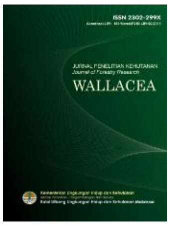

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HIGH TEMPERATURE DRYING PROPERTIES AND BASIC DRYING SCHEDULE OF 5 LESSER-KNOWN SPECIES FROM RIAU

(Sifat Pengeringan Suhu Tinggi dan Bagan Pengeringan Dasar 5 Jenis Kayu Kurang Dikenal Asal Riau)

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ABSTRACT

Drying process is a crucial stage in the utilization of any wood for construction and furniture purposes. The study aimed to: (i) investigate the sensitivity of several lesser-known wood species from natural forest in Riau to drying process at high temperature; and (ii) develop basic drying schedule for each wood. Five lesser-known species from Riau were investigated, namely punak *(Tetramerista glabra)*, mempisang *(Diospyros korthalsiana)*, pasak linggo *(Aglaia argentea)*, meranti bunga *(Shorea teysmanniana)* and suntai *(Palaquiumburckii).* Modified Terazawa's (1965) method was used for the experiment. The result shows that deformation was found for all species. The most severe deformation level was observed for both punak (score value of 4-6) and mempisang (score value of 4-5). On the other hand, pasaklinggo experienced the most severe initial end/surface check/split (score value of 6) and honeycombing (score value of 5). The result also showed that punak and pasaklinggo can be dried with the same drying schedule at the temperature range of 40-65° C and the humidity range of 38-88%. The proposed temperature and humidity ranges (or drying schedules) are 50-80° C and 28-80% for suntai, 50-70° C and 25-80% for mempisang, and 50-70° C and 40-84% for meranti bunga. Mempisang and suntai can use the same drying condition until fiber saturation point, then different drying condition applies.

Kata kunci:
Jenis-jenis kurang dikenal
Cacat pengeringan
Deformasi
Bagan pengeringan

ABSTRAK

Pengeringan merupakan satu tahapan pengolahan yang penting dalam pemanfaatan kayu untuk keperluan konstruksi dan mebel. Studi ini bertujuan untuk: (i) memeriksa level sensitivitas beberapa jenis kayu kurang dikenal asal Riau terhadap proses pengeringan pada suhu tinggi (100°C); dan (ii) menyusun bagan pengeringan untuk setiap jenis kayu. Obyek penelitian adalah 5 jenis kayu kurang dikenal asal Riau yaitu punak (Tetramerista glabra), mempisang (Diospyros korthalsiana), pasaklinggo (Aglaia argentea), meranti bunga (Shorea teysmanniana) dan suntai (Palaquium burckii). Metode Terazawa (1965) yang sudah dimodifikasi digunakan untuk studi ini. Hasil menunjukkan bahwa semua jenis kayu rentan mengalami cacat deformasi. Deformasi terparah ditemukan pada kayu punak (skor cacat adalah 4-6) dan mempisang (skor cacat adalah 4-5). Di sisi lain, pasaklinggo mengalami pecah/retak ujung/permukaan terparah (skor adalah 6) dan pecah dalam terparah (skor adalah 5). Hasil penelitian juga menunjukkan bahwa punak dan pasaklinggo dapat dikeringkan dengan bagan pengeringan yang sama pada kisaran suhu pengeringan 40-65° C dan kelembapan 38-88%. Kisaran suhu dan kelembapan (bagan pengeringan) yang diusulkan untuk proses pengeringan masing-masing jenis kayu adalah 50-80° C dan 28- 80% untuk suntai, 50-70° C and 25-80% untuk mempisang, serta 50-70° C dan 40-84% untuk meranti bunga. Bagan pengeringan untuk kayu mempisang dan suntai sama hingga keduanya mencapai titik jenuh serat dan setelah itu diterapkan kondisi pengeringan yang berbeda.

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I. INTRODUCTION

It is acknowledged that Indonesia has approximately 4000 wood species growing in the whole region of country's natural forest. Of this number, there are only 267 species that have been used commercially so far (Djarwanto *et al.*, 2016). The remaining species in the forest have not been utilized well due to the lack of information on their properties, proper processing technology and potential use. Without this knowledge, the use of the lesser-known species cannot be fully optimized.

One of the information seek by the industries regarding the use of new wood species is the drying process of the timber such as the proper drying schedule, the length of drying time, susceptibility to any defect, etc. Drying process is a crucial stage in the utilization of any wood for construction and furniture purposes. It improves the quality of every wood as raw material for the construction/furniture industries in various contexts such as increased strength and dimensional stability during the service. Improper drying technique could lead to serious damage and cause the wood no longer available for further usage.

There are various techniques to dry wood including the most advanced one such as microwave drying (Torgovnikov & Vinden, 2010; Vongpradubchai & Rattanadecho, 2011; Zhang *et al.*, 2013; Hannani, 2014). Nevertheless, kiln drying is still considered the most popular technique for commercial use. Regrettably, not every wood species is easy to be kiln-dried without developing any defect. According to Effah (2014) each wood species has its own sensitivity to drying temperature. Yuniarti *et al.* (2015) has even proven that the sensitivity of one particular species will be also different under different drying temperatures. Therefore, it is assumed that each wood will also have different drying schedule to be applied in a kiln.

This study aimed to: (i) investigate the sensitivity of several lesser-known wood species from natural forest in Riau to drying process at high temperature; and (ii) develop basic drying schedule for each wood. The continuous, high temperature drying (HTD) at 100° C is the technique used in Terazawa method in order to identify the sensitivity of any wood species to drying defect. Whilst there is no clear explanation in Terazawa method regarding the principles of using HTD to investigate the drying defect tendency of wood (Terazawa, 1965), HTD is actually a common method for drying easy-to-dry species such as pine. It is assumed then that not every species will suit HTD. Therefore, at HTD, it is expected that the wood species will give its maximum response.

The study itself was a part of the regular research program on exploring and enhancing the basic properties of lesser-used and lesser-known wood species in Forest Products Research and Development Center (FPRDC). The basic properties investigated include wood anatomy, physical-mechanical properties, chemical content, natural durability, sawing, drying, preservation, and woodworking. The annual program commits to do the investigation on different wood species from different forest region in Indonesia for each year. In 2011-2014, the program has conducted research on 85 wood species (Muslich, 2015). In last 2016, the program focused on investigating the basic properties of several lesser-known wood species from Riau province which became the study object. These species have been used and known to the community living surrounding the forest, but their properties, including drying behaviour, have not been studied yet.

II. RESEARCH METHODS

A. Materials and equipment

Five wood species, namely punak *(Tetramerista glabra)*, mempisang *(Diospyros korthalsiana)*, pasak linggo *(Aglaia argentea)*, meranti bunga *(Shorea teysmanniana)* and suntai *(Palaquium burckii)*, were used as the main material for the experiment. The selection of these species was based on the information provided by the local community in the origin of the species. The trees selected from the field were those with diameter at breast height is equal to or above 400 mm (Djarwanto *et al.*, 2016). The equipment used included laboratory oven, balance, band saw, digital calliper, ruler, aluminium foil, wood adhesive, and writing tools.

B. Time and place

The experiment was carried out in July-December 2016. The logs of the 5 wood species were collected from the natural forest in Riau Province. The forest is acknowledged as parts of the production forest area managed by PT Diamond Raya Timber. The logs were transported to and processed at the Sawing and Drying Laboratories of Forest Product Research and Development Center in Bogor, West Java.

C. Research procedure

1. Samples preparation

For each wood species, 2 logs, at length of 4000 mm each, were collected randomly so that each log represented different trees. Each log was sawn to produce boards measuring 4000 mm (L) x 25 mm (T) x 300 mm (W). Terazawa method was applied to investigate the drying properties at high temperature and the determination of basic drying schedule of the 5 wood species. Based on this method, approximately 2-3 tangential boards produced were randomly collected and further re-sawn to yield 5 drying samples measuring 200 mm (L) x 25 mm (T) x 100 mm (W).

Several small specimens, measuring 20 mm (L) x 25 mm (T) x 100 mm (W), were also taken between the drying sample(s) from the same board. These specimens were used to determine the initial moisture content and calculated oven-dry weight of the samples. The remaining boards were separated from the main samples and used for other purposes.

2. Drying process

The prepared drying samples were dried at 100°C. Every 3-4 hours, the samples were taken out of the oven, weighed and observed for any defects occurred. The drying process was stopped after each sample reached the moisture content below 3-4%. The presence of surface and end check was observed. Afterward, the samples were sawn into 2 equal parts to check the presence of internal check in the mid part of the boards. The measurement of any deformation occurring was carried out for each board afterward.

3. Data collection and analysis

The data collected were initial moisture content, external check/split (surface check, end check/split), internal check and deformation. Each defect was further scored according to the modified Terazawa (Basri, 2011). The modification made by Basri (2011) covers the score range for the developed deformation and initial checks/splits, and the correspondent minimum-maximum temperature and wet bulb depression. In original Terazawa method (Terazawa, 1965), the score range was from 1 to 8 for external/initial check and deformation. In the modified method, the score range is from 1 to 7 for external/initial check and deformation. For internal check, the score range is still the same, which is from 1 to 6. However, similar to the case for initial checks/splits and deformation, the correspondent minimum-maximum temperature and wet bulb depression for each score are also modified.

Higher score indicates more severe defect than the lower score does. The scoring result obtained were tabulated and analysed. Afterward, the highest scoring result from each wood was used to determine the initial temperature, the final temperature and the initial wet bulb depression according to Table 1. These values, combined with the relative humidity chart, were further used to develop the basic drying schedule for each wood (for maximum thickness of 25 mm).

III. RESULTS AND DISCUSSION

A. High temperature drying properties

Table 2 shows the high temperature drying properties (100° C) of 5 wood species from Riau province. Deformation was found in all species but with different degrees (Figures 1-5). The highest score of deformation level was observed for both Punak (score value is 4-6) and Mempisang (score value is 4-5). On the other hand, together with Suntai wood, Pasaklinggo had the lowest deformation level.

Further observation showed that not all species were susceptible to initial end/surface check/split and honeycombing, such as punak and mempisang. Among all, pasaklinggo experienced the most severe initial end/surface check/split (score value was 6) and honeycombing (score value was 5). Figure 1 -5 below display the defects developed in each species.

Table 1. Relationship between defect degrees and drying condition (modified Terazawa method) (Basri, 2011)

Tabel 1. *Hubungan antara derajat cacat dan kondisi pengeringan (metode Terazawa yang sudah dimodifikasi) (Basri, 2011)*

Type of defects/ *Jenis cacat*	**Drying condition/*Kondisi pengeringan***	**Degrees of defect/*Derajat cacat***						
		1	**2**	**3**	**4**	**5**	**6**	**7-8**
Initial end/surface check/split/ *Pecah atau retak permukaan/ujung*	Initial temp, °C/*Suhu awal*	70	65	60	55	50	40	38
	Initial wet bulb depression/ *Depresi bola basah awal*	6,5	5,5	4	4	3	2	2
	Final temp, °C / *Suhu akhir*	95	90	85	80	70	65	50
Deformation/ *Deformasi*	Initial temp, °C/*Suhu awal*	70	66	58	54	50	40	38
	Initial wet bulb depression/ *Depresi bola basah awal*	6,5	6	5	4	4	3	3
	Final temp, °C / *Suhu akhir*	95	88	83	80	70	65	50
Honeycomb/*Pecah dalam*	Initial temp, °C/*Suhu awal*	70	55	50	48	48	45	-
	Initial wet bulb depression/ *Depresi bola basah awal*	6,5	4,5	4	3	3	2,5	-
	Final temp, °C / *Suhu akhir*	95	83	77	73	71	70	-

Table 2. High temperature drying properties of 5 wood species from Riau
Tabel 2. *Sifat pengeringan suhu tinggi untuk 5 jenis kayu asal Riau*

Species (*Jenis*)	Initial moisture content (average) (*Kadar air awal (rata-rata)*), %	Defect type and level*		
		End/surface check/split (*Pecah/retak permukaan/ ujung)*	Deformation (*Deformasi*)	Honeycombing (*Pecah dalam)*
Punak	86.56 – 103.81 (*95.33*)	1 – 2	4 – 6	1 – 2
Mempisang**	74.67 – 82.78 (*79.86*)	1	4-5	1
Pasaklinggo	39.16 – 69.43 (*52.91*)	6	2-3	5
Meranti bunga	77.94 – 107.96 (*96.10*)	2 – 3	3 – 4	2 – 3
Suntai	59.35 – 66.90 (*62.5*)	2 - 4	2 – 3	2 - 4

Remarks:
* The number of samples is 5 for each species, measuring 100 mm (width) x 25 mm (thickness) x 200 mm (length)
** Data for mempisang has been presented in 2016 at the Seminar of Indonesian Wood Researcher Society in Ambon (Yuniarti & Basri, 2016)

Keterangan:
* *Jumlah contoh uji per jenis kayu adalah 5 dengan ukuran 100 mm (lebar) x 25 mm (tebal) x 200 mm (panjang)*
** *Data kayu mempisang telah dipresentasikan pada Seminar Masyarakat Peneliti Kayu tahun 2016 di Ambon (Yuniarti & Basri, 2016)*

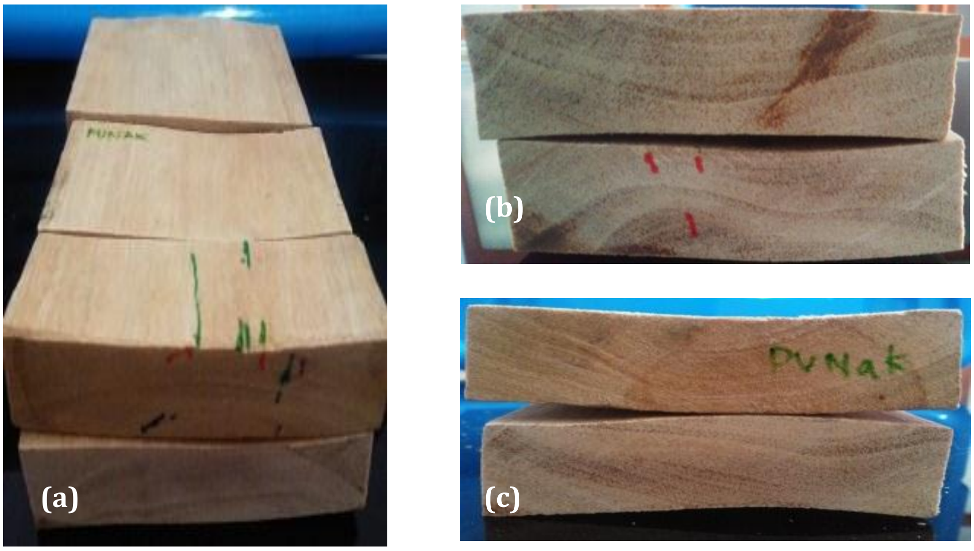

Figure 1. Initial end/surface check/split (a), honeycombing (b) and deformation (c) observed in punak
Gambar 1. *Pecah/retak ujung/permukaan (a), pecah dalam (b) dan deformasi (c) pada kayu punak*

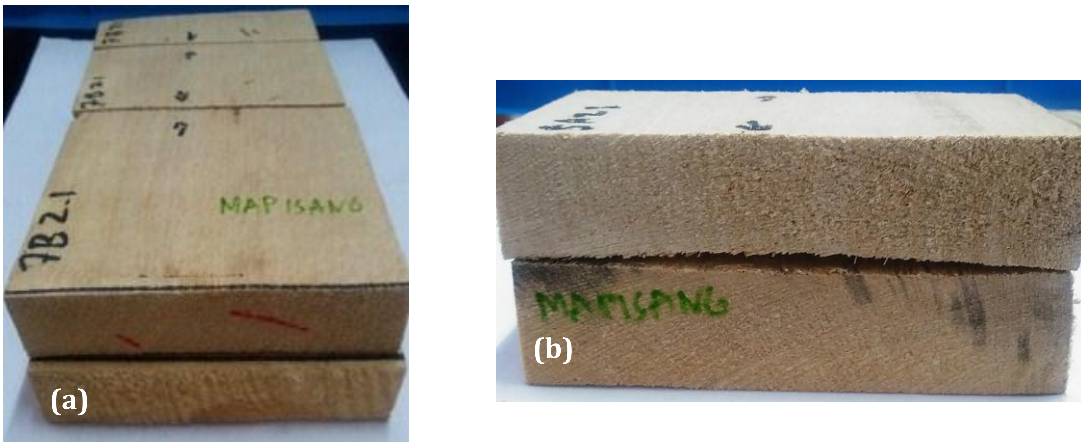

Figure 2. Initial end/surface check/split (a) and deformation (b) observation in mempisang
Gambar 2. *Pecah/retak ujung/permukaan (a), dan deformasi (b) pada kayu mempisang*

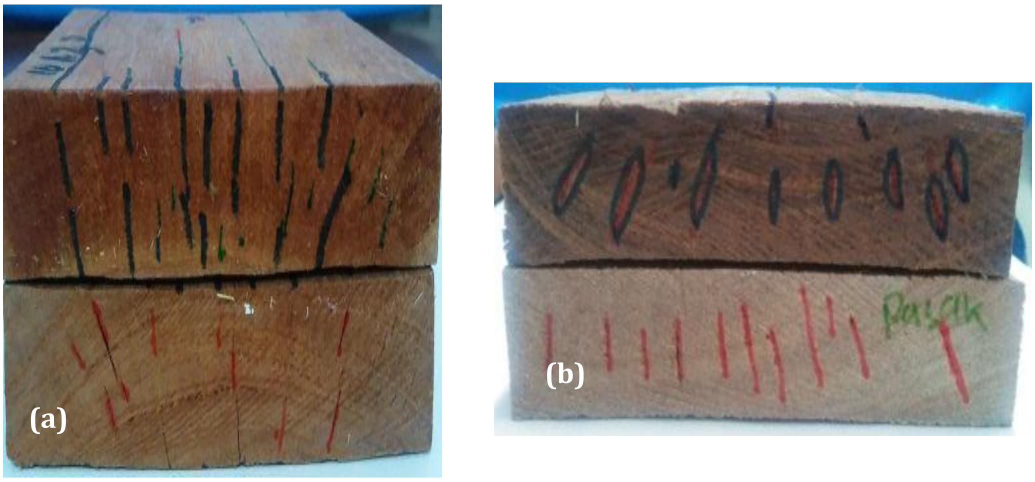

Figure 3. Initial end/surface check/split (a), honeycombing and deformation (b) observed in pasaklinggo
Gambar 3. *Pecah/retak ujung/permukaan (a), pecah dalam dan deformasi (b) pada kayu pasaklinggo*

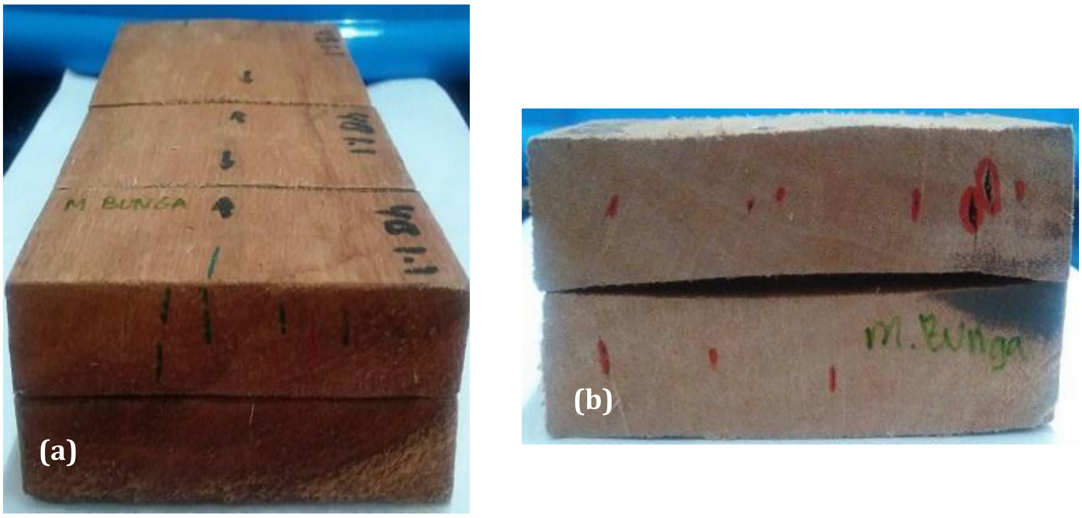

Figure 4. Initial end/surface check/split (a), honeycombing and deformation (b) observed in meranti bunga
Gambar 4. *Pecah/retak ujung/permukaan (a), pecah dalam dan deformasi (b) pada kayu meranti bunga*

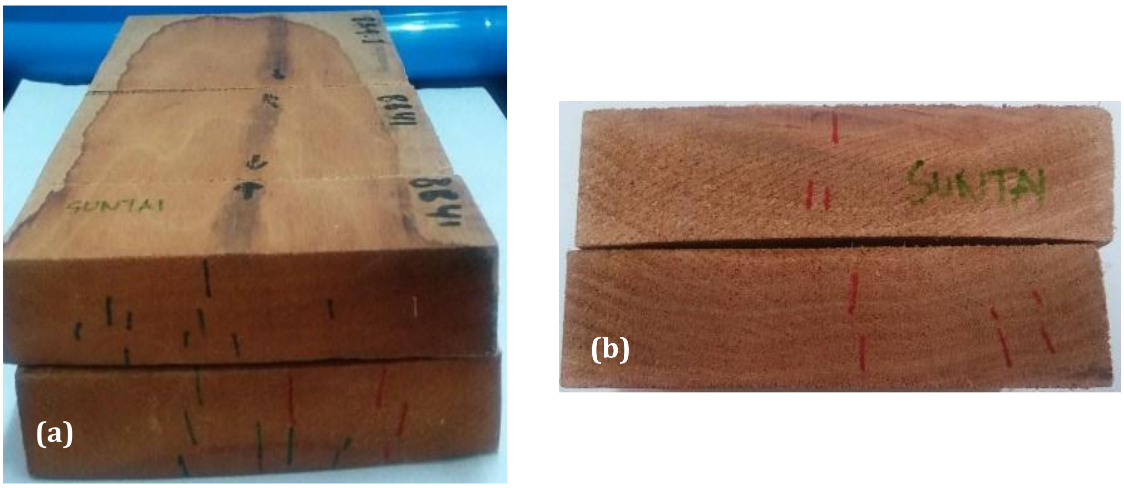

Figure 5. Initial end/surface check/split (a), honeycombing and deformation (b) observed in suntai
Gambar 5. *Pecah/retak ujung/permukaan (a), pecah dalam dan deformation (b) pada kayu suntai*

Temperature, in particular high temperature such as 100°C and up, has been proven to be the potential driver for the development of defects in any wood species being dried (Oltean *et al.*, 2007). Therefore, suitable temperature for each species should be selected carefully, one of which is through the Terazawa method applied for this study.

In addition, a number of internal factors within the wood being dried also have potential contribution to the defects development. One of those is the dimension of the sample which could affect the susceptibility of wood to several drying defects such as checking or deformation (Yamashita *et al.*, 2014).

Different anatomical features of each species is also considered to contribute to different tendency of each wood species to develop each defect. The moisture evaporation from a wood is a complex process, moreover in hardwood species which have more complicated structure than the softwood species. A number of anatomical features that possibly affect the drying process of a particular wood include the sapwood depth, vessels, ray cells, fiber wall and parenchyma (Basri *et al.*, 2005; Mugabi *et al.*, 2010). Vessels and ray cells are considered as important pathway for moisture movement within the hardwood(Keey *et al.*, 2000; Basri *et al.*, 2005).

It is observed that all species have different vessel dimension, vessels frequency, vessel types, ray cells length, frequency of ray cells, ray cells types, fiber dimension, fiber orientation and deposition location of crystallite substance (Djarwanto *et al.*, 2016). These differences are potential causes for any differences observed in the tendency and degree of defects developed by each species.Small vessel diameters and thick cell wall could cause the wood difficult to dry without any defect (Basri & Rulliyati, 2008).

The presence of crystallite substances was observed in various cells of all wood species being investigated in this study. Other deposits, red-coloured, were also found in the ray cells of Punak (Djarwanto *et al*, 2016). Several species, such as Mempisang and Meranti bunga, were also reported to have intercellular channels in their inner side (Djarwanto *et al*, 2016). These crystallite and channels presence could affect the moisture transport within those 5 wood species. Any deposits of tyloses, crystallites and other substances in the vessels, ray cells, parecnhyma and other hollow cells could negatively affect the moisture transport within the wood and cause the wood to deform or split/check during drying process (Basri *et al.*, 2015). The presence of any kind of deposits could block the channel or pits interconnecting the wood cells, thus decreasing or even hindering the moisture flow between wood cells.

Nevertheless, up to now, there is still a missing information on the relationship between the size, shape or frequency of any wood cells or components and the drying behaviour of each wood. Among the experts, wood drying itself is always considered a complex process involving not only the external factors (i.e temperature, humidity, etc) but also the whole features of the wood itself (including both physical and chemical components). In addition, there has not been any information found which explains whether different types of deposits will cause different or same degree of effect on the moisture flow within the wood or the defects formed. A particular, further study on this particular issue will be advantageous and provide answers to the quest.

B. Basic drying schedule

Table 3 shows the maximum and minimum temperature and relative humidity that can be applied for the drying process of each wood. These temperature, humidity and initial depression values were determined based on the most severe defect occurred on each wood (Table 2). However, when the degrees of these defects are found to be comparable and not really different from one to another, the above values will be mostly based on the honeycombing/internal check degree. For example, in this study, it was observed that the defects scores for Suntai were 2-4 for initial check/split and honeycombing/internal check, and 2-3 for deformation. Thus, it was decided to determine the ranges of drying temperature and humidity ranges based on the score of honeycombing/internal check.

Honeycombing/internal check could weaken the wood strength, thus affect the quality and the value of wood (Phonetip *et al.*, 2017). In several species, such as *Eucalyptus* spp., the presence of honeycomb is often accompanied by severe collapse (Mugabi *et al.*, 2010; Mugabi *et al.*, 2011; Yuniarti, 2015; Yuniarti *et al.*, 2015). Nevertheless, its presence is invisible within the inner side of the wood and can only be viewed when the wood is further re-sawn. Therefore, it is considered to choose the best drying condition that will not allow the development of any honeycomb in the wood.

Table 3 shows that punak and pasaklinggo can be exposed to the same temperature and humidity ranges, which are 40-65°C and 38-88% respectively. On the other hand, suntai, mempisang and meranti bunga had higher drying temperature and lower humidity ranges than punak and pasaklinggo. The proposed temperature and humidity ranges for suntai are

50-80°C and 28- 80%; for mempisang are 50-70°C and 25-80%; and for meranti bunga are 50-70°C and 40-84%, respectively.

Table 3. Proposed minimum and maximum temperature and humidity for the drying process of 5 wood species from Riau
Tabel 3. *Suhu dan kelembapan minimum dan maksimum yang diusulkan untuk pengeringan 5 jenis kayu asal Riau*

Wood species (*Jenis kayu*)	Average initial moisture content, % (*Kadar air awal rata-rata*)	Temperature (*Suhu pengeringan*) °C		Initial wet bulb depression (*Depresi awal bola basah*)	Relative humidity (*Kelembapan relatif*) %	
		Min.	Max		Min	Max
1. Punak	95.33	40	65	3	38	88
2. Mempisang	79.86	50	70	4	25	80
3. Pasaklinggo	52.91	40	65	2	38	88
4. Meranti bunga	96.10	48	73	3	40	84
5. Suntai	62.15	50	77	4	22	80

Remarks: The determination of the maximum and minimumdrying temperature and humidity is based on the most severe defect occurs for each wood species.
Keterangan: *Penetapan suhu pengeringan dan kelembaban minimum dan maksimum berdasarkan cacat terparah yang dialami setiap jenis kayu.*

Table 4-7 show the basic drying schedules for each wood species which are determined based on the proposed drying temperature and humidity ranges in Table 3. Punak and pasaklinggo can be dried using the same drying schedule for the whole process (Table 4). The drying schedule for both species can be considered the mildest among others. The drying schedule for punak is found to be slightly milder from the one that has been recorded by (Boone *et al.*, 1988). The reason possibly lies on the age difference of the tree being used as the samples in this study and previous study.

The drying condition for mempisang (Table 5) and suntai (Table 7) are the same until both reach the fiber saturation condition and starts to be different afterward. Meranti bunga appears to have the same initial drying temperature range with mempisang (Table 6). However, it generally needs higher humidity range than mempisang. The proposed drying schedule of meranti bunga is a little bit lower than those used to be recommended for white and yellow meranti (Martawijaya *et al.*, 2005), but found to be higher than red meranti (Suranto & Prasetyo, 2012).

Table 4. Basic drying schedule for punak and pasaklinggo
Table 4. *Bagan pengeringan dasar kayu punak dan pasaklinggo*

Moisture content (*Kadar air*) %	Temperature (*Suhu*) °C	Humidity (*Kelembapan*) %
Basah ~30	40	88
30~25	45	83
25 ~ 20	50	75
20 ~ 15	55	64
<15	65	38

Table 5. Basic drying schedule for mempisang
Tabel 5. *Bagan pengeringan dasar kayu mempisang*

Moisture content (*Kadar air*) %	Temperature (*Suhu*) °C	Humidity (*Kelembapan*) %
Basah ~30	50	80
30~25	55	72
25 ~ 20	60	62
20 ~ 15	65	45
<15	70	25

Table 6. Basic drying schedule for meranti bunga
Tabel 6. *Bagan pengeringan dasar kayu meranti bunga*

Moisture content (*Kadar air*) %	Temperature (*Suhu*) °C	Humidity (*Kelembapan*) %
Basah ~30	50	84
30~25	55	81
25 ~ 20	60	73
20 ~ 15	65	60
<15	70	40

Table 7. Basic drying schedule for suntai
Tabel 7. *Bagan pengeringan dasar kayu suntai*

Moisture content (*Kadar air*) %	Temperature (*Suhu*) °C	Humidity (*Kelembaban*) %
Basah ~30	50	80
30~25	55	72
25 ~ 20	60	58
20 ~ 15	65	45
<15	80	28

I. Conclusion

All wood species were susceptible to deformation during high temperature drying process. Punak and mempisang were observed to have the highest score of deformation level (score value 4-6 for punak and 4-5 for mempisang). On the other hand, not all species were susceptible to initial end/surface check/split and honeycombing, such as punak and mempisang. Pasaklinggo had the most severe initial end/surface check/split (score value is 6) and honeycombing (score value is 5).

The drying temperature and humidity ranges varied from one species to another. Punak and pasaklinggo can be exposed to the same basic drying schedule at the temperature range of 40-65°C and the humidity range of 38-88%. On the other hand, the proposed basic drying schedule for suntai are 50-80°C and 28-80%; for mempisang are 50-70°C and 25-80%; and for meranti bunga are 50-70°C and 40-84%.

Mempisang and suntai can only be dried under the same drying condition until fiber saturation point and different condition applies afterward.

II. Recommendation

The basic drying schedule presented in the paper still need to be trialled prior to commercial practice. It is considered that the condition presented for each drying schedule is the maximum drying point which can be applied for each species. Different manufacturer fabricates different kiln design which could affect its performance. Kiln practictioners should take this particular aspect into consideration and adjust the developed drying schedules in this paper with their own drying kiln.

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