TECHNICAL ASPECTS OF COCONUT STEM UTILIZATION

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Summary

When processing the stem of the coconut palm (*Cocos nucifera* L), various aspects have to be taken into consideration in order to achieve satisfactory results.

Sawing and handling

- remove the stems from the plantation immediately after felling and convert them quickly
- use tungsten carbide or stellited sawblades
- apply large bites as recommended for hardwoods
- maintain saw properly
- dip the timber in fungicide after sawing
- segregate and stack the sawn timber in accordance with at least two, preferably three density classes

Seasoning

- air season the timber properly stacked (in airy place under cover, off the ground, with fillets between)?
- air dry timber down to 30% before kilndrying it
- do not dry batches of mixed densities

Preservation

- all timber in exterior use and/or with ground contact should be (preferably pressure–) treated
- for pressure treatments, the material should be dried below fibre saturation point

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logs for powerpoles have to be debarked and then dried under shelter at least 4 months before treatment

Utilization

- choose carefully timber of right density for the product envisaged.

1. Introduction

Lately various countries have started to remove overaged, typhoon or disease stricken coconut palm plantations. Mostly the palms are just felled and dumped aside by dozer to rot. There are very sound reasons, however, to make use of this biomass:

Plantation – Hygienics

Rhinoceros beetles (*Oryctes rhinoceros*) breed in the rotting debris and attack from there newly planted palms.

Rawmaterial shortage

In many countries with coconut palm populations there is a shortage of timber for construction as well as for furniture and other utility items.

Economics

By utilizing the stem of the felled coconut palm an economic return can be achieved to help finance new plantations.

Up to now the woody stem has only sporadically been utilized. Reasons for this are various:

- prejudice ("no use", "material too fibrous" etc.)
- experience of blunting tools
- experience of failure of coconut timber in service due to wrong seasoning and/or application

Based on practical experience in processing and utilizing coconut palm wood problems and methods to tackle them are pointed out.

2. Anatomical and physical features

Being a monocotyledon, *Cocos nucifera* L. is more closely related to hardwoods (Dicotyledons, both belong to the Angiospermae) than to softwoods (conifers of the Gymnospermae). However, there are basic differences between hardwoods and "coconut wood", which strongly influence its conversion methods as well as later utilization. Coconut wood does not have:

- cambium cells (i.e. no secondary growth, no increase in diameter, no annual rings)
- ray cells
- heart – and sapwood
- branches and knots
- demarcated bark

The fibres are grouped together in distinct vascular – and fibre bundles. Within a matrix of spherical parenchyma cells vascular bundles are scattered indiscriminately containing xylem, phloem cells and sclerenchyma fibres. The number of vascular bundles per square unit increases towards the periphery of the stem. A mature palm of about 60 years of age and ca. 20 m stem height at breast height counts in average 10 bundles/cm^2 in its central portion and about 50 bundles/cm^2, near the bark. This increase in number towards the periphery of the stem combined with increasing cellwall thickness is reflected in a density increase from pith to bark. Especially the sclerenchyma fibres can have cellwalls almost swallowing up the luminae (Butterfield and Meylan, 1980). Thus the density of a mature stem at breast height can reach 800 kg/m^3 (ovendry) and more under bark and only 300 kg/m^3 in the center. Density is as well decreasing with increasing height, since the cell walls of the fibres reduce with stem height. 5 Philippine palms (Malayan Tall, San Ramon variety) chosen at random from a mature, ca. 80 years old plantation showed a density (ovendry) of 255 kg/m^3 at the periphery and of 110 kg/m^3 in the center at 20 m stem height, Since density is closely related to strength values of timber, the density gradients are a major problem in producing homogenous material for various enduses, especially construction.

3. Sawing

Coconut wood is hard to saw. It easily blunts conventional sawblades, a property of ten preventing possible use, if other timber is available. Workshop experience in the Philippines has shown that high speed steel blades on a ripsaw were already worn out after having cut 1000 in^2, while stellite lasted 10 times and tungsten – carbide even 15 times that long before they had to be resharpened. The blunting seems to be rather the result of woodstructure than of an excess of abrasive components (e.g. silica). It mainly is due to:

- hard, thickwalled fibres
- parenchyma cells ground to a fine abrasive powder, which clings to sawn surface and to the blade, increasing friction and heating up the blade. To tackle this problem, tungsten – carbide or stellite – tipped blades have to be used. Compared to conventional saw-blades (mostly of high – speed steel) they have the disadvantages of:
- higher initial costs
- higher maintenance costs due to expensive equipment (e.g. diamond grinding

wheels)

- need of highly skilled labour both for operation and maintenance. Thus, utilization of coconut palm stems up to now is restricted to larger, well capitalized enterprise rather than being handled by small-scale cottage industries. This is a severe draw back, since a large portion of palms occur in clusters in villages and around farms.

On band sawing coconut wood scarce data are available. However, according to trials in Papua New Guinea (personal communication Mr. K. Bergseng) it does not seem to create any problems as long as the sawblades are properly maintained and stellited.

More detailed information is available on circular sawing coconut wood. The most important factor for good sawing is to choose the proper bite*. Smaller bite will produce smoother boards, but

- shortens sawlife, because the teeth contact the timber a greater number of times for same production
- increases power consumption
- produces chips smaller than saw clearance, causing sawdust to pack on the sides of the sawblade, creating blunting due to frictional heat as well as miscut timber.

Therefore the bite should be larger especially in cutting a species as abrasive as coconut wood. Table 1 gives an example for successful combinations of sawmill data.

Another problem to be coped with while sawing is the density (and strength) distribution. In order to achieve homogenous material for various enduses, a special sawing pattern has to be adopted. After every second cut the log should be turned. Thus four slabs with high – density timber (ovendry 600 kg/m^3 and more) and four planks with medium (ovendry 400–600 kg/m^3) to high – density timber can be recovered. The remaining center scantling of low – density (ovendry below 400 kg/m^3) material is then sawn into boards. This sawing pattern is rather time consuming and excludes the utilization of gangsaws. It is recommended that

- the freshly felled palms should be sawn as soon as possible, because:
  - the timber is much more easy to saw, when green
  - coconut wood is prone to contract blue stain

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* bite=distance the timber advances into the saw between each successive tooth Bite=*feed speed* (*m*)*x pitch* (*mm*) surface speed of saw (m).

– the sawn timber should be dipped in fungicide immediately after sawing in order to prevent blue stain attack during seasoning.

4. **Grading**

It is advised to segregate the timber into three density groups:

I	soft or low density	(up to 400 kg/m^3 ovendry)
II	medium density	(400–600 kg/m^3 ,,)
III	hard or high density	(600 and more kg/m^3 ,,)

The most reliable method to assess the quality of timber would be that of stress grading. But since in most cases neither sophisticated equipment nor skilled personnel are available, visual grading is suggested. Strength properties are closely related to density which in turn has a high correlation with amount of vascular bundles per square unit over the cross section (0.9068, Killmann, 1983). By visual assessment of the relative amount of vascular bundles on both ends of a board even an unskilled person can segregate the sawntimber into three groups after some elementary instructions.

5. **Seasoning**

Coconut wood of high and medium density can be airdried relatively problem free under cover. Air seasoning to equilibrium moisture content in Southern Mindanao (17%) took about 60–70 days for boards of 25 mm thickness, dependent on initial moisture content. The moisture content (mc) is increasing from bark to pith as well as from butt to top. At breast height the mc can differ between 50% under bark and 200% in the center while at a level of 20 m it can reach 230% and 400% in the respective zones (Killmann, 1983). When kiln dried at low temperatures (60–65 °C Dry bulb: 4–6 °C wet bulb depression) it took about 8–10 days for boards of the same dimensions to reach equilibrium moisture content from green condition.

For 50 mm boards of densities between 400 and 900 kg/m^3 air seasoning from green to equilibrium moisture content (emc) takes up to 120 days, kiln seasoning, at the same mild schedule about 20 days. Harsh kiln seasoning, especially of the high density material, may result in surface checking. This is due to

– different shrinkage of vascular bundles and parenchyma cells
– absence of rays and thus a restricted moisture exchange in radial and tangential directions.

Low density timber is prone to collapse. Collapse becomes more prominent towards the top of the stem (over above 15 m stem height). The amount of collapse can be reduced by first airdrying the timber below fibre saturation point and afterwards kiln season it. As Kininmonth (1980) reports, some of the collapsed material recovers after reconditioning. Trials in the Philipines have shown that forced airdrying from green to emc (in kiln with running fan at 4 m/s, open vents and without heating) for 25 mm material in 10 days considerably reduced the occurrence of collapse and produced better quality timber than the conventional airseasoning method. However, more research is necessary.

Twist and, to lesser extent, warp, occur in coconut wood of all densities. It can be prevented by applying pressure on the stack during drying. Fungi (especially bluestain) and mould frequently infect the softer material, if not previously treated.

Shrinkage is correlated to the amount of vascular bundles per square unit (0.84 . . . . Killmann, 1983), i.e. it increases from center to bark as well as with stem height. Other than Mc Quire (1980_1), who stated that tangential shrinkage from 30% to 17% is double the radial shrinkage, the author found little difference between both, tangential shrinkage being slightly higher when seasoning from green to 0% mc. However, at the same stem height, the dense material shrinks double (4% at breast height) as much as the low density timber, (Killmann, 1983) poles should be debarked before airdrying and stacked under cover.

6. Woodworking

As in sawing, in all other woodworking operations the density gradients coconut wood require special attention, planer – and jointerblades as well as cutterheads blunt after 6-7 effective working hours, while tungsten carbide lasts 10 times that long.

Due to the run of vascular bundles raised and fussy grain easily occur especially in low density material. Compressed during planning, the parenchyma stays plane, while the vascular bundles spring out after release of pressure. Nailing coconut wood, especially if it is dry and of high density, can result in splitting. Screwing in no, stage of density or seasoning creates problems. Lamination of coconut wood – essential for providing timber for larger (glulam) structure, since the planks recovered are relatively thin, proved rather successful. Naturally the boards have to be planed before glue application, and only medium or high density material should be used.

Summarizing, in working with coconut wood the following aspects should be considered:

- preferably machine the timber in wet conditions
- use tungsten – carbide or stellited tools
- control the sharpness and state of tools often and maintain them properly
- apply moderate to slow feed speed, but apply firm feed to avoid vibrations
- sand the surface thoroughly before applying lacquer, varnish etc.
- when dry if, hard timber is to be nailed, it should be predrilled.

7. Preservation

Stake tests and service trials have shown that coconut wood has no natural durability. Its high moisture content when green as well as its starch content attract both fungi and insects (e.g. ambrosia beetles). Low density timber is more susceptible to attack by deterioriators than high density material. To prevent the attack of sapstain fungi

- logs should be removed from the plantation immediately after felling. Further protection should be given:

- timber in ground contact and for exterior use should be pressure treated

- from quartersawn fenceposts the pith should be removed before putting them into service

For antisapstain treatment dipping of sawn timber in a mixture of sodium pentachlorophenate (2 kg) and Borax (5.5 kg) in 45 l water has proved successful.

For timber in exterior use and/or groundcontact, pressure treatment with 2–6% chrome – copper – arsenate has been applied. The timber was treated by full-cell-method (35 min vacuum of –85 kpa, 50 min pressure of 1400 kpa, 5 min end vacuum of –85 kpa). Penetration, absorption and retention of low density material is better than of high density wood (Palomar, 1980). At 20–25% moisture content a retention of 15–18 kg/m^3 was achieved. But even above fibre saturation point intermediate retention can be achieved (Mc Quire, 1980,[2])

Sap displacement trials have only partly been successful – the absence of rays has proved to be a hindrance to distribution of preservative in the stem.

8. Timber production and Utilization

Due to its light – and nutrient requirements, the average density of a coconut palm plantation is 100 palms. The total volume of mature, over 60 years old palms with an average height of 20 m comprises 0.7 – 1 m^3, dependent on its diameter. Of this biomass, ca. 90% can be industrially used. The recovery lies at 35%. Thus a plantation yields about 35 m^3 of usable timber. This figure, however, is very conservative (Jensen & Killmann, 1980) and already takes into consideration natural defects as well as losses due to "harvesting steps". Coconut wood has the advantages of total absence of knots and branches as well as the identity of properties in radial and tangential direction due to the absence of secondary growth. However, due to the small diameters (40 cm at butt end) and the density variation within the stem at the most 4 boards of up to 50 mm (2 inch.) thickness and 100–125 mm (4-5 inch.) width of high and medium dense material can be recovered perlog, and about 4–6 boards of 25 x 100 mm (1 x 2 inch) low density timber. The length of log depends on the amount of sweep and taper of the palm. It is a function of variety as well as of climatical conditions and plantation management. In Mindanao, e.g., it is possible to recover 6 m logs, while from Fiji only 4 m logs have been reported useful.

Possible endproducts in relationship to density groups are given below:

Low	*Medium*	*High D.*
insulation	panelling	panelling
charcoal	charcoal	charcoal
pulp	pallets	pallets
	boxes	parquet
	mouldings, touguld & grooved (T&G)	mouldings, T & G
	furniture	flooring
	toys	toolhandles
	utility items	stairs
	fenceposts	mining timber
	construction (GS)	construction (SS)
		window/door jambs

Whole stem: powerpoles, jetties, studs in housing

Peeled veneer cannot be made out of coconut wood. Due to its anatomical structure (lack of rays) it would disintegrate after peeling. Its anatomical structure and strength properties make coconut wood ideal for power poles. However, drying and preservation of logs in a whole still create some difficulties.

Sudo (1980) shows that pulp can be manufactured from low density material especially from the upper portion of the stem. But the large amount of fines produced from the parenchyma tissue reduces the yield and quality, an observation made as well by Semana and Ballon (1976) for hardboard manufacturing and by Pablo, Seguerra, Tamolang and Ella (1977) for chipboard production. In charcoal production low density material, if used, should be mixed with high density timber – low density coconut wood alone produces charcoal of inferior quality. In Mindanao slabs, offcuts of medium and high density coconut wood and air seasoned billets of low density material were mixed for charcoal production in a Tropical Products Institute Mark V steelkiln. The recovery (20–25% by weight) depends on the amount of high density material present in the batch.

Further research is needed in the following fields:

Sawmilling

– bandsawing of coconut logs

Seasoning

– defectfree seasoning of lowdensity material from the top (possibly by forced air drying) in order to improve sawntimber yield

– development of seasoning schedules for the three density groups of coconut timber

Preservation

- treatment trials of coconut timber with Chromium-Copper-Boron (CCB) and Chromium-Copper-Fluorine (CCF) in order to reduce its toxicity for cattle and humans
- determination of preservative loadings needed to guarantee economic service life

However, basically the use of coconut timber has been proved. Thus, it is felt that apart from some further research a larger practical attempt is needed to utilize this vast rawmaterial resource on commercial level (e.g. in the Philippines, Sri Lanka, Zanzibar, the Caribbean or other countries) to prove that utilization is not only technically but as well economically feasible (Jensen & Killmann, 1980_2).

Coconut wood is a unique material which requires special equipment, methods and skill in processing. If properly processed and utilized, it very well can perform if not as a competition on the international market but as a suitable substitution for conventional timber in areas where timber is in short supply.

REFERENCES

Butterfield, B.G.; Meylan, B.A. 1980: Three dimensional structure of wood. London, Chapman & Hall.

Jensen, P. 1980. Recovery in Sawn timber from *Cocos nucifera* log. In: Proceedings of the Seminar Coconut Wood 1979: 88–98. Philippine Coconut Authority, Manila, Philippine.

Jensen, P. Killmann, W. 1980,: Utilization of palm wood. In: Proceedings of the Seminar Coconut Wood 1979: 75–79. Philippine Coconut Authority, Manila, Philippine.

Jensen, P.; Killmann, W. 1980_2: Production Costs of Sawn Coconut timber. In: Proceedings of the Seminar Coconut Wood 1979: 207–240. Philippine Coconut Authority, Manila, Philippine.

Kininmonth, J.A. 1980: Current state of knowledgé of drying coconut wood. In: Proceedings of the Seminar Coconut Wood 1979: 104–113. Philippine Coconut Authority, Manila, Philippine.

Killmann, W. 1983. Some physical properties of the coconut palm stem. Wood Science and Technology, (in press.)

Mc Quire, A.J. 1980_1: Anatomical and morphological features of the coconut palm stem in relation to its utilization as an alternative wood source. In: Proceedings of the

Seminar Coconut Wood 1979: 24–28. Philippine Coconut Authroity, Manila, Philippine.

Mc Quire, A.J. 1980_2: Exposure tests of treated and untreated coconut stem wood in the South Pacific. In: Proceedings of the Seminar Coconut wood 1979: 125–129. Philippine Coconut Authority, Manila, Philippine.

Pablo, A.A; Seguerra, J.B. Tamolang, F.N.; Ella, A.B. 1977: Coconut trunk and wood/coconut trunk particle board mixtures. NSDS Techn. J. II, 2: 34–43.

Palomar, R.N. 1980: Pressure impregnation of coconut sawn lumber for building construction materials. In: Proceedings of the Seminar Coconut Wood 1979: 129–135. Philippine Coconut Authority, Manila, Philippine.

Semana, J.A. Ballon, C.A. 1976: hardboard from coconut trunk. In: Proceedings of the coconut stem utilization seminar held in Tonga 1976: Ministry of Foreign Affairs, Wellington, N.Z.

Sudo, S. 1980: Some anatomical properties and density of the stem of the coconut palm (*Cocos nucifera*) with consideration for pulp quality. JAWA Bulletin, 1: 161–171.

TABLE 1

Technical Data of two Saws for Coconut wood conversion in the Philippines[1]

Saw	Power (Kw)	Diameter (cm)	Diameter (inches)	Gauge (mm)	Gauge (BWG)	No. of Teeth	RPM	Feedspeed (m/min)	Feedspeed (ft/min)	Bite (mm)	Bite (inch)	Daily Input (logs)	Daily Input (m^3)	Daily Output (bd. ft)	Daily Output (m^3)	Recovery (%)
Headrig[2]	75	137	54	5.18	6	23	770	15	50	0.85	0.035	100	35	5000	12	
								23	75	1.25	0.050	120	42	5500	13	30 – 35%
Breastbench[2]	60	91	36	4.19	8	48	1220	30	100	0.50	0.020	see above		see above		
								46	150	0.75	0.030	”		”		
Headrig[3]	68	112	44	4.19	8	19	680	9	30	0.71	0.028	50	17.5	2500	6	
								12	40	0.91	0.037	”		”		30–35%
								15	50	1.42	0.046	”		2750	6.5	
Breastbench[3]	37	76	30	3.76	9	13	1200	32	105	2.02	0.079	see above		see above		
								37	120	2.31	0.091	”		”		
								41	135	2.59	0.102	”		”		

(1) data collected in the Coconut Research and Development Project, Zamboanga, Philippines, see also Jensen, 1980.
(2) stationary sawmill, blades fit with tungsten-carbide teeth.
(3) transportable sawmill, blades fit with stellited inserted teeth.