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Wood and Cellular Properties of 4 New *Hevea* Species

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ABSTRACT

Increasing demand for timber and the depletion of natural forest have encouraged utilization of many non-popular species. The understanding of wood properties and behavior is important to evaluate the potential of these species to produce high quality end products. This study determines the anatomical and physical properties of *Hevea* species viz *Hevea pauciflora, Hevea guianensis, Hevea spruceana, Hevea benthamiana* and *Hevea brasiliensis*. Each sample tree was cut into three different portions along the height (bottom- B, middle- M and upper -T parts) and two radial samples (outer- O and inner- I parts). *H. brasiliensis* clone *RRIM 912* exhibited the longest fibre with 1214μm, followed by *H. benthamiana* (HB, 1200μm), *H.pauciflora* (HP, 1189μm), *H. spruceana* (HS, 1158μm) and *H. guianensis* (HG, 1145μm). Fibre length has a positive correlation with specific gravity. The largest fibre diameter (24.9μm) and lumen diameter (12.5μm) were recorded in *H. guianensis*. The highest moisture content was obtained from *H. spruceana* (64.34%) compared to the lowest with 60.01% (*Clone RRIM912)*. The higher moisture content is normally associated with lower strength. Overall, the properties of clone *RRIM 912* is found to be comparatively better because of higher strength due to longer fibre length, thicker cell walls and higher specific gravity than the other *Hevea* species. Therefore, this species can be used as a general utility timber.

Key words: Wood anatomy, forest products, rubber trees, *Hevea* species, moisture content.

INTRODUCTION

Rubberwood is valuable species of timber for furniture manufacture on a commercial scale due to its beautiful, light and even coloured texture, comparable strength and easy machining and processing properties (Chew 1993; Lew; Sim 1983). In general, the rubber tree is an easy to recognize species because it woody, medium to large sized, and presents a typical leaf shedding and renovation pattern (Wycherley 1992).In 2000, 80% of wooden furniture in Malaysia was made of rubberwood. The rubberwood furniture industry has gained tremendous achievement (Hashim et al. 2000). For decades, Malaysia has been acknowledged as the world's leading supplier of natural rubber.

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Thus, the rubberwood (*Hevea brasiliensis*) was well documented since 1970's, and it is possible to document the properties of other *Hevea* species in order to complement for the shortage of *Hevea brasiliensis* in down stream wood processing industries. They are capable of turning out a wide range of products of high quality. Significant research had been carried out to identify new clones or species that will increase its timber yield. Other than *Hevea brasiliensis, H. nitida* has been found to have potential to produce 9 times more timber than the RRIM 600 clone (Najib et al. 1997). Since these various rubberwood species are in the same genus with *Hevea brasiliensis,* it is expected that other *Hevea* species may be having almost the same or even better properties than *H. brasiliensis*.

The understanding of anatomical properties and wood structure is important because it can depict the density, mechanical and strength properties and determine the characteristics of the potential products. The most common anatomical properties studied are the proportion of early and latewood, fibre length, cell wall thickness, lumen diameter and the parenchyma proportion (Desch and Dinwoodie 1983). Fibre length, an important aspect of fibre morphology, is related to the mechanical strength and longitudinal shrinkage and is known to affect strength properties of paper (Dinwoodie 1981). Fibre cross-sectional dimensions such as fibre diameter, lumen diameter and wall thickness affect some properties such as strength, shrinkage and swelling, permeability, gluing and machining characteristics (Van Buijtenen 1969).

Among the physical factors that influence strength, specific gravity, moisture content, shrinkage and swelling are the most important one (Lavers, 1969). The specific gravity of wood is its single most important physical characteristics, which is most mechanical properties of wood are closely correlated. And if the specific gravity increases, the strength of wood as well as the stiffness is also increased. In the utilization of rubberwood, the study of its structure is important as it is establishes the variation in properties of the wood (Lim and Ani 1994).

This study was conducted to determine the difference of rubberwood properties from five different *Hevea sp.* i.e. clone RRIM *912* from *Hevea brasiliensis, Hevea pauciflora, Hevea guainensis, Hevea spruceana* and *Hevea benthamiana.*.

MATERIALS AND METHODS

Sample collection

Five rubberwood species used in this study were *Hevea pauciflora, Hevea guainensis, Hevea spruceana, Hevea benthamiana* and *Hevea brasiliensis* clone *RRIM 912.* Trees of 15 years old were felled from Rubber Research Institute Malaysia (RRIM) Plantation at Bandar Penawar, Johor. After felling, the trees were cut into 3 boles of 2 meter length. In between each bole, a disc was taken and labeled as top, middle and bottom parts. Discs were wrapped in plastic to avoid any changes in moisture content.

Anatomical properties

This phase covered the study of fibre morphology and cellular structure along the stem of the rubberwood. Disc from each height was cut into strip with wide 6 cm wide across the centre. They were then cut into a cube of 2 cm x 6 cm on both sapwood and heartwood areas. The cube was further cut into 1 cm x 2 cm x 2 cm specimen for slide preparation in the process of determining the cellular structure in three different planes, include cross, tangential and radial sections. The samples for anatomical assessment through thin sections slides and macerated wood elements were prepared in accordance with the Botanical Microtechnique (Berlyn and Miksche 1976).

The microscopic structures of each species were examined using the optical microscope, projection microscope and scanning electron microscope (Image Analyzer) for the measurements of vessel diameter and frequency, fibre diameter and length, lumen diameter, cell wall thickness and proportion of fibres and rays.

Physical properties
Samples for the physical test were cut from the discs of the tree. The samples for physical tests were cut in accordance with ISO 3129-1975 (E) – Wood Sampling Methods and General Requirements for Physical and Mechanical Tests. For each small block following experiments were carried out:

(1) Moisture content: moisture content based on green condition.
(2) Specific gravity: specific gravity based on dry weight.
(3) Shrinkages: shrinkages at air dry condition and oven dry condition at three different directions (radial, tangential and longitudinal).

Statistical Analysis
All the samples were analyzed using analysis of variance (ANOVA) and significant differences between mean values using Least Significant Difference Test (LSD) at $\alpha = 0.05$.

RESULTS AND DISCUSSION

Anatomical properties
The means on the anatomical properties of rubberwood are shown in Table 1.

Table 1. Mean values on the anatomical properties of rubberwood

Property	Species	Portion	Radial Position
Fibre length	1214^a (RRIM912)	1257^a (T)	1220^a (O)
	1200^a (HB)	1234^a (M)	1144^b (I)
	1189^a (HP)	1056^b (B)	
	1158^b (HS)		
	1145^b (HG)		
Fibre diameter	24.9^a (HG)	24.5^a (T)	24.3^a (O)
	24.3^a (HP)	24.3^a (M)	23.7^b (I)
	23.7^b (HS)	23.3^b (B)	
	23.6^b (HB)		
	23.5^b (RRIM912)		
Lumen diameter	12.5^a (HG)	11.73^a (T)	11.64^a (O)
	11.5^a (HP)	11.52^a (M)	11.29^a (I)
	11.4^a (HB)	11.14^a (B)	
	11.3^a (HS)		
	10.4^b (RRIM912)		
Cell wall thickness	6.51^a (HS)	6.35^a (M)	6.34^a (O)
	6.37^a (RRIM912)	6.32^a (T)	6.16^a (I)
	6.17^b (HG)	6.08^b (B)	
	6.13^b (HB)		
	6.08^b (HP)		
Vessel diameter	155.3^a (RRIM912)	162.4^a (T)	143.5^a (O)
	154.7^a (HS)	157.1^b (M)	134.4^b (I)

	139.4^{b} (HB)	101.3^{c} (B)	
	138.4^{b} (HP)		
	122.6^{b} (HG)		
Vessel frequency	2.61^{a} (HG)	2.57^{a} (T)	3.18^{a} (I)
	2.48^{a} (HP)	2.52^{a} (M)	2.37^{b} (O)
	2.47^{a} (HB)	2.34^{a} (B)	
	2.46^{a} (HS)		
	2.33^{b} (RRIM912)		
Proportion of fibres	55.1^{a} (HB)	51.2^{a} (B)	49.5^{a} (O)
	49.9^{b} (HP)	49.4^{b} (M)	48.9^{b} (I)
	48.6^{b} (RRIM912)	47.2^{c} (T)	
	47.5^{b} (HG)		
	45.1^{c} (HS)		
Proportion of rays	33.3^{a} (RRIM912)	32.1^{a} (B)	31.7^{a} (O)
	32.8^{a} (HP)	31.9^{a} (M)	31.4^{a} (I)
	31.5^{b} (HB)	30.8^{b} (T)	
	30.4^{b} (HG)		
	29.8^{c} (HS)		

Note: Means in each column followed by the same letters are not significantly different at $p>0.05$. T- top, M- middle, B- bottom, I- inner, O- outer, HP- *Hevea pauciflora*, HG-*Hevea guianensis*, HB-*Hevea benthamian*, HS- *Hevea spruceana* and RRIM- *RRIM 912*.

Figure 1 showed that the fibre length between upper and middle part were not significantly different. Roslan (1998) noted that the mean fibre length of rubberwood fibres is 1.10mm. The length of fibres varies according to tree height, where middle part possessed the longest fibres, followed by upper and bottom part, respectively. From the results, it showed that fibre length of rubberwood species increased from bottom to the top of the tree. Dinwoodie (1981) noted that fibre length could be considered as the most important aspect in determining quality of wood because it relates to mechanical strength, shrinkage and also influence the paper strength properties.

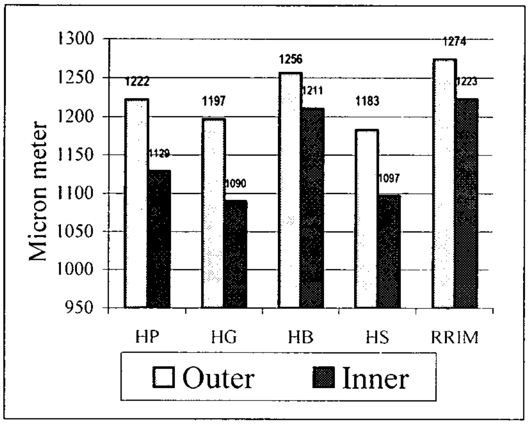

Fig.1. Mean fibre length for different species of rubberwood at two radial positions.

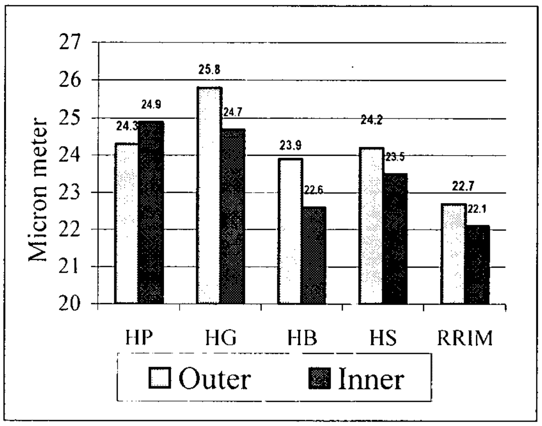

Fig.2. Mean fibre diameter for different species of rubberwood at two radial positions.

Hevea guianensis has the highest value of fibre diameter with 24.9µm (Table 1). Figure 2 showed that there was significant difference between species at different radial positions. According to Sekhar (1989) and Peel and Peh (1960), the mean fibre diameter of rubberwood is about 22.0 µm. Ashaari (1980) noted that rubberwood fibre diameter decreases in the location outward pith and increase in the location inward pith. Higher value of fibre diameter will increase the strength properties of the wood (Izham 2001).

The lumen diameter for *Hevea pauciflora, Hevea benthamiana* and *Hevea spruceana* are in the same class, with the value of 11.5µm and 11.4µm and 11.3µm, respectively. This is quite closely to the research of Norhayati (1995), where she found the lumen diameter was in the range of 10.00µm to 12.00µm. The results indicated that the mean lumen diameter increased with height while results for the radial zones showed that the mean lumen diameter increased from the pith to bark (Figure 3). Basically, the larger the lumen diameter is, the lower the percentage of shrinkage will be. This is due to the content in the lumen that will affect the shrinkage. The specific gravity is also lower if the lumen diameter is large.

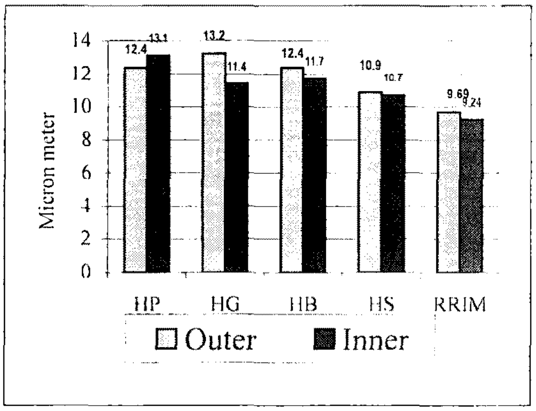

Fig.3. Mean lumen diameter for different species of rubberwood at two radial positions.

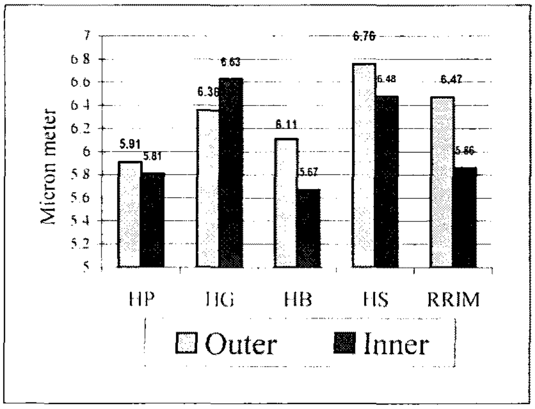

Fig.4. Mean cell wall thickness for different species of rubberwood at two radial positions.

Hevea pauciflora fibre has the thinnest fibre walls compare with other species, which is 6.08µm (Table 1). There was no significant difference for cell wall thickness between the outer and inner radial positions (Figure 4). Fibres are important as supporting elements in tree. Specific gravity, shrinkage and strength of the trees are also related to the cell wall thickness.

The result showed that the mean values were higher for the outer samples than those in inner samples (Figure 5). Basically, the value of mean vessel diameter increased from the stump upwards to the branch though this pattern of increment was not consistent (Roslan 1998).

The vessel frequency for *Hevea pauciflora, Hevea guianensis, Hevea benthamiana* and *Hevea spruceana* are in the same class, with the value of 2.60 vessel per sq. mm, 2.48 vessel per sq. mm, 2.47 vessel per sq. mm and 2.46 vessel per sq. mm respectively (Table 1). Sekhar (1989) noted that the mean vessel frequency for rubberwood was 3 to 4 per sq. mm. Results showed that the mean vessel frequency decreased from pith to bark (Figure 6).

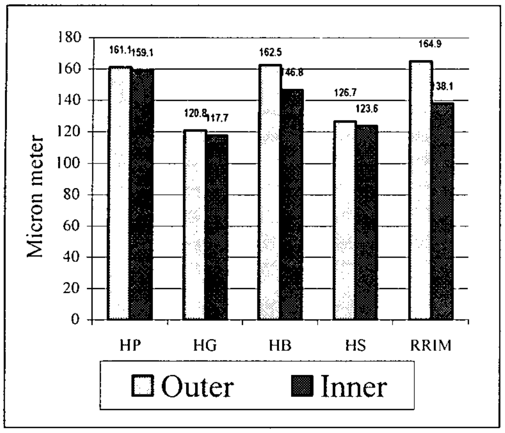

Fig.5. Mean vessel diameter for different species of rubberwood at two radial positions.

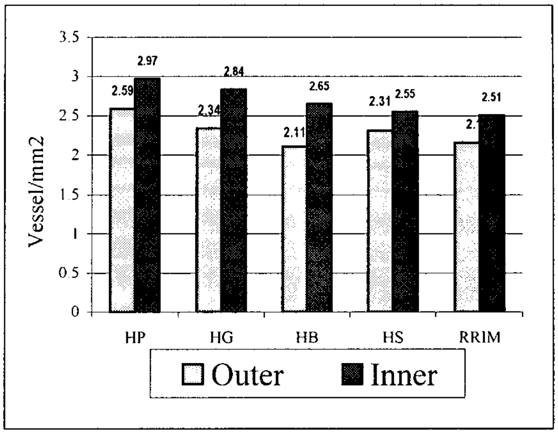

Fig.6. Mean vessel frequency for different species of rubberwood at two radial positions.

The highest percentage of fibres is recorded in *Hevea benthamiana* (55.1%), followed by *Hevea pauciflora* (49.9%), *RRIM 912* (48.6%), *Hevea guianensis* (47.5%) and *Hevea spruceana* (45.1%). The highest percentage of ray is recorded in *RRIM 912* (33.3%), while *Hevea spruceana* showed the lowest percentage (29.8%) of fibres. Haygreen and Bowyer (1982) stated that rays play an important role in restraining dimensional change in the radial direction, and their presence is partially responsible for the fact that upon drying, wood shrinks less radially than in tangentially.

Physical properties

Table 2. Mean values on the physical properties of rubberwood

Property	Species	Portion	Radial Position
Moisture content	64.34^{a} (HS)	62.25^{a} (B)	62.61^{a} (I)
	63.80^{b} (HG)	62.22^{a} (M)	61.20^{a} (O)
	60.69^{c} (HP)	60.24^{b} (T)	
	60.68^{c} (HB)		
	60.01^{c} (RRIM912)		
Specific gravity	0.60^{a} (RR)	0.60^{a} (B)	0.59^{a} (O)
	0.59^{a} (HB)	0.59^{a} (M)	0.57^{a} (I)
	0.59^{a} (HS)	0.57^{a} (T)	
	0.58^{a} (HP)		
	0.57^{a} (HG)		
Tangential shrinkage (AD)	1.61^{a} (HG)	1.46^{a} (T)	1.45^{a} (I)
	1.48^{b} (HS)	1.35^{b} (M)	1.39^{b} (O)
	1.37^{c} (HB)	1.29^{b} (B)	
	1.36^{c} (RRIM912)		
	1.35^{c} (HP)		
Radial shrinkage (AD)	0.81^{a} (HG)	0.89^{a} (T)	0.63^{a} (I)
	0.79^{a} (HS)	0.69^{b} (M)	0.55^{b} (O)
	0.61^{b} (HB)	0.68^{b} (B)	
	0.59^{c} (RRIM912)		
	0.55^{c} (HP)		

Longitudinal shrinkage (AD)	0.31[a] (HG) 0.30[a] (HS) 0.28[b] (HB) 0.28[b] (RRIM912) 0.25[b] (HP)	0.37[a] (T) 0.31[a] (M) 0.29[a] (B)	0.28[a] (I) 0.25[a] (O)
Tangential shrinkage (OD)	3.62[a] (HG) 3.44[b] (HS) 3.16[c] (HB) 3.11[c] (RRIM912) 3.07[c] (HP)	3.12[a] (T) 2.91[b] (M) 2.85[b] (B)	3.03[a] (I) 3.16[b] (O)
Radial shrinkage (OD)	1.64[a] (HG) 1.55[a] (HS) 1.34[b](HB) 1.28[c] (RRIM912) 1.21[c] (HP)	1.78[a] (T) 1.39[b] (M) 1.23[b] (B)	1.78[a] (I) 1.56[b] (O)
Longitudinal shrinkage (OD)	0.78[a] (HG) 0.77[a] (HS) 0.74[a] (HB) 0.73[a] (RRIM912) 0.71[a] (HP)	0.88[a] (T) 0.71[a] (M) 0.67[a] (B)	0.86[a] (I) 0.79[a] (O)

Note: Means in each column followed by the same letters are not significantly different at $p>0.05$. HP- *Hevea pauciflora*, HG-*Hevea guianensis*, HB-*Hevea benthamiana*, HS- *Hevea spruceana* and RRIM- *RRIM 912*

The highest moisture content is obtained from *Hevea spruceana* (64.34%), while the lowest is recorded by *RRIM912* (60.01%). Moisture content is very important in the drying process as well as when timber is transported or traded by green weight (Roslan 1988). The higher moisture content normally associated to lower strength. The results indicated that there are significant differences in moisture contents between the upper part, compared to the middle and bottom part. The bottom part of the tree should have lower moisture content than the other parts as the specific gravity is increased from the bottom part towards the upper part of the tree (Lavers 1969; Findlay 1975). Figure 7 show the mean moisture content at two radial positions.

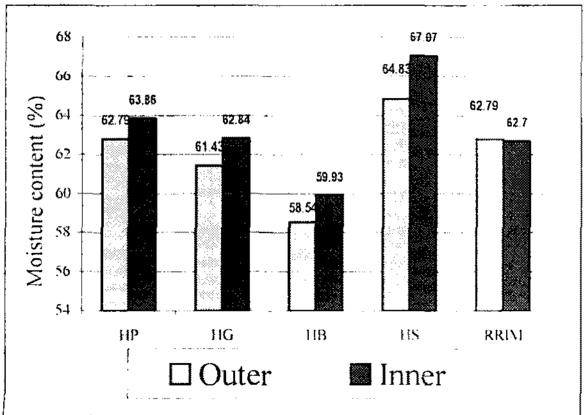

Fig.7. Mean moisture content for different species of rubberwood at two radial positions.

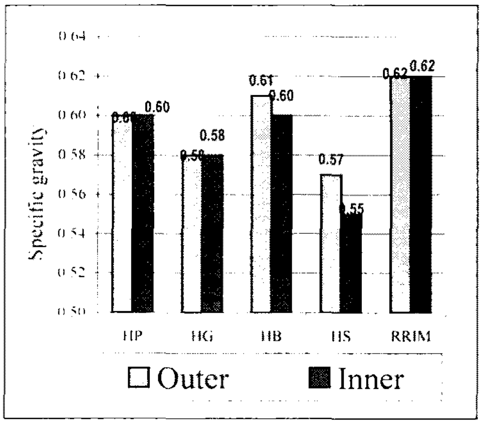

Fig.8. Mean specific gravity for different species of rubberwood at two radial positions.

Results showed that there is no significant difference in specific gravity between *Hevea* species. The specific gravity has a great effect to the growth performance in wood. Subsequently, specific gravity indicates the strength of a particular wood. Dinwoodie (1981) stated that specific gravity and density of wood is important in research because it is the single most important criteria for good strength properties and is very important in determining the minimum strength value for timber. Armstrong *et al.,* (1984) agreed based on a well-known fact that there are direct relations between the strength properties of wood and its specific gravity or density. In general, the heaviest timber is at the base of the tree, and the mass decreased up the tree. Hence, from the Table 2 it showed that the bottom part of the tree has highest specific gravity compared to other parts. Figure 8 show the mean specific gravity at two radial positions.

Hevea guianensis showed the highest percentage of tangential shrinkage at air dry condition (1.61%), *Hevea spruceana* (1.48%), *Hevea benthamiana* (1.37%), *RRIM 912* (1.36%) and *Hevea pauciflora* (1.35%). The results showed that the tangential shrinkage is the greatest value followed by radial and longitudinal shrinkage (Figure 9 and 10). This was supported when Kollman and Cote (1968) who noted that the shrinkage is not the same in the different directions as explained by a straining influence of the wood rays in the radial direction that due to the different helical arrangement of fibrils in radial and tangential cell walls. The shrinkage is higher for the inner samples compared to the outer samples for all three directions (tangential, radial and longitudinal). Khoo et al. (1991) discovered that shrinkage in *Hevea* wood can be considered quite low with radial and tangential shrinkage averaging 0.83% and 1.22% respectively, from green to air dry conditions. For oven dry shrinkage, *Hevea guianensis* showed the highest percentage of tangential shrinkage (3.62%), *Hevea spruceana* (3.44%), *RRIM 912* (3.16%), *Hevea pauciflora* (3.11%) and *Hevea benthamiana* (3.07%). The result showed that tangential shrinkage was greater than radial shrinkage, while longitudinal shrinkage was very small.

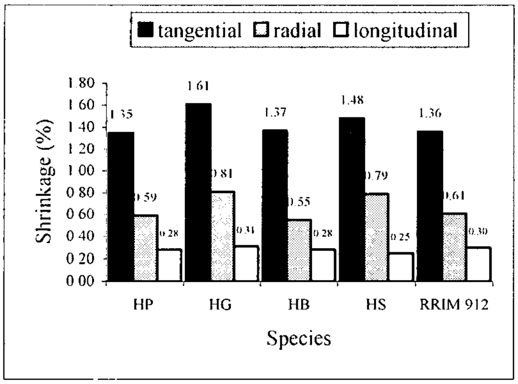

Fig.9. Distribution of shrinkage (radial, tangential, longitudinal) at air dry conditions for different species of rubberwood.

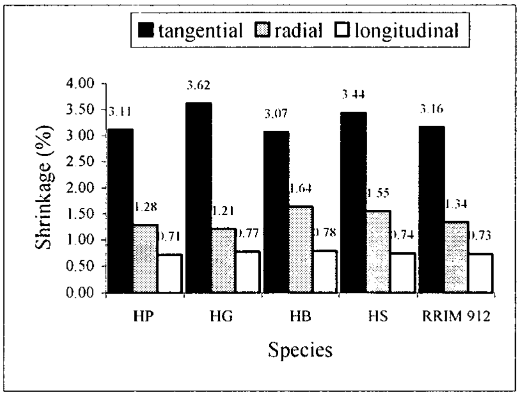

Fig.10. Distribution of shrinkage (radial, tangential, longitudinal) at oven dry conditions for different species of rubberwood.

Table 3 shows the comparison between five species of *Hevea* wood. The result indicated that *RRIM 912* has the longest fibre length than the other *Hevea* species. Due to the thickest cell wall thickness and higher specific gravity, *RRIM 912* has a better potential to be use as solid wood because the higher the proportion of thick wall fibres, the strength of the wood will also be higher. However, *Hevea guianensis* can be regarded showed the lower wood quality than *RRIM 912* because it recorded the shortest fibre length and largest lumen diameter which contribute to the greater longitudinal shrinkage. The values of *Hevea pauciflora* are much closer to *Hevea guianensis* in all anatomical properties measured.

Table 3. Comparison in anatomical features and physical properties of five different species of *Hevea* wood

Properties	HP	HG	HB	HS	RRIM
Fibre length (µm)	1189	1145	1200	1158	1214
Fibre diameter (µm)	24.3	24.9	23.6	23.7	23.5
Lumen diameter (µm)	11.5	12.5	11.4	11.3	10.4
Cell wall thickness (µm)	6.07	6.17	6.13	6.51	6.37
Vessel diameter (µm)	138.4	122.6	139.4	154.7	155.3
Vessel frequency (v/mm^2)	2.48	2.61	2.47	2.46	2.33
Percentage of fibres (%)	49.9	47.5	55.1	45.1	48.6
Percentage of rays (%)	32.8	30.4	31.5	29.8	33.3
Moisture content (%)	60.69	63.80	60.68	64.34	60.01
Specific gravity	0.58	0.57	0.59	0.59	0.60
Shrinkage					
Tangential* (%)	1.35	1.61	1.37	1.48	1.36
Radial* (%)	0.55	0.81	0.61	0.79	0.59
Longitudinal* (%)	0.25	0.31	0.28	0.30	0.28
Tangential# (%)	3.07	3.62	3.16	3.44	3.11
Radial# (%)	1.21	1.64	1.34	1.55	1.28
Longitudinal# (%)	0.71	0.78	0.74	0.77	0.73

Note: HP- *Hevea pauciflora*, HG-*Hevea guianensis*, HB-*Hevea benthamiana*, HS- *Hevea spruceana*, RRIM- *RRIM 912*, * - shrinkage at air dry conditions and # - shrinkage at oven dry.

CONCLUSIONS

The understanding of anatomical properties and wood structure of *Hevea* wood is important because it can depict the density, mechanical and strength properties and determine the characteristics of the potential products. Overall, the properties of clone *RRIM 912* is found to be comparatively better because of higher strength due to longer fibre length, thicker cell wall and higher specific gravity than the other 4 *Hevea* species. Therefore, this species can be inferred as a potential general utility timber.

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REFERENCES

Anon. 1975. International Standard. ISO 3133-1975 (E): Wood Determination of Density for Physical and Mechanical Test.

Armstrong, J.P., C. Skaar and C. De Zeeuw. 1984. The Effect of Specific Gravity and Several Mechanical Properties of Some World Woods. Journal of the International Academy of the Woods Science – Wood Science and Technology 18: 137-146.

Ashaari H.A. 1980. Variation in Certain Wood Properties of Rubber Trees *(Hevea brasiliensis Muell Agr.)* M.Sc. Thesis, Louisiana State University.

Berlyn and Miksche. 1976. Botanical Microtechnique and Cytochemistry. The Iowa State Univ. Press, Ames, Iowa. Pp: 5-8.

Chew, L.T. 1993. Rubberwood Development in Malaysia. Paper presented at the International Forum on Investment Opportunities in the Rubberwood Industry. 20-22 September 1993. Kuala Lumpur, Malaysia.

Desch, H.E. and J .M. Dinwoodie. 1983. Timber. It's Structure, Properties and Utilization. 5th Edition. Lowe and Brydone (Printers) Ltd., Theford, Norfolk.

Dinwoodie, J.M. 1981. Timber Its Structure, Properties and Utilization. Timber Press, Forest Grove, Oregon, USA.

Findlay, W.P. 1975. Timber: Properties and Uses. Crosby Lochwood Staples. Britain. 224 pp.

Haygreen, J. G. and J. L. Bowyer. 1982. Forest Products and Wood Science - An Introduction. pp 36-37.

Kollmann, F.F.P., and Jr. W. A. Cote. 1968. Principles of Wood Science and Technology Solid Wood. Vol. 1. Springer-Verlag Heidelberg. Pp 292-414.

Lavers, G. M. 1969. The Strength of Timbers for Products. Bulletin No.5 (2nd.Edn.Metric Units.) London. Pp.62.

Lew, H.C and H.C. Sim. 1983. Rubberwood Present and Potential Utilization. In Proceedings of Rubberwood Utilization Seminar 15th June 1982. Kuala Lumpur (Hong L.T). FRIM Report No.28. Kepong. Pp 109.

Lim, S.C. and A. Sulaiman. 1994. Structure and Characteristics of Rubberwood. Rubberwood Processing and Utilization. Forest Research Institute, Kepong Malaysia. 248pp.

Hashim, M. N., Z. Ahmad, and N. L. M. Halip. 2000. Supply, Demand and Pricing for Rubberwood. Paper Presented at the Seminar on "Rubber Forest Plantation: Smart Partnership towards Rubber Forest Development". Sungai Buluh, Selangor. 22 May 2000.

Izham M. Y. 2001. Juvenility of Rubberwood at Different Age. Unpublished Master Science Thesis. Faculty of Forestry, UPM.

Najib, L. A., M. Johari, M.H., A. Ghani Ibrahim, Dan Y.M., Mahdan B. and Mahmud A.W. 1997. Viability of Hevea Plantation for Wood Production. Paper presented at the Seminar on Commercial Cultivation of Teak, Sentang, Acacia and Hevea for Timber. 9 January 1997, Kuala Lumpur. 30pp.

Norhayati, N. 1995. Anatomical Properties of Rubberwood from Three Clones and Two Age Groups. Unpublished final year project report. Faculty of Forestry, UPM.

Peel, J.D. and T. B. Peh. 1960. Para Rubberwood *(Hevea brasiliensis Muell Arg.)* for Pulp and Paper Manufacturer. An Account of Laboratory Experiment. Research Pamphlet No 34: pp20.

Roslan, M. 1998. Juvenility in Rubberwood *(Hevea brasiliensis)* and its Relation with the Physical and Mechanical Properties. Unpublished Master Science Thesis. Faculty of Forestry, UPM.

Sekhar, A. C. 1989. Rubberwood Production and Utilization. Rubber Research Institute of India, Kottayam. Pp 219.

Van Buijtenen, J.P. 1969. Controlling Wood Properties by Forest Management. TAPPI 52(2): 257-259.

Wycherley, P. R. 1992. The Genus Hevea – Botanical Aspects. In: Natural Rubber: Biology Cultivation and Technology. (Sethuraj, M.R. and Mathew, N.M., eds.). Developments in Crop Science 23, Elsevier, Amsterdam, pp 50-56.