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Machinability of Kempili (*Lithocarpus Ewyckii* (Koth.) Rehd.) and Ubar (*Syzygium* Sp.) Wood from Borneo Forest

Obradivost drva kempili (*Lithocarpus Ewyckii* (Koth.) Rehd.) i drva ubar (*Syzygium* sp.) iz šume Borneo

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ABSTRACT • *This paper presents information on the machinability of Kempili (Lithocrapus ewyckii (Koth.) Rehd.) and Ubar (Syzygium sp.) for different machining operations at 14 % and 10 % moisture content. Both species are lesser-known species from the Borneo forest of Indonesia. The basic testing procedures followed ASTM D-1666-87. The machining operations applied were planing, shaping, boring, turning, and sanding. The surface quality for determining the machinability were defect percentage and defect-free value. Ten replications were used for each machining property and randomly collected from flat-sawn boards for each wood. The results showed that fuzzy grain defects were found for both species, resulting from all machining operations. Decreasing moisture content from 14 % to 10 % tended to increase the defect-free value of the wood. Wood species significantly affected the machinability of Kempili and Ubar wood in planing, shaping, boring, and sanding operations. Moisture content only significantly affected the machinability of both wood species in turning operation. Based on their defect-free values in all investigated machining operations, both Kempili and Ubar wood have good machining quality. Therefore, both species are recommended as raw materials for producing various wood-based products such as furniture, molding, leaf doors, dowels, or laminated wood.*

KEYWORDS: *wood surface quality; planing; shaping; boring; turning; sanding*

SAŽETAK • *U radu su prezentirane informacije o obradivosti drva kempili (Lithocrapus ewyckii (Koth.) Rehd.) i drva ubar (Syzygium sp.) različitim postupcima mehaničke obrade pri sadržaju vode 14 i 10 %. Obje vrste drva manje su poznate vrste iz šume Borneo u Indoneziji. Osnovni postupci ispitivanja slijedili su normu ASTM D-1666-87. Primijenjene operacije mehaničke obrade bile su blanjanje, profilno glodanje, bušenje, tokarenje i brušenje. Kvaliteta površine za određivanje obradivosti evaluirana je na temelju postotka površine drva s greškama i površine bez grešaka. Svakim mehaničkim postupkom obrađeno je po deset uzoraka. Uzorci su uzeti nasumično iz ravnih piljenica svake od dvije ispitivane vrste drva. Rezultati su pokazali da je nakon svake operacije mehaničke obrade na objema vrstama drva nastala čupava površina. Smanjenjem sadržaja vode s 14 na 10 % povećao se postotak površine drva bez grešaka. Vrsta drva znatno je utjecala na obradivost blanjanjem, profilnim glodanjem,*

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bušenjem i brušenjem. Sadržaj vode također je znatno utjecao na obradivost obiju vrsta drva samo tokarenjem. Na temelju postotka površine drva bez grešaka za sve se istraživane operacije mehaničke obrade može zaključiti da se na drvu kempili i drvu ubar postiže dobra kvaliteta mehaničke obrade. Stoga se obje vrste drva preporučuju kao sirovina za proizvodnju različitih proizvoda od drva kao što su namještaj, kalupi, vratna krila, moždanici ili lamelirano drvo.

KLJUČNE RIJEČI: *kvaliteta površine drva; blanjanje; profilno glodanje; bušenje; tokarenje; brušenje*

1 INTRODUCTION
1. UVOD

Wood is one of the raw materials from the forest that can be easily converted into various products. Wood is different from other materials as it is hygroscopic, can shrink and swell, and has a certain pattern, gloss, texture, and fiber arrangement. The community rarely uses wood in the form of logs and usually converts the logs into sawn timber before its use as raw material for building, furniture, or other needs.

Knowledge of the basic properties of a particular wood is required to optimize its utilization and economic value (Sandak *et al.*, 2017). Machining properties are one of basic properties of wood that need to be identified prior to further use of a particular wood. Any improper machining work during the conversion of logs into sawn timber could cause defects and reduce the quality of sawn timber and consequently of the final product (Sofuoglu and Kurtoglu, 2014). Even though wood is more easily machinable than metal and plastic products, it has a high characteristic variation within and between species, which significantly affects its machining process (Malkoçoğlu and Özdemir, 2006).

Indonesia's tropical forest has a high number of wood species, up to approximately 4000. However, many wood species remain lesser-known and lesser-used due to minimal information on their existence and properties. On the other hand, they are potentially an alternative material for construction and furniture purposes. Kempili (*Lithocarpus ewyckii Korth.*) and Ubar (*Syzygium sp.*) are two such species (Budiharta, 2010; Efiyanti *et al.*, 2020; Kaul, 1987; Kusuma *et al.*, 2018; Wyk *et al.*, 2004). Both species grow naturally in Borneo Island and several other countries of South-East Asia (Soepadmo *et al.*, 2000; Ismail and Ahmad, 2019; Efiyanti *et al.*, 2020; Raharjo *et al.*, 2021). Nevertheless, up to now, the information on Kempili and Ubar has been limited to their resistance to fungus attack and chemical components or the potency of Ubar plant as an antidiabetic agent (Efiyanti *et al.*, 2020; Raharjo *et al.*, 2021; Zulcafli *et al.*, 2020). Their basic machining properties or machinability have not been reported elsewhere.

Many previous studies on the machinability of wood used samples with air-dry moisture content level of around 14-15 %, as instructed in ASTM D 1666-87 (Sutisna *et al.*, 2004; Martawijaya *et al.*, 2005; Malkoçoğlu and Özdemir, 2006; Muslich *et al.*, 2013; Sofuoglu and Kurtoglu, 2014; Rianawati and Setyowati, 2015). However, moisture content (MC) and wood species are 2 of several intrinsic factors affecting the machinability of wood (Naylor *et al.*, 2011; Lhate *et al.*, 2017). Studies on the impact of both factors have rarely been carried out for tropical wood species from Indonesia's forests. This study aimed to investigate the effect of wood species and 2 MC levels (10 % and 14 %) on the machinability of Kempili and Ubar wood. The starting assumption was that decreasing wood MC from 14 % to 10 % would increase the defect-free value in both types of wood. Working with hard and dry wood will give better results than that with soft and wet wood, although it requires higher cutting forces and power (Wengert, 2006).

2 MATERIALS AND METHODS
2. MATERIJALI I METODE

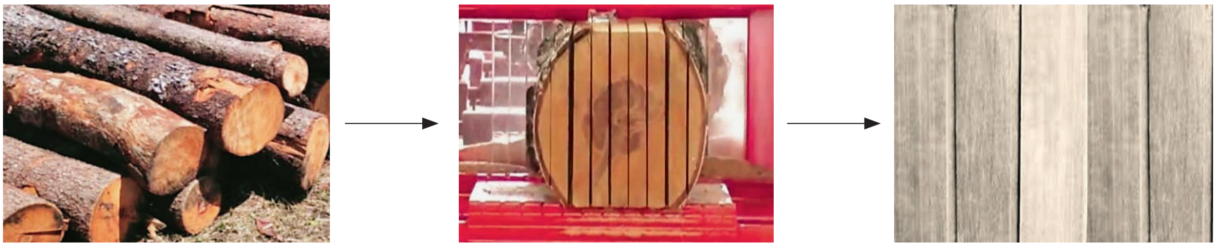
2.1 Material and equipment
2.1. Materijal i oprema

The main materials used for the research were the boards of Kempili (*Lithocrapus ewyckii* (Koth.) Rehd. and Ubar (*Syzygium sp*) wood. The location for collecting Kempili and Ubar logs was the natural forest region in Tanjung Asam, West Borneo, with coordinates of (S 01.09190°, E 111.23429°) and (S 01.09114°, E 111.23114°), respectively. Prior to the study, both wood species identities were synchronized with the existing wood collection at Xylarium Bogoriense, West Java, Indonesia. They were identical to the collection numbers of 34432 (Kempili) and 34433 (Ubar) from Xylarium Bogoriense.

2.2 Preparation of master samples and test specimens
2.2. Priprema glavnih i ispitnih uzoraka

The logs were all sawn to obtain flat-sawn large boards (further termed master samples) with less natural defects such as knots and surface crack/checks (Figure 1). Approximately 10 master samples were initially prepared for each species, each with a dimension of 30 mm (thickness) × 125 mm (width) × 1200 mm (length). The remaining boards produced during the sawing process were used for different studies.

The moisture content of each master sample was determined by using a moisture meter. The master samples were divided into 2 groups based on the targeted MC, 10 % and 14 %. All boards were further subdivided



Logs / *trupci* **Sawing pattern** *način piljenja* **Sawn board/master samples** *piljenice / glavni uzorci*

Figure 1 Master samples
Slika 1. Glavni uzorci

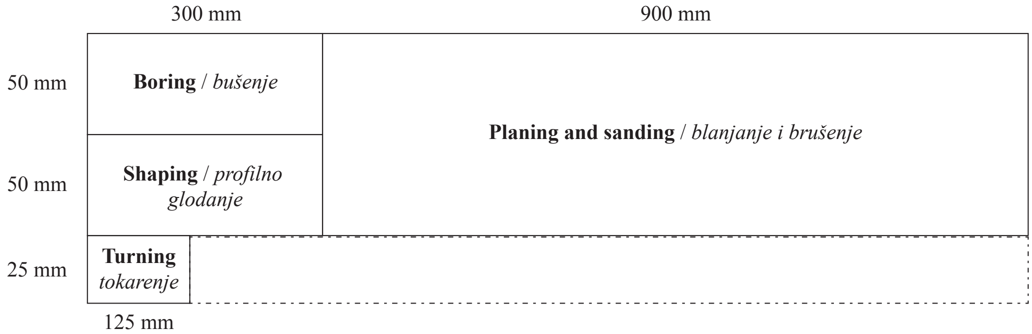


Figure 2 Preparation pattern for each machining property
Slika 2. Shema pripreme uzoraka za svaku vrstu mehaničke obrade

into several test specimens with various dimensions for different tests of machining properties. The pattern for preparing the test specimens from each master sample and their dimension is presented in Figure 2 and Table 1. The specimen dimensions were adjusted to the existing defect-free area space from each master sample. Boring and shaping specimens were separated, considering different machines used for these tests.

2.3 Machining properties test
2.3. Ispitivanje svojstava mehaničke obrade

The planing process was carried out with a planer (MB206D/AKS) at rotational frequency of 2200 rpm, tool diameter of 113 mm, cutting speed of 13.022 m/s, rake angle (γ_o) of 32° and feed per knife of 0.5 mm. The boring process was carried out with DTBM15/AEG at rotational frequency of 1200 rpm, tool diameter of 22 mm, cutting speed of 1.382 m/s, cutting angle of 45° and feed per cutting edge of 0.5 mm. The shaping process was carried out with BER/2 Wadkin machine at rotational frequency of 2800 rpm, rake angle of 45°, and cutting depth of 0.25 mm concave type knife surface. The sanding process was carried out with the T3EN/Sandmax machine at rotational frequency of 1200 rpm, feed speed of 6 m/s, and sanding grit of 120. The turning process was carried out with ML- 60/

Table 1 Various types of defects observed and specimen dimensions for each machining property
Tablica 1. Uočene različite vrste grešaka i dimenzije uzorka za svako svojstvo mehaničke obrade

Machining operations *Mehanička obrada*	**Types and characteristics of machining defects on wood surface** *Vrste i obilježja grešaka mehaničke obrade na površini drva*	**Dimension of specimens (width by length by thickness), mm** *Dimenzije uzoraka (širina × duljina × debljina),* mm
Planing / *blanjanje*	Raised grain, fuzzy grain, chip marks, torn grain *izdignuta vlakanca, čupava površina, tragovi oštrice alata, pokidana vlakanca*	100 × 900 × 20
Shaping / *profilno glodanje*	Raised grain, fuzzy grain, chip marks *izdignuta vlakanca, čupava površina, tragovi oštrice alata*	50 × 300 × 20
Boring / *bušenje*	Fuzzy grain, crushing, smoothness, tear cut *čupava površina, zdrobljena površina, zaglađena površina, resavost*	50 × 300 × 20
Turning / *tokarenje*	Fuzzy grain, torn grain, roughness *čupava površina, pokidana vlakanca, hrapava površina*	25 × 125 × 20
Sanding / *brušenje*	Fuzzy grain, scratching marks *čupava površina, ogrebotine*	100 × 900 × 20

a) b) c) d) e)

Figure 3 Post-test pictures of specimens for each machining operation: a) planing, b) shaping, c) boring, d) turning, e) sanding
Slika 3. Slike uzoraka nakon ispitivanja za svaku operaciju mehaničke obrade: a) blanjanje, b) profilno glodanje, c) bušenje, d) tokarenje, e) brušenje

Shengpeng at elevated rotational frequency of 1000 rpm, tool diameter of 22.9 mm, cutting speed of 1.198 m/s and rake angle of 32°. The number of specimens used for each test was 10 pieces (5 represented 10 % MC and 5 represented 14 % MC). This number was smaller than that recommended in ASTM D1666-87 due to the limited number of sawn boards that could be chosen as master samples. The specimen condition after each test is shown in Figure 3.

The presence or absence of defects on the specimens, such as raised grain, fuzzy grain, chip marks, torn grain, roughness, crushing, and scratching mark (Table 1), was examined during each planing, shaping, sanding, boring, and turning tests. The defects percentage for each specimen was calculated based on the area of the defective part on the cross-section of the specimen (Eq. 1). The defect-free values were obtained by subtracting the defects percentage from 100 % (Eq. 2) and used to classify the machining quality categories for the wood (Table 2).

$$Defects\ percentage(\%) = \frac{Defective\ area}{Total\ cross-section\ area} \cdot 100\ \% \quad (1)$$

$$Defects-free\ values = 100\ \% - defects\ percentage \quad (2)$$

2.4 Data analysis
2.4. Analiza podataka

A 2-way analysis of variance (ANOVA) was applied to investigate the significant effect of wood species and MC on the average defect-free values of each machining property. Tukey test was further carried out when ANOVA showed significant results. Minitab 16 software was used to perform all tests.

3 RESULTS AND DISCUSSION
3. REZULTATI I RASPRAVA

3.1 Planing
3.1. Blanjanje

Table 3 shows that the common defects that occurred during the planing of Kempili and Ubar wood were fuzzy grain and torn grain. Table 4 shows that Kempili wood had a good planing property (classified as grade II). The average defect-free values of Kempili wood were 62 % at MC of 14 % and 66 % at MC of 10 %. On the other hand, Ubar wood had an excellent planing property (classified as grade I) with its average defect-free values of 88 % at MC of 14 % and 94 % at MC of 10 %. Further statistical test results confirmed the significant effect of wood species on the planing property (Table 5). Reducing the moisture content of wood from 14 % to 10 % decreased the percentage of torn grain defect in Kempili wood by 50 % and the percentage of fuzzy grain defect in Ubar wood by 80 %.

The results revealed that the prevalent defects in Kempili wood were fuzzy grain (20 %) and torn grain (16 %), while Ubar wood exhibited fuzzy grain defects at 10 %. Kempili wood, with a moisture content of 14 % and 10 %, showed a lower average defect-free

Table 2 Relationship between defects-free values and machining properties grade classification (Abdurachman and Karnasudirdja, 1982)
Tablica 2. Odnos između postotka površine bez grešaka i klasifikacija svojstava mehaničke obrade (Abdurachman i Karnasudirdja, 1982.)

Defects-free values, % *Postotak površine bez grešaka, %*	**Grade classification** *Razred klasifikacije*	**Categories** *Kategorije*
0 – 20	V	Very poor / *vrlo loša kvaliteta*
21 – 40	IV	Poor / *loša kvaliteta*
41 – 60	III	Medium / *srednja kvaliteta*
61 – 80	II	Good / *dobra kvaliteta*
81 – 100	I	Excellent / *izvrsna kvaliteta*

value than Ubar wood. Consequently, the planing quality of Ubar wood is deemed excellent, while Kempili wood is considered good (as referred to Table 4). Moisture content, however, did not significantly impact planing properties. In conclusion, both wood species exhibit suitable characteristics as raw materials for wood products requiring a high-quality surface appearance, such as tables, chairs, and cupboards. The results of planing test for Kempili wood are similar to those of *Cinnamomum iners Reinw. Ex Blume*, *Erythrina fusca Lour*, *Pempis adiculata*, *Hymenaea sp*., and *Euretia acimunate R*. (Muslich *et al.*, 2013; Supriadi, 2017). In addition, the results of planing test for Ubar wood is similar to those of *Timonius sericeus* (Desf) K.Schum and *Acacia leucophloea* (Roxb.) Willd. from East Nusa Tenggara (Rianawati and Setyowati, 2015).

3.2 Shaping
3.2. Profilno glodanje

During the shaping process of both Kempili and Ubar wood, fuzzy grain and raised grain were the dominant defects (Table 3). Decreasing the moisture content of wood from 14 % to 10 % reduced the percentage of fuzzy grain in Kempili and Ubar wood (Table 3). This result is in line with several previous studies on the same topic (Sofuoğlu and Kurtoğlu, 2014; Sütçü, 2012).

Based on its defect-free values range (60 % - 80 %), Kempili wood has a good shaping property and can be classified into II grade (Table 4). On the other hand, Ubar wood can be classified as a wood species with excellent planing properties (grade I) (Table 4) due to its high defect-free values (89 % - 94 %). Further statistical test results confirmed the significant effect of wood species on the shaping property (Table 5). Due to their good shaping properties, both Kempili and Ubar wood can be used as molding materials or for crafting purposes

The results of the shaping test for Kempili wood are similar to those of *Sterculia cordata Blume*, *Sloane sigun* (*Blume*) *K. Schumann*, *Pouteria duclitan* (*Blanco*) *Baehni*., *Litsea angulate Blume*, *Melicope-ankenda* (*Gaertn*.) T.G. *Hartley*, *Mangliatia glauca Blume*, *Euretia acuminate* R., *Pempis adicula*, and *Tetra merista glabra* Miq. (Muslich *et al.*, 2013; Supriadi, 2017, 2019). On the other hand, the results of the shaping test for Ubar wood are similar to those of *Timonius sericeus* (Desf) K.Schum and *Acacia leucophloea* (Roxb.) Willd. from East Nusa Tenggara (Rianawati and Setyowati, 2015).

3.3 Boring
3.3. Bušenje

The fuzzy grain was the dominant defect during the boring process of Kempili and Ubar wood. Decreas-

Table 3 Types and percentages of defects observed in Kempili and Ubar wood at 2 MC levels for various machining operations (average values, %)
Tablica 3. Postotci i vrste grešaka za različite mehaničke obrade drva kempili i drva ubar s dva različita sadržaja vode (prosječne vrijednosti, %)

Machining operation / defects types and percentage *Mehanička obrada / vrste grešaka i postotci*	**Kempili**		**Ubar**	
	MC 10 %	**MC 14 %**	**MC 10 %**	**MC 14 %**
1. Planing / *Blanjanje*				
Fuzzy grain / *čupava površina*, %	20	11	2	10
Raised grain / *izdignuta vlakanca*, %	6	1	4	1
Torn grain / *pokidana vlakanca*, %	8	16	0	1
Chip marks / *tragovi oštrica alata*, %	0	10	0	0
2. Shaping / *Profilno glodanje*				
Fuzzy grain / *čupava površina*, %	20	20	6	11
Raised grain / *izdignuta vlakanca*, %	0	3	0	0
Chip marks / *tragovi oštrica alata*, %	1	0	0	0
3. Boring / *Bušenje*				
Fuzzy grain / *čupava površina*, %	20	26	9	4
Crushing / *pokidana vlakanca*, %	1	0	0	1
Smoothness / *zaglađena površina*, %	0	2	0	1
Tear-cut / *resavost*, %	1	1	0	0
4. Turning / *Tokarenje*				
Fuzzy grain / *čupava površina*, %	5	11	5	11
Torn grain / *potrgana vlakanca*, %	4	3	3.5	3
Roughness / *hrapava površina*, %	8	11	6.5	13
5. Sanding / *Brušenje*				
Fuzzy grain / *čupava površina*, %	11	14	7	8
Scratching mark / *ogrebotine*, %	0	0	0	0

Table 4 Machining-defect free values and machining quality classification of Kempili and Ubar wood at 2 MC levels (average values, %)
Tablica 4. Postotak površine drva bez grešaka i klasifikacija kvalitete mehaničke obrade drva kempili i drva ubar s dva različita sadržaja vode (prosječne vrijednosti, %)

Machining properties *Mehanička obrada*	**Machining-defect free values, %** *Postotak površine drva bez grešaka mehaničke obrade, %*							
	Kempili				**Ubar**			
	MC 10 %	**Class** *Klasa*	**MC 14 %**	**Class** *Klasa*	**MC 10 %**	**Class** *Klasa*	**MC 14 %**	**Class** *Klasa*
Planing / *blanjanje*	66[a*]	II	62[a]	II	94[b]	I	88[b]	I
Shaping / *profilno glodanje*	79[a]	II	77[a]	II	94[b]	I	89[b]	I
Boring / *bušenje*	78[ab]	II	71[a]	II	95[b]	I	91[b]	I
Tuning / *tokarenje*	83[b]	I	75[a]	II	85[b]	I	73[a]	II
Sanding / *brušenje*	89[a]	I	86[a]	I	93[b]	I	92[b]	I

*Figures with the same letter(s) indicate no significant difference(s) (based on Tukey's test). / *Brojke s istim slovom (slovima) pokazuju da nema značajne razlike (na temelju Tukeyjeva testa).*

ing the moisture content of wood from 14 % to 10 % reduced the percentage of fuzzy grain in Kempili and Ubar wood by approximately 23 % and 55 %, respectively (Table 3). Based on its defect-free values at both MC 10 % and 14 %, which was 60 % - 80 %, Kempili wood was classified as having a good boring property (grade II) (Table 4). On the other hand, Ubar wood could be classified as a wood species with excellent boring property (grade I) (Table 4) due to its high defect-free values (above 90 %). Further statistical test results confirmed the significant effect of wood species and their interaction with the moisture content on the planing properties of both Kempili and Ubar wood (Table 5).

The boring properties of Kempili and Ubar wood are similar to those of *Toona sinensis* (Adr.Juss) M.J. Roemer, *Pangium edule* Reinw, *Albizia lebbeck* (Linn.) Benth, *Cinnamomum iners* Reinw. Ex Blume, *Ficus nervosa* B. Heyne ex Roth, *Garcinia celebica* Linn, *Horsfieldia glabra* (Blume) Warb., *Dillenia sp.*, *Timonius sericeus* (Desf) K.Schum and *Acacia leucophloea* (Roxb.)Willd. (Asdar, 2010; Muslich *et al.*, 2013; Wahyudi, Makrus and Susilo, 2014; Rianawati and Setyowati, 2015). Further, considering their boring properties, both wood species could be combined or jointed together with dowels/rods/pins or with gluing for assembling composite wood or laminated wood products.

3.4 Turning
3.4. Tokarenje

Fuzzy grain appeared as the dominant defect during the turning process of Kempili and Ubar wood (Table 3). Reducing the moisture content of both wood species from 14 % to 10% tended to reduce the percentage of fuzzy grain. The turning process is categorized as orthogonal lathing (Supriadi, 2017). An orthogonal lathing process is characterized by a straight and continuous cutting blade movement over the wood surface. During the turning process, the cutting is carried out perpendicular to the fiber direction and affected by the MC distribution (Koch, 1964). Therefore, due to higher MC, boards with MC of 14 % had a higher fuzzy grain defect than those with MC of 10 %. On the other hand, the moisture content reduction tended to increase the percentage of torn grain of both Kempili and Ubar wood. However, only the surface roughness of Ubar wood increased as the moisture content decreased (Table 3).

The average defect-free values at MC of 14 % and 10 % for Kempili wood were 75 % and 83 %, respectively. Ubar wood had the average defect-free values of 73 % at MC of 14 % and 85 % at MC of 10 %, respectively. Therefore, reducing the moisture content of both wood species successfully increased their turn-

Table 5 ANOVA results for the effect of wood species and MC on each machining property
Tablica 5. ANOVA rezultati analize utjecaja vrste drva i sadržaja vode na obradivost drva svakim pojedinim mehaničkim postupkom

Machining property *Mehanička obrada*	**Main factor/P-values** *Glavni čimbenik / P-vrijednosti*		
	MC	**WS**	**MC × WS**
Planing / *blanjanje*	0.20	0.00*	0.52
Shaping / *profilno glodanje*	0.39	0.00*	0.04*
Boring / *bušenje*	0.33	0.00*	0.00*
Tuning / *tokarenje*	0.00*	1.00	0.09
Sanding / *brušenje*	0.09	0.00*	0.22

*indicates significant differences; MC – moisture content; WS – wood species / **označava značajne razlike; MC – sadržaj vlage; WS – vrsta drva* ing properties grade from II at MC of 14 % to I at MC of 10 %. Further statistical test results confirmed the significant effect of moisture content on the turning properties of both Kempili and Ubar wood. Both wood species with turning property grades I-II are considered suitable for parts of furniture and other turning-related processes. Furthermore, the results of the turning test for Kempili wood are similar to those of *Nauclea orientalis* (Linn.), *Litsea angulata* Blume, *Enonimus javanica*, *Hymenaea sp*. and *Tamamaus indica* (Muslich *et al.*, 2013; Supriadi, 2017).

3.5 Sanding
3.5. Brušenje

During the sanding process of Kempili and Ubar wood, the only defect developed was fuzzy grain (Table 3). The cause of fuzzy grain defect is torn wood fibers during the sanding process. Decreasing MC from 14 % to 10 % reduced the fuzzy grain by 21.4 % and 14.3 % in Kempili and Ubar wood, respectively.

Table 4 shows that the average defect-free value of Kempili wood after the sanding process was 89 % at MC of 10 %, higher than that for boards with MC of 14 % (which was 86 %). Ubar wood has the average defect-free values of 93 % and 92% at MC of 10 % and 14 %, respectively. Based on its defect-free value during the sanding process, the sanding quality of Kempili and Ubar wood at both MCs are categorized as excellent (grade I), making them suitable for doors, tables, panels, and wall coverings. The results of the sanding test for both wood species are similar to those of *Hostfieldia glabra* (Blume) Warb., *Litsea angulata* Blume, *Nauclea orientalis* (Linn.), *Cedrus libani* A. Rich, *Quercus petraea*, *Timonius sericeus* (Desf) K. Schum, *Acacia leucophloea* (Roxb.) Willd., *Tamarmaus indica*, and (*Hymenaea sp*.) (Muslich *et al.*, 2013; Rianawati and Setyowati, 2015; Sofuoğlu and Kurtoğlu, 2014; Supriadi, 2017). Further statistical tests showed that wood species, not moisture content in the examined range, significantly affected the sanding properties of Kempili and Ubar wood. This result supported a previous study showing the tendency of sanded aspen boards to have smoother surfaces, in both radial and tangential directions, than beech boards (Kilic *et al.*, 2006).

4 CONCLUSIONS
4. ZAKLJUČAK

The study reveals that fuzzy grain was the dominant defect during the planing, shaping, boring, turning, and sanding processes of both Kempili and Ubar wood. Decreasing the MC of both wood species from 14 % to 10 % tended to improve their defect-free values. Wood species significantly affected the planing, shaping, boring, and sanding properties of Kempili and Ubar wood. Moisture content, on the other hand, only significantly affected the turning properties of both wood species.

Kempili wood at 14 % MC exhibited defect-free values of 62.5 %, 77 %, 71 %, 75 %, and 86 % for planing, shaping, boring, turning, and sanding, respectively. At 10 % MC, the defect-free values of Kempili wood were 66 %, 79 %, 78 %, 83 %, and 89 % for planing, shaping, boring, turning, and sanding, respectively. Meanwhile, the corresponding defect-free values for Ubar woods at 14 % MC were 88 %, 89 %, 91 %, 73 %, and 92 % for planing, shaping, boring, turning, and sanding, respectively. At 10 % MC, Ubar wood exhibited defect-free values of 97 %, 94 %, 95 %, 85 %, and 93 % for planing, shaping, boring, turning, and sanding, respectively. Based on their defect-free values, the grading classification of planing, shaping, and boring properties of Kempili and Ubar wood were grade II (good) and grade I (excellent), respectively. Both wood species had excellent sanding properties (grade I). Their turning properties classification increased from grade II to excellent (grade I) as their moisture content decreased. These two wood species are suitable raw materials for furniture molding, leaf doors, dowels, composite wood, and/or laminated wood.

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5 REFERENCES
5. LITERATURA

1. Abdurachman, A. J.; Karnasudirdja, S., 1982: The machining properties of Indonesian woods: BPHH Report No 160. Bogor, Indonesia: Forest Products Research Unit, Ministry of Forestry (in Bahasa).
2. Asdar, M., 2010: Sifat pemesinan kayu surian (*Toona sinensis* (Adr. Juss.) M. J. Roemer) dan kepayang (*Pangium edule* Reinw.) (*Machining Surian wood (Toona sinensis (Adr. Juss.) M. J. Roemer) and Kepayang (Pangium edule Reinw.)*). Forest Products Research Journal, 28(1): 18-28.
3. ***ASTM D 1666-87, 2006: Standard Methods for Conducting Machining Tests of Wood and Wood-Based Materials. ASTM International: West Conshohocken, PA, USA, 2006.
4. Budiharta, S., 2010: Floristic composition at biodiversity protection area in Lubuk Kakap, District of Ketapang, West Kalimantan. Biodiversitas Journal of Biological Diversity, 11 (3): 151-156. https://doi.org/10.13057/biodiv/d110309

5. Efiyanti, L.; Wati, S. A.; Setiawan, D.; Saepulloh; Pari, G., 2020: Sifat kimia dan kualitas arang 5 jenis kayu asal Kalimantan Barat (*Chemical properties and charcoal quality of five wood species from West Kalimantan*). Forest Products Research Journal, 38 (1): 45-56 (in Bahasa).
6. Efiyanti, L.; Indrawan, D. A.; Arif, Z.; Hutapea, D.; Septina, A. D., 2020: Synthesis and application of a sulfonated carbon catalyst for a hydrolisis reaction. Indonesian Journal of Science & Technology, 5 (3): 410-420. https://doi.org/10.17509/ijost.v5i3.25275
7. Ismail, A.; Ahmad, W. A. N. W., 2019: *Syzygium polyanthum* (Wight) Walp: a potential phytomedicine. Pharmacognosy Journal, 11 (2): 429-438. https://doi.org/10.5530/pj.2019.11.67
8. Kaul, R. B., 1987: Reproductive structure of *Lithocarpus* sensu lato (fagaceae): cymules and fruits. Journal of the Arnold Arboretum, 68 (1): 73-104.
9. Kilic, M.; Hiziroglu, S.; Burdurlu, E., 2006: Effect of machining on surface roughness of wood. Building and Environment, 41 (8): 1074-1078. https://doi.org/10.1016/j.buildenv.2005.05.008
10. Koch, P., 1964: Wood machining processes. The Ronald Press Company, New York.
11. Kusuma, Z.; Nihayati, E.; Prayogo, C., 2018: The plant wisdom of dayak ot Danum, Central Kalimantan. The Journal of Tropical Life Science, 8 (2): 130-143. https://doi.org/10.11594/jtls.08.02.06
12. Lhate, I.; Cristóvão, L.; Ekevad, M., 2017: Machining properties of lesser used wood species from Mozambique. Wood Research, 62 (4): 635-644.
13. Malkoçoğlu, A.; Özdemir, T., 2006: The machining properties of some hardwoods and softwoods naturally grown in eastern black sea region of Turkey. Journal of Materials Processing Technology, 173 (3): 315-320. https://doi.org/10.1016/j.jmatprotec.2005.09.031.
14. Martawijaya, A.; Kartasujana, I.; Kadir, K.; Prawira, S. A., 2005: Indonesia Wood Atlas 1. Bogor, Indonesia: Forest Products Research and Development Center, Ministry of Forestry (in Bahasa).
15. Muslich, M.; Wardani, M.; Kalima, T.; Rulliaty, S.; Damayanti, R.; Hadjib, N.; Pari, G.; Suprapti, S.; Iskandar, M. I.; Abdurrachman; Basri, E.; Heriansyah, E.; Tata, H. L., 2013: Indonesian Wood Atlas, 4th ed. Bogor, Indonesia: Research and Development Center for Forest Products Processing and Forestry Engineering, Ministry of Forestry (in Bahasa).
16. Naylor, A.; Hackney, P.; Clahr, E., 2011: Machining of wood using a rip tooth: effects of work-piece variations on cutting mechanics. In: Proceeding of the 20th International Wood Machining Seminar. Lulea University of Technology, Skellefteå, Sweden.
17. Rianawati, H.; Setyowati, R., 2015: The difference of machining properties of Timo (*Timonius sericeus* (Desf) K. Schum.) and *Kabesak* wood (*Acacia leucophloea* (Roxb.) Willd.) from East Nusa Tenggara. Wallacea Journal of Forestry Research, 4: 185-192 (in Bahasa).
18. Sandak, J.; Goli, G.; Cetera, P.; Sandak, A.; Cavalli, A.; Todaro, L., 2017: Machinability of minor wooden species before and after modification with thermo-vacuum technology. Materials, 10 (2):1-12. https://doi.org/10.3390/ma10020121
19. Soepadmo, E.; Julia, L.; Go, R., 2000: *Lithocarpus ewyckii* (Korth.) Rehder. U: Soepadmo, E.; Wong, K. M. (eds.): Tree Flora of Sabah and Sarawak, Vol 3. Malaysia, Forest Research Institute Malaysia, pp. 57-58.
20. Sofuoglu, S. D.; Kurtoglu, A., 2014: Some machining properties of 4 wood species grown in Turkey. Journal of Agriculture and Forestry, 38: 420-427. https://doi.org/10.3906/tar-1304-124
21. Supriadi, A., 2017: Sifat pemesinan 7 jenis kayu kurang dikenal (*Machining properties of 7 lesser known wood species*). Indonesian Journal of Agricultural Sciences, 22 (3): 205-210 (in Bahasa). https://doi.org/10.18343/jipi.22.3.205
22. Supriadi, A., 2019. Kualitas pemesinan kayu punak menurut kedalaman batang (*Machining quality of Punak (Tetramerista glabra Miq.) wood at different stem depth*). Indonesian Journal of Agricultural Sciences, 24 (1): 12-19 (in Bahasa). https://doi.org/10.18343/jipi.24.1.12
23. Sutcu, A., 2013: Investigation of parameters affecting surface roughness in CNC routing operation on wooden EGP. BioResources, 8: 795-805.
24. Sutisna, U.; Wardani, M.; Kalima, T.; Mandang, Y. I.; Hadjib, N.; Pari, G.; Sumarni, G.; Abdurrohim, S.; Barly; Iskandar, M. I.; Rachman, O.; Basri, E.; Lisnawati, Y., 2004: Indonesia Wood Atlas, 3rd edition. Bogor Indonesia, Forest Products Research and Development Center, Ministry of Forestry (in Bahasa).
25. Wahyudi; Makrus, M.; Susilo, A. F., 2014: Machining properties of 2 lesser used timber from West Papua. Journal of Tropical Wood Science and Technology, 12 (1): 74-81. https://doi.org/10.18343/jipi.22.3.205.
26. Wengert, E. M., 2006: Principles and practices of drying lumber. Virginia Polytechnic Institute and State University Blacksburg, Virginia, USA.
27. Wyk, M. V.; Roux, J.; Barnes, I.; Wingfield, B. D.; Liew, E. C. Y.; Assa, B.; Summerell, B.; Wingfield, M. J., 2004: *Ceratocystis polychroma* sp. Mov., a new species from *Syzygium aromaticum* in Sulawesi. Studies in Mycology, 50 (1): 273-282.
28. Zulcafli, A. S.; Lim, C.; Ling, A. P.; Chye, S.; Koh, R., 2020: Antidiabetic potential of *Syzygium* sp.: An overview. Yale Journal of Biology and Medicine, 93 (2): 307-325.

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