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Avenues of value addition in Coconut, Arecanut and Cocoa

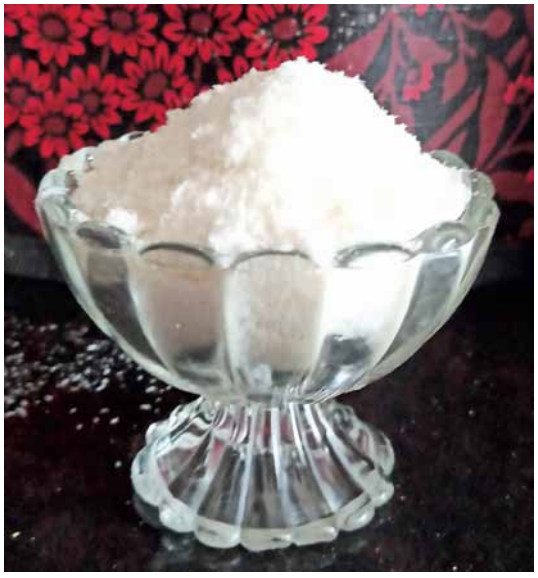
Coconut, arecanut and cocoa are considered major plantation crops and have been the mainstay of agrarian economies in the country. The products and by-products of these crops form vital ingredients for many industries and support the livelihood of millions. Adding value to farm products becomes imperative for rural growth by enhancing farm income and providing employment in the processing businesses. Apart from the main products, the by-products obtained from these crops have many alternative uses, thus adding to the total value of the crops. The by-products from these crops are spread in diverse sectors such as food, feed, shelter, decorative material, etc. This article focusses on the by-product utilization of coconut, arecanut and cocoa as a source of value addition to farmers and entrepreneurs.

THE by-products obtained from the major plantation crops have been discussed below:

Coconut

The principal value-added edible coconut products are coconut oil, desiccated coconut, virgin coconut oil, coconut chips, tender coconut, coconut inflorescence sap, and coconut sugar. Several by-products are generated while processing these value-added products, which have immense health benefits and offer scope for further value addition. These by-products are obtained from mature coconut, tender coconut, coconut inflorescence, etc., which could be of edible and non-edible nature. The different by-products and their commercial utilities are presented below.

By-products derived from mature coconut: In the coconut processing chain, virgin coconut oil (VCO), is one of the major value added products, and a number of by-products such as husk, shell, testa, nut water, coconut milk residue, and VCO cake are obtained. During VCO processing, 500 nuts yield about 200 kg of husk, 67 kg of shell, 50 L of nut water, 3.3 kg of testa, 25 kg of milk residue and 5 kg of VCO cake. The husk has immense utilities in coir industries, in the preparation of potting mixtures. Shell charcoal, activated carbon, and shell flour are the commercial products obtained from the shell. Mature coconut water is commercially utilized for the preparation of vinegar, the production of *nata de coco* and soft drinks or squash. Coconut testa is enriched with phenolic compounds and appreciable antioxidant activity and hence used as an ingredient in high-fibre digestive biscuits. Milk residue and VCO cake are the two co-products, presently underutilized or discarded as waste. In addition to VCO, husk, shell, water, and testa are the common by-products obtained during the processing of other major value added products such as desiccated coconut, coconut milk, etc.



Low fat desiccated coconut flour

Kalpa Krunch

Coconut milk residue (CMR): It is the leftover residue following coconut milk extraction, the process involved

in producing coconut milk or virgin coconut oil (VCO). The per cent recovery of CMR ranges from 38.5 to 55.6%. CMR at 2.9% moisture level contains 46.5% dietary fibre, 5.3% protein, and 49.2% crude fat. It has four folds more fibre than oat bran, a couple of times higher than wheat bran, and is calorie-free. It is loaded with nutrients and free from gluten and phytic acid. It is also a source of polyphenolics with immense antioxidant activity. As a source of dietary fibre, it can improve bowel movement and protect against coronary heart diseases, colon cancer and diabetes.

Low fat desiccated coconut flour: CMR is marketed as low-fat desiccated coconut flour having a moisture percentage of 3-5%. It can be used as fillers, bulking agents and as a substitute for wheat flour, rice flour and potato flour and incorporated into baked and extruded food products. Flour made out of CMR is incorporated (10-15%) into various products including biscuits, cake, ladoo, etc.

Extrudates: CMR flour could be utilized for the preparation of extruded snacks. CMR-based cereal snack was formulated at the ICAR-CPCRI. It was found that 20% milk residue was optimum for preparing extruded snacks using broken rice, maize and pearl millet in a twin screw extruder. The product had good acceptability with a maximum shelf life of 6 months when packed in laminated pouches. The product was commercialized as *Kalpa Krunch*. It is a healthy, nutritious, and ready-to-eat snack for people of all age groups since it is rich in dietary fibre, protein, minerals and antioxidant properties.

Pasta: CMR was utilized as a partial substitute for wheat in preparing fibre-enriched pasta. Studies conducted at CPCRI suggest that 10% of the durum wheat semolina could be replaced with CMR. Incorporation of CMR along with durum wheat semolina positively influenced the cooking, colour, textural attributes, and overall sensory acceptability of pasta. However, the firmness of the pasta gets reduced with an increased concentration of CMR beyond 10%. CMR fortified pasta can provide more than 50% of the recommended dietary allowance of fibre besides enriching the protein content of pasta.

Biscuits: CMR can be incorporated into wheat flour for the preparation of biscuits and cookies, and to enhance the crunchiness of these products. ICAR-CPCRI has developed biscuits from CMR and jackfruit seeds. The optimized combination comprise 50% wheat flour, 20% CMR, and 30% jackfruit seed flour along with coconut sugar. Kishi Vigyan Kendra, ICAR-CPCRI, Kasaragod also developed a CMR-based biscuit along with wheat flour, butter, and sugar.

CMR pasta

CMR biscuits

CMR and VCO cake infused dark chocolates: Kalpa 'bean to bite' dark chocolate developed and released by ICAR-CPCRI comprises 45% cocoa nibs, 30% coconut sugar, and 25% cocoa butter. CMR and VCO cakes partially substituted the expensive ingredient of chocolate, cocoa butter, as a source of fat which doesn't melt at ambient temperature besides enriching the nutrient content.

CMR and VCO cake infused dark chocolate

CMR-based sweets/ladoo: The recipe for the preparation of CMR-based ladoo includes, 25% CMR, 32% sucrose, 12% desiccated coconut, and 7% refined wheat flour, 12% shortening (vegetable fat), 9% water, and 3% cashew nuts. The mixture was heated until it reached the consistency essential for shaping into a ladoo.

CMR-based ladoo

In addition to these value-added food products, wet CMR can be mixed with other agricultural farm wastes and animal manure, with or without the addition of microbial inoculums, to produce organic fertilizers.

Mature coconut water: Mature coconut water has been considered a waste, especially in coconut processing plants. The liquid causes environmental pollution and is also a waste of valuable food. The most economical and practical way to enhance the value of coconut water are preparing vinegar, using it as a growth medium for yeasts, xanthan gum production, for the culture of various lactic acid bacteria or in *nata de coco* production. In addition, it can be marketed as a natural soft drink or non-

carbonated beverage following appropriate preservation and packaging strategies. Alternatively, mature nut water could be converted into concentrates (800 g from 10 L) for use in food industries. For instance, mature coconut water-based dessert (jelly), commands a huge demand in the domestic market.

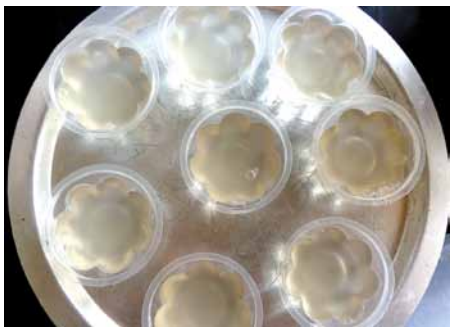
Coconut water-based vinegar: It is the product of the alcoholic and acetic fermentation of sugar-enriched coconut water. After filtration, matured coconut water with an initial sugar content of 1-3% is concentrated in a boiling process to 15% by fortifying it with sugar. The pasteurized mixture is then cooled and inoculated with active, *Saccharomyces cerevisiae* (1.5 g/L). After alcoholic fermentation (22–27 °C) for about 3-6 days, the clear liquid is syphoned off and inoculated with mother vinegar or a starter culture containing acetic acid bacteria and the acetified vinegar is then aged before bottling. Vinegar is used as a preservative and as a flavouring agent in the food processing sector.

Natural vinegars

Mature coconut water-based squash: Squash is an unfermented beverage generally made from fruit pulp or juice (at least 25%) and is diluted before serving. The standardized coconut water based formulation consists of coconut water, sucrose, citric acid, and a combination of lemon and ginger with or without preservatives. The prepared coconut water squash can be served as a 1:3 dilution in water.

Coconut water jelly: Mature coconut water could be converted into a semisolid by increasing the total soluble solids to 8-10°Brix with sucrose, followed by the addition of a gelling agent such as agar agar, pectin, or gelatin at a 1% concentration.

Coconut water Squash



Coconut water jelly

Coconut testa: Coconut testa, a brown skin covering of a coconut endosperm, is a rich source of phenolics.

Coconut water-based Jelly

Jelly infused with testa-based colourants

Coconut jelly with testa-derived colourant

It constitutes 2-7% of the whole coconut. Coconut testa has multiple phenolic acid and flavonoids with potent antioxidant activity. A direct solvent and ultrasonication assisted extraction yielded biocolourant from coconut testa. The colourant was infused in coconut water based jelly.

VCO cake: It is the residue obtained during the preparation of VCO in hot process. The brown-coloured VCO cake is rich in protein, fat, crude fibre, and dietary fibre. It can be utilized for protein enrichment in snacks and VCO cake incorporated extruded snack was prepared with a biochemical composition of 11.14% protein, 5.07% fat, 2.3% ash, and 74.19% carbohydrate using maize and broken rice (2:1). Because of its high protein content and sweet taste, it can be utilized in preparation of confectionary products such as cakes, muffins, etc. VCO cake can be used to replace 40–50% of the refined wheat flour used in confectionaries. Refined wheat flour (26 g/100 g) was replaced with 40% VCO cake flour, sugar (26 g/100 g), egg (21 g/100 g), full fat milk (13 g/100 g), shortening (12 g/100 g), sodium bicarbonate (1.1 g/100 g), and salt (0.1 g/100 g) were used in the development of a muffin formulation.

VCO cake incorporated extrudate

VCO cake-muffins

Coconut haustorium: It is a spongy tissue found inside the germinated coconuts, which is rich source of nutrients including fibres, minerals and antioxidants. Haustorium is discarded while the mature nuts are processed for coconut oil extraction. It has two distinct portions, the outer oil-rich yellow portion and inner carbohydrate-rich white portion. Completely dried haustorium (270 g from 400 g of fresh haustorium) can be mixed with cereals and marketed as health supplement. In addition, haustorium powder (20%) can be incorporated to make extrudates along with corn (30%) and rice (50%).

Coconut cabbage (Heart of palm): Palm cabbage, or heart of palm, is an underutilized, nutritious edible product of palm trees. Palm cabbages are relatively rich in protein and contain 17 amino acids. They are low in fat and sugar and are an excellent source of dietary fibre, moderate source of calcium and high concentration of vitamins and minerals. Fresh hearts of palm are good source of 'heart healthy diet' because of very low fat, no cholesterol, and low sodium contents. It is sometimes referred to as the 'millionaire's salad' and is also used in vegetarian spreads. It is minimally processed into ready-to-use salads. Application of minimal processing using pre-treatments such as blanching and sugar solution, the shelf life of palm cabbage could be enhanced.

Vinegar from coconut inflorescence sap: Coconut inflorescence sap is a healthy drink and the sap extracted from the CPCRI technology is known as *Kalparasa*®. Bottled ready-to-drink sap, coconut syrup, honey, jaggery and coconut sugar are the value added products from sap. The partially fermented sap is also marketed as 'toddy' Fermented sap is processed into natural vinegar loaded with nutrients and phytochemicals in addition to acetic acid content.

Byproducts from coconut shell and husk

Charcoal: The most important produce derived from coconut shell is charcoal. Charcoal is an indispensable industrial commodity, especially in metallurgy and as an adsorbent. Development of the chemical industries and legislative measures aimed at preserving the environment has markedly increased the application of charcoal in the purification of industrial waste. In the barbecue fuel market, charcoal has little competition, and in almost all other applications, charcoal could be substituted by coal, coke, petroleum coke or lignite. Coconut shell charcoal is one of the best fuels for cooking because of its pleasant smell. The yield of shell charcoal is about 30% of the weight of the shells, and it is generally reckoned that about 17,000-24,000 whole shells make one metric tonne of charcoal. Shell charcoal is made by burning clean, fully dried and matured coconut shells in a limited oxygen supply. The drum and pit methods are the most widespread among the different methods of producing coconut shell charcoal.

Coconut cabbage as raw and salad

Activated carbon: Activated carbon is a carbonaceous, highly porous adsorptive medium that has a complex structure composed primarily of carbon atoms. Coconut shells are mainly used for manufacturing of activated carbon. Activated carbon plays a very important role in solvent recovery processes, water and effluent treatment and in treatment of flue gas before discharge into the atmosphere. The intrinsic pore network in the lattice structure of activated carbon allows the removal of impurities from gaseous and liquid media through adsorption. This is the key to the performance of activated carbon.

Chemical activation or high temperature steam activation mechanisms are used in the production of activated carbon. In the activation process, shell charcoal is fed continuously into a retort. The normal activation process involves the use of steam at selected temperature for the selective oxidation of material, resulting in production of carbon with pores of molecular dimension. Approximately, three tonnes of shell charcoal is needed to produce one tonne of activated carbon. Retorts designed to produce activated carbon usually operate in one of the three ways-vertically, horizontally, or by means of a series of hearths.

Shell flour: The coconut shells are available from all coconut-producing states in India, namely Kerala, Tamil Nadu, Karnataka and Andhra Pradesh which contribute more than 90% of the production in the country. A second important product derived from the shell is shell flour. It is prepared by grinding clean coconut shells to a fine powder, the particle size depending on the end use. The shell powder is a by-product of coconut oil industries and individual households. The powder has various uses as a filler in synthetic resin glues, filler and extender in phenolic moulding powders, a burning medium in mosquito repellent coils, mastic adhesives, resin casting, bituminous products, etc. Coconut shell powder finds its applications in manufacturing mosquito coils as a burning medium.

Coconut husk biochar: Coconut husk is one of the important by-products of coconut tree and coconut-based activities. Husk is the outer fibre (35%) of the nut, followed by the hard protective shell (12%). Except the husk obtained during de-husking at household level, the entire husk, including the unorganized marketing sector, reaches the coir industry, where it fetches a market value. In the coir industries, fibre is extracted from coconut husk. The thickness of the husk of an ordinary nut varies from 2.5-3.0 cm in thin-husked nuts to 4.0-5.0 cm for thick husked ones.

Coconut husk, especially tender husk, is a bio-waste which accumulates on the road sides. ICAR-CPCRI has standardized a protocol for the preparation of coconut husk biochar which could be utilized for crop production

Husk biochar

without any concern of environmental pollution. It is the carbon-rich product obtained by the thermal decomposition of organic material under a limited supply of oxygen. Biochar production systems are generally classified as either pyrolysis or gasification systems. Two types of prototypes that utilize pyrolysis and gasification systems were fabricated. The technical performance of the pyrolysis method was much inferior to that of the gasification method.

Arecanut

Arecanut, also known as '"betel nut"', is the kernel obtained from the fruit of the arecanut palm. It is mostly a masticatory and forms an integral component of several religious, social and cultural functions of India. The fruit has a fibrous mesocarp and seeds with a truncate base, and the endosperm deeply ruminates with a basalar embryo. Arecanut is reported to have pharmacological properties, which may be attributed to its biochemical components such as polyphenols, alkaloids, polysaccharides, fat and proteins. Arecanut extract possesses potential anti-oxidative activity and inhibition of free radicals and reactive oxygen species. Other parts of the arecanut palm, like sheath, stem, leaf, etc., are used in farms and households for manuring, packaging, construction, etc. The major arecanut products are *kalipak*, *kottappak*, scented supari, etc. There are several by-products of arecanut which have huge commercial potential.

Arecanut plates: There is a tremendous commerce potential for preparing bio-degradable, eco-friendly plates from arecanut leaf sheaths. Farmers in Karnataka, Kerala, Tamil Nadu and Andhra Pradesh have started this venture. Arecanut plating involves various activities such as collecting arecanut leaf sheaths, drying and washing the leaves, plate making, packaging and marketing. Currently, these biodegradable plates are exported to many countries, including European countries, UAE, etc.

Other uses of leaf sheaths: Every year 5-6 leaves are shed from each palm, and it is expected that about 1000 million leaf sheaths, weighing about lakhs of tonnes, are available annually in India alone. Leaf-sheaths can be used as an alternate feed for cattle. Farmers are using arecanut leaf sheath fodder as cattle feed, considering the nutrient richness. Other possible uses of the arecanut leaf sheath are for making ply boards, veneer boards and picture mounts, decorative panels of wooden almirahs and teapotys, house sandals, file boards, bags, trays, spectacle cases, etc. Areca leaf sheath and husk could be used as a substitute for growing *Pleurotus* sp., (an edible mushroom).

Tannins: Arecanut contains 17-35% tannins depending upon its maturity. Tannins obtained as a by-product from preparing immature nuts for masticatory purposes could be utilised successfully for a wide range of leathers. Whole nut tannins have better tanning properties. Long before the nature and properties of tannins were determined, tannins in arecanut were used for dyeing cloths, rope, etc. and tanning leather in South-east Asia and Pacific Ocean countries. Tannins extracted from defatted arecanut were of better quality and percentage recovery. Tannins are used as an adhesive in plyboard manufacture and as a textile dye. It is also used in the clarification of beer, extraction and purification of germanium ores, manufacture of adhesives, flocculation in water treatment, manufacture of corrosion inhibitors and floral foams, removal of chlorine from the air, as an antioxidant, and used in the preparation of commercial inks by combining with salts of iron.

Arecanut husk: After extracting the kernel, the husk remains an almost waste product. It is used as cheap, inferior fuel and mulch. About 1,00,000 tonnes of dry husk are estimated to be available annually in India. In Indonesia and the Philippines, the husk is utilised for making toothbrushes. The husk fibres are predominantly composed of cellulose with varying proportions of hemicellulose (35-36%) and protopectin (1.5-2.1%). The average filament length of areca husk fibre is too short (2.4 cm, C.V. 30%) compared to the filament in jute yarn (68 cm, C.V. 75%). Areca husk fibres consist of mostly two types of filaments, very coarse and very fine. Spinning trials with standard jute and coir machinery were not quite successful. However, non-woven fabric using synthetic rubber latex as a binding agent at 8% concentration could be prepared. Areca husk fibre could be used to manufacture thick boards, fluffy cushions and non-woven fabrics.

Several studies were conducted to see if arecanut husk could be utilised to prepare hard boards and plastics. Insulation and hard boards of satisfactory quality were prepared from areca husk. These boards were compared favourably with standard boards like Masonite in respect of thermal conductivity, thickness, density and strength but water absorption and swelling properties were not satisfactory. Arecanut husk could be used for the production of activated charcoal and xylose. Fibre boards and plastic boards can also be prepared from arecanut husk. Insulation wool can also be produced, and it is useful in thermal insulations, acoustical correction, packing, etc. A soft cushion pad prepared from the green husk (with 5% NaOH solution for 30 min) could be used as packaging for books, for making cushioned envelopes, soft boards, etc. Brown wrapping papers in satisfactory yields and

quality could be prepared from blends of arecanut pulp and bamboo or banana pseudostem pulp. Kraft paper can also be made by blending areca pulp with bamboo pulp (3:1 ratio) and the kraft paper has comparable physical properties to paper made with the pure pulp of bamboo. Possibilities exist for utilising areca husk as manure as it contains 1.0-1.1% N, 0.4-0.5% $P_2 0_5$ and 1.0-1.5% K_2O. Hence it could be a good organic manure if properly composted.

Arecanut stem and leaf: Arecanut stem is a useful building material in the village and is widely used throughout south and south-east Asia for various construction purposes. Arecanut stem, owing to its hardness, is widely used as a building material in rural areas. Stationary articles like rulers, shelves, waste paper baskets, etc., could be made from stem. Nails made of areca stem are widely used in the furniture industry. Hollow stems lend themselves to drainage and irrigation pipes in the villages. Leaves are a good source of organic manure and also used for thatching the roofs in villages.

Cocoa

The beans make up about 33% of the fruit by weight. Many by-products of cocoa could be generated from the rest of the fruit, and that could form the basis of small- and medium-scale industries in cocoa-producing countries.

Cocoa pulp juice (Sweatings): Cocoa beans are surrounded by an aromatic pulp that arises from the bean teguments. Pulp is composed of spongy cells containing cell sap rich in sugars, citric acid, and salts. After harvesting, the ripe pods are broken open and the beans removed are placed in baskets for transport to fermentaries. The bruising of the pulp during handling and the pressure of the weight of the mass release some of the pulp juices, which trickle from the collected bean mass as a slightly turbid, whitish liquid. This liquid is known in the industry as cocoa pulp juice or sweatings. Often this is consumed by labourers and children as a refreshing drink. It can be made into jelly and juice.

Cocoa pulp juice contains between 10-18% of fermentable sugars. The pulp juice can therefore serve as a suitable medium for fermentation. Fermentation of the sugars in cocoa sweatings by naturally occurring yeasts led to the production of alcohol and blended into gin and brandy of the finest quality. The wine was developed from cocoa sweatings by pasteurizing the sweatings to destroy these natural yeasts and introducing specific wine yeast.

Cocoa pod husk: Cocoa pod husk is the leftover pod material of the matured cocoa fruit after the wet cocoa beans, sweating, and placenta have been removed. It is often discarded as waste/residue while processing raw cocoa beans on the farm. After removing the beans, the pod is about 75% of the weight of the whole fruit. The amount of protein and fibre in the pod is closely related to grass hay, which suggests that this by-product could be used in feeding ruminant animals. When the pod meal was fed, milk production was just as high as when the cows were fed on corn. It has been reported that pods had been used with good results as an ingredient in pig feed, but that with cows, the results were not satisfactory. The pods have a very much lower content of bromine than the cocoa shell and are therefore less dangerous as a feedstuff.

Most growers leave the empty pods to rot on their farms. While this should have been a good practice, as it would return nutrients to the soil, the pods also serve as a reservoir for the causative agent of the cocoa black pod disease. As a result, farmers are encouraged to remove the pods from their farms after harvesting. CPH ash has, however, been convertedd into a potassium-rich fertiliser by the addition of starch and then pelletising the mixture.

Cocoa bean shell: The seed coat, testa, or cocoa bean shell is removed during the processing of cocoa beans. Cocoa shell has been used from time-to-time as feeding stuff, and its value is about that of good roughage. It has, however, an advantage over roughage in being a good source of vitamins. Untreated cocoa bean shells could be included in rabbit diets at a level of 100 g/kg. After treatment with hot water, however, it could be included at 200 g/kg. The major use of cocoa bean shells is as mulch. This mulch contains approximately 2.5% nitrogen, 1% phosphate, 3% potash, and a natural gum that is activated when watered. This enables the cocoa shell mulch to slow soil moisture loss through evaporation and retarding weed growth. The texture of the cocoa shell also deters slugs and snails and helps prevent plant damage. Cocoa bean shell mulch has been implicated in methylxanthine toxicosis in dogs. Methylxanthine is the breakdown product of bromine, one of the main alkaloids in cocoa.

Cocoa meal: The cocoa meal comprises fragments of the bean collected from the chocolate factory. The crude protein content is about 26% for the extracted meal. The quantum of cocoa bean shells that are incorporated in the meal may affect the meal composition of the cocoa meal. It has the essential amino acid index (EAAI) of 65·5. The apparent digestibility coefficients of the proximate principles have been found to be 37% for crude protein, 40% for nitrogen-free extract (NFE) and 89% for ether extract when fed to cattle.

CONCLUSION

Enormous potential exists for utilising by-products of coconut, arecanut and cocoa processing into diversified value-added products for income generation and livelihood enhancement. Many such products are found to be healthy and environmentally friendly. Thus, the by-product utilisation of these crops assumes significance in the present era. It paves the way for employment generation at the respective production catchment areas. Effective market promotion activities such as exhibitions, workshops and trade fairs should also be organised to create consumer awareness and boost the demand for these by-products to keep the wheel of the industry moving fast for doubling the income of farmers for their sustainable livelihood.

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