Tropical Woods as Pulp Stuffs

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With an increasing consumption of papers in the world, pulp wood resources have been decreasing remarkably. Particularly, the pulp industry in Japan, highly dependent on imported foreign woods, has shown a rapid increase of consumption of tropical woods. As tropical trees grow very rapidly, it is quite likely that they will be utilized in future as a major world resource of pulp woods. A critical reason why such prospective tropical trees have not been utilized so far as a pulping material is found in the constitution of tropical virgin forests. As tropical virgin forests are mixed-stands, it is said that the economical volume to be used as pulp woods is only 30–50 m^3/ha due to the difficulty to sustain a large volume skidding of individual species. Imported pulp woods in Japan are mostly confined to para rubber tree refuse[1] and mangrove woods[2], which are available in relatively large amount, and also plywood wastes such as lauan woods[3,4]. However, if natural trees come to be used positively in future, the pulping of mixed chip containing various woods will have to be practiced. In this case, the pulping process will be limited to only the Kraft process. Even with the mixed chip of Japanese hardwoods, other methods than the Kraft process are hardly applicable. The mixture-cooking of tropical hardwoods which are more diverse than Japanese woods must cause many troubles. Such problems will be discussed based on the characteristics of tropical woods.

Firstly, as to the wide diversity of tropical woods, it can be said that there are many species belonging to the same genus. For example, eucalyptus consists of about 600 species in the world. In case when the number of species are few, planting trees of different original home are often used.

Even with a same species, chemical components of wood varies to a great extent[9] depending on its growing area. An example is shown with keruing woods in Table 1. Ash content varies particularly by regions. Great variations related to tree age are also a problem. Hills[4] examined relations between tree age and morphological characters or extractives with eucalypt woods (*E. Obliqua*), and reported an enlarged fibre and increased extractives in parallel to the tree age. Further-

Table 1. Morphological properties and chemical components of keruing woods (*Dipterocarpus* spp.) from every growing regions

Growing regions		Specific gravity of wood O. D. g/cm³	Morphological properties			Chemical components*1					
			Fibre length mm	Fibre diameter	Cell wall thickness	Ash	Hot-water exts.	Alc-ben. exts.	Holo-cellulose *2	α-cellulose *2	Lignin
Malaya	(A)	—	1.50	30.2	12.3	0.71	2.0	3.2	72.7	50.8	30.6
	(B)	0.74	1.53	30.2	13.2	1.15	4.7	3.9	68.4	47.7	32.3
	(C)	0.83	1.75	26.7	12.1	0.83	2.5	1.5	77.7	55.3	25.3
Kalimantan	(D)	0.83	1.72	32.0	13.5	0.49	1.5	3.3	74.6	54.8	28.8
	(E)	0.71	1.77	30.0	11.6	1.26	2.9	2.3	73.5	54.3	28.0

*1 All results are based on O. D. wt. wood.
*2 Ash and lignin free.

Table 2. Morphological properties and paper strength of unbleached sulphate pulps from various tropical hardwoods
Pulpling condition: Total alkali (as Na_2O) 16%, Sulphidity 25%, Liquor to wood ratio 4-6; Cooking, 1.5 hr at 170°C

Species	Specific gravity of wood O. D. g/cm³	Morphological properties: Fibre length mm	Fibre diameter μ	Cell wall thickness μ	Handsheet properties (basis weight 60±3 g/sqm): Freeness* C. s. f. cc	Density g/m³	Breaking length km	Burst factor	Tear factor	Folding endurance M. I. T. rev
Erima (*Octomeles sumatrana*)	0.33	1.87	40.1	6.9	225	0.85	12.9	10.4	112	7600
Amberoi (*Pterocymbium beccarii*)	0.38	1.52	43.2	7.0	240	0.86	7.5	5.9	141	320
Labura (*Anthocephalus cadamba*)	0.38	1.65	37.5	7.5	220	0.82	7.9	6.6	141	460
Terminalia (*Terminalia* sp.)	0.38	1.46	26.7	5.0	200	0.85	10.4	9.4	175	1780
Evodia (*Evodia elleryana*)	0.35	1.44	29.0	6.8	330	0.85	9.1	8.4	144	1100
Campnosperma (*C. brevipetiolata*)	0.43	1.64	31.5	9.5	220	0.84	10.5	8.0	134	4000
Yellow meranti (*Shorea* sp.)	0.44	1.35	26.1	5.9	215	0.81	8.9	8.4	191	500
Taum (*Pometia pinnata*)	0.51	0.97	25.6	6.6	234	0.86	9.1	7.6	127	600
Canarium (*Canarium indicum*)	0.55	1.32	26	7.5	330	0.81	7.9	6.4	140	94
Celtis (*Celtis* sp.)	0.59	1.30	23.3	6.7	200	0.78	8.0	5.9	94	120
Jongkong (*Dactylocladus stenostachys*)	0.50	1.51	43.0	7.8	200	0.85	10.2	8.4	128	2000
Sepetir paya (*Pseudosindora palustris*)	0.56	1.04	27.7	6.8	238	0.89	11.6	8.9	113	1400
Yellow hardwood (*Neonauclea maluensis*)	0.62	1.63	31.6	6.6	235	0.75	7.4	5.1	170	98
Ramin (*Gonystylus bancanus*)	0.62	1.28	37.6	9.7	230	0.85	7.8	4.6	98	120
Malas (*Homalium foetidum*)	0.84	1.72	28.4	11.7	220	0.62	6.3	4.3	150	55
Bangkirai (*Shorea laevis*)	0.84	1.29	19.0	7.3	205	0.69	6.7	3.8	109	25
Balau (Sect. *Shorea* [*Eushorea*])	0.97	1.35	18.2	8.2	230	0.68	7.4	4.9	131	72
Japanese beech (*Fagus crenata*)	0.48	1.13	20.0	3.5	220	0.86	10.7	7.3	95	590

* Beating by PFI mill.

more, it is almost impossible at present to measure exactly the tree age of tropical hardwoods.

Based on these facts, it must be taken into consideration that the values of characteristics of tropical hardwoods show the wide range of variations, which is not observed with Japanese hardwoods, even within a same species.

Morphological properties of tropical hardwoods

For the pulp industry, specific gravity of woods is an important factor. Woods with lower specific gravity cause an increased cost of transportation, decreased filling volume, and higher liquid to wood ratio, but result in generally good physical properties of paper.

Morphological properties of some tropical woods and paper strentgh of kraft pulps are given in Table 2. As compared with Japanese woods, the typical feature of tropical woods is more or less longer fibres with very thick cell walls, which gives generally an increased tear strength. Woods with higher specific gravity give lower paper strength in general.

As shown in Table 3, tropical woods have vessels with thicker walls and wider diameter than Japanese ones[9]. Vessels with large width apt to cause picking troubles during printing. Vessels and parenchyma, which contain a large amount of resin and ash, stiffen and cause various rejected speck troubles. Oka[3] reported that rejected speck contents in the pulps prepared from lauan woods by the kraft process were more than two times that of original woods. However, more than 80% of the speck can be removed by the centri-cleaner treatment.

In addition, there is a big problem of spongy heart which appears at the central portion of ripe trees with a large diameter. As many fibres are being destroyed, woods containing the spongy heart results in lower paper strength and lower yield of pulp, in addition to its economic problem.

Chemical components of tropical hardwoods

As compared with Japanese woods, the tropical hardwoods always contain more lignin, and generally more ash and extractives. Examples of woods with relatively high contents of ash and extractives are shown in Table 4.

Among the ash components, the EDTA ash (Ca, Mg, Si, etc.) is difficult to be removed by cooking, and particularly high contents of silica cause an abrasion of cutting tooth of saw and chipper, resulting in a low efficiency. Ash is contained more in parenchyma, as stated earlier, so that it can be removed to a

Table 3. Constructive proportion of wood elements and morphological properties of vessels on some tropical woods

Species	Specific gravity of wood O. D.	Constructive proportion		Morphlogical properties of vessels			
		Vessel	Fibre	Length	Diameter		Wall thickness
					Radial direction	Tangential direction	
	g/cm³	%	%	μ	μ	μ	μ
Erima (*Octomeles sumatrana*)	0.31	13.1	72.0	360–680	150–360	150–290	—
Yellow meranti (*Shorea* sp.)	0.42	17.5	66.3	240–660	180–300	140–220	4–6
Jongkong (*Dactylocladus stenostachys*)	0.41	11.2	67.0	300–750	60–230	60–170	2.5–3
White meranti (*Shorea* sp.)	0.47	28.1–30.2	59.2	200–600	150–370	140–290	4–9
Ro yong (*Parkia streptocarpa*)	0.43	9.7	63.2	150–520	100–360	100–290	2–3
Teraling (*Tarrietia* sp.)	0.61	16.7	47.2	300–500	140–400	150–330	—
Balau (Sect. *Shorea* [*Eushorea*])	0.66	35.2	57.4	260–550	120–370	110–320	—
Ban Kirai (*Shorea laevis*)	0.75	29.7	48.7	120–600	70–340	70–250	3–5

Table 4. Ash, extractives and lignin of some tropical hardwoods

Species	Specific gravity of wood O. D. g/m³	Ash %	Solubility in Hot-water %	Solubility in Alc-ben %	n-Hexan %	Ether %	Acetone %	Methanol %	Total %	Lignin %
Artocarpus (*Artocarpus incisus*)	0.32	2.30	2.53	2.82	0.77	0.18	0.69	1.45	3.09	30.74
Terminalia (*Terminalia* sp.)	0.38	1.92	5.87	1.74	0.18	0.32	1.43	3.04	4.97	25.83
Antiaris (*Antiaris toxicaria*)	0.31	1.89	3.21	0.94	0.06	0.06	0.33	1.70	2.15	31.23
Erima (*Octomeles sumatrana*)	0.33	1.83	3.64	2.63	2.62	0.90	0.19	1.57	5.28	23.25
Sepetir paya (*Pseudosindora palustris*)	0.50	—	—	—	0.04	0.94	11.08	5.23	17.29	—
Black bean (*Castanospermun australe*)	0.60	0.30	12.2	12.4	0.39	0.29	10.31	5.25	16.24	27.6
Kwila (*Intsia bijua*)	0.74	0.99	9.60	6.56	0.46	0.24	5.42	5.20	11.32	29.40
Water gun (*Syzygium* sp.)	0.63	0.95	5.03	7.01	0.79	5.76	0.90	1.97	9.42	28.74

considerable extent during the refining process of pulp. Kai et al.[2] reported that the addition of 0.1 N HCl in the Cl stage of bleaching process was effective in removing Ca. Silica is soluble to hydrofluoric acid, but no other methods than physical removal can be employed.

Woods with high specific gravity have generally more extractives. n-Hexan extractives are difficult to be removed by the pulping process: They cohere in pulps to produce cohesive bowls, and which cause paper-making troubles, yellow scabs trouble, and brightness reversion. The principal ingredients are mainly higher hydrocarbons, higher fatty alcohol, steroid, triterpen, higher fatty acids (C_{20}–C_{30}) and unsaturated fatty acids (linoleic acid, etc.)[5]. With the progress of successive extraction from using ether to methanol, polymeric fatty compounds increased. Many of them are of important usage. Particularly famous are dammar resin and kino, which are secretions of resin canals and harvested by tapping. They are chiefly styrol, stilben, and derivatives of pyrogallol and catechins, with very low oxidation and saponification values. A part of polyphenols consisted of these substances combines with hemicellulose and lignin. This is a reason for high lignin contents of tropical woods[6]. The fact that polyphenols give different colors according to the difference in their construction is used as a criterion in making broad grouping of tree species. However, these compounds cause various troubles in pulping. Compounds having more than two OH radicals produce chelates with metals, so that they corrode saw and digester, giving deep brown adhesive substances clinging on them. Polyphenols cause an increased consumption of chemicals in cooking. When polypenolic carboxylic acids are oxidized, they turn into dark brown and stain strongly the fibers so that the bleaching treatment has to be done excessively. Ellagitannin, contained much in eucalypt woods, is easily changed by enzymes to quinone, which becomes dark color by repolymerization. As it is highly resistant to alkali-hydrolysis it effects the staining of cold soda refiner ground pulp. It gives also a casue for higher tackiness of black liquor, and effects the evaporation and combustion of black liquor[7]. Mg-base sulphite cooking should be avoided because it produces chelate compounds. Neutral sulfite semichemical process is more influencial than the kraft process.

Although mechanical and chemical methods are made against these resin troubles, there is

Table 5. Comparison of unbleached kraft pulps from tropical and Japanese softwoods Pulping condition: Sulphidity (as Na_2O) 25%; cooking 1.5 hr at 170°C

Species		Tropical pines[10]	Japanese red pine (*Pinus densiflora*)	Agathis (*Agathis* sp.)	Sugi (*Cryptomeria japonica*)
Total alkali (as Na_2O)	%	18	17	18	21
Pup yield: Total	%	46.9–49.0	45.6–50.5	48.5	45.2–47.8
Screenings	%	0.2– 3.7	1.3– 2.0	0.2	0.1– 0.3
Roe No		5.5– 6.8	4.9– 7.3	8.0	6.9– 8.7
Brightness		24.9–26	18.2–21.9	18.9	22.3–22.6
Paper testing					
Freeness (C. s. f.)	cc	220±10	220±10	160	220±10
Density (O. D.)	g/cm^3	0.70–0.72	0.76–0.77	0.76	0.80–0.83
Breaking length	km	8.1– 8.8	11.1–11.4	8.7	6.1– 9.6
Burst factor		7.5– 8.1	8.3– 9.7	9.2	8.0– 8.2
Tear factor		132–160	110–117	243	166–179
Folding endurance (M. I. T.)	Rev	—	1600–2200	4200	2400–3000
Morphological properties of fibre					
Length	mm	2.8– 3.2	1.5– 6.0	6.9	1.3– 6.0
Diameter	μ	38.4–50.1	30–55	68.7	10–50
Wall thickness	μ	5.1– 8.2	2.5– 8.0	11.1	1– 7

no definite method yet. A method to break down rejected specks and to disperse resin by beating with ball mill is not much effective, because the destruction of vessels results in an increased tacking[3]. In cooking with cooking liquor containing organic solvents and surface active agents, the solvents give a high effect in eliminating resin, while the surface active agents have no effect[2,8]. When surface active agents are added at the NaOH extraction stage of bleaching process, cation agents rather inhibit resin elimination. Nonion and anion agents are ineffective, whereas highly hydrophilic surface active agents are effective to some extent. All these results indicate that tropical hardwood have a number of considerable disadvantages as pulp woods. For the cooking by the kraft process, appropriate grouping of the tree species will be needed[9].

Future outlook

If the tropical forests are expected to develop as a world source of supply of pulp woods, the reforestation of species suited for pulp would be necessary. At the cycling with 12 years of age of maturity, relatively uniform woods with less resin content will be obtained continuously from fast growing trees.

Already at present in Australia, Brasil, India, and other tropical regions, systematic reforestation of eucalyptus (*E. Deglupta, E. Tereticornis. E. Saligna, E. Grandis, E. Alba,* etc.) is in progress, and future expansion is expected. As occarpa pine, caribaea pine and agathis are adapted to heavy rain regions, they are very promising as species for tropical forestry. Tropical soft woods are mostly suited for pulp stuffs. Their properties are similar to those of Japanese woods and, as shown in Table 5, their pulp characteristics are also similar to that of Japanese woods. There are many species adapted to the planting at various areas, such as *Albizzia falata, Terminalia calamaneanai, T. brassii, Anthocephalus cadamba, Gmelina arpora, Cratoxylum arborescens,* etc.

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