annual sales turnover	Rs.4.0 lakhs
Net profit	Rs.0.8 lakhs
Return on investment	20 per cent

(*Source:* Coconut Development Board)

Nata-de-coco

Nata-de-coco is a translucent gelatinous product prepared from matured coconut water by the action of cellulose forming bacteria namely *Acetobacter aceti* sub species *xylinium*. *Acetobacter xylinum* metabolizes glucose in coconut

water that act as carbon source and converts it into extracellular cellulose as metabolites. The organism can be cultured either in coconut water or skimmed coconut milk. (Hagenmaier *et al.*, 1974). It is widely used in desserts and confectioneries especially in ice creams and fruit cocktails.

Coconut water is strained and mixed with sugar and glacial acetic acid in stipulated proportions (for every litre of coconut water, 100 g refined sugar and 5 g monobasic ammonium phosphate is added). It is then boiled for ten minutes and cooled. Then, add *Acetobacter xylinium* culture solution (150 ml) along with glacial acetic acid (10 ml) and fill in glass trays or wide mouthed jars covered with a muslin cloth and keep for 2-3 weeks without any disturbance. During this period, a white or cream coloured jelly-like substance forms and floats on top of the culture medium. At this stage, the jelly-like substance or Nata will be about an inch thick. Harvest this surface growth; slice into cubes, approximately 1x3 cm or according to requirement. Then, wash it thoroughly to remove the acid taste smell. Drain the nata and equal quantity of sugar is added, mix thoroughly and keep overnight. Next day, stir the mixture to disperse any undissolved sugar. Add small amount of water. Heat the mixture to the boiling point with occasional stirring. Any flavour material can also be added at this stage. Keep the mixture overnight and repeat the heating process until the nata is fully penetrated with sugar as evident by the clear and crystalline appearance of the sweetened nata and preserve in either tin containers or bottles. Optimum temperature for nata production is in the range of 23-32°C (Fig.9).

Techno economic analysis

Capacity	100 litres mature coconut/ day
Land required	5 cents
Building	Rs. 2 lakhs
Equipment/glassware	Rs.0.5 lakhs
Yield	20 kg Nata-de-coco
Annual sales turnover @ Rs.40 / kg	Rs. 3.75 lakhs
Net profit	Rs. 1 lakh per annum
Return on investment	40%

(*Source:* Coconut Development Board)

Fig. 9: Nata- de- coco

Bottled coconut water

National Institute for Interdisciplinary Science and Technology, Thiruvananthapuram has developed a process for the upgradation and preservation of mature coconut water. Main operation involves collection, upgradation, pasteurization, filtration and bottling. Process essentially consists of upgrading the flavour of mature coconut water to the level of tender coconut water by supplementation with additives including sugar and preserving it by a judicious combination of heat pasteurization and permitted chemicals.

Coconut water squash and ready to serve beverage

Coconut water squash and ready to serve beverage can be prepared from mature coconut water. The process involves filtration, heating, mixing with sugar, lime juice and ginger, cooling, mixing with preservatives (sodium benzoate) and packaging in sterilized bottles. It contains sodium, potassium, vitamin C and carbohydrate with a calorific value of 300 Kcal/100ml. The carbonated and non-carbonated beverages stored in aluminium and poly ethylene laminated packages has a shelf life of six months at room temperature.

Products derived from tender coconut water

Tender coconut water is the liquid endosperm, and is the most nutritious beverage that nature has provided for the people of the tropics to fight the sultry heat. It has a calorific value of 17.4Kcal per 100 g of water. It contains water (95.4%), protein (0.1%), fat (<0.1%), mineral matter (0.4%), carbohydrates (4.0%), calcium (0.02%), phosphorous (<0.01%) and iron (0.5mg/100g) (Fife, 2011).

Minimal processing of tender coconut

Once the tender coconut is detached from the bunch, its natural freshness will get lost within 24 to 36 hours even under refrigerated conditions unless treated

scientifically. The bulkiness of tender coconut is due to the husk which accounts for two-third of the volume of tender nut. (Haseena *et al.*, 2010). Technologies for minimal processing of tender coconut have been developed by Kerala Agricultural University (KAU) for retaining the flavour and to prevent discolouration. The process involves dipping (partially) dehusked tender coconut in a solution of 0.50% citric acid and 0.50% potassium metabisulphite for three minutes. The product can be stored up to 24 days in refrigerated condition at 5-7°C. By using this process, tender coconut can be transported to distant places and served chilled like any other soft drink. Optimized uniform size facilitates using of plastic crates and insulated chill boxes for transporting and storage (Fig. 10).

In Thailand, young coconut is trimmed, treated with 1-3% sodium metabisulphite and packaged with opener, straw and spoon. These are commercially produced, marketed and exported. The shelf life of processed young coconut is 45 days at 3-6°C or 3 weeks at 7 –10°C.

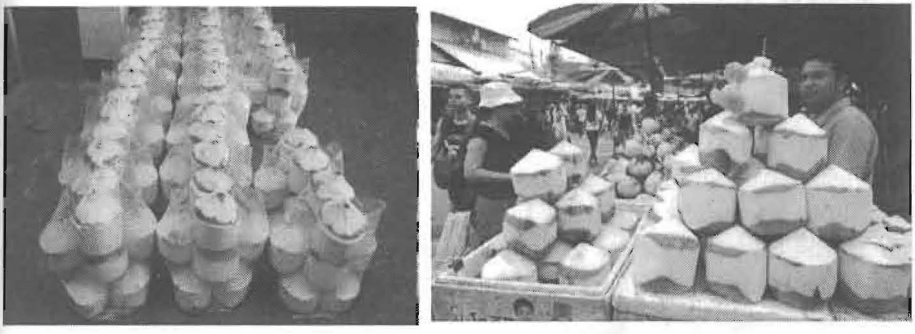


Fig. 10: Minimally processed tender nuts

Snow ball tender coconut

Snow ball tender nut is a tender coconut without husk, shell and testa which is ball shaped and white in colour. This white ball will contain tender coconut water, which can be consumed by just inserting a straw through the top white tender coconut kernel (Fig.11). Seven to eight months old nut is ideal for making snow ball tender nut in which there is no decrease in quantity of tender nut water and the kernel is sufficiently soft. Technology for preparing snow ball tender nut (SBTN) has been developed at ICAR-CPCRI, Kasaragod. This is served in an ice cream cup. User can drink the tender nut water by piercing the kernel with a straw. After drinking water, the kernel can be consumed using a fork. Coconut water is not exposed to the atmosphere and is natural and sterile.

The machine consists of a circular blade having 24 teeth of 8 mm width that rotates at a speed of 1440 rpm. The prime mover of the machine is a 0.5 HP

single phase electric motor. The prime mover attached with the circular blade is fixed on an angle iron frame with a covering made of mild steel sheet. A stop cutter box of stainless steel with a clearance of 15 mm is used to cover the circular blade. The adjustable stop cutter box helps the user to control the depth of cut and protects the user from possible injury while operating the machine. A flexible knife known as scooping tool also has been developed for scooping out the tender nut kernel from the shell. The scooping tool is made of nylon and is flexible at one end. The scooping tool is inserted in between the kernel and shell through the groove and is rotated slowly to detach the entire kernel from the shell.

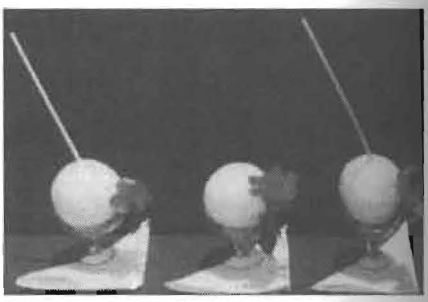


Fig. 11: Snow ball tender coconut

Packaged tender coconut water

Coconut Development Board (CDB) in collaboration with Defence Food Research Laboratory (DFRL), Mysore has developed a technology for preservation and packing of tender coconut water in aluminium cans/pouches with a shelf life of three months under ambient conditions and six months under refrigerated conditions (Fig.12). A tetra pack technology has also been established in Tamil Nadu. The products are available both in domestic and international markets. Major exporters of the product are Philippines, Indonesia, Malaysia and Thailand (Muralidharan and Jayashree, 2011).

Techno economic details

Machineries required	Mechanical washing system with conveyor, automatic boring and sucking system, ss filter/clarifier, collection tank, treatment tank, pasteurization unit, boiler, filling and sealing machine, shrink wrapping machine, air compressor, coding machine
Capacity	5000 coconuts / day
Total project cost	Rs.131.4 lakhs
Plant & machinery cost	Rs.65 lakhs
Internal rate of return	18%
Breakeven point (sales)	51%

(*Source:* Coconut Development Board)

Coconut water beverages

The processing technologies for coconut water beverages available are given below:

i. RRL technology

Regional Research Laboratory (RRL), Thiruvananthapuram/National Institute for Interdisciplinary Science and Technology, Kerala has developed a process for the upgradation and preservation of tender and mature coconut water. The main operations involve collection, upgradation, pasteurization, filtration and bottling. The process essentially consists of upgrading the flavour of mature coconut water to the level of tender coconut water by supplementation with additives including sugar and preserving it by judicious combination of heat pasteurisation and permitted chemicals. The drink can be carbonated and marketed as beverage.

Fig. 12: Packaged tender coconut water

ii. German technology

Spray evaporation Technique (SET) for making fruit juice concentrate developed by M/s Winter Umwelttechnik, Germany is adopted in this technology. The product retains all the original characteristics of juice such as retention of vitamins and enzymes, aroma, colour, taste etc. This technique was first used by M/s Miracle Food Processors International (P) Ltd. Perinthalmanna, Kerala for concentrating tender coconut water. Coconut water concentrate has a shelf life varying from 6 months to 24 months depending upon the degree of concentration. Ten liters of tender coconut water is required to make about 800g of concentrate. Aerated and bottled ready to drink coconut water beverages also can be made from coconut water concentrate.

Preserved tender coconut water

Preserved tender coconut water involves collection of coconut water, filtration, adjustment of pH, total soluble sugar and taste, pasteurization, filtration and packaging. Ultra filtration system can also be used to clarify tender coconut water. It can be packed in bottles. Bottled drink can be stored for three months at ambient temperature. A system for non thermal preservation of tender coconut water was developed using low ash filter paper and cellulose nitrate membrane which reduced the microbial population and retained the organoleptic properties. Since the tender coconut water is highly susceptible to heating, it is subjected to minimum heating and bio preservatives like Nisin is added, which helped in maintaining the natural pH of 4.9-5.2. Product has a shelf life of three months under ambient storage conditions.

Frozen coconut water

Fresh tender coconut water is collected under hygienic conditions and suspended solids and oil in the sample are removed by means of three-way centrifuge. Salts present in coconut water may be removed if desired, prior to concentration, to produce a very sweet product by centrifugation and passing the centrifuged coconut water through a mixed-bed ion-exchange resin. Ten litres of coconut water will yield about 800 g of concentrate. Concentrate can be frozen or preserved in cans and can be used after dilution to the desired strength. It can be used as base for the production of carbonated and non-carbonated coconut beverages. Concentrated coconut water is also used successfully in the brewery industry.

Tender coconut water jelly

Tender coconut water is a suitable option for the preparation of jelly as its delicate flavour can be well preserved in the form of jelly. Ingredients such as tender coconut water, sucrose and solidifying agent (china grass) are needed to prepare jelly. Standardized quantity and concentration are tender coconut water 1L, sugar-150 g (15% of tender coconut water) and china grass- 10g (1% of tender coconut water).

Tender coconut water is heated in a sauce pan with sucrose and china grass. Care should be taken to continuously mix the content during heating with a stainless steel spoon/ladle to melt the china grass in the tender nut water. Once it is completely melted, remove from the heat, cool it and pour in a wide mouthed vessel/tray and keep inside the refrigerator for about 3 hrs to solidify. After solidification, cut the pieces in cubes or squares and serve along with ice cream/ any other desserts as toppings.

Products derived from tender coconut kernel

Preservation of tender coconut kernel

Tender coconut kernel is a good source of carbohydrate, fiber and other nutrients. Protein content is high in the eight months old fresh coconut meat. Products such as tuty-fruity, candy, preserve and chips can be prepared from the fresh kernels. Tender nut kernel is made into pieces, mixed with cane sugar and subsequently drained and dried are called candied fruits.

Tender coconut is washed and split open to remove the water. Soft kernel is scooped out and cut into cubes. Pricking should be done with stainless steel forks. After pricking, immerse the fruit pieces in dilute lime water (1.5%) or alum (2%) for few minutes before further processing. Wash the pieces 3-4 times with fresh water and blanch for 5 minutes in boiling water to make them soft. This assists in absorption of sugar and prevents enzymatic browning. Spread sugar (50%) on the blanched pieces in alternate layers. Next day, drain the syrup and add enough sugar to raise the concentration of the syrup to about 60°Brix. Citric acid can be added as preservative. Process is repeated every day until the Brix of residual syrup reaches 70-75°. Then, drain the syrup and dry the pieces in hot air and store in glass bottles/polyethylene bags. To prepare crystallized candy the concentration of sugar syrup is continued till Brix value reaches 70-78°. Syrup is drained off and the pieces are rolled in finely ground sugar. Crystallized candy can be stored for 3 months (Lontoc *et al.*, 1973).

Canning of tender kernel

For canning, kernel from 8-10 months old nut is first scooped out, the adhering testa is removed by using a sharp knife and the pared meat is cut into stripes of 0.5 cm thick and 6 cm long after washing. The stripes are put in cans to which is added 50°B syrup with 0.01 per cent sodium metabisulphite. Filled cans are then exhausted at 78°C, sealed and processed at 110°C for about 20 minutes. A jelly like meat formed during the process is scraped out and to every part of the meat, a corresponding amount of refined sugar is added. Mixture is cooked in low heat until the sugar is totally dissolved, hot packed in sterilized bottles and closed tightly.

Tender coconut jam

Tender coconut jam is an intermediate moisture food prepared from the residual pulp left after removal of water from the kernels. It is a high-sugar coconut food product with light to dark brown in colour, thick and spreadable in consistency, with a rich creamy flavour. Coconut jam is prepared by boiling the pulp with sugar, pectin, acid, and other minor ingredients such as preservative, colouring, and flavouring materials, to a reasonably thick consistency. The desired

amount of sugar is added to the pulp mixture and heated continuously under low flame. When the total soluble solids reach 60°Brix, pectin (1.25 %) and citric acid (0.5 %) are added to the boiling pulp and the mixture is stirred continuously using a steel ladle. Heating can be stopped when the total soluble solids is 67–68°Brix. The hot mixture is filled into sterilized glass bottles and cooled under ambient conditions. Prepared jam can be stored for a period of 6 months at ambient temperature without compromising the quality. Chauhan *et al.*, (2013) studied the organoleptic properties and shelf stability of mixed fruit jam and the combination of tender coconut pulp and pineapple pulp in the ratio of 75:25 resulted in a jam with good organoleptic and textural characteristics. Jam with increased palatability and sensory acceptability can also be prepared with pineapple pulp and guava pulp with tender coconut pulp.

Coconut pulp ice cream

Tender coconut pulp can be used in ice cream formulation. The product is free from dairy milk, lactose and cholesterol with low fat. Formulation includes the following ingredients: coconut pulp, cocoa powder, sucrose, water, carrageenan gum, guar gum and hydrogenated vegetable fat. Liquid ingredients and the pulp are blended and heated in a tank until the temperature is 45-50°C, when the powdered ingredients are added. Then, the mix is pasteurized at 87°C for two minutes. After 24 hour of ageing, the freezing-whipping step is accomplished using shaved surface heat exchanger. Finally, the product is kept at -5°C to complete the freezing stage and stored at -18°C. Most satisfactory product had 41% coconut pulp, 11% cocoa, 17% sucrose and 31% water. The product contains 65% water, 1.0% fat, 2.4% protein, 0.36% ash and 31.2% carbohydrate (Igutti *et al.*, 2011)

Tender nut pudding

The ingredients for the tender nut pudding followed in ICAR-CPCRI contains coconut milk (100 ml), coconut sugar (15 g), china grass (1%), tender coconut water (200 ml) and tender coconut pulp (50 g). Initially, the china grass is mixed in tender coconut water in a sauce pan and is heated till it completely melts in coconut water. Then, add coconut milk and coconut sugar into it. Heat the contents for 15 min and immediately pour in a pudding dish or a tray. Add tender nut pulp (preferably cut in the form of small cubes) into the pudding mixture and keep inside the refrigerator. Maximum time required for complete setting of tender nut pudding is 1 hr.

Tender coconut water lemonade

Coconut water lemonade is a refreshing drink made of tender coconut water and lemon juice with addition of flavouring ingredients. The product contains

tender coconut water (500 ml), tender coconut pieces (100 g/1 cm^3), lemon juice (15 ml), ginger juice (2 ml), pepper powder (0.5 g) and coconut sugar (10 g). Tender nut is cut open to collect the water and the pulp is scrapped and cut into uniform sized cubes. Tender nut water is mixed with lemon juice, ginger juice, pepper powder and sugar. Mix well using a hand mixer at a low speed for 2 minutes. Then, add tender nut cubes into the lemonade and serve under chilled condition.

Products derived from coconut inflorescence sap

Coconut sap popularly known as neera is highly prone to fermentation, and collection of unfermented sap is a challenging task. This has been resolved with the development of CPCRI developed 'Coco sap chiller'. The sap collected by coco-sap chilller at low temperature is observed to be entirely different from the neera collected by traditional method with or without preservatives; hence, it was christened as "Kalparasa". Sap collected using the coco-sap chiller is golden brown in colour, delicious and free from contaminants like insects, ants and pollen as well as dust particles.

Coco-sap chiller is a portable device characterized by a hollow PVC pipe of which one end is expanded into a box shape to house a sap collection container bound by ice cubes and the other end is wide enough to insert and remove a collection container of 2 to 3 litres capacity (Fig.13). Each side wall of the pipe from outside is covered with an insulating jacket excluding the portion of spadix holder which retains the internal cool temperature for a longer period. This coco-sap chiller is lighter in weight, water proof, easy to connect to the spadix, requires less ice and retains low temperature for longer period as compared to commercially available ice boxes.

Kalparasa collected by coco-sap chiller under low temperature meets the Codex Alimentarius (International Food Standards WHO/FAO) definition of juice as "unfermented but fermentable juice, intended for direct consumption, obtained by the mechanical process from extractable fluid contents of cells or tissues, preserved exclusively by physical means". Thus, it is amenable to be sold as fresh juice under local market with the adherence to quality standards prescribed by CPCRI. It does not require lot of machineries but requires cold chain or refrigerated system

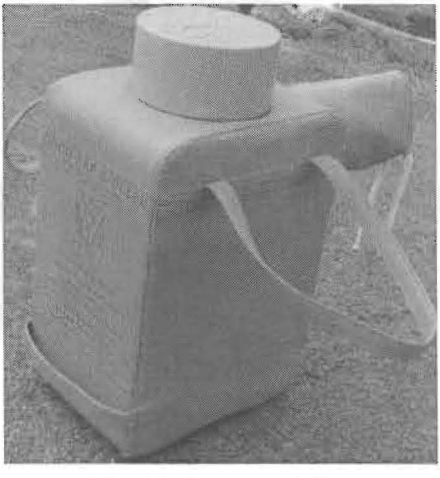


Fig. 13: Coco sap chiller

CPCRI has developed simple quality standards to check the quality of sap. Fresh sap has a pH above 7 to 7.5. Depending on the pH, sap can be used for different purposes. pH >7 is ideal for health drink, Ph >6.5 is good for preparation of sugar, pH >6.0 is used for jaggery and pH >5.5 is used for concentrate. pH below 5.5 can be used for the preparation of vinegar. Other quality parameters easily judged are brix around 14; colour golden brown; and taste sweet and delicious.

Distinct differences are noticed between the sap collected by traditional method and CPCRI technique (Table1 and Fig.14).

The collected sap can be stored for any length of time under sub-zero temperature. Deep freezers are used for the purpose. Sap gets frozen and just before use it is thawed to get the original liquid form. However, under refrigerators the quality gets deteriorated within few hours.

Table 1: Quality attributes of sap collected by CPCRI technique and traditional technique

Attribute	CPCRI technique	Traditional technique
Soluble solids (°Brix)	15.5 to 18	13 to 14
pH	7 to 8	6 or low
Colour	Golden brown or honey	Oyster white
Defects, decay, insects, pollen, dust	Absent	Present
Flavour	Sweet and delicious	Harsh odour
Pathogens, chemicals and extraneous matter	Absent	Present
Microbial load	Low	High

Fig. 14: Coconut sap collected by coco-sap chiller (left) and traditional method (right)

Techno economic details

Machineries/ devices required	Tapping gear (knives, tapping stick, scissor, mallet etc), o-sap chillers, neera collection ice box, ice carrying box, pH meter, measurement jug, neera storage container, neera transport box, freezer, neera dispenser etc.
Capacity	1000 liter of sap per day
Capital investment	Rs. 35,10,200
Operational cost per month	Rs. 75,875
Total cost of production	Rs. 1,06,91,785
Total sap production (l)	Rs. 3,65,000
Selling cost	Rs. Rs 50/ L
Unit cost of production	Rs. Rs. 29/L
Breakeven period	Rs. 176
Net profit %	Rs. 41.41

Coconut sugar

The hygienic, zero alcoholic sap collected by CPCRI method is easy to process in a natural way without the use of chemicals into various value added products which fetches premium price both in domestic and international markets. Very good quality coconut sugar, jaggery, nectar or syrup can be produced in double jacketed cookers with temperature regulation and stirring facility.

Coconut sugar (Fig.15) is the best natural sweetener with several health benefits and thus has a high market potential. It contains essential amino acids, minerals, electrolytes, dietary fibers and phenolics . Moreover, its glycemic index (GI) is low in the range of 35 to 54 GI/ serving.

Fig. 15: Coconut sugar

Techno economic details

Labour cost	Rs. 5,04,000
Total fixed cost	Rs. 20,19,975
Total variable cost	Rs. 1,01,72,500
Total cost of production	Rs. 1,21,92,475
Total sugar production (kg)	Rs. 54,750
Selling cost	Rs. 275/kg
Unit cost of production	Rs. 223
Breakeven period	Rs. 150
Net profit %	20

Kalpa bar

It is a coconut sugar based chocolate purely made from plant based ingredients without milk. It is a joint venture between ICAR-CPCRI and CAMPCO (Central Arecanut and Cocoa Marketing and Processing Cooperative Ltd.) (Fig. 16). It contains cocoa powder, coconut sugar, natural vanilla extract and GMO free sunflower lecithin. It is low in glycemic index. It is a delicious dark chocolate for a healthy life and can be stored under room temperature.

Fig. 16: Kalpa bar dark chocolate from coconut sugar

Kalpa drinking chocolate

It is an instantised blend of coconut sugar crafted from fine cocoa powder formulated to produce the delicious drinking chocolate (Fig.17). It is to titillate the taste buds of drinking chocolate lovers who want a healthier life style. The product is produced by a unique technology of instantisation and agglomeration technique that makes the product soluble instantly in hot or cold milk releasing the chocolate aroma.

Fig. 17: Kalpa drinking chocolate

Methodology for the preparation of fresh coconut inflorescence sap (Kalparasa) based milk sweets have been standardized at West Bengal (Fig 18). It is a way of transporting neera to long distance in the form of sweets. These sweets impart minerals, vitamins, valuable fiber which will not be available in normal cane sugar based milk sweets and their glycemic index is low.

Thus, various value added products can be prepared from Kalparasa which have huge demand in both domestic and international markets. As these products are nutritious, they fetch premium price which will in turn empower farmers/ growers who are dependent on coconut for their livelihood.

Fig. 18: Sweets prepared from Kalparasa

Diabetic friendly cookies

Diabetic friendly cookies are made with whole wheat, desiccated coconut or grated coconut and neera jaggery. Different types of cookies are possible by varying the main contents like oats, multigrain, arrow root, corn, whole wheat and spices. Cookies made with neera jaggery have a low glycemic index (GI 35). Ingredients to prepare wheat based cookies are wheat flour (5 kg), butter (3.25kg), powdered jaggery(5 kg), grated coconut/desiccated coconut powder (1.87 kg), baking powder (0.200kg), vanilla essence-(0.100kg) and salt.

Techno economic details

Machineries required	Oven and mixing unit
Cost of ingredients/cookie	Rs. 3.55/-
Selling price of cookies	Rs. 85/ packet of 7 cookies
Land	10 cents
Building (2000 sq. feet @ Rs. 1000/sq. feet)	20 Lakhs
Other civil works (internal roads, compound wall, water tanks+ neera jaggery making unit)	Rs. 2 Lakhs
Machinery and equipment	Rs. 13.49 Lakhs
Electrification	Rs. 0.50 Lakhs
Preliminary & pre-op expenses	Rs. 1.11
Working capital margin	Rs. 0.90
Net profit after tax on sales	Rs. 17.20 %
Payback period	3 yr 10 months
Selling price	Rs. 85 per pouch
Breakeven point (sales)	60.96%

(*Source:* Coconut Development Board)

New technologies/ innovations in value addition of coconut

Kalpa krunch

Kalpa krunch is a coconut milk residue enriched ready to eat extruded snack. It is prepared from 60% rice flour, 25% corn flour and 15% coconut milk residue (CMR) flour (Fig 19). It is coated with natural and healthy flavours. The flavours are formulated from ten different types of spices and vegetables including coriander, garlic, turmeric, clove, cinnamon, chilli, mint, cardamom, tomato and celery. Kalpa krunch is rich in dietary fiber, protein, fat and carbohydrate with antioxidant activity. The steps involved in extrusion process are mixing, extrusion (140°C extrusion temperature and 220 rpm screw speed), drying (130°C for 20 min), flavour coating and packaging. The torque should be maintained around 12-14 for uniform and high expansion ratio.

Mix all the raw materials in a laboratory mixer (Basic Technology Pvt. Ltd., India) for 15 minutes. Determine the initial moisture content of blend using infrared moisture analyzer. Spray calculated amount of water onto the flour blend before extrusion so as to achieve the required moisture content of 14% and blend again for 10 min.

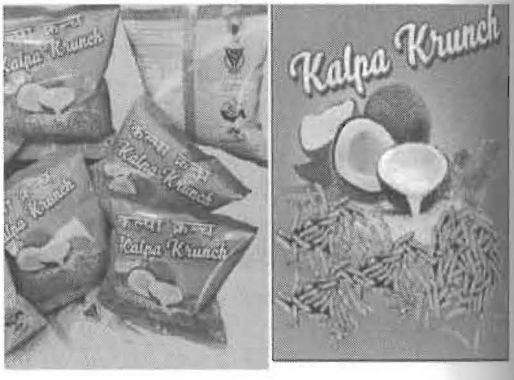


Fig. 19: Kalpa krunch

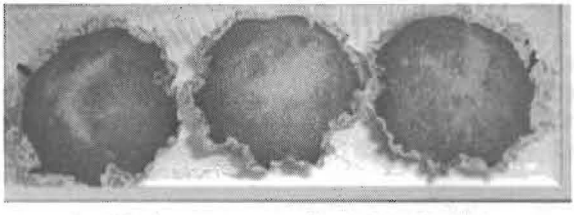
Extrude the prepared homogenous blends in a co-rotating twin screw extruder (Basic Technology Private Ltd, Kolkata, India). An extruder die with a diameter of 3 mm can be used for this purpose. The screw speed and barrel temperature of the last zone will be 220 rpm and 140°C. Collect the extrudates after 5 min of steady state processing and dry in a coating machine (M/s Pharma Fab Industries, Mumbai, India) at 130°C for 20 min. The dried extrudates can be coated with different flavours. The oil should be sprayed before coating flavours.

Techno economic details

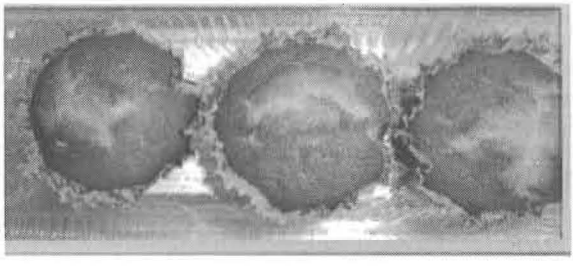
Cost of machinery	Rs. 44,00,000
Working capital	RS.47,80,000
Selling cost	Rs. 5/packet
Unit cost of production	Rs.3
Breakeven period	Rs. 131.9
Net profit %	21

VCO cake based muffins

Muffin batter formulations can be made by progressively replacing the refined wheat flour with VCO cake. The optimized formulation consist of refined wheat flour (26 g/100g) which can be replaced with 40% VCO cake flour, sugar (26%), egg (21%), full fat milk (13%), shortening (12%), sodium bicarbonate (1.1%) and salt (0.1%) (Fig. 20).



Muffin incorporated with 40% VCO Cake



Muffin made of refined wheat flour (Control)

Fig. 20: VCO cake based muffins

Conclusion

Coconut has the greatest importance in the national economy as a potential source of employment and income generation among the plantation crops. The demand for coconut is high because of its usage and the adaptability of coconut palm to grow under various climatic and soil conditions. With the use of coconut oil in the production of soap and margarine in Europe in the 19th century, it was converted into a commercial crop. In the beginning of 20th century copra was the king among the oil seeds. In East Indies it was known as green gold. However, the period after the Second World War saw the substitution of vegetable oils and oleo chemicals for coconut oil in international trade. Price of coconut oil fluctuated heavily due to frequent short supply situations. A campaign against coconut oil alleging that it causes cardiovascular diseases aggravated the situation. The newly industrialized countries in the East such as Taiwan, South Korea are fast emerging as key importers of coconut products. One of the main reasons for the fall in price of coconut and its products is dependency of price of coconut oil which again depends on the cost of other vegetable oils. Thus, product diversification of coconut and development of value added products become very important in the coconut industry. Effective market promotion activities are to be organized by way of organizing exhibitions, workshops and trade fairs in order to create consumer awareness and boost the demand of coconut products to keep the wheel of the coconut industry moving fast for doubling the income of coconut farmers for their sustainable livelihood.

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