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Utilization of non-conventional tropical lignocellulosic resources for the hardboard production

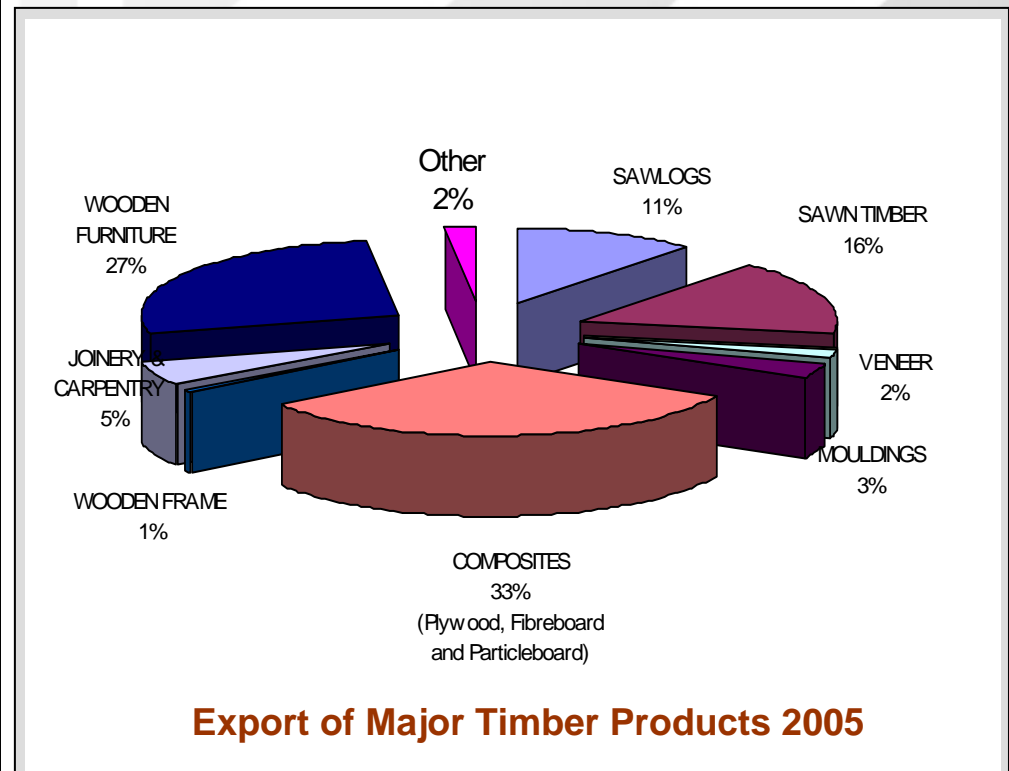
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MALAYSIA

Introduction



Wood Based Panel Industry: Current Scenario in Malaysia

- Revenue from timber products in 2005 were RM 21.5 (USD6.14) Billion. (Particleboard and Fibreboard ~ RM 1.31 (USD 0.37) Billion or 6.1%.
- >70% of MDF and particleboard plants use rubberwood as raw material.
- Average consumption of Rubberwood (logs below 7.5 cm diameter) is estimated 2,000,000 m³ annually





Issue of raw material

- 1.2 mil. ha of total rubber tree planting area. Current practice – extracted after 25-30 years cycle
- Total installed capacity of these industries which is about 2.5 million m³
- Do we have enough rubberwood supply??

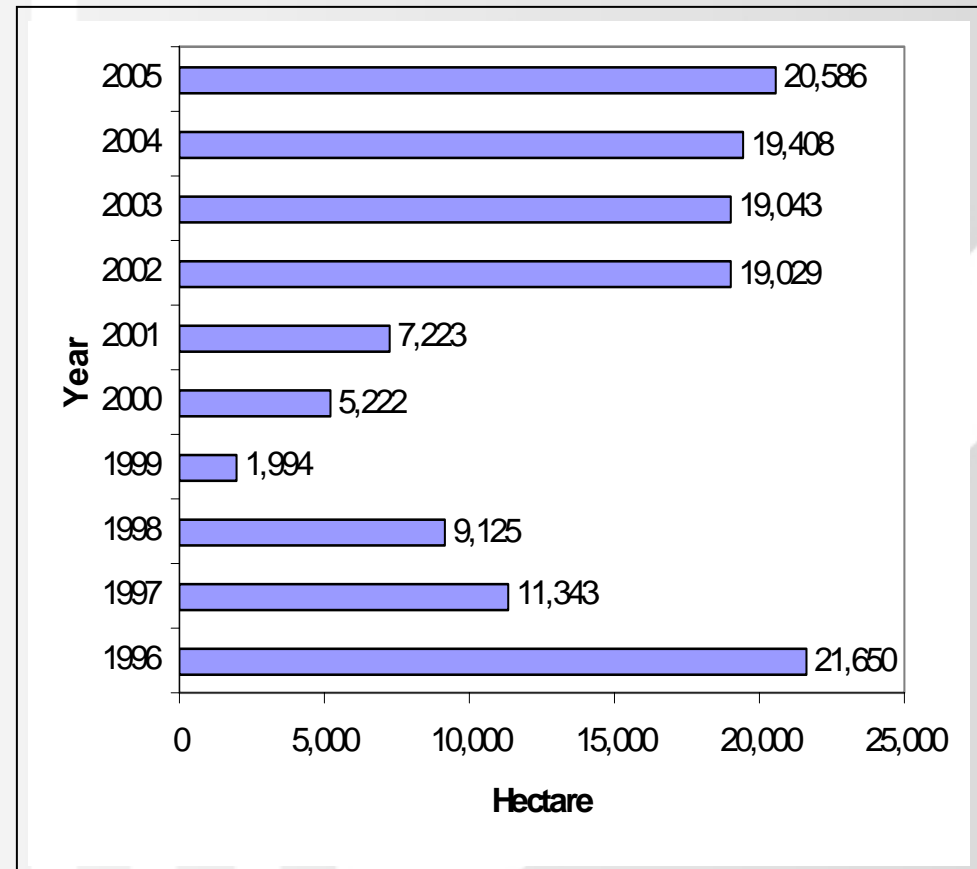


Figure : Rubber replanted area in Malaysia 1996 - 2005



NEW POTENTIAL LIGNOCELLULOSIC MATERIALS

1. Bamboo
2. New clones of rubber trees
3. Empty fruit bunches (EFB) of oil palm trees

Introduction



BAMBOO



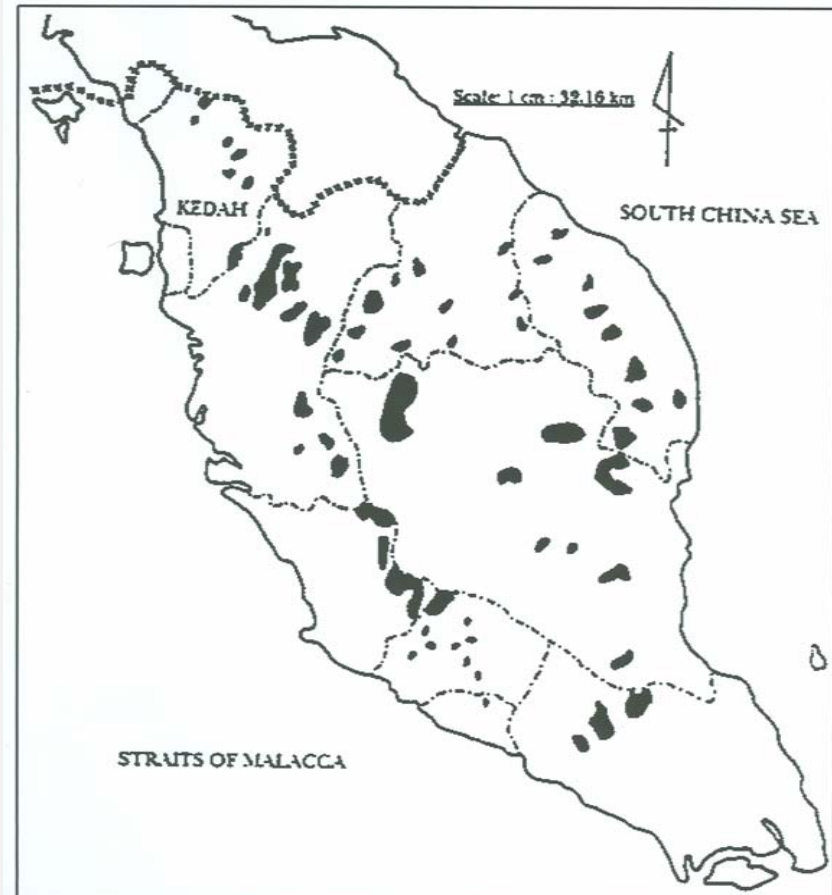
- The biggest grass in the world and grows naturally in all continents except Europe
- Malaysia has more than 50 species of bamboo which 25 of them are indigenous, while the rest are known only in cultivation
- Genera that can be found in Malaysia are *Bambusa*, *Dendrocalamus*, *Gigantochloa*, *Chusquea*, *Dinochloa*, *Melocanna*, *Phyllostachys*, *Racemobambos*, *Schizostachyum*, *Thyrsostachys* and *Yushania*.
- Regarded as eco-friendly which grows and matures quickly
- Has potential to be used as an alternative material for wood



Introduction

DISTRIBUTION OF BAMBOO IN PENINSULAR MALAYSIA

- Natural resource, minor forest product
- Bamboo area: 6.9% of Pen. Malaysia's forest land
- Largest natural bamboo area : Pahang, Kelantan, Perak
- Plantation- 500 ha planted (Forestry Department of Pen. Malaysia, 2004)
- *G. scortechinii* or Buluh Semantan – local species, widely utilized



Introduction



TRADITIONAL USES OF BAMBOO



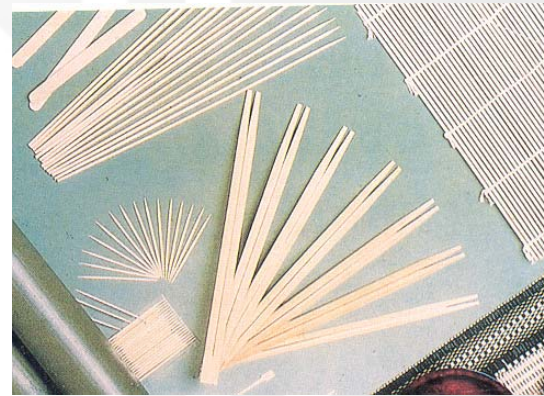
Introduction



LESS VALUE ADDED PRODUCTS



Edible shoots



Higo products



Basketry



Handcrafts



Cooking apparatus



Religious apparatus

Introduction



HIGH VALUE ADDED PRODUCTS



Laminated bamboo
for parquet and paneling



Bamboo plywood



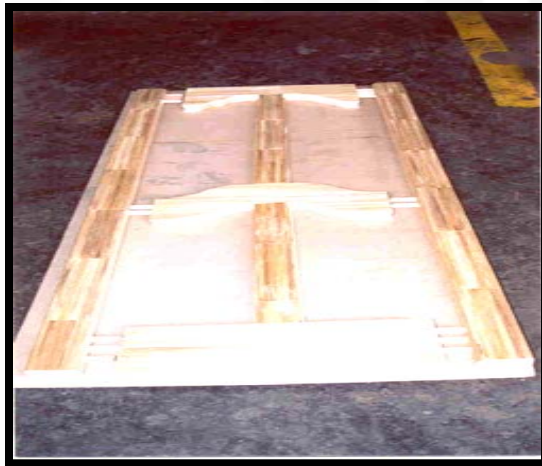
High quality
paper



Introduction



Potential product



Solid door from LAMBOO
or BAMWOOD



Introduction



Advantages over wood

- Easy and fast grown – Maturity age 3-4 years
- Environmental friendly plants
- Tough and stable
- Unique appearance

Material	Strength/vol.	Stiff / vol.
Concrete	0.003	10
Steel	0.02	27
Wood ¹	0.013	18
Bamboo ¹	0.17	33

¹ Parallel to the grain, Source: Janssen 1996

Introduction



New Rubberwood Material for Future Consumption : RRIM 2000 Series



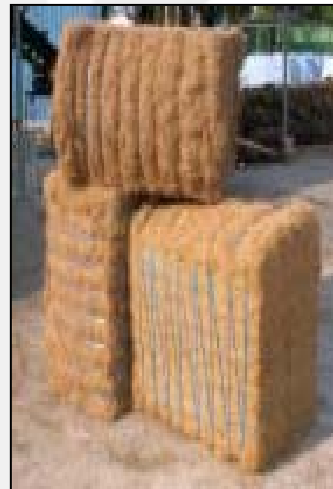
- Latex Timber Clones (LTC) E.g. RRIM 2002, RRIM 2020, RRIM 2025
- Relatively better growth performance
- Good growth form
- Resistance to certain disease (Odium, Pink disease etc)

Introduction



Oil Palm (*Elaeis guineensis* Jacq.)

- Originated : Brazil
- Grown commercially: Africa, Equatorial America, South East Asia and South Pacific
- Introduced to M'sia : 1870 (as ornamental trees)
- Economic value : drupe type fruits – vegetable oil.
- Oil palm waste : trunks, frond and EFB (source of natural fibre)
- Composite technology : from wood-based resource to non wood lignocellulosic materials





Why Oil Palm EFB Fibre ?

Oil palm
biomass :
40 mill t/yr
EFB : more
than 2 mill
t/yr

Low fibre
production
cost :
RM79/tonne

Field
disposal
cost :
RM15/tonne

Introduction



Oil palm biomass in Malaysia (t/yr)

	Year				
	2004-2006	2007-2010	2011-2013	2014-2016	2017-2020
A. Oil palm trunk					
Amount of fibre bundles	2,166,178	1,742,360	2,307,450	1,930,724	1,601,088
Amount of parenchyma	1,273	1,024,599	1,356,902	1,135,367	941,524
Amount of bark	580,848	467,204	618,730	517,713	429,323
Amount of the whole trunk	4,020,852	3,234	4,283,082	358,803	2,971,934
B. Pruned fronds					
Amount of leaf stalks	13,421,645	13,163,181	12,997,026	13,458,568	13,643,185
Amount of petiole	7,025,525	6,890,233	6,803,260	7,044,853	7,141,490
C. Empty fruit bunches					
Amount of bunch stalks	626,175	618,184	619,637	636,345	626,901
Amount of spikelets	2,234,019	2,205,511	2,210,694	2,270,303	2,236,611
Amount of the whole EFB	2,860,194	2,823,695	2,830,331	2,906,647	2,863,512



Problems with EFB

Lack of understanding

Processing

Dimensional stability

Anatomical features

Processing requirements

Cutting tools degradation (silica)

Fibre morphology during refining

Low thickness swelling

Water absorption

Introduction



FIBER AND CHEMICAL PROPERTIES

FIBRE PROPERTIES

Materials	Fibre length (mm)	Fibre width (μm)
Bamboo	3.20	21
Rubberwood (Hardwood)	1.43	33
Softwood	3.70	38
EFB from oil palm tree	0.82	25

CHEMICAL PROPERTIES, %

	Bamboo	Softwood	RW Hardwood	EFB
Cellulose	26-43	40-45	55	42.7
Hemi-cellulose	28-35	23.0	22	27.3
Lignin	21-31	26-34	16	17.2
Silica	0.7	-	-	-

Introduction



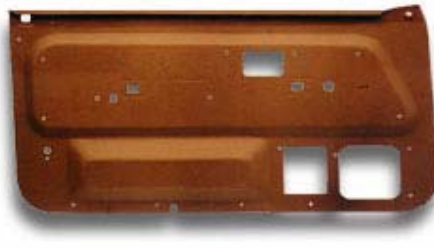
HARDBOARD

- Definition: High density fibreboard ($800-1000 \text{ kgm}^{-3}$)
- Process involved: wet process or dry process
- Wet process: using pulp and water with additives followed by tempering
- Dry process: Dry fiber mixed with resin and additives
- Type of hardboard: S-1-S (smooth on one surface) and S-2-S (smooth on two surfaces) – differentiate by the use of wire mesh screen

Introduction

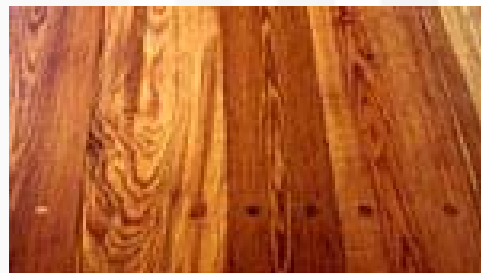


PRODUCTS OF HARDBOARD

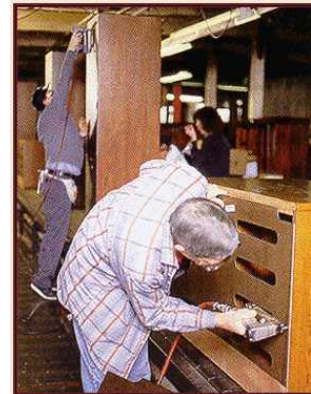


Automotive interior

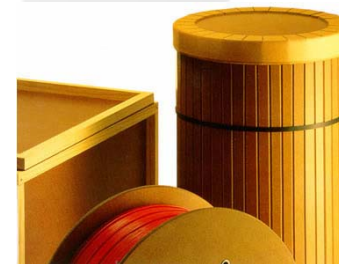
Flooring



Furniture



Packaging



Aims and methods



1. To determine the effect of pre-treatments and mechanical refining process of bamboo on pulp quality
2. To determine the effect of additives (PF resin, wax and emulsion) on mechanical and physical properties of wet-processed bamboo hardboard
3. Evaluate properties of hardboard from bamboo, rubberwood, EFB and rubberwood + EFB blend
4. Compare properties of these hardboards with commercial hardboard (pine)

Aims and methods



MATERIALS

- 3-yr-old grown *Gigantochloa scortechinii*
- 4-yr-old rubberwood (Clone RRIM 2002)
- Loose fiber empty fruit bunches from oil Palm tree



Aims and methods



Pre-treatments of materials before RMP

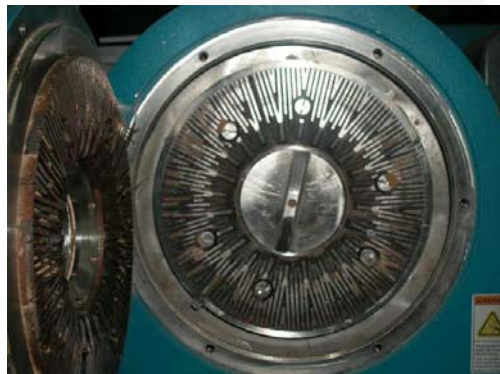
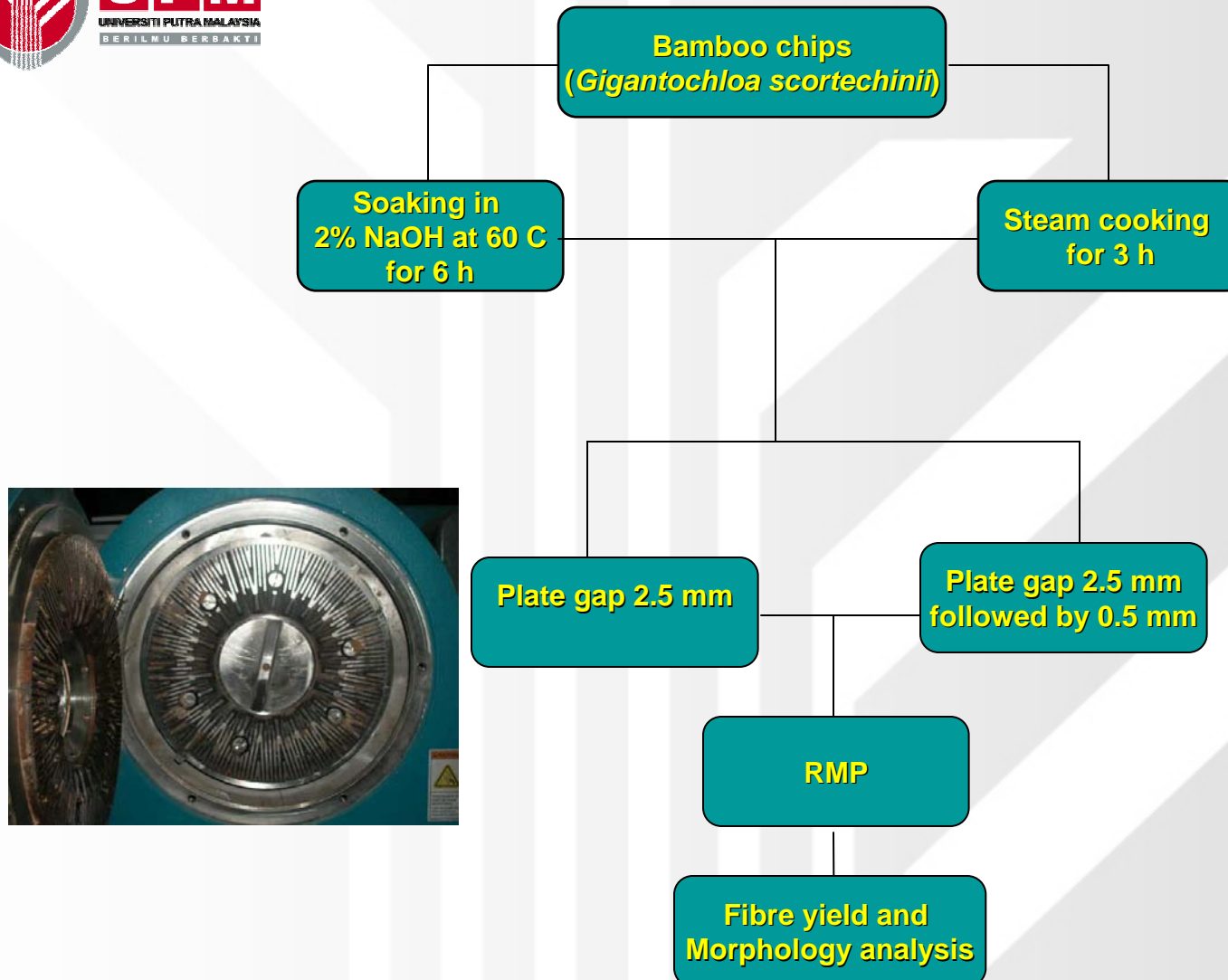
- Aim: to soften chips and to optimise yield of fibers
1. Steaming of chips for 3 h
 - To soften lignin and help to fiberized chips
 2. Alkali treatment at 60 C or mercerization
 - Remove lignin and hemicellulose
 - Change cellulose I to II
 - As a bleaching agent
 - Help fibrillation



Aims and methods



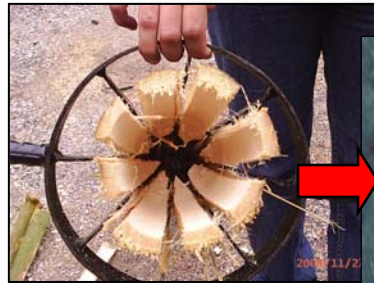
PULP QUALITY STUDY



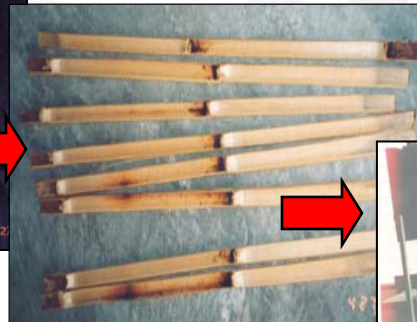
Aims and methods



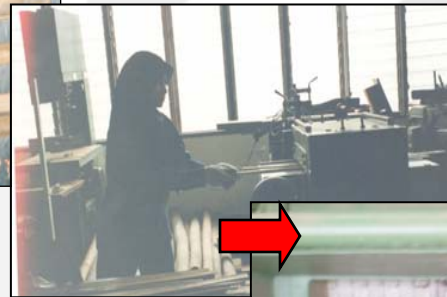
PREPARATION OF BAMBOO FIBRE



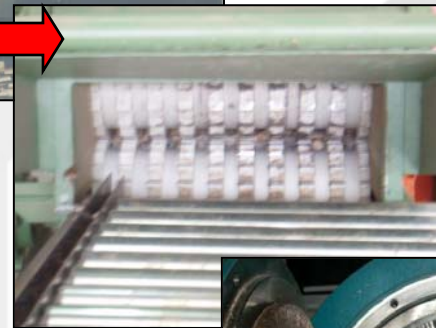
Splitting



Splits



**Planing
(strips)**



Chipping



Refining

Pre-treatments



Aims and methods



Board Description

Material	Pre-treatments	No of board	OD wt of fibre (g)	Additives per board (% based on OD wt)		
				PF	Wax	Alum
Bamboo	Steam cooking for 3 h	5	250	0	0	0
		5	250	0	0	0
	Soaking in 2% NaOH for 6 h	5	250	1	1	0.25
		5	250	2	1	0.25
		5	250	2	2	0.25
RW	Soaking in water 24 h	5	250	2	1	0.25
EFB		5	250	2	1	0.25
RW+EFB (1:1)		5	125:125	2	1	0.25
Pine	NA	5	NA	1	1	0.25

Aims and methods



Fabrication of Wet-process Hardboard



Beating (Pulp consistency 1:60 with or without additives) for 10 min



Wet forming (S-1-S)



Pre press and Hot Press (180°C and 9.8 kg/m² for 10 min)



3-mm thick board

Tempering in oven at 180 C for 6 h

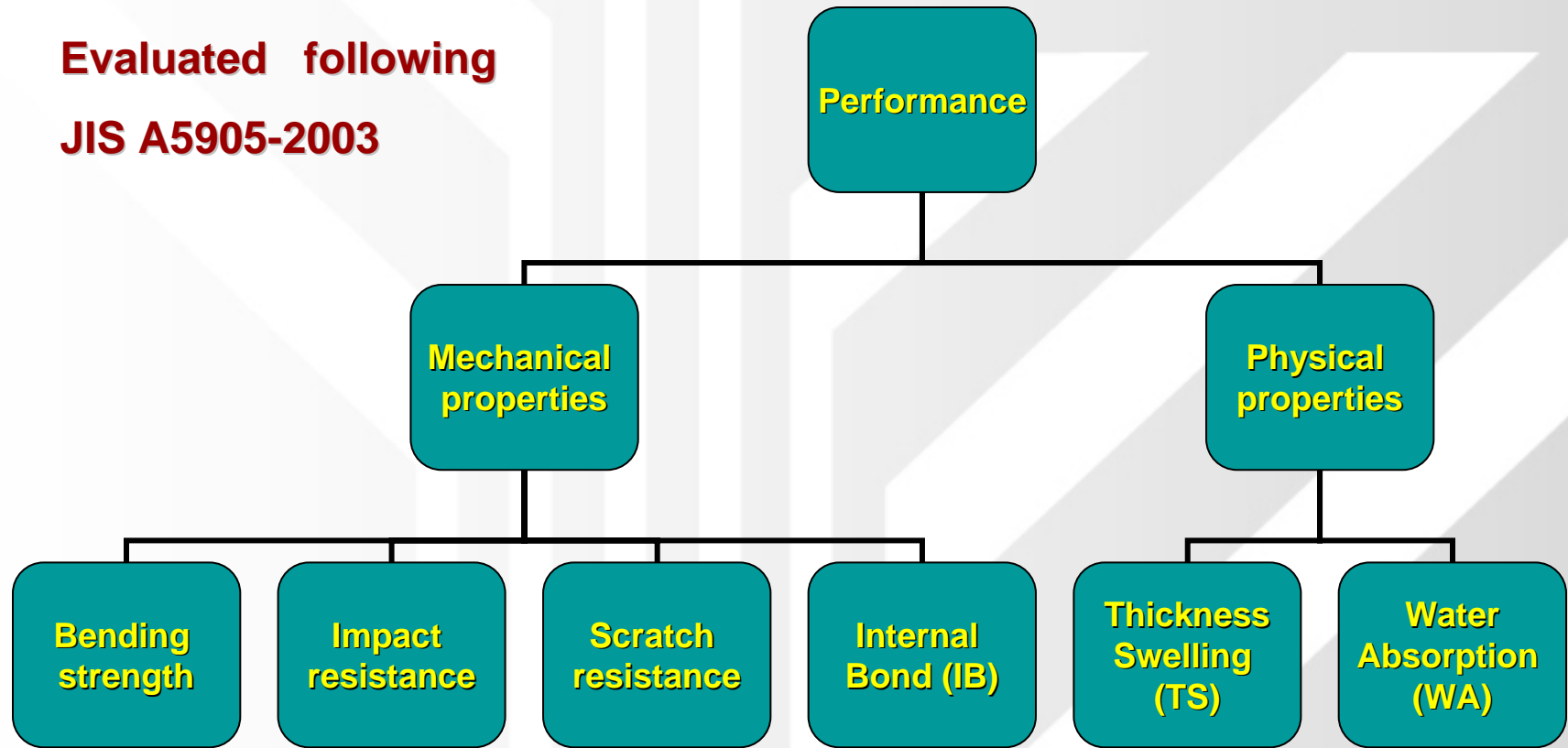
Conditioning

Aims and methods



PROPERTIES EVALUATION

Evaluated following
JIS A5905-2003



Aims and methods



Statistical analysis

- Statistical analyses – to detect any differences in performance among the types of hardboard.
- Since a wide variation of density was found in the boards (10-18%) an analysis of covariance (ANOCOV) was performed to correct for expected differences in physical and mechanical properties due to density.
- Adjusted means were separated using Least Significant Difference (LSD) method.

Results



Effect of pre-treatments and refining cycle on fiber morphology of bamboo

	Steam cooking for 3 h		Soaking in NaOH (2%) at 60 C for 6h		Lab. Processed fiber
	2.5 mm	2.5 followed by 0.5 mm	2.5 mm	2.5 followed by 0.5 mm	
Refiner plate gap	2.5 mm	2.5 followed by 0.5 mm	2.5 mm	2.5 followed by 0.5 mm	None
Length, L (mm)	2.39 \pm 1.14	1.45 \pm 0.87	2.18 \pm 0.10	1.96 \pm 0.13	3.20
Width, D (μ m)	26.58 \pm 6.87	26.84 \pm 6.96	26.63 \pm 1.93	26.77 \pm 1.90	20.64
Cell wall thickness, w (μ m)	4.80	5.51	10.72	10.76	3.37
Lumen width, l (μ m)	18.98	17.82	5.19	5.25	14.04
Felting power (L/D factor)	90	54	82	73	156
Aspect ratio (D_{max}/D_{min})	NA	1.70	NA	1.15	NA
Flexibility ratio (l/D)	NA	66.4	NA	19.6	67.3
Runkel ratio ($2w/l$)	0.51	0.62	4.13	4.10	0.48

Results



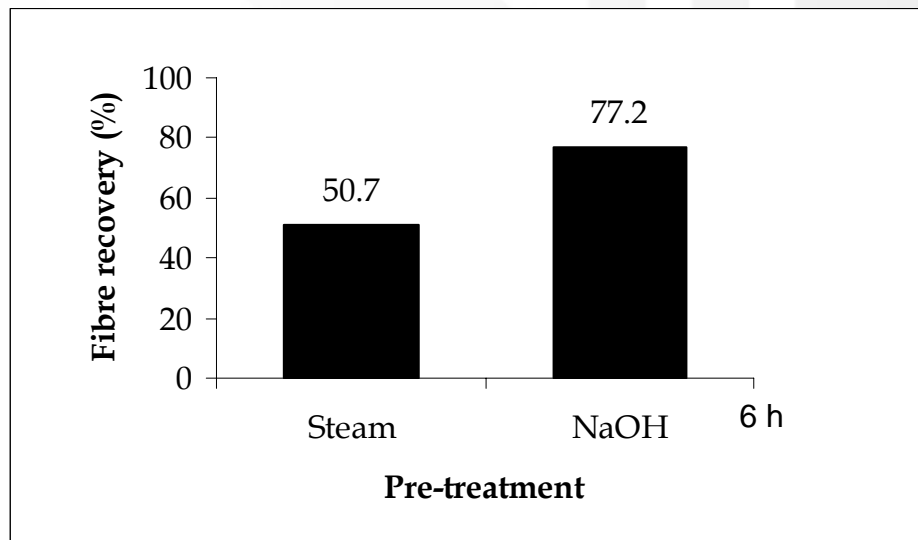
Effect of refining cycle on fiber quality bamboo





Results

Fibre yield from different pre-treatments chips after 2 cycles of refining



Steam-treated chips

- More broken fibers
- Rigid and stiff fibers
- Lumpy fibers
- Dark brown fibers

NaOH-treated chips

- Less broken fibers
- Treatments capable of removing more hemicellulose and lignin
- Swollen fibers and become more plastic
- High degree of fibrillation
- Increase Runkel and Felting power
- Borwnish yellow fiber

Results



Fibers produced from steam-treated chips after 2 cycles of mechanical refining



Damaged

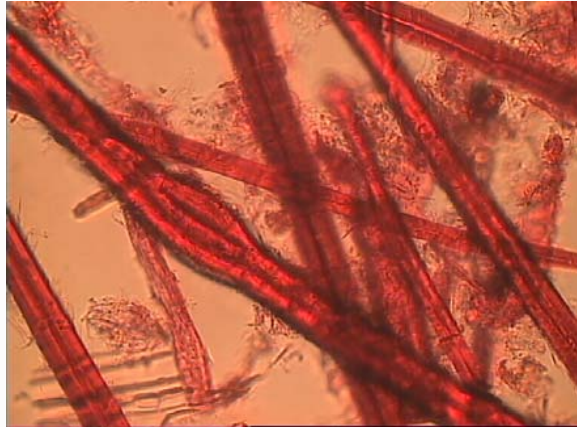


Broken

Results

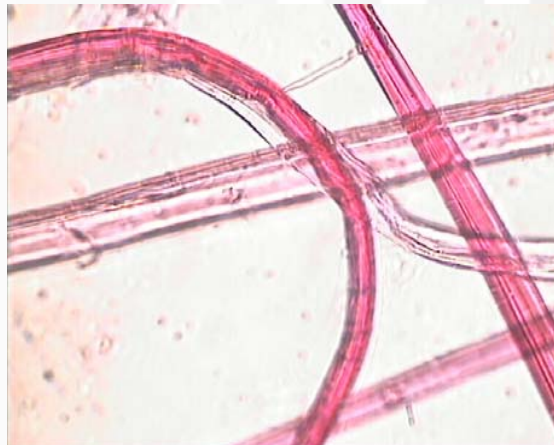


Fibers produced from NaOH-treated chips after 2 cycles of mechanical refining



Swollen

Fibrillation



Results



Effect of additives on properties of bamboo hardboard

Pre-treatment	Resin (%)	Wax (%)	Alum (%)	Spring Back (%)	MOR (MPa)	MOE (MPa)	Impact resistance	Scratch resistance	IB (MPa)	WA (%)	TS (%)
NaOH	0	0	0	10.45 ^B	41.82 ^B	2342 ^F	Free	Free	0.95 ^{CD}	56 ^{AB}	29.4 ^A
	1	1	0.25	10.2 ^B	42.57 ^B	6296 ^D	Free	Free	1.17 ^C	53 ^B	27.8 ^A
	2	1	0.25	6.56 ^C	50.83 ^A	7392 ^C	Free	Free	1.27 ^C	54 ^B	27.6 ^A
	2	2	0.25	6.06 ^C	50.87 ^A	8626 ^B	Free	Free	1.64 ^B	51 ^B	27.3 ^A
Steam	0	0	0	11.54 ^A	33.85 ^C	4324 ^e	Dent (6.75mm)	Scratch	0.60 ^D	62 ^A	29.6 ^A
Pinus Hardboard	na	na	na	na	43.37 ^B	9993 ^A	Dent (9.71mm)	Free	1.92 ^A	36 ^C	14.0 ^B
JIS A 5905	0	0	0	na	20	na	Free	Free	na	35	na

Means within a column followed by the same alphabet is not significant different at $p < 0.05$



Impact Resistance test



(a) Small dent resulted in commercial test sample, (b) big dent of bamboo steam pre-treated, and (c) Indistinguishable dent on NaOH pre-treated bamboo hardboard

Results



Properties comparison with hardboard from other lignocellulosic resources

Properties	Bamboo	EFB	RW	EFB-RW	Pine
PF resin	2	2	2	2	1
Wax	1	1	1	1	1
Alum	0.25	0.25	0.25	0.25	0.25
Spring back (%)	6.56 ^A	1.29 ^B	2.43	4.32 ^B	Na
MOR ¹	50.83 ^A ± 4.21	38.09 ^{BC} ± 2.62	32.64 ^C ± 4.37	39.90 ^{BC} ± 2.36	43.37 ^{BC} ± 2.11
MOE	7392 ^B ± 771	2342 ^C ± 371	3085 ^C ± 755	2618 ^C ± 215	9994 ^A ± 2226
IB	1.27 ^B ± 0.13	1.02 ^B ± 0.20	1.00 ^B ± 0.37	1.67 ^A ± 0.42	1.92 ^A ± 0.22
WA	54 ^A ± 1.4	46 ^A ± 14.2	54 ^A ± 8.8	27 ^B ± 11.6	36 ^B ± 3.2
TS	27.6 ^A ± 0.81	28.2 ^A ± 4.86	27.6 ^A ± 4.99	11.5 ^B ± 4.38	14.0 ^B ± 2.25

Means within a column followed by the same alphabet is not significant different at $p < 0.05$

Conclusions



1. Higher yield of refined mechanical bamboo pulp produced from Pre-treatment by soaking in 2% NaOH at 60°C for 6 h than steam treatment.
2. Two cycles of refining helps to reduce lumpy of bamboo fiber but produced fiber of lower properties including felting power, aspect ratio, flexibility ratio and Runkel ratio.
3. Additives are needed to reduce spring back and improved physical and mechanical properties of bamboo hardboard - optimum content - 2% PF, 2% wax and 0.25% alum
4. MOR and MOE for bamboo hardboards are superior compared to those fabricated from EFB, rubberwood and EFB+rubberwood blend

Conclusions



4. As regards to internal bonding and physical properties, admixture hardboards had the highest properties
5. Compared to pinus produced hardboard, tropical lignocellulosic boards had lower properties but bamboo hardboard had better MOR.



THANK YOU



With Knowledge We Serve