

CHEMICAL PROPERTIES OF *Terminalia catappa* WOODKEMIJSKA ZGRADBA LESA VRSTE *Terminalia catappa*Richmond Acheampong<sup>1\*</sup>, Kwaku Antwi<sup>1</sup>, Mark Bright Donkoh<sup>1</sup>,  
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## Abstract / Izvleček

**Abstract:** Ghana's forest is fast depleting as a result of over-dependency on the traditionally known timber species and high demand for wood products for structural works. This study seeks to determine the chemical properties and basic density of *Terminalia catappa* wood and its potential for structural application. Three mature trees of *Terminalia catappa* were acquired based on the diameter at the breast height (dbh) greater than 40 cm. In this study 160 samples of wood were used for the chemical properties and density tests. Chemical analyses were performed by using the TAPPI standards. The study revealed that there were higher cellulose and hemicellulose contents in the sapwood than in heartwood, and in the branchwood than in stemwood. Lignin and extractives content were higher in the heartwood than in sapwood, and in the stemwood than in branchwood. The basic density of the sapwood ranged from 473 to 649 kg/m<sup>3</sup> and in the heartwood from 444 to 579 kg/m<sup>3</sup> being the highest in the base portion and the lowest in the branches. The difference in wood density, which is greater in the base area than the branches, emphasizes how crucial it is to take wood quality into account for the best possible use across various tree portions. The study also clarifies the wood's suitability for structural and non-structural uses. These findings have the potential to influence sustainable forest management strategies and encourage the use of alternative timber to supplement the resource base.

**Keywords:** *Terminalia catappa*, wood, cellulose, hemicellulose, lignin, extractives, stemwood, branchwood

**Izvleček:** Gozdovi Gane se zaradi prevelike odvisnosti od tradicionalnih lesnih vrst in velikih potreb po lesnih izdelkih za gradbeništvo hitro krčijo. Namen te študije je določiti kemijske lastnosti lesa vrste *Terminalia catappa* in njen potencial za uporabo v gradbeništvu. Za raziskave smo uporabili tri odrasla drevesa vrste *Terminalia catappa* s premerom v prsni višini nad 40 cm. Za različne teste je bilo uporabljenih 160 vzorcev ali ponovitev. Kemijske lastnosti vzorcev smo preučili v skladu s TAPPI standardi. Študija je pokazala, da je bila vsebnost celuloze in hemiceluloz večja v beljavi kot v jedrovini in večja v vejah kot v deblu. Vsebnost lignina in ekstraktivov je bila višja v jedrovini kot v beljavi in višja v deblu kot v vejah. Osnovna gostota beljave je bila od 473 do 649 kg/m<sup>3</sup>, jedrovine pa od 444 do 579 kg/m<sup>3</sup>, pri čemer je bila najvišja v spodnjem delu debla, najnižja pa v vejah. Razlike v gostoti lesa kažejo, kako pomembno je upoštevati lastnosti lesa iz različnih delov drevesa, za najboljšo možno uporabo. Študija nakazuje tudi primernost lesa za konstrukcijske in nekonstrukcijske uporabe. Te ugotovitve so pomembne za strategijo trajnostnega gospodarjenja z gozdovi in spodbujajo uporabo lesa manj znanih lesnih vrst za pokrivanje potreb po lesu.

**Ključne besede:** *Terminalia catappa*, les, celuloza, hemiceluloze, lignin, ekstraktivi, les debla, les vej

## 1 INTRODUCTION

### 1 UVOD

Over-dependence on the traditionally known timber species such as odum or iroko (*Milicia excelsa*), ofram or limba (*Terminalia superba*), wawa or

samba (*Triplochiton scleroxylon*) and the high demand for wood products in the timber industry in Ghana has led to the over-exploitation of these traditionally known timber species (Obiri et al., 2019). As a result, many researchers are looking for other,

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alternative materials, such as the use of agricultural waste for the production of fibre board and light-weight wood panels, and the use of lesser-known and lesser-utilized timber species to replace the traditionally known ones (Ndulue et al., 2023). For example, Appiah-Kubi et al. (2016) studied the mechanical properties of four lesser-known Ghanaian wood species and showed that timber of the lesser-known wawabima (*Sterculia rhinopetala*), akye (*Blighia sapida*), awiemfosemina (*Albizia ferruginea*) and bediwonua (*Canarium schweinfurthii*) could also be used for structural work.

*Terminalia catappa*, with the common names of sea almond, ketapang, and tropical almond tree, is one of the lesser-known tropical tree species of the Combretaceae family that grows mainly in the tropical regions of Asia, Africa, and Australia (Pham & Bechtold, 2023). The tropical almond tree grows up to 40 m with upright and horizontal branches. Its branches are characteristically arranged in a symmetrical crown tier. The leaves are large, broad, and ovoid-shaped, and generally have a dark green colour. It is a monoecious plant, with male and female flowers found on the same plant. The fruit is

ovoid-shaped with a single seed. The fruit appears green in colour when raw, but when it ripens it turns into a reddish-yellow colour. The seed is edible when the fruit ripens. *Terminalia catappa* is one of the lesser-known and a less utilized timber species abundant in Ghana, and grows to utilizable timber size (Habibullah et al., 2023; Fasona et al., 2022).

There have been several studies on *Terminalia catappa*. Ben et al. (2021) studied the antioxidant properties of *Terminalia catappa* leaves and indicated that the plant has numerous medicinal properties, including anti-indigestion, antimicrobial, antifungal, anticancer, diaphoretic, anti-dysentery, antibacterial, antidiabetic, anthelmintic, haematological and antitumor activities. A study by Ihuma et al. (2021) revealed that extracts from the leaves contain bioactive constituents with high antimicrobial activity against salmonella, and could potentially possess rich medicinal constituents when subjected to further chemical and pharmacological studies. Devi et al. (2019) presented *Terminalia catappa* as herbal biomedicine in the aquaculture industry in India, and indicated that the extract from the leaves can be used to treat tilapia fish ectoparasites. Dianala (2019) studied the utilization of the extracted substances from the *Terminalia catappa* in Thailand and showed that leaves are rich in tannins and organic compounds that help in conditioning the culture water, resulting in improving survival, growth and health of cultured aquatic species.

The study of Oduro et al. (2009) on the proximate composition and basic photochemical assessment of the two common varieties of *Terminalia catappa* trees in Ghana (red and yellow varieties) revealed that the nut of both varieties has promising medicinal and nutritive properties. Islam et al. (2008) also studied some physical (density, moisture content) and mechanical (static bending, compression and tension parallel to grain and screw withdrawal test) properties of *Terminalia catappa* wood and suggested that the timber is moderately or medium dense and can be used as a structural material, fuel or industrial raw material. Quartey et al. (2022) indicated that *Terminalia catappa* has a medium-density wood with medium strength, elasticity and rupture, but high shear strength.

This study seeks to determine chemical properties of wood from different parts of a tree (stem

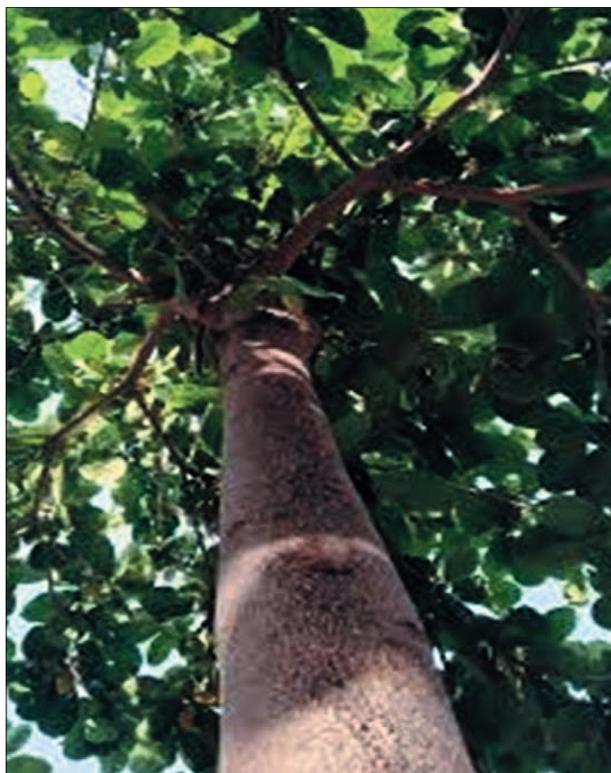


Figure 1. *Terminalia catappa* tree.

Slika 1. Drevo vrste *Terminalia catappa*.

and branches). For this purpose, analyses of made of the cellulose content, hemicellulose content, extractives content, and basic density of stemwood and branchwood.

## 2 MATERIALS AND METHODS

### 2 MATERIALI IN METODE

#### 2.1 MATERIALS

##### 2.1 MATERIALI

Three *Terminalia catappa* trees of similar diameters at breast height (dbh) were identified by the researchers, assigned a GPS Code (CU-1278-9796), and selected for harvesting (Figure 1). Three trees with a diameter at breast height greater than 40 cm and heights greater than 15 m were felled.

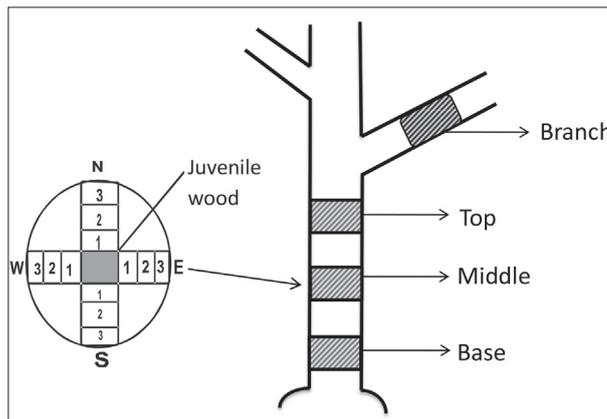


Figure 2. Schematic illustrations, showing the sampling of wood from the stem and branches.

Slika 2. Shema odvzema vzorcev lesa iz debla in vej.



Figure 3. Harvesting and wood sampling from *Terminalia catappa* trees at Dunkwa-on-Offin.

Slika 3. Posek in vzorčenje lesa iz dreves *Terminalia catappa* v območju Dunkwa-on-Offin.



Figure 4. Samples (discs) of *Terminalia catappa* wood from the different parts of the tree.

Slika 4. Vzorčni diski z različnih delov drevesa *Terminalia catappa*.

The full lengths of the tree stems were divided into three equal parts and demarcated with permanent markers and 50 cm from the knot a portion of 1.5 m was extracted from the first and second branches of each tree to obtain varied diameters of branch wood for the study (Figure 2). Discs of about 50 cm thickness at breast height and 70 cm from the branch of each tree were taken for chemical investigations (Figures 3, 4). The mean lengths of the clear bole between the first butt-end, middle portion and top portion of each stem were measured and recorded. The recorded average lengths were 1,809 cm. This criterion was adopted to ensure the straightness of the stem discs and possibly avoid the inclusion of obvious tension wood.

The following tools and machinery were used in the harvesting and processing of the specimens: tape measure, band saw, circular saw machine, vernier caliper, electric oven, climate chamber and electronic balance.

## 2.2 CHEMICAL PROPERTIES

### 2.2 KEMIJSKE LASTNOSTI

The samples for the chemical analysis were prepared, air-dried and placed in a Wiley mill and milled. Each material was then placed in a shaker with sieves to pass through a 40-mesh sieve (425  $\mu\text{m}$ ), then retained on a 60-mesh sieve (250  $\mu\text{m}$ ) and stored for chemical analyses. About 10 g air-dried *Terminalia catappa* milled sample that passed through a number 60 (250  $\mu\text{m}$ ) sieve and then retained by a number 80 (180  $\mu\text{m}$ ) sieve was placed in an extraction thimble ensuring that it did not extend above the level of the top of the siphon tube. The sample was extracted for 4 hours with an ethanol-acetone mixture (1 : 2) in the Soxhlet extraction apparatus. The excess solvent was removed with suction and the wood in the thimble was held with ethanol to remove the excess acetone. The sample in the thimble was returned to the extractor and extraction continued with 95% ethanol (about 200 ml) for 4 hours until the ethanol siphoned over colourless. The sample was removed from the thimble and spread out on a thin layer and allowed to dry in the air until it was free of alcohol. The dried alcohol-free sample was returned to the thimble and extracted with 200 ml of hot water for 4 hours, the same as was done previously using ethanol. After hot water extraction the ma-

terial was air-dried thoroughly and used as extractive-free material for the determination of lignin, cellulose and hemicellulose.

All tests were conducted under the TAPPI standards, except for the alcohol benzene solubility of wood. There was a minor modification for the extractive content test. Instead of benzene, acetone was used. The ethanol-benzene method was reclassified as Classical by committee action in 1997, and revised by a Standard-Specific Interest Group (SSIG) vote in 2006. Revisions in this version were due to safety concerns about the use of benzene; in this revision, the chemicals were changed from benzene and ethanol to acetone. The moisture content was expressed as a percentage weight loss on drying. About 2 g of air-dried sample from the sap- and heartwood of the stem and branch of each tree was weighed and oven dried at 105 °C for several hours to a constant weight. The experiment was done in three replications and an average of the three replicates was taken. The percentage weight loss on drying was then calculated (TAPPI T264 cm-2007). The total extractives were determined in three successive steps, an extraction with acetone, an extraction with alcohol, i.e. ethanol, and a hot water extraction, according to the TAPPI standard (TAPPI T207cm-2008). The amount of extractive content was measured gravimetrically and expressed as a percentage on the bases of dry samples.

Holocellulose content was determined by weighing 2 g of extractive-free sample in a 250 ml conical flask with a small watch glass cover. The sample was then treated with 180 ml of distilled water, 8.6 g of sodium acetate, 6.0 ml of acetic acid and 6.6 g of sodium chlorite. The sample was covered and placed in a hot-water bath for 3 hours. The samples were filtered into a coarse porosity-fitted glass of known weight and washed free of  $\text{ClO}_2$  with distilled water. The crucible was oven-dried at 103 °C, cooled in desiccators, and weighed until a constant weight was reached. The amount of holocellulose content was measured gravimetrically and expressed as a percentage on the bases of dry samples.

Cellulose was determined by weighing 1.5 g of the holocellulose into a 250 ml Erlenmeyer flask with a small watch glass cover. The flask was placed into a water bath at 25 °C and 100 ml of 17.5%

NaOH solution was added thorough stirring. After 30 minutes of stirring, 100ml of water was added and stirring continued for another 30 minutes. The Erlenmeyer flask was removed and filtered with a fritted-glass crucible of known weight. The residue was washed with 25ml of 9.45% NaOH solution and then with 40 ml of 10% acetic acid, and finally washed free of acid with plenty of water. The residue was oven-dried in an oven at 103 °C, cooled in desiccators, and weighed until a constant weight was reached (TAPPI T203cm-2007). The quantity of cellulose was expressed as a percentage based on the moisture-free sample.

Lignin was determined by weighing 1 g of extractive-free sample into a conical flask. Fifteen ml of cold sulphuric acid (72%) was slowly added while stirring and mixing very well. The reaction proceeded for two hours with frequent stirring in a water bath maintained at 18 °C–20 °C. When the two hours had expired, the specimen was transferred by washing it with 560 ml of distilled water into a 1,000 ml flask, diluting the concentration of the sulfuric acid to three percent. A condenser was attached to the flask and the insoluble material was allowed to settle. The contents of the flask were filtered by vacuum suction into a fritted glass crucible of known weight. The residue was free of acid with 500 ml of hot tap water and then oven-dried at 103 °C. Crucibles were then cooled in desiccators and weighed until a constant weight was obtained (TAPPI T222cm-2011). The weight of lignin was then expressed based on the moisture-free sample.

### 2.3 WOOD DENSITY

#### 2.3 GOSTOTA LESA

The wood density and moisture content were determined according to ASTM D2395-07 and ASTM D4442-07, respectively. The same samples were used for both tests. Each strip was sawn into 20 mm x 20 mm sections and cross-cut into 20 mm cubes. The mass of the samples was taken immediately after preparation using a VWR Science Education RS232 digital electronic balance (with a precision of 0.001g) to obtain the initial mass ( $W_1$ ). The samples were then soaked in water for 24 hours to obtain the swollen volume ( $V_1$ ), which was determined by the immersion method. According to Archimedes' principle, the increase in the mass of water displaced by the submerged wood sample is

numerically equal to the volume of water displaced. Afterward, the wood samples were oven-dried at  $103 \pm 2$  °C with intermittent weighing until constant mass, and oven-dry mass ( $W_0$ ) was attained (ASTM D 2395-07). The test was done under an ambient temperature condition of 20 °C. The test duration was within 24 hours. The basic density (BD) of the samples was then calculated.

## 3 RESULTS AND DISCUSSION

### 3 REZULTATI IN DISKUSIJA

#### 3.1 CHEMICAL COMPOSITION OF STEM AND BRANCH WOOD

##### 3.1 KEMIJSKA SESTAVA LESA DEBLA IN VEJ

Table 1 presents the mean chemical composition of the stemwood and branchwood of the studied species with variations of the chemical composition in the sapwood and heartwood. The lignin, cellulose and hemicellulose contents in the branchwood and stemwood showed moderate variation across the species. We found statistically significant differences in the chemical composition between the sapwood and the heartwood portions for both the stemwood and the branchwood.

The average lignin contents in the stemwood was lower in the sapwood ( $21.45 \pm 1.22\%$ ) than in the heartwood ( $24.95 \pm 1.08\%$ ), and the differences were statistically significant ( $P > 0.05$ ). A similar trend was observed in the branchwood of *Terminalia catappa* where the lignin content was significantly lower in the sapwood ( $22.55 \pm 1.21\%$ ) than in the heartwood ( $24.13 \pm 1.10\%$ ).

This agrees with other studies, for instance the one of Gonzalez and Mitsushashi (2007) who noted that the amount of lignin in wood usually decreases from the heartwood to the sapwood and from the base to the crown. Similarly, Gominho (2003), Mariani et al. (2005), Miranda et al. (2007), Sitsofe (2016) recorded lower lignin contents in sapwoods of *Eucalyptus globulus*, *Eucalyptus nitens*, *Quercus* sp., *Terminalia ivorensis* and *Acacia robusta*. According to Iversen and Wannstrom (1986), lignin decreases the permeation of water through the cell walls of the xylem, thereby playing an intricate role in the transport of water and nutrients, and also impedes the penetration of destructive enzymes through the cell wall and protects cellulose and hemicellulose from degradation. Hence, the resist-

ance of the wood structures is largely influenced by lignin (Majaila, 2000).

Cellulose is the main constituent of wood carbohydrates and forms the structural framework of the cell, making up 40% to 50% of total components in hardwoods (e. g., Rózanska et al., 2011; Cole, 2012). The average cellulose content of the stemwood was 32.22% ± 1.21 and of the branchwood 33.10% ± 1.09, respectively (Table 1). The cellulose contents in both the stemwood and branchwood were higher than in the heartwood. However, the

branchwood had a slightly higher cellulose content than the stem. This trend is similar to the one described by Magel (2000) and Taylor et al. (2002).

The average hemicellulose content recorded for stemwood and branchwood was 26.35% ± 1.19 and 26.55% ± 1.29, respectively (Table 1). Furthermore, the sapwood had more hemicellulose than the heartwood. This is also in agreement with the results of Magel (2000), which showed that heartwood had less hemicellulose than sapwood. The differences between the hemicellulose content in

Table 1. Lignin, cellulose and hemicellulose content in wood of stem and branches of *Terminalia catappa*. The contents are presented as mean values with standard deviations (in parentheses). Mean values with the same letters (a, a or b, b) are not significantly different, while different letters (a, b) indicate significant differences (P<0.05).

Preglednica 1. Vsebnost lignina, celuloze in hemiceluloz v lesu debla in vej *Terminalia catappa*. Vsebnosti so predstavljene kot povprečne vrednosti s standardnimi odkloni (v oklepajih). Srednje vrednosti z enakimi črkami (a, a ali b, b) niso statistično značilno različne, medtem ko različne črke (a, b) nakazujejo statistično značilne razlike (P<0,05).

Tree section	Chemical compound (%)	Content (%) (standard deviation)		
		Sapwood	Heartwood	Average
Stem	Lignin	21.45a (1.22)	24.95b (1.06)	23.20 (1.14)
	Cellulose	32.71a (1.18)	31.32b (1.24)	32.22 (1.21)
	Hemicellulose	28.23a (1.14)	24.47b (1.24)	26.35 (1.19)
Branch	Lignin	22.55a (1.14)	24.13b (1.02)	23.34 (1.08)
	Cellulose	33.43a (1.06)	31.14b (1.13)	33.10 (1.09)
	Hemicellulose	28.10a (1.02)	25.00b (1.56)	26.55 (1.29)

Table 2. Extractives (% per dry wood) in stem and branch wood of *Terminalia catappa*. The contents are presented as mean values with standard deviations (in parentheses).

Preglednica 2. Ekstraktivne snovi (% na suh les) v lesu debla in vej vrste *Terminalia catappa*. Vsebnosti so predstavljene kot povprečne vrednosti s standardnimi odkloni (v oklepajih).

Specie	Tree section	Tissue	Content of extractives (%)			
			Cold water	Hot water	Acetone	Ethanol
Stem	Sapwood	Heartwood	9.09 (0.67)	7.43 (1.82)	1.95 (1.24)	2.93 (0.61)
		Heartwood	15.86 (2.01)	11.40 (1.78)	3.87 (0.69)	3.74 (0.43)
		Average	14.15 (1.84)	11.16 (1.63)	3.30 (0.84)	4.18 (0.68)
						<b>8.19</b>
Branch	Sapwood	Heartwood	8.06 (1.86)	7.22 (1.64)	1.40 (0.52)	1.59 (0.24)
		Heartwood	12.34 (2.89)	11.87 (1.94)	2.80 (0.83)	2.78 (0.72)
		Average	11.75 (2.60)	10.85 (1.87)	2.29 (0.74)	2.54 (0.67)
						<b>6.85</b>

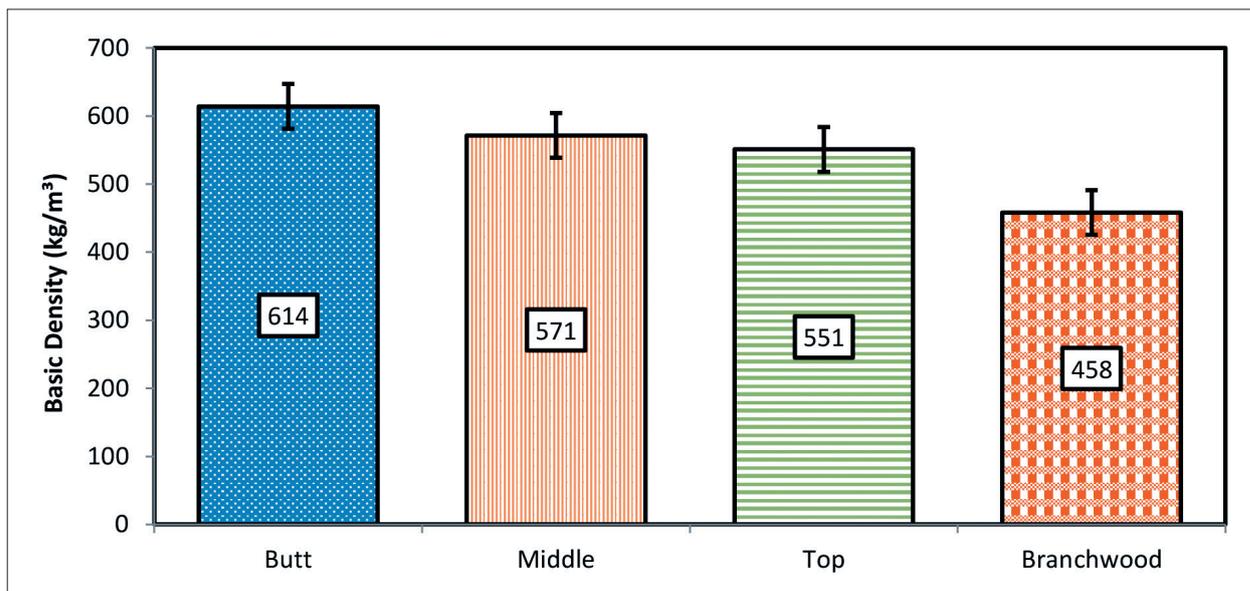


Figure 5. Average basic density of *Terminalia catappa* wood of the basal, middle and top part of the stem and in the branchwood. Error bars = standard deviation.

Slika 5. Povprečne vrednosti (in standardni odkloni) osnovne gostote lesa vrste *Terminalia catappa* v spodnjem, srednjem in zgornjem delu debla ter v vejah. Ročaji = standardni odklon.

Table 3. Basic density (means and standard deviations) of *Terminalia catappa* wood based on oven dry mass and maximum volume at the given moisture contents.

Preglednica 3. Srednje vrednosti in standardni odkloni za osnovno gostoto lesa (masa absolutno suhega lesa na maksimalni volumen pri danih vlažnostih) vrste *Terminalia catappa*.

Tree Sections	Position	Moisture Content (%)	Basic Density (kg/m <sup>3</sup> )
Butt	Sapwood	63.59± 4.71a	648.88±40.76a
	Heartwood	76.98±3.35b	579.25±53.18b
Middle	Sapwood	68.38±8.64c	581.87±46.39c
	Heartwood	82.80±6.79d	560.94±42.18d
Top	Sapwood	80.91±3.89e	572.88±65.88c
	Heartwood	88.76±11.59f	529.19±96.23d
Branchwood	Sapwood	98.88±8.31s	472.81±93.20e
	Heartwood	110.99±10.84t	443.56±72.43f

the sapwood and the heartwood of the stemwood were statistically significant ( $P>0.05$ ) (Table 1). The hemicellulose content was also significantly lower in the heartwood (25.00%) than in the sapwood (28.10%) in the branchwood of *Terminalia catappa*.

Table 2 contains the percentage variation of extractives obtained by different less and more po-

lar organic solvents for the stemwood and branchwood, and also the variation of extractives across the sapwood and the heartwood of *Terminalia catappa*. The stemwood had higher total extractive content than the branchwood. The stemwood and branchwood had extractive contents of 8.19% and 6.85%, respectively. The comparison of the extrac-

Table 4. ANOVA for moisture content and density of *Terminalia catappa* tree sections. Variability.

Tabela 4. Analiza variance (ANOVA test) za vrednosti vlažnosti in gostote lesa v deblu in vejah vrste *Terminalia catappa*.

Source	Df	Moisture Content			Basic Density	
		F-Value	Sig.	Var. (%)	F-Value	P-value
Tree sections (TS)	3	151.885	0001**	75	38.527	0.001**
Position (P)	1	93.107	0.001**	38	14.871	0.001**
TS × P	3	1.36	0.255ns	2.6	1.014	0.388ns

Note: \*\* = highly significant at  $p < 0.01$ , \* = significant at  $p < 0.05$ , ns = not significant

Opomba: \*\* = stopnja statistične značilnosti visoka ( $p < 0.01$ ), \* = pomembna ( $p < 0.05$ ), ns = razlike niso statistično značilne.

tion yields obtained with cold water, hot water, acetone and ethanol showed that the highest amounts of extractives were obtained with cold water. This was followed by the use of hot water, ethanol and acetone respectively. The amount of the extractives obtained by the acetone was the lowest. The extractive contents were also lower in the sapwood and higher in the heartwood (Table 2).

### 3.2 DENSITY OF WOOD

#### 3.2 GOSTOTA LESA

The basic density of the wood of *Terminalia catappa* in the sapwood ranged from 473 to 649  $\text{kg/m}^3$ , while in the heartwood (HW) it ranged from 444 to 579  $\text{kg/m}^3$ . The average mean densities were the highest in the basal portion (614  $\text{kg/m}^3$ ) while the branches had the lowest density of 458  $\text{kg/m}^3$  (Table 3. and Figure 5).

The result of ANOVA (Table 4) indicates that at a 5% significance level, the tree sections and position significantly affect density. The results of Tukey's multiple comparison tests show that for the tree sections, the density differences are significant across the sections.

## 4 CONCLUSIONS

### 4 SKLEPI

We concluded that the cellulose and hemicellulose content were higher in the sapwood than in heartwood, and in the branchwood than in stemwood. However, the lignin and extractive content were higher in the heartwood than in sapwood, and in the stemwood than in branchwood.

The basic density of the sapwood ranged from 473 to 649  $\text{kg/m}^3$ , while in the heartwood from 444

to 579  $\text{kg/m}^3$  being the highest in the butt portion (average 614  $\text{kg/m}^3$ ) and the lowest in the branches (average 458  $\text{kg/m}^3$ ).

The study addresses a gap in the literature by offering in-depth details about the basic density and chemical characteristics of *Terminalia catappa* wood, an alternate timber species. It adds to our knowledge of the properties of the wood by revealing new information, such as the fact that the sapwood and branchwood have higher cellulose and hemicellulose concentrations than the heartwood and stemwood. The study also emphasizes how *Terminalia catappa* has the potential to be a sustainable substitute for traditional wood species for structural applications. This will help in creating jobs and encouraging diversification in the wood sector. Overall, this study contributes to scientific research by offering useful information and guiding sustainable methods for using substitute wood species.

## 5 SUMMARY

### 5 POVZETEK

Prevelika odvisnost od tradicionalnih znanih lesnih vrst, kot so odum ali iroko (*Milicia excelsa*), ofram ali limba (*Terminalia superba*), wawa ali samba (*Triplochiton scleroxylon*), veliko povpraševanje po lesnih proizvodih ter visoke potrebe lesne industrije v Gani so privedle do prekomernega izkoriščanja omenjenih tradicionalnih in dobro znanih lesnih vrst. Zato številni raziskovalci iščejo druge alternativne materiale in rabe, kot so kmetijski odpadki za proizvodnjo različnih plošč. Potencialno zanimiva je tudi uporaba manj znanih in manj izkoriščenih lesnih vrst iz Gane, kot so wawabima

(*Sterculia rhinopetala*), akye (*Blighia sapida*), awimfosemina (*Albizia ferruginea*) in bediwonua (*Canarium schweinfurthii*).

Med manj znanimi vrstami je tudi *Terminalia catappa* iz družine Combretaceae z lokalnimi imeni morski mandelj, ketapang ali tropski mandelj (angleško sea almond, ketapang, tropical almond). Vrsta uspeva predvsem v tropskih območjih Azije, Afrike in Avstralije. Oblikuje velika, do 40 m visoka drevesa s pokončnimi in vodoravnimi vejami. Listi so veliki, široki in jajčaste oblike. Zrela semena (oreščki) so užitna. *Terminalia catappa* je ena od manj znanih in manj uporabljenih lesnih vrst, ki je v Gani dobro zastopana z drevesi primerne velikosti za uporabo.

Na različnih delih dreves *Terminalia catappa* je bilo opravljenih več študij. Ben in drugi (2021) so na primer opravili biološke študije listov in ugotovili, da rastlina deluje zdravilno s protimikrobnimi, protiglivičnimi, protirakavimi, diaforetičnimi, protibakterijskimi, antidiabetičnimi, protiglivičnimi, hematološkimi in protitumorskimi aktivnostmi.

Podatki o lastnostih lesa so redki. Islam in sodelavci (2008) so preučevali les vrste *Terminalia catappa* in sicer nekatere fizikalne (gostota, vlažnost) in mehanske lastnosti (statični upogib, tlačna in natezna trdnost vzporedno z vlakni ter preskus izvleka vijakov) ter ugotovili, da je les srednje gost in se lahko uporablja kot konstrukcijski material, gorivo ali kot industrijska surovina. Quartey in drugi (2022) so navedli, da ima *Terminalia catappa* les srednje gostote s srednjo trdnostjo in e-modulom ter visoko strižno trdnostjo.

Nobena od navedenih študij ni preučevala kemijskih lastnosti *Terminalia catappa*, ki so bile glavni cilj te raziskave. Raziskana je bila tudi variabilnost gostote lesa različnih delov debla in vej.

Preučevali smo les treh dreves, vzorce smo odvzeli iz treh delov debla in iz ene velike veje. Študija je v prvem koraku zajemala pripravo materiala in zračno sušenje vzorcev lesa. Sledila je kemijska analiza vzorcev, pri čemer smo s standardnimi protokoli (TAPPI) vzorcem izmerili vsebnost celuloze, hemiceluloz, lignina in ekstraktivov. Osnovna gostota je bila določena v skladu s standardom ASTM D2395-07. Povprečna vsebnost lignina v vzorcih beljave in jedrovine debla je bila 21,45 % oziroma 24,95 %, značilno več lignina smo izmerili vzorcem jedrovine. Povprečna vsebnost celuloze v lesu je

bila 32,22 % za vzorce debla in 33,10 % za vzorce vej. Povprečna vsebnost hemiceluloz je bila v lesu debla 26,35 % in v lesu vej 26,55 %. V beljavi debla in vej je bila vsebnost hemiceluloz značilno večja kot v jedrovini, kar potrjuje predhodne raziskave.

S pričujočo študijo smo ugotovili tudi to, da ima les debla vrste *Terminalia catappa* večjo vsebnost ekstraktivnih snovi kot les veje (8,19 % in 6,85 %). Kemijska analiza je pokazala, da smo največ ekstraktivov pridobili z ekstrakcijo s hladno vodo, manj z uporabo vroče vode in etanola, najmanj ekstraktivov pa se je iz lesa ekstrahiralo z acetonom. Vsebnost ekstraktivov je bila v beljavi značilno nižja kot v jedrovini.

Predstavljeni so tudi rezultati o variabilnosti osnovne gostote lesa vrste *Terminalia catappa*. Osnovna gostota beljave je bila od 473 do 649 kg/m<sup>3</sup>, jedrovine pa od 444 do 579 kg/m<sup>3</sup>, pri čemer je bila najvišja v spodnjem delu debla (srednja vrednost 614 kg/m<sup>3</sup>), najnižja pa v vejah (srednja vrednost 458 kg/m<sup>3</sup>). Vrednosti osnovne gostote les uvrščajo v razred nizke do srednje gostote, ki je primeren za lahke notranje konstrukcije in širok nabor drugih izdelkov.

Rezultati študije dopolnjujejo objavljene podatke o gostoti lesa ter povsem nova spoznanja o kemijskih lastnostih lesa *Terminalia catappa*. Novost predstavlja tudi ugotovitev, da je v primerjavi z jedrovino debla in vej višja vsebnost celuloze in hemiceluloz značilna za beljavo debla in vej.

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