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Research Note

Subterranean Termite *Coptotermes formosanus* Resistance of Twenty Commercial Wood Used in Taiwan

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Abstract

Termites cause problems to wood products in use, especially in a termite hazardous area such as Taiwan. Information of termite resistance of wood products help wood users make choice and to decide the treatment a certain wood product needs to receive. Eight softwood, 11 hardwood and 1 monocot commercial wood species along with 7 of their heat treated specimens acquired from local wood factories were tested for their resistance to *Coptotermes formosanus* by following the AWPA E1-09 standard. Comparative subterranean termite resistances were recorded for reference and measure for termite resistance suggested. Results indicate that the dry-heat oxygen-free heat treating process applied to produce the heat treated specimens tested in this study increases or decreases termite resistance depends on wood species treated. Extractives appear to be the major factor of termite resistance of wood and hardness of hardwood specimens of specific gravity over 0.8 may retard termite biting. Termite resistance of the woody tissue of coconut, the monocot tested, appears highly correlated to its specific gravity.

Keywords: subterranean termite resistance, *Coptotermes formosanus*, commercial wood species, heat-treated wood, coconut

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二十種台灣商用木材之地棲型白蟻 (*Coptotermes formosanus*)抵抗性

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摘　要

白蟻對使用中的木質材料造成危害，在白蟻高危害環境的台灣地區尤其嚴重。木質材料對白蟻抵抗性的資訊，能幫助木材使用者決定該使用哪種木質材料或應對木材進行哪種處理，以降低白蟻危害。本研究利用美國木材保護協會 E1-09 標準，對本地木材廠商提供的 8 種針葉樹材、11 種闊葉樹材、1 種可可椰子及 7 種熱處理木材，進行家白蟻(*Coptotermes formosanus*)抵抗性試驗。結果顯示，在無氧及乾熱條件之熱處理木材與未處理材比較，其白蟻抵抗性依不同樹種，呈現提升或降低的情形。抽出物應爲木材抵抗白蟻危害的主要因子，闊葉樹材比重超過 0.8 者，亦可能因其較硬而阻礙白蟻啃食。椰子木木質部位所採取的試材，其白蟻抵抗性與比重有顯著的相關性。

關鍵詞：地棲型白蟻抵抗性、家白蟻、商用木材、熱處理木材、椰子木

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Introduction

Taiwan is an island in subtropics and tropics with vigorous termite activities ready to bite edible cellulosic materials foraged. Wood products in use obtain their resistance to termites by inherited characteristics, physical treatments, and chemical treatments (Coulson and Lund, 1973; Grace and Yates, 1999; HDRA, 2001). The types or degrees of physical and/or chemical treatments depend highly on the natural resistance of wood products and the environmental termite hazardous index of which wood products are designed to be used (Li, 2006). Although termite resistant wood species had been listed in articles (Li, 2006; Schmidt and Meke, 2008), it is believed that only a very few wood species are free from termite attack (Eaton and Hale, 1993), especially in a vulnerable region such as Taiwan.

A heat treatment facility has been equipped in Su-ao, Taiwan to produce heat-treated wood products by dry-heat oxygen-free (N_2 filled) treating process. According to articles concerned about the effect of heat treatments to termite resistances of wood products indicated that effects varied from process to process and also from species to species. Doi *et al.* (1997, 1999) worked on termite resistant effects created by steam heat and dry heat treatment to wood species in Japan showed that steam heat treatments decreased termite resistance of all the specimens tested and dry heat treatments increased resistances of specimens to termites, however, the degree of increment depended highly on the species treated. Smith *et al.* (2003) treated Scots pine and Norway spruce with a combination of hot oil treatment then vacuum pressure treated with hot oil and found effects on increasing termite resistances, but details in combination of the two treatments and wood species had to be taken care to receive desired effectiveness.

Twenty commercial wood species generally used in or recently imported into Taiwan provided by local wood factories together with 7 heat-treated specimens of 5 of the 20 species were evaluated of their termite resistance in accordance with AWPA standard E1-09 (AWPA, 2010). The inclusions of heat-treated specimens are to reveal effects of dry-heat oxygen-free (N_2 filled) heat treating process to the termite resistance of the treated wood. Results obtained from this study may provide information on designing these wood species and their products to use in concerns of termite hazards.

Materials and Methods

Twenty wood species (8 softwoods, 11 hardwoods and 1 monocot) and 7 heat-treated samples of 5 of the 20 species (Table 1) provided by local wood factories were tested. The size of the test blocks were 20 mm by 20 mm by 6 mm in longitudinal direction. Ten replicate blocks were prepared for each of the 27 test specimens. The standard procedure of AWPA E1-09 were followed to perform the termite resistant test with *Coptotermes formosanus* obtained from a termite field test site located at Sin-nan Village, Chuang-wei Township, Yi-lan County by wood and cardboard filled plastic water tube termite traps. Containers used were glass screw-top jars, 85 mm diameter by 90 mm in height, prepared in accordance with the standard, 400 termites (with 5-10% soldiers) and 2 blocks of the same specimen were put into each jar.

Test results were reported by the rating of blocks following the rating system described in the standard (App. Table 1) and by the percentage of weight loss (%) of blocks at end of test.

Table 1 The 20 wood species and 7 heat-treated samples tested

Scientific name	English name	Chinese name/commercial name	Specific gravity[(2)] Avg.	Specific gravity[(2)] SD	Code	Heat treatment temp.(℃)[(3)]
Softwoods						
Araucaria spp.	Klinki pine	南洋杉	0.52	0.021	KP	190, 210
Chamaecyparis formosensis	Taiwan red cypress	紅檜	0.42	0.022	TRC	
Chamaecyparis nootkatensis	Yellow cedar	阿拉斯加扁柏/北美黃檜	0.43	0.034	YC	170, 190
Cryptomeria japonica[(1)]	Japanese cedar	柳杉(心材)	0.34	0.022	JCH	
Cunninghamia lanceolata var. *konishii*	Luanta fir (Samu)	香國香杉	0.33	0.023	LF	
Pinus radiata	Radiata pine	放射松	0.55	0.069	RP	
Pinus spp.	Southern Yellow Pine	南方松	0.53	0.030	SYP	210
Pseudotsuga menziesii	Douglas fir	花旗松	0.58	0.062	DF	190
Hardwoods						
Acacia confusa	Taiwan acacia	相思樹	0.76	0.037	TA	170
Bagassa guianensis	Tatajuba	圭亞那乳桑/金檀木	0.83	0.047	TJ	
Eusideroxylon melagangai	Borneo ironwood	婆羅洲鐵木	0.81	0.034	BI	
Martiodendron parviflorum	Tatabuballi	馬蹄豆木/南美櫻桃木	0.95	0.059	TB	
Newtonia suaveolens	Pikinmisiki	香甜落腺豆/黃金柚木	0.73	0.068	PI	
Scorodocarpus borneensis	Ungsunah	蒜果木/南洋鐵木	0.74	0.054	UN	
Shorea spp.	Red lauan	紅柳桉	0.63	0.050	RL	
Shorea spp.	White meranti	白柳桉	0.47	0.046	WM	
Swietenia macrophylla	Mahogany	大葉桃花心木	0.75	0.024	MA	
Tabebuia serratifolia	Ipe	鋸葉風鈴木/巴西紫檀	0.93	0.065	IP	
Tectona grandis	Teak	柚木	0.69	0.067	TK	

Table 1 (continued)

Scientific name	English name	Chinese name/commercial name	Specific gravity(2) Avg.	Specific gravity(2) SD	Code	Heat treatment temp.(℃)(3)
Monocot						
Cocos nucifera	coconut	可可椰子/椰子木	0.82	0.179	CO	

1: heartwood only
2: determined after specimens been oven dried at 60℃ for 48 hrs with a moisture content about 4%
3: specimens treated for 2 hrs at the highest temperature (℃) as the values indicated; code for each heat-treated specimen is a combination of the species code and the treating temperature

Comparative termite resistance (CTR, %) of the untreated wood specimens were calculated according to the method, as shown in equation 1, cited by Coulson and Lund (1973) from an unpublished paper prepared by D. D. Nicholas to denote the relative susceptibility of wood species tested.

$$\text{CTR (\%)} = \frac{\text{Average percentage of weight loss of a species}}{\text{The highest average percentage of weight loss of the 20 species tested}} \times 100 \quad (1)$$

Anti-termite effects (ATE, %) were calculated by the equation below (equation 2) to illustrate the possible influences of heat treatments to termite resistance of wood species in comparing the average percentage of weight loss of the treated and the untreated specimens of a same wood species.

$$\text{ATE (\%)} = \left(1 - \frac{\text{Average percentage of weight loss of a heat treated specimen}}{\text{Average percentage of weight loss of the untreated specimen of the same species}}\right) \times 100 \quad (2)$$

Results and Discussions

I. Termite resistance

1. Percentage of weight loss and rating

Percentages of weight loss and ratings of wood species are collected in table 2. It seems to be difficult to sort test wood species into termite resistance categories. The rating range of the 10 replicate blocks of each specimen varied from species to species, as shown in table 2, which indicates the variation of termite resistance within a species. It is much easier to picture the variation of each species from figure 1. Among the softwoods tested, Luanta fir (LF)

Table 2 Percentages of weight loss and ratings of untreated wood species

English name	Chinese name	Avg. Percentage of Weight Loss (%)(1)	Rating Range of Blocks(2)
Softwoods			
Klinki pine	南洋杉	25.99 (9.14)	0～7
Taiwan red cypress	紅檜	5.35 (3.52)	7～9.5
Yellow cedar	阿拉斯加扁柏	9.24 (6.18)	4～9.5
Japanese cedar	柳杉(心材)	11.87 (6.36)	4～9
Luanta fir	寮國香杉	43.93 (28.45)	0～7
Radiata pine	放射松	27.12 (12.16)	0～4
Southern Yellow Pine	南方松	46.48 (9.18)	0～4
Douglas fir	花旗松	44.29 (7.20)	0～7
Hardwoods			
Taiwan acacia	相思樹	18.86 (8.78)	4～7
Tatajuba	圭亞那乳桑	4.03 (3.43)	7～9.5*
Borneo ironwood	婆羅洲鐵木	2.37 (2.22)	7～9.5*
Tatabuballi	馬蹄豆木	3.49 (0.89)	8～9*
Pikinmisiki	香甜落腺豆	5.36 (1.46)	7～9
Ungsunah	蒜果木	3.81 (2.88)	7～9.5*
Red lauan	紅柳桉	12.85 (10.70)	0～9
White meranti	白柳桉	35.27 (11.92)	0～7
Mahogany	大葉桃花心木	5.11 (2.80)	7～9.5
Ipe	鋸葉風鈴木	5.57 (3.04)	7～9
Teak	柚木	17.57 (8.79)	4～9
Monocot			
coconut	可可椰子	12.05 (9.14)	0～9

1: numbers in parenthesis are standard deviations
2: * means 90% of replicate blocks rated at least 9

indicates the widest range on percentage of weight loss, while Red lauan's (RL) is the widest of the hardwoods and for the narrowest are Taiwan red cypress (TRC) and Tatabuballi (TB) for softwoods and hardwoods respectively. Among the hardwoods, Borneo ironwood (BI) and TB are the two species of the lowest percentage of weight loss (2.37% and 3.49%), however, TB with its narrower range of percentage of weight loss (1.83-5.30%) than the BI's (0.39-7.32%) may be as resistant or even more resistant than BI to termite while in service. The varied ranges of percentage of weight loss of species tested denote the requirement of extensive test with sufficient replicates on varied samples from wide ranges and representative field test to reveal termite resistance of a wood species.

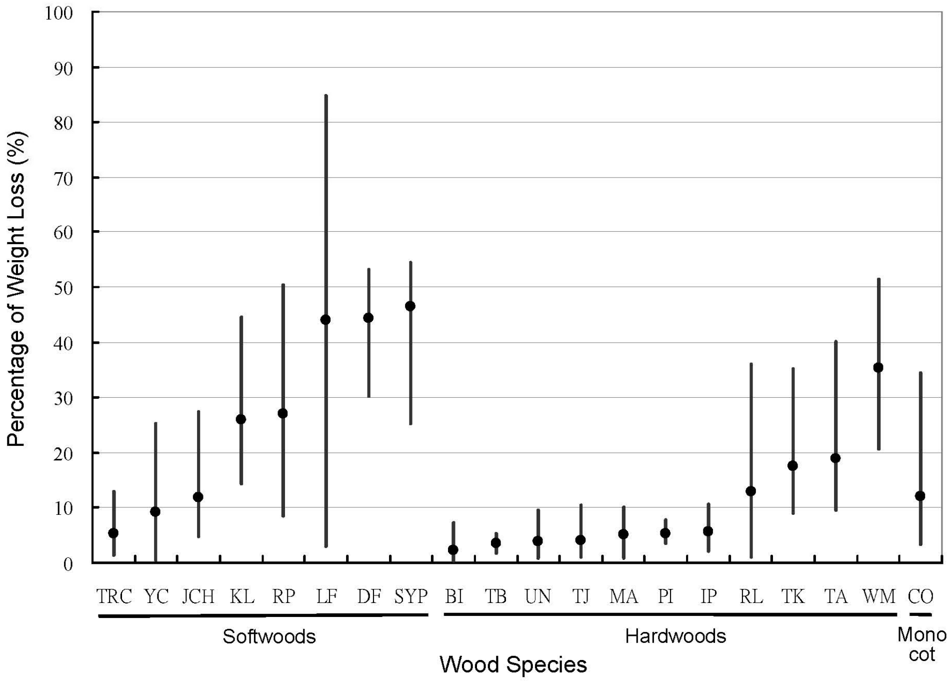

Fig. 1 Averages and ranges of percentage of weight loss of replicate blocks of the 20 wood species tested

2. Comparative termite resistance (CTR)

The CTRs are shown in table 3 to give a general idea of relative *C. formosanus* resistance of the 20 wood species tested, and the relative termite susceptibility among them.

Table 3 Comparative termite resistance (CTR, %) of the 20 wood species tested

English name (in Chinese)	CTR (%)	English name (in Chinese)	CTR (%)
Borneo ironwood (婆羅洲鐵木)	5.10	Coconut (可可椰子)	25.93
Tatabuballi (馬蹄豆木)	7.51	Red lauan (紅柳桉)	27.65
Ungsunah (蒜果木)	8.20	Teak (柚木)	37.80
Tatajuba (圭亞納乳桑)	8.67	Taiwan acacia (相思樹)	40.58
Mahogany (大葉桃花心木)	10.99	Klinki pine (南洋杉)	55.92
Taiwan red cypress (紅檜)	11.51	Radiata pine (放射松)	58.35
Pikinmisiki (香甜落腺豆)	11.53	White meranti (白柳桉)	75.88
Ipe (鋸葉風鈴木)	11.98	Luanta fir (巒國香杉)	94.51
Yellow cedar (阿拉斯加扁柏)	19.88	Douglas fir (花旗松)	95.29
Japanese cedar* (柳杉)	25.54	Southern yellow pine (南方松)	100.00

* heartwood only

The southern yellow pine (SYP) tested with an average percentage of weight loss of 46.48% appears to be the most susceptible species among the species tested while the lowest four (BI, TB, Ungsunah (UN) and Tatajuba (TJ)) average percentages of weight loss seem to be 90% less susceptible to *C. formosanus* in comparison with SYP.

3. Suggestion of termite resistance measure

No termite resistance category based on laboratory test method such as AWPA standard E1-09 has been proposed. CTR had been used to give ranking picture by standardizing average percentages of weight loss of specimens with the factor to adjust the highest percentage to 100%. However, this is not enough to answer the sensible question ask by manufacturers and users of “is the wood resistant to termites ?”

In a previous study (Lee, 2013) carried on *C. formosanus* resistance of leached alkaline copper quat (ACQ 1 and 3, retention level K4 of CNS 3000 (2011)) treated SYP specimen indicated that most of the blocks were nibbled by termites. No block in the study was rated 10 by the rating system and also none is below 9. This reveals a possible phenomenon that unless test blocks create termite repellency with their inherent extractives or by chemicals treated, termites intend to bite whatever they foraged.

If a 10% deviation is allowed for wood products to be of acceptable quality then wood specimens indicate at least 90% of the 10 replicates rated no less than rate 9 may possibly be a measure for wood products with acceptable termite resistance. TJ, BI, TB and UN are the 4 out of the 20 tested wood species that meet the measure, the average percentages of weight loss are 4.03, 2.37, 3.49, and 3.81% respectively which may denote another measure for acceptable termite resistance by percentage of weight loss, less than 5% maybe, obtained from laboratory test. The CTR’s of the 4 species stated are less than 10% (table 3) which may also be a measure when a susceptible specimen as SYP or Douglas fir (DF) is included.

II. Effects of heat treatment

Effects on termite resistance on the 7 heat-treated specimens of 5 of the wood species tested are indicated by the percentage of termite resistance increased in comparison with the untreated specimens of the same wood species as ATE’s in table 4, which shows varied effects on increasing or decreasing resistance. Heat treatments with different highest treating temperatures (170℃ or 190℃ or 210℃) applied in this study appears to improve termite resistance of Taiwan acacia (TA), DF, and SYP specimens but impair Yellow cedar (YC) and Klinki pine (KP) ones. The tendency of highest treating temperature effects are not to be discussed because of insufficient data.

Table 4 Average percentages weight loss, rating ranges and anti-termite effects (ATE's) of heat-treated specimens

Code	Specimen name in Chinese	Avg. Percentage of Weight Loss (%)*	Rating Range of Blocks	ATE
YC170	阿拉斯加扁柏 170	12.04 (11.67)	4～9	-30.3%
YC190	阿拉斯加扁柏 190	10.58 (8.86)	4～9	-14.5%
TA170	相思樹 170	10.26 (3.80)	4～9	45.6%
KP190	南洋杉 190	37.37 (6.99)	0～4	-43.8%
KP210	南洋杉 210	26.52 (6.11)	0～7	-2.0%
DF190	花旗松 190	18.45 (9.92)	0～9	58.3%
SYP210	南方松 210	21.11 (3.80)	4～7	54.6%

* numbers in parenthesis are standard deviations

Wood products been heat treated may increase or decrease their termite resistance. The effect of heat treatment to wood products' termite resistance seems depend on the possible chemical, especially extractives, changes come along the heat treating processes applied (Hill, 2006).

III. Effects of specific gravity

It is well understand that termite resistance comes from the effectiveness and amount of extractives in wood (Kadir and Hale, 2012). However, Coulson and Lund (1973) noted hardness may also be a factor of termite resistance of wood which means the harder the wood the lesser termites bite. Out of curiosity, the correlation of specific gravity and percentage of weight loss were checked on untreated softwood and hardwood species separately. The hardwood species shows an obviously negative correlation between specific gravity and percentage of weight loss ($r = -0.71$, figure 2), softwoods indicate a slightly positive correlation ($r = 0.31$, figure 3) from which effects of extractives to termite resistance could be

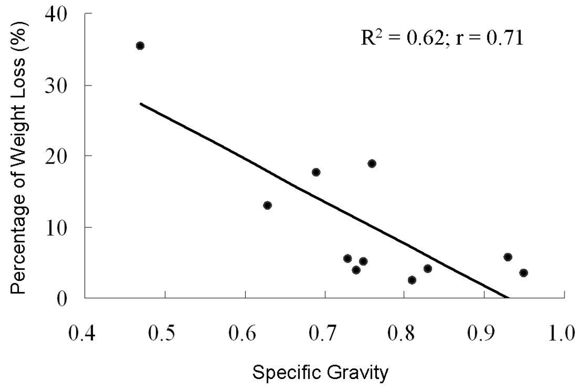

Fig. 2 Correlation of specific gravities and percentages of weight loss of hardwood species tested

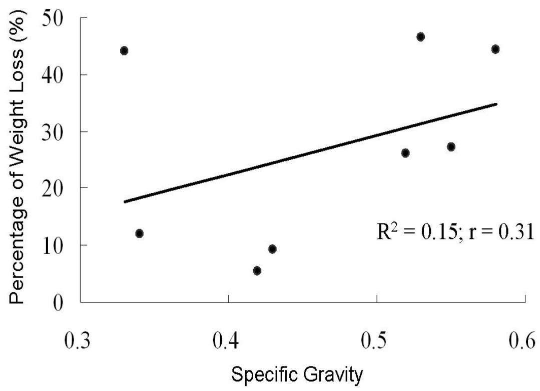

Fig. 3 Correlation of specific gravities and percentages of weight loss of softwood species tested

inferred. It is dangerous to make a suggestion based on so few data but it seems that hardwood species of an average specific gravity over 0.8 may have better chance to present termite resistance to a certain degree.

No correlation between the specific gravity and the percentage weight loss of the 10 replicate blocks tested of a same wood species except the coconut which indicates a significant correlation between the two (r = 0.91, figure 4).

The formation of the woody part of a monocotyledon is different from that of the dicotyledons'. Without the extractive accumulating heartwood formation process, there may only be small amounts of extractives in monocotyledon woody tissue to resist termite attack which renders hardness the major factor that affect the vulnerability of test blocks to termite attack.

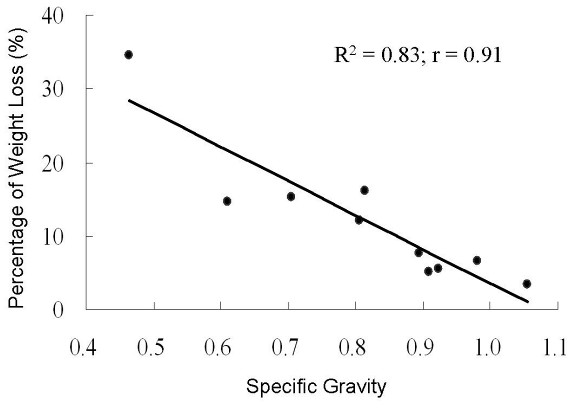

Fig. 4 Correlation of specific gravities and percentages of weight loss of coconut blocks tested

Conclusions

The laboratory termite resistance test gives primary idea of termite resistance of wood species and wood products. Of the two major indices, rating gives susceptibility of wood to termite attack, percentage of weight loss make comparison of resistance among wood specimens possible. For both indices, variation of test blocks of a specimen or specimens of a wood species should be taken into account by observing distribution of data obtained from test replicates while accessing the possible susceptibility. It appears to depend on wood species and the highest treating temperature, dry-heat oxygen-free (N_2 filled) heat treating process increases or decreases treated wood specimens' termite resistance in comparison to its untreated specimens of the same wood species. Extractives should be the major factor that renders termite resistance to wood species. Hardwood species of specific gravity higher than 0.8 may has better chance to retard termite biting than the one of lower specific gravity. The higher the specific gravity of the woody tissue of coconut the better termite resistance it performs.

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Appendix

App. Table 1 Rating system of termite resistance test (from AWPA E1-09, 2010)

Rating	Description
10	Sound
9.5	Trace, surface nibbles permitted
9	Slight attack, up to 3% of cross sectional area affected
8	Moderate attack, 3-10% of cross sectional area affected
7	Moderate/severe attack, penetration, 10-30% of cross sectional area affected
4	Very severe attack, 50-75% of cross sectional area affected
0	Failure

App. Table 2 Range of percentages of weight loss of the 10 replicate blocks of wood species and their heat-treated specimens

Code	Chinese name	Percentage of Weight Loss (%)	
		Min.	Max.
Untreated			
Softwoods			
KP	南洋杉	14.25	44.55
TRC	紅檜	1.48	12.90
YC	阿拉斯加扁柏	0.48	25.19
JCH	柳杉(心材)	4.71	27.31
LF	寮國香杉	3.02	84.85
RP	放射松	8.54	50.36
SYP	南方松	25.23	54.40
DF	花旗松	30.29	53.26
Hardwoods			
TA	相思樹	9.49	40.16
TJ	圭亞那乳桑	1.00	10.42
BI	婆羅洲鐵木	0.39	7.32
TB	馬蹄豆木	1.83	5.30
PI	香甜落腺豆	3.47	7.86
UN	蒜果木	0.83	9.48
RL	紅柳桉	1.14	36.09
WM	白柳桉	20.61	51.47
MA	大葉桃花心木	0.88	10.11
IP	鋸葉風鈴木	2.12	10.57
TK	柚木	9.00	35.19

App. Table 2 (continued)

Code	Chinese name	Percentage of Weight Loss (%)	
		Min.	Max.
Monocot			
CO	可可椰子	3.36	34.46
Heat-treated			
YC170	阿拉斯加扁柏 170	1.52	33.93
YC190	阿拉斯加扁柏 190	1.08	34.74
TA170	相思樹 170	1.54	14.42
KP190	南洋杉 190	24.59	45.43
KP210	南洋杉 210	15.16	34.65
DF190	花旗松 190	3.60	31.48
SYP210	南方松 210	16.09	26.32

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