TECHNOLOGY OPTIONS FOR THE PROCESSING AND UTILIZATION OF COCONUT SHELL IN ASIAN AND PACIFIC COUNTRIES

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1. Introduction

Coconut shell or endocarp is the hard, stony, dark brown, thin layer in between the coconut husk (mesocarp) and kernel of the mature coconut fruit. It is soft and dark cream in color when the nut has not yet reached maturity. This is where the coconut kernel is attached. It represents about 15 – 20 % of the total weight of the whole coconut. As reported in the PCA Technical Data Handbook on Coconut (1979), coconut shell has the following composition:

Calorific Values of Coconut Shell Charcoal (As reported by Different Author/Researchers)

Author	Calorific Value, kcal/kg
Lozada (1978;1980)	6540
Cruz (1978)	6654
Tamolang (1978)	6784
Grimwood (1975)	7500 to 7600
Paddon and Harker(1979	7204
Breag and Harker(1979)	7108 to 7339

Source: Guarte (1993)

The usefulness of coconut shell is clearly illustrated by the description of Dr, W.R.N. Nathanael, former director of the Coconut Research Institute in Ceylon (now Sri Lanka) as cited by Guarte (1993) who stated that:

"*In the hands of the beggar, a coconut shell serves as his begging bowl; in the hands of the artist, it turns into a thing of beauty; it provides the humble housewife with a brightly burning fire to cook her simple fare; it lets the chemist unlock its secrets and yields a dozen new things. Such is the coconut shell, versatile part of the world's most versatile tree – the coconut palm.*"

The coconut postharvest practices in Asian countries greatly differ with the Pacific Island countries (PICs) and these affect the way in which coconut shell can be processed or utilized in each region. In Asian countries, coconuts are harvested either by climbing or the use of long poles and husked on farm before they are processed into copra or sold to coconut plants that process fresh coconuts. Hence, coconut shell is generated as a by-product in the form of half cups or cut pieces in the case of coconut milk and desiccated coconut processing plants. On the other hand, in the PICs, coconuts are just allowed to fall on the ground and collected only when the Pacific islanders need money or when they need coconut for household use. Likewise, husking of nuts is not generally practiced in the PICs. Husking is only done for coconuts which are used in the households and to a limited extent processed into products that require fresh coconuts like VCO. Otherwise, whole coconuts are just cut into halves and the fresh kernels (termed as "green copra" in PICs) are taken out by means of a knife or a special tool. In this case, the generated by-product is coconut shell which is still attached to the coconut husk. Generally speaking, coconut shell is not being processed in PICs and its utilization is very limited due to the abovementioned reason. Majority

Figure 1: Two Versions of Drum Kiln

of coconut shell with attached coconut husks after cutting green copra are just being allowed to rot in the farms. Even coconut shells from husked coconuts which are generated in households are just also being left on the ground. It should be noted that a relatively big volume of coconuts produced in PICs are used daily in the households for making home-made coconut oil in the villages for cooking and hair/skin conditioning and for extracting coconut milk as ingredient in traditional meals. The most widely known use of coconut shell in Fiji is its use as a cup for drinking kava during social and cultural gatherings.

2. Processing and Utilization Technologies

There are four general ways by which coconut shell are currently processed and utilized. These are:

a. Utilization as fuel for heating applications by direct burning
b. Conversion into coconut shell charcoal for various heating applications or further conversion into activated carbon
c. Processing into coconut shell handicrafts, fashion accessories and novelty items
d. Processing into coconut shell flour

2.1 Utilization as Fuel for Heating Applications by Direct Burning

Coconut shell is one of the agricultural residues which has a relatively high heating value. This amounts to 5,500 kcal/kg (Paddon and Harker,1979). As such, it is considered as a good solid fuel for heating applications by directly burning it. In the villages of coconut producing countries in Asia, coconut shell is used for cooking by burning it in traditional stoves. In Sri Lanka and Malaysia, coconut shell is the major fuel used for drying copra in the so-called Ceylon kilns where the half cup shells are bonded together in interlocking positions and arranged like a snake in an enclosed area underneath the copra loading bed. In the Philippines, coconut shell is also used as fuel in specially designed boilers for generation of process steam in desiccated coconut processing plants.

In the PICs where VCO is produced using the Direct Micro Expelling (DME) process, coconut shell is generally used as fuel in DME flat bed type conduction dryers to dry grated coconut kernel prior to oil extraction. In Fiji, coconut husks with attached coconut shells are used as fuel for copra drying in estate plantations or on farms if cutting of green copra is done near the dryer. Otherwise, it is just allowed to rot in the farm. It should be noted that in Fiji, the general practice is that farmers sell the green copra and it is the traders who normally do the copra drying. In this case, firewood is generally used as fuel. At the Cocoa and Coconut Research Institute in Papua New Guinea, coconut shell is used as fuel in big copra dryers where it is burned similar to the system in Ceylon kilns.

A special system of utilizing coconut shell is currently applied at the Wainiyaku Estate Plantation in Taveuni Island, Fiji. Dried coconut husks with attached shells are being used as fuel in a biomass fired boiler. The generated steam from the boiler is then piped to a steam turbine to produce electricity to supply the power needs of the estate including the operation of machineries for coconut oil production. The heat which was given out when exhaust steam from the turbine is condensed to water simultaneously heats the air that is being blown through the condenser. This heated air is then directed to pass through an enclosed bed of green copra for drying.

2.2 Conversion into Coco Shell Charcoal, Activated Carbon and Charcoal Briquettes

2.2.1 Coconut shell charcoal

Coconut shell is converted into charcoal to increase its calorific value and to make it smokeless and clean burning when utilized as fuel for cooking in urban areas and for industrial heating applications. Coconut shell charcoal is generally defined as the product derived from carbonization of coconut shell from fully matured nuts under a limited or controlled amount of air. It contains the highest percentage of fixed carbon of all ligneous charcoal. High grade coconut shell charcoal is uniformly black in color and snaps with a clean shiny fracture. It is free from dust and ash and produces a metallic sound when dropped on hard ground. Under-burnt shells do not give a metallic sound and do not show a clean fracture, while the over-burnt shells are friable and easily crumble when dropped. Coconut shell charcoal has the following general specifications with regards to impurities and size as reported in the PCA Technical Data Handbook on Coconut (1979):

CONSTITUENT	SPECIFICATIONS
Volatile Matter	Not > 15.0 %
Ash	Not > 2.0 %
Moisture	Not > 10.0 %
Chloride	Not > 0.1 %
Size	Not more than 0.5 % shall pass 0.63 cm mesh sieve

Coconut shell charcoal is a clean burning fuel and has a higher heating value or calorific value as compared to wood charcoal.

The calorific values of coco shell charcoal as measured and reported by different researchers are shown below.

In Asian countries, charcoal making is generally done by the pit method and the kiln method. The type of pit which is either rectangular or round varies in sizes and depth depending on the volume of operation. It can be a simple hole dug on the ground as in certain areas in the Philippines or the pit could be lined with bricks or stones as practiced in Sri Lanka and India to prevent the shell charcoal from being contaminated with soil. Likewise, the type of kiln used could be either second hand, 200 liter-capacity metal drums, fabricated metal kilns or brick kilns. The most commonly used by small coconut landholders is the drum kiln which can also vary in design, from the simplest type which is just open on one side to a more sophisticated type with a chimney and air combustion ports at specific points around the drum (Figure 1). The processing capacity of a drum kiln is about 450 – 500 whole shells (900 to 1000 half cups) per batch. Charcoal making operation takes about 6 hours plus overnight cooling. A skilled operator can operate eight drum kilns at the same time.

The simplest charcoal making process using the drum kiln involves the following steps:

a. Place the drum in a flat and clean ground.
b. Ignite two to three pieces of coconut husk or three or four pieces of coconut shell and carefully drop them into the bottom of the drum. Arrange them evenly around the bottom by poking them with a stick and allow them to burn vigorously.
c. When these husks or shells are burning vigorously, add about 20 half coconut shells. Loosely cover the drum with the top portion which was removed before. Allow the shells to carbonize. The start of carbonization is signified by the release of heavy dark smoke.
d. Additional shells are added whenever the smoke becomes lighter or when flames start to break-out. The cover is replaced every after every charge of a fresh batch of coconut shells.
e. Charging of fresh batches of shell is continued until the pile reaches the top of the drum.
f. When the smoke coming out of the loosely covered drum becomes clear, fit the cover on the lid of the drum.
g. Turn the covered drum upside down. The bottom of the drum becomes cooler as the carbonization moves towards the top, which allows the worker to hold the bottom portion. Seal the kiln by pressing relatively wet soil around the lid. The absence of smoke indicates that the drum is completely sealed. The drum can also be sealed while in upright position using wet clay. However, sealing is more efficient if the drum is turned upside down.

In 1983, the Natural Resources Institute of United Kingdom transferred to the desiccated coconut sector of Sri Lanka the technology on coconut shell carbonization with waste heat recovery. Simply referred to as WHU, it is a combination of vertical cylindrical kiln with conical bottom for carbonization of coconut shell and furnace system where the gases generated during the carbonization process are burned to heat air in a heat exchanger. The hot air can then be used in the desiccated coconut dryer or other drying applications. The standard WHU has a processing capacity of 1.5 tons of coconut shell per batch while the scaled-up unit has a capacity of 3.5 tons per batch. One batch of operation takes about 10 – 11 hours. This carbonization technology is only applicable in big commercial operation because of the relatively high initial investment cost and the large amount of coconut shell required.

In coconut producing countries in Asia, coconut shell charcoal is traditionally used as fuel for household cooking, for barbecue grills in restaurants and for ironing of clothes in areas where there is no electricity. Granulated coconut shell charcoal is used as deodorizer for refrigerators, bedroom closets and kitchen cabinets.

It should be noted that the processing technologies and utilization of coconut shell charcoal are not yet generally known in the PICs. The most appropriate charcoal making technology that can be easily adopted in the PICs is the drum kiln method. Second hand 200 liter-capacity metal drums are relatively cheap in the PICs because of their regular imports of petroleum products which are normally shipped in metal drums. In addition, the processing capacity of drum kiln fits well the relatively small coconut production in the PICs. Information dissemination and training on coconut shell charcoal making should be done to introduce the technology for wider adoption so that Pacific islanders can get more value from their coconuts or reduce their energy cost for cooking.

2.2.2 Activated Carbon

In the Philippines, Sri Lanka and Malaysia, subsequent processing of coconut shell charcoal into activated carbon brings in a lot of foreign exchange because it is

one of the most high valued coconut products in the world market.

Activated carbon can be produced using any carbonaceous materials such as coal, lignite, wood and coconut shell charcoals. Activation is done to yield a porous structure of the amorphous carbon thereby creating a very large internal surface area for adsorption of materials, both in the liquid and gaseous phase. Activated carbon is sold either in granular or powdered form. The most commonly adopted processes for the production of activated carbon are steam and chemical activation. Coconut shell based activated carbon is generally produced using steam activation. This is done either in horizontal or vertical retorts/kiln by reacting steam with the coconut shell charcoal under controlled temperature and pressure. Activation is done at a temperature (normally ranges from 900 – 1100 ^{0}C) sufficiently high to remove all the volatile constituents in the charcoal but low enough to avoid cracking of the evolved hydrocarbons. Coconut shell charcoal undergoes the granulation process prior to steam activation.

The general specifications for coconut shell-based activated carbon as reported in the Spectrum of Coconut Products (PCA, undated) are the following:

Grain Size	4 – 48 mesh
Iron Content	0.15 % max
Chlorides	0.015 % max
Ash	3 % max
Hardness	95 % min
Moisture	2 % max
Specific Gravity (when packed)	0.35 – 0.50

Activated carbon from coconut shell charcoal has certain natural outstanding properties and for some specific purposes, it is superior to other amorphous carbon. It has more resistance to abrasion, higher capability for adsorption and higher purity in ash (Hauser,1995). It is specifically superior for gas adsorption because of its small micropore structure. Coconut shell charcoal-based activated carbon is used in big quantities in sugar, waste-water treatment, mining and mineral processing, oil and fats, food and beverage, pharmaceutical, electroplating industries and others. It is also currently used for reducing the PAH (a potent carcinogen) levels in coconut oil derived from smoke dried copra. Owing to the fact that activated carbon is the best all-around adsorbent for toxic gases, it is almost universally used in most gas masks and for removing and abating industrial stench (Guarte, 1993). Activated carbon is also used in cigarette filters.

2.2.3 Charcoal Briquettes

In the process of making coconut shell charcoal and granulation for activated carbon processing, considerable amount of very small charcoal pieces and fines are generated which charcoal producers and granulators dismiss as wastes. These charcoal fines may amount to 15 to 20 % of the total usable charcoal/granulated charcoal per batch. Charcoal fines cannot be burned by the usual simple charcoal burning method. Hence, it is a by-product which cannot be sold as is. In addition, it is a fire hazard when it accumulates. It is also a source of air pollution on windy days and water pollution on rainy days. Converting the said charcoal fines into briquettes solved the abovementioned problems at the same time improves the profitability in charcoal making and granulation operation.

Charcoal briquettes, also called "patent fuel" is a compacted mass of fuel material made from a mixture of charcoal fines and a binder and molded under pressure (FPRDI, 1992). Coconut shell charcoal fines is first mixed with a suitable binder (e.g starch solution) at a specific ratio and then fed to either a briquetting machine or an extrusion machine. The resulting briquettes are then dried to harden. Charcoal briquettes produced by a briquetting machine are available in various sizes and shapes with the pillow shaped block as the most common. On the other hand, briquettes produced by extrusion are cylindrical in shape with hole in the middle for efficient combustion.

While Filipinos generally prefer coconut shell charcoal for grilling and barbecue, charcoal briquettes are already used as household fuel in Europe, America and some countries in Asia where big hotels and restaurants use charcoal briquettes for grilling and roasting. A major portion of charcoal briquettes produced in the Philippines are exported to Japan and South Korea.

When properly processed, charcoal briquette has a slow burning rate and delivers more intense heat per unit volume (Caro, 1999). It also burns with very little smoke. As such, it is a cheaper alternative to electric light or LPG when used as heating medium for eggs and newly-hatched chicks in poultry farms. Most poultry farms in Southern Philippines use charcoal briquettes in their chicken brooders.

Figure 2: Novelty items and fashion accessories from coconut shell

2.3 Processing into Handicrafts and Novelty Items for Tourists

Processing of coconut shell into handicrafts and novelty items like bags and fashion accessories (Figure 2) is currently practiced in the Philippines, Thailand and Sri Lanka. It was also reported that coconut shell handicrafts are being made to a limited extent in Samoa. In the said countries, coconut shell handicrafts are done on cottage level.

Production of coconut shell handicrafts only requires little investment, creativity and artistic capability of would be producers. The equipment being used is just simple motorized cutting and grinding machines. One set of equipment composed of 2 pcs cutter, 1 grinder and 1 finishing machine with second hand electric motors cost about US $ 1,700 in the Philippines

This coconut shell utilization technology can be easily adapted in PIC's especially in countries where there is a well-developed tourist industry like Fiji, Samoa, Cook Islands and Tahiti. For Fiji, potential products are coco shell buttons for "Bula" shirts, key chains and novelty items like bags, cellphone holders and fashion accessories like necklaces which can be sold in souvenir shops.

2.2.4 Processing into Coconut Shell Flour

Coconut shell flour is a high value product which has a special "niche" in the world market. Coconut shell is thoroughly cleaned to remove adhering coir pith and fibers, grinded and pulverized to very fine particles of 100, 300 and 600 mesh grades through the use of a series of grinder and pulverizers In one processing run, all mesh grades are produced at the same time and separated using cyclone separators and vibrating fine screens. Coconut shell flour is used extensively as compound filler for synthetic resin glues and as filler and extender for phenolic molding powders. This unique filler is also used successfully with specialized surface finishes, liquid products (as an absorber), plastic adhesives, resin casting, mild abrasive products, hand cleaners, polyesters types laminates, and bituminous products. Coconut shell flour is also a major raw material in the production of mosquito repellant coils.

3. Final Remarks

All available processing and utilization technologies for coconut shell are already well established in Asian coconut producing countries with the Philippines as the leader. Likewise, these are already generating incomes for coconut producers and manufacturers either through domestic sales or through export of coconut shell based products and downstream products. However, this is not yet the case with regards to the PICs. To expand the utilization of coconut shell in the PICs for income generation, international development agencies involved in the PICs should initiate programs involving information dissemination, training and transfer of appropriate coconut shell processing technologies. Pacific islanders should also be encouraged to husk coconuts prior to splitting so that coconut shell will be free from the attached coconut husk thereby providing more flexibility in the processing of the shell.

Among the various utilization technologies for coconut shell, the production of coco shell flour and the downstream processing of coconut shell charcoal into activated carbon require high investment costs. However, both products belong to the category of high valued coconut products. At this stage where coconut shell processing in PIC's will just start at almost zero level, it should initially consider expanding its utilization for fuel (either for direct burning or as charcoal) for heating applications and the processing of specialty coco shell handicrafts where investment requirements are relatively low. For instance, coconut shell charcoal can be easily processed in used petroleum drums which just cost about FJ$ 14.00 per piece. Later, after doing a feasibility study, it can consider the processing of high value product like coconut shell flour.

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