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REGULAR ARTICLE

Enhancement of date palm as a source of multiple products: Examples from other industrialized palms

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Abstract

Multipurpose palm species development would benefit from a broader consideration of the varied economic products palms can potentially provide. All economic palm species have a primary product which accounts for their exploitation or domestication and industrialization. A nearly-exclusive emphasis on the primary product has often obscured the potential value of secondary products. Responsible disposal of residues from harvesting and processing of primary palm products often has the potential of being transformed from a disposal expense and potential source of environmental pollutants into secondary products of value. Examples from other palms which may have applicability to date palm production include: 1) In the oil palm industry, empty palm oil fruit bunches are used as fuel to generate electrical energy and yield a fine ash with industrial uses. 2) In coconut plantation operations, pruned leaves and unwanted husks can be used as fertilizer for the plantation or burned to generate energy. 3) Replacement of ageing plantation trees provides an abundance of woody material requiring disposal, affording a periodic opportunity for innovative secondary product harvest. Technical research on the utilization of palm by-products is typically focused on an individual species, but the results often have broad potential adoption for other economic palms.

Key words: Biofuel, By products, Edible oil, Fruit bunch, Endosperm, Organic fertilizer, Palm, *Phoenix dactylifera*, Sap, Stem wood

Introduction

The palm family (Arecaceae) is comprised of 183 genera and over 2,400 species, and has a worldwide distribution between 44° north and south latitudes (Govaerts and Dransfield, 2005; Dransfield et al., 2008). Five major palm species are domesticated fully and are grown as economic species: areca or betel nut palm (*Areca catechu*), peach palm (*Bactris gasipaes*), coconut palm (*Cocos nucifera*), oil palm (*Elaeis guineensis*) and date palm (*Phoenix dactylifera*). The taxonomic relationship among the five species, which represent three of the five palm subfamilies, is presented in Table 1.

Although the five palm species are classified in different subtribes they are comparable, in terms of the variety of products they yield. The five share certain characteristics, for they are all pinnate-leafed, large, erect and slender to thick palms. Two produce basal suckers (date and peach palms) which can be used for propagation. The date palm's oasis habitat differs from the other four species which are tropical wet climate palms. All five were domesticated primarily for their fruits. Within the subsistence economies where domestication took place, every part of the five palm trees would have been evaluated carefully for any possible utility or product.

The purpose of this paper is to outline the multipurpose character of the areca, peach, coconut, oil and date palms. The information presented can serve as a stimulus to broader consideration of the date palm, to enhance current secondary products and to promote potential new uses.

Shared fruit characteristics

Fruit of palms in the Arecoideae subfamily (areca, peach, coconut and oil palms) are similar. Each has a well-developed exocarp, mesocarp, endocarp (shell) and endosperm (kernel). The terms *nut* and *seed* as applied to palms often create confusion. In the coconut, for example, both *nut* and *seed* may refer to either the entire fruit or to the fruit after the husk has been removed. Generally, use of more precise botanical terms is preferable.

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Table 1. Taxonomic Relationship of Five Major Economic Palm Species.

Family	Subfamily	Tribe	Subtribe	Genus and Species/Common Name
Arecaceae	Arecoideae	Areceae	Arecinae	*Areca catechu* (areca palm)
		Cocoseae	Attaleinae	*Cocos nucifera* (coconut palm)
			Bactrinidae	*Bactris gasipaes* (peach palm)
			Elaeidinae	*Elaeis guineensis* (oil palm)
	Coryphoideae	Cryosophileae	Phoeniceae	*Phoenix dactylifera* (date palm)

The arecanut mesocarp is a source of alkaloids. Coconut has a mesocarp fiber (coir), activated carbon and other products from the endocarp, and oil and other food products from the endosperm (meat). Peach palm has an oily starchy mesocarp which can be cooked and eaten or processed into starch. Peach palm also furnishes palm heart (apical meristem) as a commercial green vegetable. Major products from the oil palm derive from the mesocarp and endosperm, both yield excellent quality food oils.

Coconut and oil palms, once they reach sexual maturity, produce fruit continuously over the year, but with month-to-month fluctuations. Spreading of the harvest of these two tree crops over the entire calendar year is a major economic advantage.

Unique among the five palms, the date palm, in desert climates, has intangible value by creating shade and microclimatic conditions suitable for the growth of other crop plants. Also, the palms function in oases as windbreaks and to stabilize earthen irrigation works.

Once established, palm plantations can provide a sustainable and reliable supply of fruits and other products for decades. Modern commercial palm plantation development has focused almost exclusively on a single economic product; as a result, insufficient attention has been paid to secondary products from the fruits and other parts of the palms.

Individual Multipurpose Palms

An effective approach in this article is to examine and describe the areca, peach, coconut, oil and date palms in terms of their individual harvest and processing practices, focusing on products. Summary descriptions of the individual palms provide a background for a general discussion of enhanced utilization of present and future date palm products.

Areca catechu

The areca palm was domesticated in South and Southeast Asia for its fruit. This solitary slender tropical palm is grown from seed in either pure stands on large estates or by small farmers in mixed systems. Commercial cultivation is limited to the Asian realm. The palm is quite attractive and is also grown ornamentally.

The fruit endosperm is the chief economic product, chewed for its mild narcotic effect derived from presence of the alkaloid arecoline. The endosperm also contains about 10% oil. Fruit bunches are produced seasonally, cut when mature and transported out of the field. At a processing site, fruits are removed from the bunches, husked and then dried or boiled, to reduce the tannin content, and cut into pieces for chewing. Boiling of the fruits yields a tannin-rich liquid. Betel chewing is almost exclusively limited to the areas where the palm was domesticated; like tobacco use, it is linked to the occurrence of mouth cancer.

Areca fruit husks represent about 70% of the entire fruit and research has shown that the material has potential use in making hard board, latex-bound fabric, pulp and paper and as a source of furfural, an industrial chemical compound. Husks can also be used directly as fertilizer.

Other tree products include leaves for thatch; the large leaf sheaths made into biodegradable plates, sandals; also suitable for plyboard and panels. Dead pruned leaves serve as mulch and fertilizer.

Areca palms have an economic life of about 40 years. Replacement plantings generate other products from the trees removed. The palm heart has a bitter taste, but is edible. Entire stems are employed in construction of rustic structures, and the attractive yellow wood cut into a variety of articles such as rules, shelves, etc. Residue can also be incorporated into the soil of plantations as fertilizer.

Detailed accounts of areca palm products and utilization are provided by Bavappa et al. (1982) and Bhat and Nair (1985).

Bactris gasipaes

This tropical Central and South American palm was domesticated by indigenous people for its fruit, which must be cooked before eating. Peach palm is a lesser-known commercial palm because its cultivation is restricted to the region of domestication. Traditionally a small farmer tree crop in mixed systems, the palm produces multiple

slender stems. Chiefly propagated by seed, the palm bears one or two fruit crops annually. Peach palms also are cultivated to produce seed to establish new plantings; the palm is also grown as a handsome ornamental, but has the disadvantage that most specimens have a spiny stem. Long known as a source of quality heart of palm, in recent decades the palm has been cultivated specifically for that product which is consumed locally and exported. Palm heart extraction destroys the stem and precludes fruit production.

Mature fruit bunches are cut from the trees and taken to a processing site. Removed from the bunches, the fruit are sold fresh or cooked. Fruit destined for flour production must be cooked within about a day of harvest. A traditional alcoholic beverage is prepared by cooking, mashing and fermenting the mesocarp pulp. The fruits are also a source of cooking oil and meal for animal rations; the male flowers are edible.

Harvesting palm hearts consists of felling the stem and extracting the apical meristem from the top of the stem, where it is surrounded by several protective sheaths. Harvested palm hearts are 60-80 cm in length, varying in diameter depending upon stem size. They must be transported quickly for processing to avoid moisture loss and fungal damage. At the factory, the hearts are peeled to expose the soft core, cut into short lengths and cooked in cans or jars. Peelings are suitable animal feed. Stem and leaf remains are left in the field as mulch and fertilizer for the remaining smaller stems of the cluster.

Other peach palm products include green leaves from felled stems for thatching and entire stems as framing for simple rural shelters. When older thicker stems are cut, the hard dark wood can be sawed into parquet flooring, made into furniture and carved into decorative or useful articles.

The economic life of a peach palm plantation for fruit production is estimated to be 50-75 years. Clearing and cutting of an old stand to replace it with new seedlings affords an opportunity for palm heart harvest and stem utilization. Growth of peach palm for palm heart production is done at a high planting density. Harvest begins after 1-2 years, before flowering, with natural regeneration from basal offshoots.

Detailed information regarding peach palm cultivation, for both fruit and palm heart, is contained in Villachica (1996), Mora-Urpí et al. (1997) and Mora-Urpí and Gainza (1999).

Cocos nucifera

The most widely cultivated of economic palms, and the best known, the coconut was domesticated in the southern Pacific and Indo-Atlantic regions for its remarkable fruit. The fruit has been described as a portable source of water, food and fuel (Gunn et al., 2011). A short to tall, solitary palm of moderate diameter, seed and tissue culture propagated palm; it flowers and fruits continuously. Coconuts are grown by small farmers in mixed cropping and grazing systems, and also as a large-scale monoculture. It is also a popular tropical ornamental.

A large number of primary products are derived from this remarkable tree, which aptly has been called the *tree of life*. The entire fruit provides an endosperm for copra which contains an excellent edible oil, along with fresh coconut meat; coconut water; the endocarp (shell) has numerous uses; and the mesocarp (husk) yields coir fiber. Palm toddy (sap) can be obtained from tapping the unopened inflorescence, although this practice is incompatible with fruit production. The apical meristem (heart) is an edible green vegetable, although harvest destroys the tree. The coconut stem can be sawed into lumber for construction and furniture, and a variety of useful objects.

The most valuable product from this palm is the endosperm oil, which has numerous food, cosmetic and industrial uses, and is a suitable biofuel. Coconut fruit harvest involves cutting individual fruits from the bunch while it is still on the tree. If mature fruits are harvested solely for copra (oil), they are typically husked in the field and only the nut transported to a copra processing or fresh coconut processing facility. Copra cake, after oil extraction, can be used in animal feed and as fertilizer. With integrated coconut processing, the entire fruit is taken to the factory where the husks are removed to extract the coir fiber. Coconut shells may be made into charcoal, activated carbon, or carved into buttons etc. Waste coconut water of mature fruits is unsuitable as a beverage but can be used in industrial fermentation. Green immature nuts are harvested when fresh coconut water is desired, which can be drunk directly from the nut or drained, processed, and preserved in containers.

Tapping the unopened coconut inflorescence yields a sap consumed as a sweet drink; sweet sap can be boiled down to palm sugar or left to ferment naturally into a palm wine. In turn, the wine can be distilled into spirits (arrack). All four of these products are commercialized in South and Southeast Asia.

Nonedible residues from any of the processing steps described can serve as fuel or transported back to the fields for mulch or buried as organic fertilizer. Pruned leaves and empty fruit bunches have similar uses.

Coconut palm leaves have utility as thatching material, and fresh young leaves can be woven into mats, strong baskets and coarse hats. Leaf midribs can serve as basket framing, to make animal cages and fish trips, or split to make hand brooms. Fences can be constructed from the petioles.

Coconut plantations have an economic life of 60-70 years. Clearing of old unproductive fields affords an opportunity for timber and leaf harvest, as well as palm hearts. Residues can be incorporated into the soil as fertilizer for the new plantings.

Grimwood (1975), Ohler (1984) and Killmann et al. (1996) are basic published sources of information on both commercial and subsistence products from coconut.

Elaeis guineensis

The oil palm is native to Tropical West Africa where it was domesticated as a subsistence crop by indigenous people for its fruit as a source of edible oil, and it continues to be a small farmer crop of West Africa. Another subsistence item is palm wine. The palm is often referred to as the African oil palm to distinguish it clearly from several palm species native to Tropical America which also are sources of palm oil. The African species is the world's major commercial oil palm species and has been introduced to Asia and the Americas where it is cultivated. Oil palm has the distinction of giving the highest yields per unit area of any oilseed crop plant. A solitary palm, it develops a moderately thick stem and is propagated by seed and tissue culture. Once mature, it continuously flowers and fruits.

Cultivation continues as a subsistence crop in Africa where the palm is a common feature of cleared forest areas, in association with food crops and livestock. In regions where it was introduced as an improved crop, such as Southeast Asia and Tropical America, the palm is grown in pure stands on large estates in association with processing factories.

The palm is a source of two similar oils, from the mesocarp and endosperm. Ripe fruit bunches are cut from the trees and transported to the factory. There, the fruit bunches are steam sterilized, fruits stripped from the bunches, mesocarp oil is extracted and seeds are separated to undergo a separate extraction process. Both oils are refined and have wide food and industrial uses. Subsistence farmers primarily extract the mesocarp oil using simple means, mixing the fruits with water and boiling them in a steel drum until the oil at the surface can be skimmed off.

Several secondary processing products are of value. Empty fruit bunches are burned as oil mill fuel and the ash collected to use as fertilizer, in soap making, mixed with concrete, etc. Palm oil bunch ash is a commercial raw material sold internationally. Dried mill effluent and palm kernel cake can be added to animal rations at a low proportion. Solids from effluent are returned to field.

In Africa, tapping the male inflorescence, and sometimes the stem, yields sap which is collected in jars fastened to the tree. Once or twice a day the accumulated sap is transferred to larger containers and taken from the field. It ferments naturally into a mild palm wine. Although chiefly a subsistence beverage, on a small scale it is processed and bottled for commercial sale. The sap contains yeast and also is used in making leavened bread.

Secondary products are fresh leaves pruned for thatch, construction etc., especially by small-scale subsistence growers. Leaves can be added to animal feed. Pruned dead leaves serve as mulch and fertilizer.

An oil palm plantation has an economic life of only about 25 years, the least of any of the five palms. When old plantations are cleared for replanting, huge quantities of stem and leaf materials are generated. Often the residue is burned and the ashes spread on the field. Denser portions of stem can be used as an ingredient in particleboard, but economic viability is unclear. Oil palm has an edible heart, but apparently this food item is not utilized. Leaves, trunks, roots are recycled as fertilizer on site.

Poh et al. (1994), Killmann et al. (1996) and Corley and Tinker (2003) are key references on African oil palm.

Phoenix dactylifera

The date palm is believed to have been domesticated in the Mesopotamian region more than 6,000 years ago, and is among the oldest cultivated tree crops. From its homeland, the date palm was dispersed to North Africa, the Arabian Peninsula and to South Asia, and subsequently to southern Africa, the Americas and Australia, wherever suitable climatic conditions were found to enable commercial fruit production. The date palm develops a moderately thick stem, may reach a height of 20 m. and produces basal suckers in its

earlier years. It may be propagated by seed, offshoot separation and tissue culture. A single annual fruit crop is produced under normal conditions.

Date palm is second only to the coconut with regard to being a source of numerous useful products, but among the palms it holds the distinction of having the greatest number of named cultivars on the basis of fruit characteristics. Date fruits overwhelmingly represent the economic value of the tree; all other products combined are of comparatively minor importance.

Harvesting of ripe date fruits commonly consists of cutting the fruit bunches from the trees, stripping the fruits in the field and transporting them to a processing plant. In a very few elite cultivars of high value, ripe fruits are individually handpicked from the fruit bunch while it is still on the tree. Fruits are sold fresh or dried, and they store well under low temperature conditions. Many food products are prepared from the date fruit, including date paste for bakery products, preserves, condiments, juice, spread, syrup and sugar. Second grade fruits unsuitable for sale can be processed into wine and alcohol, the latter a biofuel resource; organic acids and protein. Date pits contain up to 10% of good quality oil. Waste products from fruit and pit processing can be fed to animals. Pollen is reputed to have medicinal properties.

Under modern plantation practices, field operations generate quantities of empty fruit bunches, cull fruits and pruned leaves. Commonly these residues are left in the field as mulch and fertilizer. However, in desert oases of small-scale agriculture, where woody material is scarce, the date palm provides leaves for shading, thatching and weaving into baskets, mats, rope, hats etc. Midribs and petioles have utility in construction and fencing. Stem wood can be split or sawed into construction material. All of these are also fuel sources. The entire date palm and date palm leaves have symbolic and ritual significance in major religions.

The productive economic life of a date palm is not known with precision. A rough estimate is about 75 years; however trees may be replaced when they reach excessive heights because of the difficulty of pollination, pruning and harvesting. When the palms are cleared for replanting, abundant quantities of leaves and stem wood create a disposal problem. Felled trees also represent a source of edible palm hearts. Currently, these materials are little utilized.

Comprehensive information on date palm growing and its numerous products can be found in Barneveld (1993), which updates earlier studies by Dowson (1962, 1982), and Zaid (2002).

Discussion

Because the harvest and most processing of primary and secondary palm products occur in two separate locations, field and factory, it is logical to discuss enhanced utilization in two sections.

Field

As with every tree crop, field harvest consists of taking from the plant its key economic product, commonly the fruit or fruit bunch, and transporting it to another location for processing. Field harvest may involve on-site primary processing to reduce bulk and weight, such as removal of fruits from the bunches and leaving the empty bunches in the field. Areca, peach and oil palm bunches are cut and transported away; coconuts are harvested individually without bunch cutting; date fruits commonly are stripped from the bunches in the field.

Date harvest typically involves leaving the empty date fruit bunches in the field. In coconut harvest, if coir mesocarp fiber is not to be extracted, the fruits may be husked after harvest and the husks left in the field. If the fiber is to be exploited, the entire fruit is taken to the factory. As part of the fruit harvest of all five palms, some green leaves may be pruned from the trees to afford easier access to the fruit bunches.

Factory

Palm fruit processing varies from simple to complex, the facilities also ranging from small household sites to modern factories. In all cases, the processing generates residue or waste products. These may be empty fruit bunches, shells, peelings, spent pulp or seeds.

Arecanut palm fruit processing is a relatively simple operation, consisting of detaching fruits from the bunches and boiling them whole to reduce tannins. Next the fruits are husked and the endosperm removed and cut up, dried, often mixed with a pigment and other ingredients, and packaged for sale. Some variation exists in the processing procedures employed. Arecanut husks have utility in hardboard and paper making, and as fuel.

Peach palm processing involves stripping fruits from the bunches which are sold fresh or boiled; fruits may also be canned. The only residue is the empty fruit bunch. Processing the peach palm mesocarp into flour generates waste made up of fruit peelings and endosperm. In processing palm

hearts, the incoming palm heart lengths are peeled to remove the inedible outer sheaths, cut into sections, cooked and preserved. Residues from flour and palm heart processing can serve as partial livestock rations. Empty fruit bunches are not utilized.

Oil palm fruit bunches arriving at the factory are steamed, the fruits stripped off and the mesocarp and endocarp oil separately extracted. Empty fruit bunches are employed as fuel and the ash collected for industrial uses. Livestock can consume press cake as part of their rations and other waste products are returned to the field as fertilizer.

Coconut processing may be simple, involving removal of the endosperm from the split endocarps if the product is dried copra for later oil extraction. This is the practice when coconut production is insufficient to support a local processing facility. Alternatively, the endosperm may be removed and immediately processed into various fresh coconut products (e.g. shredded coconut, coconut milk) or oil. In some integrated coconut processing operations, the husk fiber is also an important product. Husks must be retted in water for a period of time to loosen the coarse fiber, after which it is separated, dried and spun into numerous coir products.

The coconut shell (endocarp) is a valuable product. As a direct fuel it has high caloric value, and can be made into excellent charcoal as well as activated carbon. Splitting mature coconuts to extract the endosperm releases coconut water, which is commonly allowed to drain away. However, the liquid contains some carbohydrates and amino acids. If the coconut water is captured, it has use as a raw material for fermentation processes, and can be added to cattle feed before fermentation occurs.

Considering these palm species together, they have the most in common in terms of some residues being used as fuel, often mixed with other combustible material, to generate electrical energy. Depending upon physical and chemical characteristics, waste products of the five palms also serve as an additive in animal rations, or are returned to the plantation fields as fertilizer. Because conveyances bringing fruits to the factory return empty, transporting the biomass back to the field is efficient. Utilization of crop and processing waste products is important because rather than creating environmental pollutants through their disposal, they can become low-value products themselves.

Significant research has been carried out in recent years on secondary product use of the palms discussed in this paper. However, there has been inadequate evaluation of the results across major economic palm species. Three selected examples stimulated by this study, applicable to date palm, can be cited. One, empty fruit bunches of the date palm appear to be little used; yet, evidence from the oil palm suggests that the ash derived from burning them has exceptional qualities with potential industrial applications. Two, the palm heart (apical meristem) of the date palm is edible; yet this food item is scarcely mentioned in the literature. In the Philippines, when coconut plantations are replaced, the palm hearts are extracted and processed into a preserved product sold domestically and internationally. Three, date palm leaves and stems have shown potential in the manufacture of paper, panel board, particle board, etc. A concerted effort to valorise these raw materials should be undertaken.

Conclusion

The date palm has been a multipurpose species since it was first domesticated some 6,000 years ago. In modern times, significant progress has been made in the development of direct and derived date fruit products and the utilization of by-products from packing and processing; however, comparatively minor attention has been given to date palm products other than the fruits. By highlighting the multipurpose character of five major economic palm species, this paper attempts to broaden the thinking about how other nonfruit and fruit products can be developed.

General economic benefits can be derived from broader utilization of all parts of the date palm. Additional socio-economic benefits will also accrue to date farmers in terms of expanding the number of saleable products they produce, and diversifying their income sources.

One key recommendation is that the excellent study *Date Palm Products* (Barreveld, 1993) be updated in light of the numerous published studies over the past two decades. The revision should also place greater emphasis on nonfruit products and include relevant research on comparable palm species.

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