

PROCESSING TECHNOLOGY FOR COCONUT BY-PRODUCTS, UTILIZATION AND VALUE ADDITION

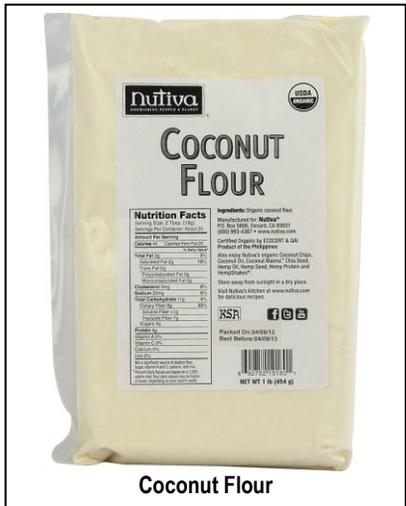
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Each component of the coconut, from husk and fiber to the natural extracts has an extremely valuable route to market, which contributes to increasing the value of the crop.

The coconut tree's ability to supply an abundance of essential nutrients and life supporting materials has earned it the titles of 'Jewel of the Tropics', 'King of Trees' and 'The Tree of Life'. Some of the most valuable products are gathered below, but the list is by no means comprehensive.

Coconut by-products may define differently depending on the product focused by the manufacturer. They include, husk, shell, coconut water, low fat DC remains after milk extraction, kernel oil cake after oil extraction, skim milk in extra live virgin coconut oil production and coconut pairing leftovers. Many coconut by-products are widely used for construction, household items and fuel. Coconut husk yields a fiber (coir) for local woven goods, geotextile mats, insulation filler for car upholstery and plant mulch.

The 'dust' can be used as mulch and for compost preparation. The coconut shell is used mostly to fire coconut dryers, but is in demand for bowls, jewellery, ornaments and other handicrafts, and for high value activated carbon used for filters. Copra meal and copra cake (expeller) from copra oil production are in demand for cattle feed, both locally and exported (if the quality is adequate and consistent), and food grade meal is used in bakery goods. Accessing higher value markets



Coconut Flour

for all by-products would improve profitability for all copra processors and provide an alternative to disposal or low-cost local applications.

The distinctively patterned timber "cocowood" is used widely in craft, utensils, furniture and other household items. The timber trunks are used in construction and the high density wood component of mature trees has been trialed successfully as a flooring material to encourage the clearing of senescent plantations and replanting.

This article will focus on few new innovative products in which considerable value addition is possible. Most of them are currently used by many manufactures and some are in research stage.

Types of value added Coconut by products

1. Coconut Milk Non Fat

- As value added beverage
- As a high protein powder
- As curry thickener
- As a health food
- Sweeten condensed milk
- Coconut syrup

- Low calorie coconut Jam
- Yoghurt
- Ice cream

2. Coconut water

- Carbonated coconut water
- Coconut water with fruits and frits cocktails
- Coconut Water Concentrate
- Frozen coconut Water
- Nata-de-coco
- Coconut Jelly
- Coconut Vinegar

3. Organic compost and vermy compost and liquid fertilizer for foliar application

- Compost

4. Coconut oil from mixture of coconut pairing and low fat DC

- Coconut Margarine
- Coconut mayonnaise

5. Coconut flour

- Coconut flour biscuits with dried fruits
- Slimming tablets Coconut/ginger and bee honey

6. Dilatory fiber

7. Coconut honey

8. Coconut cheese

9. Fermented beverages

1. Coconut Milk Non Fat

It is the major by-product that derived by wet process of virgin coconut oil industry. It is rich in protein, carbohydrate and minerals but is currently not utilized and is being let out to the environment as waste. The environmental impact on releasing them to environment is extensive as it contain high amount of protein. Different dehydration methods such as drum drying, spray drying and freeze drying were employed for drying CSM.

Wet process includes centrifugation operation in the process flow and depending on the rpm of the centrifuge, different quality SNF are given. With the removal of the fat/oil fraction the chemical, physical and rheological behaviors of the remaining protein rich milk become different to the coconut milk. This leads several physical and organoleptic changes during further processing. Due to this constraint, most of the manufacturer discards NSF part as waste.

Skim milk can be concentrated to a protein rich non-fat solid-product for industrial use. Skim milk can be used for the production of a variety of products like spray dried powder, coconut honey, coconut jam and sweetened condensed milk. In addition, it can also be used as a substitute for the preparation of fermented beverage concentrate and also as a source of vegetable casein. The gastro-intestinal disturbances in infants can be treated by feeding coconut milk, which shows that coconut skim milk having the same protein level (1.6 percent) as mother's milk is well-utilized by infants.

a. As a Value Added Beverage

- SCM added with 15% sugar, 10% water and 10% fruit juice can be considered as the best combination. The pH of the product has to be maintained closer to the iso electric point so as to keep the stability and solubility. Product can be packed aseptically of under canning process. Ideally a rotary sterilizer will be useful in reducing the heat effect to the SCM as rotary in turn of sterilizer make it possible to have shorter time and temperature combination.
- SCM can be used a low fat coconut beverage by



standardizing the fat content to 2-3%. Stabilizing agents and thickeners are important to have better physical properties, uniform distribution in the suspension and prevent heat damage.

It can be marketed as high value product due to following reasons.

Niacin Content

It serves as a much richer source of niacin, also called vitamin B-3, than regular milk. It contains 1.8 milligrams per cup -- 13 percent of the recommended daily intake for women and 11 percent for men -- compared to just 0.23 milligrams found in a serving of dairy milk. Niacin, along with other B-complex vitamins -- helps you metabolize the nutrients in your food so that you're able to use them for energy. It also helps to produce sex hormones essential for reproductive health, as well as stress hormones.

Iron Content

It is also rich source of iron. Each 1-cup serving of SKM provides with an impressive 3.9 milligrams of iron, which makes up almost half the recommended daily intake for men and 22 percent for women. Iron directly supports your metabolism by aiding in energy production. It also indirectly supports your

cellular metabolism by helping transport essential oxygen to your tissues.

b. As a High Protein Powder

- SCM is pasteurized at 65C for 15 min and vacuum evaporated at 57C. After moisture content reduces to 60%, concentrate can be either spray dried at 108C or further concentrated with rotary evaporator 43C under controlled condition of heat transfer. The pH adjustment to 6.5 to 7.5 important to keep the solubility after rehydration and functional properties of the protein. Acidic pH coagulates the protein by disturbing its quaternary structure due to breakage of Hydrogen bonding and disulfide bonding.
- SCM spray dried with coconut water result better product due to retention of all essential minerals. It has been experimentally and commercial shown better results and revenue generation for few processors.

The tendency of coconut skimmed milk to bind with water is very high as it is very hygroscopic. It is also responsible for difficulty in drying product. It regains water at wide range of water activity (0.43 to 0.91). As coconut producing countries are generally humid extra precaution has to be taken in the packaging. It is assumed that sodium, potassium and sugars in the SCM powder are responsible for this character. The product can be stored at 20-30 C for 6 months as dry powder in glass containers. Product is also stable for microbial growth at 32% moisture. The protein content of the product is given in the table below

c. As curry thickener

- SCM with added starch, guar gum or locus bean gum, spices and lemongrass extract would serve excellent curry thickener properties in Asian household preparation of curries. It is impotent to maintain amino acids at its electric point to have better solubility and thickeners will suppress the effect denaturation of milk protein. Product can be heat sterilized as can and would have shelf life of one year.

This product can serve as a good solution for local demand of the coconut and would be a greater solution to reduce the dilatory intake of high calories.

d. As a Functional Food

SCM with added Soursoppulp serves as a better alternative for controlling inflammatory diseases, immunological disorders and cancer. The pulp of *Annona muricata* stabilized the diluted SCM and processing become problem less in tubular movements of liquid in commercial operations.

The principal interest in this plant is because of its strong anti-cancer effects. Although it is effective for a number of medical conditions, it is its anti-tumor effect that is of most interest. This plant is a proven cancer remedy for cancers of all types. Research shows that with extracts from this miraculous tree it now may be possible to:

- Attack cancer safely and effectively with an all-natural therapy that does not cause extreme nausea, weight loss and hair loss
- Protect your immune system and avoid deadly infections
- Feel stronger and healthier throughout the course of the treatment
- Boost your energy and

improve your outlook on life.

e. Sweeten Condensed Milk

Skim milk as stated above as a base for the production of sweetened condensed milk. The process involves adding pasteurized milk, corn oil, coconut cream and sugar and passing the mixture through a colloid mill. It is then heated in a steam jacketed kettle with constant stirring to a total soluble solids content of 68 percent. The finished product is packed hot in sterilized tin cans and cooled immediately in cooling tanks.

f. Coconut Syrup

- Coconut syrup is a translucent, free-flowing liquid with the characteristic creamy, nutty flavor of the coconut. Coconut syrup is produced from coconut milk. Coconut milk extracted from the freshly grated pared coconut meat. After homogenization, an equal quantity of sugar and 0.05 percent citric acid or 0.25 percent sodium phosphate are added and then steam-cooked to a total soluble solids content of 65 to 68 percent. The boiling hot syrup is poured into lacquered tin cans, sealed and cooled under running water. It gives a delicious instant drink, which is milk-white in color when mixed



Coconut Syrup & Nata de Coco

with water and is also an excellent bread spread. It is used as a topping or bakery products or a mixer in alcoholic drinks, or may be diluted in water and used in cooking rice cakes and other delicacies. Coconut syrup is becoming an important export oriented product to countries, where coconut is not grown.

g. Low Calorie Coconut Jam

- Coconut jam is a high-sugar coconut food product commonly consumed as dessert, bread-spread, etc. It is prepared by cooking sweetened coconut milk to a very thick consistency at low heat with constant stirring. Process for preparation of coconut jam using tender coconut pulp with a shelf life of 6 months has already been standardized. Coconut milk is extracted after mixing coconut gratings with equal quantity of water and mixed with brown sugar and glucose in the proportions of 10.25 percent and 5.5 percent respectively based on the weight of the milk, and cooked over a slow fire with constant stirring for about 20 minutes. The mixture is strained for removing suspended matter and again cooked over high heat. Before the mixture begins to thicken, citric acid at the rate of 0.25 percent of the original weight of the milk is added and cooking continued over low heat until the mixture thickens. The product is hot filled in sterilize containers and sealed hermetically. The jam so obtained has a rich creamy coconut flavor

h. Yoghurt

Coconut milk can serve the purpose of extracting the cow's milk for the preparation of yoghurt which has high

commercial value in providing highly nutritious food items at reduced price. The process involves reconstitution of milk containing 50% nonfat dry milk and 50% coconut milk, pasteurization, inoculation with bacteria, packaging, incubation and chilling.

2. Coconut Water

a. Carbonated Coconut Water

Coconut water needed to be acidified, sweetened and carbonated. It can be acidified with malic acid to a pH around 4.30, sweetened by glucose at a level of 0.7% (w/w), having a Brix of 6.0, and carbonated at 4C and 184 KPa pressure. Use dense phase carbon dioxide technology is recommended

DPCD Treatment Systems
Several batch, semi-continuous and continuous treatment systems have been developed since the first DPCD applications. In a batch system, CO₂ and treatment solution are stationary in a container for a certain period of time during treatment. A semi-continuous system allows a continuous flow of CO₂ through the treatment chamber, while a continuous system allows continuous flow of both CO₂ and the treatment solution through the system.

A typical batch system consists of a CO₂ gas cylinder, a pressure regulator, a pressure vessel, a water bath or heater, a CO₂ release valve, and a data logger at the beginning of the operation, the solution is placed into the pressure vessel and temperature is set to the desired value. Next, CO₂ is introduced into the vessel until the product in the vessel is saturated at the desired pressure and temperature. The solution is left in the vessel for a certain amount of time and then the CO₂ outlet valve is opened to release the gas. Some systems contain an

agitator that decreases the time to saturate the sample solution with CO₂.

A continuous micro-bubble system is very effective in the inactivation of microorganisms. In this system, liquid CO₂ and a saline solution were pumped through a CO₂ dissolving vessel at certain flow rates. Liquid CO₂ was changed to gaseous state using an evaporator and then dispersed into the saline solution from a stainless steel mesh filter with 10 μm pore size. The micro-bubbles of CO₂ moved upwards while dissolving CO₂ into the saline solution. Then, the saline solution saturated with CO₂ was passed through a heater to reach the desired temperature 43. Another coil with a heater was used to adjust the residence time.

A continuous membrane contact CO₂ system was developed by Sims in 2001. This system consists of four in series hollow polypropylene membrane modules. Each tubular module has 15 parallel fibers of 1.8 mm ID, 39 cm length and 83 cm² active surface area. A CO₂ pump is used to pressurize the system, and the test liquid is pumped continuously into the system with a HPLC pump.

This setup is very efficient in saturating the liquid with CO₂ since it provides a large contact area between CO₂ and the test liquid by the use of the membranes. In the membrane contactor, CO₂ is not mixed with the test liquid but instead diffuses into it at saturation levels instantaneously. CO₂ is recycled back and re-used.

A continuous CO₂ membrane contactor system In 1999, Praxair (Chicago, IL) developed a continuous flow DPCD system. This system consists of CO₂ tanks and a CO₂ pump, a product tank and product pump, a high pressure pump, holding

coils, decompression valve and a vacuum tank. CO₂ and the product are pumped through the system and mixed before passing through the high pressure pump. This pump increases the pressure to the processing levels, and the product temperature is brought to the desired level in holding coils. Residence time is adjusted by setting the flow rate of the product passing through holding coils. At the end of the process, an expansion valve is used to release CO₂ from the mixture. It is possible to pull out the remaining CO₂ in the product by a vacuum tank. This system has been shown to be very effective in killing pathogens and spoilage bacteria for short periods of time.

b. Coconut water with fruits and fruits cocktails

This provides a concrete answer to the pinking of coconut water during processing. The effect of browning of coconut water can start at day zero. This could be due to enzymatic browning that was accelerated by introducing phenolic compounds from the outer surface of the green shell, as well as heating and metal contact during drilling of the coconuts. Aeration and heating of coconut water accelerate pinking. Therefore oxygen scavenger or enzyme inhibitor needed for the preventing pinking.

With the color of fruits added with coconut water provide a solution for pinking. This would help small processors who does not have advance technology and also help to prevent the loss of organoleptic qualities during heating and processing, persuading the processor to use low heat treatment and less controlled process condition.

c. Coconut Water Concentrate

The technology used in this process is through spray evaporation technique. Spray

Evaporation Technique (SET) is adopted in this technology. It is a technology used for separating clear water from any liquid. It has got a variety of applications like extracting drinking water from sea water, removal of water from sewage and industrial waste water, preparation of fruit juice concentrate, concentration of Ayurveda and herbal medicine etc. The special advantage of fruit juice production by this technique is that the product retains all the original characteristics of juice such as retention of vitamins and enzymes, aroma, color, taste, etc. which is not possible in the conventional methods.

The technique was developed and patented by Winter Umwelttechnik of Germany. The application of the technique for concentration of tender coconut water was first attempted by Miracle Food Processers International Ltd (MFPI) Perinthelmann, Kerala in 1996. The concentrated tender coconut water 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 800 g. of concentrated MFPI is also marketing aerated and bottled ready — to — drink coconut water Beverage, which has comparatively short shelf life.

d. Frozen coconut Water

While using a cold/frozen process, the coconut water keeps its freshness, unique aroma, typical coconut taste and most importantly all of its nutrition content and health benefits.

Coconut water when exposed to the air will rapidly lose most of its organoleptic and nutritional characteristics and will begin to ferment. Some manufacturer use high temperature pasteurization, UHT but it has a disadvantage. It

will not only eliminate the risk of bacteria such as E-coli but also several nutrients and almost the whole coconut water delicate flavor. Therefore it is recommended to use high pressure Nano filtration process and subsequent freezing to have good quality coconut water for export market.

e. Nata-de-coco

Nata de-coco is a gelatinous product prepared from matured coconut water by the action of cellulose forming bacteria namely *Acetobacter aceti* sub species *xylinium*. The culture solution is prepared by mixing coconut water with sugar and acetic acid at a stipulated proportion, which is inoculated with *Acetobacter*, *xylinium* through a culture liquid. It is filled in glass jars covered with thin cloth and kept for 2-3 weeks without any disturbance.

During this period a white colored jelly like substance forms and floats on the top of the culture medium. It is harvested, cut into pieces and washed in pure water to remove all acids, immersed in flavored sugar syrup for 12 hours and packed in glass bottles. It is an excellent ingredient for sweet fruit salads, pickles, fruit cocktails, drinks, ice cream, sherbets and other recipes

f. Coconut Jelly

The process for preparation of coconut jelly using tender coconut water was developed through the sponsored research program of the Board. Coconut jelly stored in glass bottles was found to be best up to 180 days

g. Coconut Vinegar

Coconut water is a good base for vinegar, but its sugar content is too low (only about 1%). Sugar needs to be added to bring the level of sugar up to 15%. After

the addition of sugar, the coconut juice is allowed to ferment for about seven days, during which time the sugar is converted to alcohol. An alternative method is to pasteurize the coconut water and sugar mixture and add yeast. After this initial fermentation, strong vinegar (10% v/v) is added to stimulate the growth of



Coco Vinegar

acetic acid bacteria and discourage further yeast fermentation. The acetic acid fermentation takes approximately one month, yielding vinegar with approximately 6% acetic acid. The fermentation will take less time than this if a generator is used.

After fermentation, the vinegar must be stored in anaerobic conditions to prevent spoilage by the oxidation of acetic acid. Clarification can be achieved by stirring with a well beaten egg white, heating until the egg white coagulates and filtering.

3. Organic Compost and Vermicompost and Liquid Fertilizer for Foliar Application

Worm composting is using worms to recycle food scraps and other organic material into a valuable soil amendment called vermicompost, or worm compost.

Worms eat food scraps, which become compost as they pass through the worm's body. Compost exits the worm through its' tail end. This compost can then be used to grow plants. To understand why vermicompost is good for plants, remember that the worms are eating nutrient-rich fruit and vegetable scraps, and turning them into nutrient-rich compost

a. Enhancement of the performance organic fertilizer through coconut factory waste water sludge.

Targeted crops:

In-put developments have been done targeting five crop categories, given in the table below;

Category	Harvest interval (days)	Type of crop
1	7	Tea
2	15	Lemon grass
3	45	Coconut

Expected in-put components to be developed:

1.

- a) Certified organic manure (fertilizer) specifically developed for each group of crops.
- b) Biotechnological inputs – Beneficial fungi, mycorrhiza, and beneficial bacteria.

a. Certified Organic manure specifically developed for each group of crops

Whether certified or not, organic manure or compost is a stable product obtained from microbial degradation process of digestible organic matter. The composition of organic manure is undefined and contains a combination of all

macro and micro nutrients in varying concentrations depending on the types of in-put raw materials used. In addition, organic manure or compost contains varying types of natural organic substances which enhance plant growth, improve resistance to diseases and control pathogenic fungi and bacteria which are formed during the composting process.

Most of the time, soils that are being used for crop production have lost the natural biological, physiological and chemical composition due to continuous use (over use) of artificial fertilizers which often contain only macro nutrients such as nitrogen, potassium and phosphorous. Continuous application of such leads to upsetting the well being of the soil ecosystem in relation to crop production. This happens due to the destruction of intricate balance between macro and microorganisms, plant nutrients and the soil structure leading to poor crop production. Application of artificial fertilizers to such soils would only results in quick leaching of nutrients in to deeper layers of soil without being used by the plants.

Different plant species require different quantities of macro and micronutrients and in different proportions for them to grow and fruit well and therefore, applying undefined organic manure too would not produce good results if they are not well suited for the crop species. It is believed that applying organic fertilizers with right combination particularly, macro nutrients to a targeted crop would bring the expected yield.

Right combination and macro nutrients abundant products are most important at initial stage of composting to start up the microbial activity. Coconut wastes are most abundant in all

macro nutrient, nitrogen and other minor minor nutrients.

b. Biotechnological inputs – Beneficial fungi, mycorrhiza, and beneficial bacteria

It has been scientifically proven that plant beneficial microorganisms, fungi, bacteria and certain species of mycorrhiza) are present in the soil and these are being commercially used for enhancing crop production, controlling plant diseases, particularly, root diseases.

Aim of Organic Fertilizer

1. Commercial scale production of certified organic manure for the four categories of crops using coconut factory waste.
2. Commercial scale production of beneficial microorganisms though de-fatted coconut waste and use of same techniques for foliar application;
 - a. Fungi
 - Trichoderma harzianum*
 - T. viride*,
 - Mycorrhiza
 - b. Bacteria
 - Bacillus subtilis* etc.

In the vent of preparation of liquid fertilizer, micro-organisms are inoculated to concentrated and almost sterile coconut waste water. The content was incubated and fast deterioration is facilitated. pH adjustment and aeration is been done as required depending on the inoculant. The nutrient release at the end of decomposition is trapped using carbon filter and flowingly carbon filter suspension could be used as a foliar application.

These products are to be used for the organic crop production for the crop categories mentioned above.

Certified organic manure (Composting):

Completely composted organic manure is an odorless, stable material. An organic compost to suit the category 1 & 2 crops should contain higher fraction of ammonia-N or nitrate compounds which are readily available to the crop for fast leafy growth. Coconut by-products, and Poultry litter are the highest nitrogen containing in-put raw material for enriching nitrogen in the compost. Among poultry litter, broiler litter and layer battery cage litter are the best source of nitrogen. Therefore, organically certified coconut waste and broiler or battery cage layer litter could suite the purpose.

Plant waste is considered most valuable in organic production systems due to less use of preservatives and advance hurdles concept. When using animal waste as a raw material for composting, human pathogenic microorganisms should be destroyed to avoid food born disease out breaks with organically grown fruits and vegetables such as what happen in Germany with the involvement of an uncommon multidrug resistant *E.coli* costing several human lives.

Therefore, strategies would be developed in order to produce hygienically safe organic compost for the five groups of crops.

4.Coconut oil from with mixture of coconut pairing and low fat DC

Promptly dehydrated coconut pairings and low fat desiccated coconut can be used an ideal combination to obtain virgin coconut oil. Under controlled drying, the brown colour development can be easily controlled and the balance between the fatty acid content can be obtained, coconut pairing contain less medium chain fatty acids and

in cooperation of low fat DC provide the short and medium chain fatty acid content. Therefore balance between the fatty acid content can be obtained to produce various products.

a. Coconut 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 600C for 10 min. filling, packing and cooling at 160 C. The product can be used as bread spread. It contains high lauric acids and no transfacts.

b. Coconut mayonnaise

Mayonnaise is a semi solid food product mixed into fresh vegetables or fruits or cooked meat to enrich flavor. It is prepared by mixing coconut oil, vinegar or citric acid or emulsifiers. Carbohydrates, spices and flavor enhances are added to modify the flavor and avoid crystallization. The final formulation would consist of 70% VCO, 6% natural vinegar, 7% fresh yolk and 1% emulsifiers and cooled boiled water. Mayonnaise production units can be commercially operated at home or micro level to enhance the income of farmer families.

5. Coconut flour

Coconut flour is unlike any other consisting of 14% coconut oil and 58% dietary fiber! The remaining 28% consists of water, protein, and carbohydrate.

- **Coconut Flour is ideal for baking.** It has fewer digestible (net) carbs than other flours, and it even has fewer digestible carbs than some vegetables
- **Coconut Flour is gluten-free and hypoallergenic.** With as much protein as wheat flour, coconut flour has none of the specific protein in wheat called

"gluten." This is an advantage for a growing percentage of the population who have allergies to gluten or a wheat sensitivity.

- **Coconut Flour consists of the highest percentage of dietary fiber (58%) found in any flour.** Wheat bran has only 27% fiber.
- **Coconut Flour can help you reach a healthy weight.** Ideal for those who follow a low-carb eating plan, coconut flour works well as part of a weight loss program because it has high fiber, and foods with high fiber can help promote a feeling of fullness.

Coconut flour biscuits with dried fruits

After expelling the milk, the protein rich residue is dried and powdered to obtain a product called coconut flour. The flour so obtained typically contains 7-8 percent protein, 3-5 percent moisture and 17 percent oil. It can be used as an ingredient in weight control foods because of its high fiber content.

The protein contained in the flour is identical to that contained in the original fresh kernel. After blanching the residue is 14dried and passed through a special type of screw press under a specified expeller setting to reduce oil content without too much change in colour.

The de-fatted flakes are re-dried to reduce its moisture content to 2.5 to 3.0 per cent which is finally ground to a fine mesh Coconut flour can be used to make gluten free cookies with combination of cross linked starch. Cross linked starch with di sulfide bonds are stronger and are huge molecules. Therefore dietary absorption is limited is also limited. To improve the texture and the nutritive value it can be added with various dried and raw fruits at preparation.

Slimming tablets Coconut / ginger and bee honey

Ginger and bee honey are been considered as indigenous medicine for enhancement of metabolic fat oxidation. One lauric acid is been in cooperated fat deposition is further reduce due to enhance metabolic effect of the fatty acid

6. Other value added products

b. Activated Carbon Filtration

Extensive research in this field is producing multiple industry applications for activated carbon produced from coconut husks and shells. Traditional uses in water purification for both groundwater and drinking water filtration are being joined by applications in nuclear plants, solvent recovery and utilization in catalytic converters.

High carbon content makes coconut shells a perfect source to produce activated carbon. Coconut based activated carbon has the most micro porous pore structure, and has the highest hardness compared to other types of activated carbon. This makes it the best carbon for water filtration. It generates the least ash during production. The carbon can be reactivated

c. Biodiesel

Coco-Biodiesel is created by processing pure coconut oil and converting it to a diesel-like product. It is set to become a more prominent part of the worldwide biofuel blend as pressure mounts on international governments to employ cleaner burning and non-toxic alternative fuels from renewable sources.

Biodiesels will reduce greenhouse gas emissions, and can be used in diesel engines without modifications. Brazil is one of the world's largest biofuel consumers and has 10 million flex-fuel cars on its roads.

The global consumption of ethanol and biodiesel is projected to reach

135 billion gallons by the year 2018. Coconut oil burns more slowly than diesel engines, reducing engine wear and lubricating the engine more efficiently

d. Fibers

Coconut husk fibers, also known as coir, come from the large outer casing that surrounds the hard brown nut. These tough fibers are used to make mats, packaging, mattresses and brushes. It can even be rubberized and used as an eco-friendly alternative to plastics, an application car manufacturer Ford is currently researching.

e. Husks and Shells

Value-Added Products from Coconut Husks the husk is 35% of the mass of the coconut melon. It is comprised of about 67% pith, a lignin which behaves like a phenolic resin⁴, and 33% fiber, also made from lignin but with a fibrous morphology. The pith and the fiber can be used in agricultural applications since they absorb about ten times their weight in water. Furthermore, the pith and fiber are biodegradable, enriching the soil much like peat or mulch, for which they may be substituted. The husks (pith and fiber mixture) brings about \$0.18/kg in country for export in 10 kg blocks. The shipping costs from the Philippines to the United States of \$0.32/kg raises the price to about \$0.50/kg wholesale in the US. Recent studies in the Netherlands⁹ support the idea that the husk can be hot pressed into particle board directly without adding any additional binder. The pith can apparently chemically react and consolidate much like a phenolic resin, with the fibers serving as reinforcement.⁴ Particle board in developing countries is usually in high demand and commands an excellent price.

The husks and shells have historically been used as charcoal and as a potting medium for growing saplings. He coconut shell also has exceptional properties. It

has a specific gravity of 1.2, which is about twice the density of hardwood. It is at least twice as hard as hardwood and is also very rich in energy. The hardness of the coconut shell is comparable to lower strength aluminum alloys, making it one of the hardest organic materials produced in nature. It can be ground into 50-micron chips to potentially be used as reinforcement for engineering plastics. Chopped glass fibers are conventionally used as reinforcement to increase strength and stiffness and reduce cost in polymeric composites. Ground coconut shell is not as hard as glass, but it should bond much better to the matrix, since the bond interface will be organic to organic, rather than organic to

Silicon oxide. We are currently studying this option. Because of its high mass-density, coconut shells also have a high energy-density. This means that they may be burned as fuel for cooking or used to make charcoal. Burning directly as a fuel would make more sense in the village, while sales to cities would be in the form of charcoal. While the burning of 10 kg of wood produces only 1 kg of charcoal, 10 kg of coconut shells produce 3.5 kg of charcoal and 5.5 kg of combustible gases.⁸ We are exploring possible cook stove designs that would make efficient use of the energy from coconut shells, and we are also exploring how we might capture and store the combustible gases that are released as coconut shells are converted into charcoal.

However, the most recent demand, and one that looks set to grow, is the use of the husks and shell as biomass fuel. Biomass energy is responsible for over 75 per cent of the world's renewable energy, and demand for woody biomass is increasing rapidly. Global demand for biomass products is estimated to increase by 600 per cent over the next 20 years, according to the International Institute for Environment and Development.

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