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PROPERTIES OF *EUCALYPTUS CAMALDULENSIS DEHNH* AND *MELIA AZEDARACH* L. BRANCHES AND THEIR POTENTIAL FOR UTILIZATION IN WOODY BIOMASS

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ABSTRACT

Wood is a magnificent natural resource that can be regarded as the single most important natural resource of the future. *Eucalyptus camaldulensis* and *Melia azedarach* trees were introduced in Iraq and planted as ornamental trees at parks and streets. A study of branch wood was conducted in order to identify its basic properties along different level in tree and to highlight its potential utilizations in Duhok-Kurdistan Region of Iraq. Specimens of six trees at three levels (DBH), Diameter at half height ($D_{0.5h}$) and top level (TL) were collected. In both species, physical properties were significantly affected by tree levels variation ($p<0.05$), and it was found a higher value in the DBHL (diameter breast height level) compared with other levels for the basic density and moisture content. The value of basic density and moisture content ranged from (0.681 g/cm^3) (89.46%) in *Eucalyptus camaldulensis* to (0.536 g/cm^3) (58.01%) in *Melia azedarach*. There were no significant differences in lignin content or heating value among tree. The physical properties of each species are affected by the level of the branches, while the chemical properties have a slight difference along the tree's crown. Based on their physical properties, the branches of two types of trees can be used in different manufacturing processes. Depending on the chemical properties and heating value, this branch can be used to obtain the best resources for efficient use of woody biomass.

***KEY WORDS**:* Woody Biomass, Moisture Content, Lignin, Heating Value, Basic Density.

INTRODUCTION

Biomass from trees and wood in varied areas is potentially large and underutilized when viewed in context with the broader production and use of biomass. In modern times, wood accounts for only 7% of global fuel sources, with developing countries using an estimated 15% of energy and developed countries using only about 2%(MacFarlane 2009).

During harvesting, approximately 35 to 50% of the tree biomass is left in the forest as stumps, branches, and crowns(Suansa and Al-Mefarrej 2020). Recent publications have extensively discussed branch wood as a component of a tree(Shmulsky & Jones, 2019;Dadzie *et al*., 2018). Zhao *et al*., (2019) stated that, wood-based panels and glued plates can also be made with branches besides papermaking.

On the other hand, branches contain more bark and their properties are not uniform (Shmulsky and Jones 2019). (Nurmi 1997) found that branches require intricate treatment before they can be utilized, which reduces harvester productivity. The characteristics of the wood vary depending on genetic and environmental factors, influencing its potential for various uses(Vieira et al. 2021).

The potential power of biomass can be captured by growing fast-growing vegetable species(Pérez et al. 2007). Therefore, *Eucalyptus camaldulensis Dehnh* and *Melia azedarach* L.are the fastest-growing species with the highest biomass production(Pérez et al. 2007);Abdulqader *et al*., (2020) respectively. Also, they are an important raw material for many industries, including steel, furniture, cellulosic pulp, and paper(Vieira et al. 2021).

Eucalyptus camaldulensis Dehnh and *Melia azedarach* L are one of the hardwood species planted in many parts in Duhok city and it has shown good adaptation to environment condition and information about wood properties is rare, consequently, the aim of study is conducted to determine the properties of wood (physical and chemical properties) and to highlight its potential utilizations.

MATERIALS AND METHODS

The branch wood from six different trees was selected randomly for this research of (*Eucalyptus camaldulensis*) and (*Melia azedarach L*.). All specimens were obtained from Malta Nursery which is located in Duhok province, Kurdistan region of Iraq (42 56'05.68 E, 36 51'27.96' N) (Figure 1). In Malta Nursery, the average annual temperature was 28.5°C, and the average annual precipitation was (396mm) for 2021-2022 (Directorate of Forest and Rangeland in Duhok city, 2022).

Fig.(1):- Malta Nursery location in Duhok City by(MAHD et al. 2018)

The majority of pruning occurs at the bottom of the tree crown, so samples were collected from various levels and tested for woody biomass. A representative area for each tree was labeled and registered based on their age, diameter and level (Table 1). Branch sectional discs were taken from each tree at diameter breast height (DBH), Diameter at half height ($D_{0.5h}$) and top level (TL). Numerous wood samples were collected from each branch free of bark after 10 cm of the tree stem, from three different aspects, to become 54 specimens representing the wood sample for the study(Zhao, Guo, Zhang, *et al*., (2019);Hassan, (2018). In order to study the properties of trees characteristics, the boundary between heartwood and sapwood was not distinguished visually. The following key indexes describe each individual tree: Tree crown length (TCL), diameter at breast height (DBHL), Diameter at half height ($D_{0.5h}$), Top diameter limit (DTL). It is worth noting that the sample collection took place in September, 2021(summer season).

Table (1) :-Characteristics of trees

Species	Tree No.	Tree age(year)	Tree height (m)	TCL (m)	DBHL (cm)	$D_{0.5h}$ (cm)	DTL (cm)
Eucalyptus camaldulensis Den.,	1	18	12.9	5.5	26.25	17.4	9.1
	2	18	11.8	4.12	26.85	18.7	9.9
	3	18	13.8	7.75	47	36.1	14.1
Melia azedarach,	1	16	7.5	4.17	19.3	13.8	4.8
	2	16	7	4.95	21.7	14.1	4.9
	3	16	7.2	5.03	19.1	13.8	4.7

Physical properties

1- Moisture content (MC %)

To study the physical properties, regular branch disc with dimensions of 1*1*2 cm^3 from each trees were taken. The wet branch specimens were freshly measured in the field by sensitive electronic balance and recorded, and then samples were kept in plastic bags to avoid loss of their weight. The specimens were then oven-dried at 105 ± 2ºC until they reached a constant weight, at which point their dry weight was recorded. According to American Society for Testing and Materials (ASTM D4442-07). For measuring moisture content the following formula was used:

$$Moisture\ content\ \% = \frac{Wet\ weight - Dry\ weight}{Dry\ weight} * 100 \qquad (1)$$

2- Basic density (BD g/cm^3)

Based on the oven-dry mass divided by the green volume of all samples, the basic density was calculated below the formula according to (Dibdiakova *et al*., (2014);(Bowyer *et al*., (2007). The wet volume of regularly shaped specimens with dimensions (20*20* 60) mm was calculated by multiplying width by length by height (ASTM D143, 1994; Hassan, 2018). Calipers were used to measure the dimensions of both the green and dry samples (Sytnyk *et al*., (2018);Sadegh & Kiaei, (2011). While for irregularly shaped samples, basic density is measured by water displacement based on (Standardization in National Bureau of Standards, 1980). Also, a thin layer of paraffin wax was applied then immersion of a sample was done by hand with a needle for both paraffin wax and cylinder. Wood specimens were oven-dried at 103 2 ± 2ºC and weighed several times until they reached a constant weight before being recorded.

$$Basic\ density = \frac{Dry\ weight}{Wet\ volume}\ g/cm^3 \qquad (2)$$

Individual tree measurement

1- Trees height: The Haga altimeter was used to determine the height of the trees(Dibdiakova, Gjølsjø, and Wang 2014).

2- Diameter of trees: The diameter of the trees was measured in centimeters using a tree caliper(Sytnyk et al. 2018).

3- Bark thickness: Bark thickness was determined by taking the average of two perpendicular measurements to the nearest 1 mm with a Verner clipper digital(Abdulqader *et al*., 2020).

4- Fresh and dry branch weight measurement: it was measured using an electronic balance.

Chemical properties

1- Extractives

In the laboratory, oven dried samples were ground to pass 0.4 mm sieves and settle on 0.6 mm sieves(ASTM E-11; ASTM Committee on Quality & Statistics 2018). The extractives were then extracted from 2 g of each sample by Soxhlet using four solvents: water, ethanol, chloroform, and then acetone for eight hours per solvent (Diehl, 2014; Hassan, 2018).

2- Lignin isolation

This process involved two steps of hydrolysis:-

1- For two hours at 20˚C, 15 ml of 72% H_2SO_4 was added to 1 gram of each extractive-free sample and stirred with a glass rod every 15 minutes to ensure sample dissolution in the acid.

2- Diluting the H_2SO_4 concentration to 3% by adding 560 ml of distilled water to each sample and boiling them in a 100˚C water bath with periodic stirring to complete the hydrolysis.

Following that, crucible filters were used and their weight was recorded then the samples were filtered through them, and the residues representing acid-insoluble lignin were washed numerous times with hot water, to remove the remaining acid.

Crucible filters were moved and dried at 105 ± 2ºC until reached constant weight. By subtracting the total weight of the crucible and the residue from the crucible weight, the outcome gave the amount of lignin. The lignin content in the tested samples was then calculated for each determination using (Tappi 2011)as shown below:-

Lignin, % = A 100 / W

Where:

A = weight of lignin in grams

W = oven-dry weight of test specimen in grams.

Heating value

The calorific value of a material is the amount of heat released when its mass unit is completely burned under certain conditions(Domingos et al. 2020). A bomb calorimeter was used to measure the heating value, it was calibrated with benzoic acid first then 1 gram of each non extracted specimens that passed 0.6mm sieve was connected to a piece of thread cotton which is connected to the firing wire inside the bomb. Two litter of distilled water add to water jacket and bomb was filled with oxygen (20 bars). The bomb was placed inside calorimeter vessel which in turn was placed into water jacket. Then it operated for 10-15 minutes(Ojelel 2015). The first recorded temperature is considering initial temperature(IT) of the water then after bombing the final temperature(FT) was recorded and heating value was measured using the following formula:-

Q= M CΔT

Where:

Q= Heating (calorific) value (J/g)

M= weight of sample (g)

C= capacity of the bomb calorimeter (12601.76)

ΔT = FT – IT (Cº)

RESULTS AND DISCUSSION

Moisture content (MC %)

In accordance with the results of the ANOVA table and factorial analysis for the whole parameters, a results showed highly significant difference effect between two species ($p<0.05$) on MC, but non-significant at levels ($p>0.05$) (Table 2). The highest value of MC mean (89.46%) was found in *Eucalyptus camaldulensis* and (58.01%) for *Melia azedarach*, with respective minimal values of (76%) and (53.24%) and maximal values of (93.82%) and (62.66%) respectively. The MC mean for *Eucalyptus camaldulensis* was relatively close to that reported by(Ashton 2019); and Owuor *et al*., (2018) which is (87.27%) and (88.72%). Hence, the MC of trees differs from season to season and it relies on the amount of storage conditions. (Hakkila, 1989) reported that, the difference in MC percentage in branches led to difference of basic density outcome. In addition to the location of the tree, its age and harvest season, MC also varies significantly based on the size of the tree(Shmulsky and Jones 2019). (Demirbas, 2002) stated that, the high MC% in tree decrease wood heating value.

Basic density (BD g/cm^3)

The experiment and statistical analysis revealed that the type of tree species had a significant influence ($p=0.001$) on BD. The overcome BD mean value obtained by *Eucalyptus camaldulensis* (0.681 g/cm^3) is denser than the mean of *Melia azedarach* (0.536 g/cm^3). Likewise, the effect of BD on levels observed highly significant difference ($p<0.000$) where the BD varied between stem height levels which increase from DBHL's (0.7 g/cm^3) to the TL's (0.436 g/cm^3). It has been mentioned(Suansa and Al-Mefarrej 2020) that BD plays an important role in the production and utilization of wood products. Compared results of *Eucalyptus camaldulensis* to previously reported stem wood values, branch wood BD is similar (0.71 g/cm^3) to (Suansa and Al-Mefarrej 2020) results and is very close to those reported by (Sadegh and Kiaei 2011) which (0.559 g/cm^3) to (0.572 g/cm^3).

the result of *Melia azedarach*, found that the BD of branch wood was higher than stem wood when compared to (Abdulqader, *et al*., 2020);(El-juhany, 2011) results, they found the mean of BD of stem wood ranged between (0.31 g/cm^3) to (0.40 g/cm^3) and (0.413 g/cm^3) to (0.4.3 g/cm^3) respectively. The BD of branch wood is higher in some species than stem wood, and this is a good indication of high-quality wood biomass generated from branches.

The overcome show significant interaction ($P=0.009$) effect on BD (Figure 2) was observed between trees and levels mean (Table 1). This interaction indicated that, there was a significant effect of levels on BD between the two species, but no significant effect of BD was recorded in DBHL and ML's. The highest BD is (0.812 g/cm^3) in *Eucalyptus camaldulensis* and the lowest value was recorded (0.426 g/cm^3) in *Melia azedarach*. In contrast, TL's in both species had lower values (0.446 g/cm^3) and (0.426 g/cm^3).

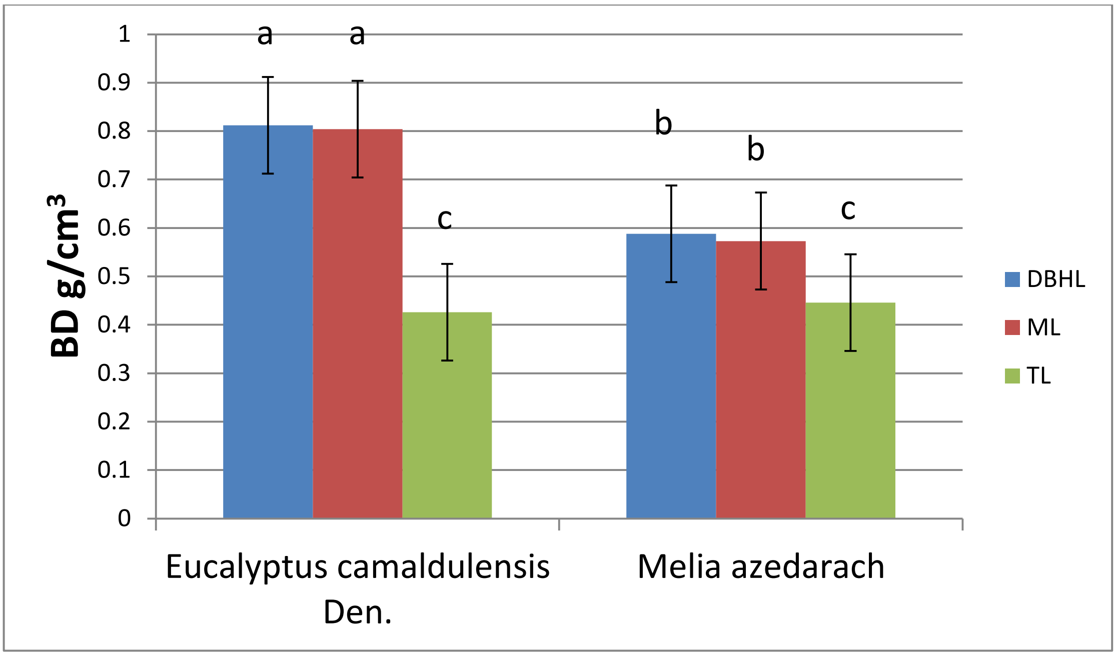

Fig.(2):-the effect of the interaction between trees and levels on BD. Bars that do not share a letter are significantly different at P= 0.05.

Chemical Properties

Lignin content

The highest value of lignin was found in *Eucalyptus camaldulensis* (30.43%), while the lowest value (26.73%) of lignin was found in *Melia azedarach L*. The results of this study did not observe any significant effect of any of the study treatments (species and levels) (p>0.05) on lignin content. Despite the fact that the treatment means differed slightly, they were not statistically significant. However, these results are in agreement with what found by(Dibdiakova, Gjølsjø, and Wang 2014) on softwood which is also showed not very significant within crown level (p>0.05). Chemical composition of branch wood was not significantly influenced by geographical location, site index, or crown level variables. According to Suansa & Al-Mefarrej, (2020), generally, lignin accounts for approximately between 20% to 30%, compared to obtained results in present study, lignin content mean for *Eucalyptus camaldulensis* was very close to the reference and which was 25% and to the results of the study conducted by (Domingos *et al*., 2020) and (Vieira *et al*., 2021) which was 27.8% and 26.7% respectively. Meanwhile, the result of *Melia azedarach* agree with previously study results by (Megra et al. 2022) which was (22.14%). Concerning the interaction no significant interaction was found among the studied treatment (Table 2).

Heating value

The value of heating value among studied species was in range 15.1 MJ/kg in *Eucalyptus camaldulensis* to 23.4 MJ/kg in *Melia azedarach*. Compared to mature wood, wood formed by trees between the ages of 5 and 20 contains less cellulose and more lignin(Kamperidou, Lykidis, and Barmpoutis 2018). Statistically, there was no significant difference in the mean of H.V. between species and their levels (p=0.352) and (p=0.326) (Table 3) respectively. Despite the slight difference between the treatment means, none of the treatments or their interactions had a statistically significant effect (P>0.05) on the total heating value. The results of *Eucalyptus camaldulensis* were in line with previous studies by (Owuor, Kirongo, and Mbego 2018) and outcome of *Melia azedarach* was close to that found by (Demirbas 2002). (White 1987) stated that the extractive-free wood samples have higher heating values because lignin has a higher thermal conductivity.

Table (2):- Main effect with means± SD of physical and chemical properties

Species	MC%			BD.			Lignin			H.V.		
	Mean ±SD	Max	Min	Mean ±SD	Max	Min	Mean ±SD	Max	Min	mean±SD	Max	Min
E.camaldulensis	89.47± 5.2a	93.82	70	0.681±0.2a	0.95	0.37	30.43±6.44a	40	22.7	18.6±1.78a	20.4	15.1
M. azedarach	58.01± 3.51b	62.66	53.24	0.536±0.07b	0.611	0.42	26.73±7.01a	37.1	19	19.56±2.42a	23.4	17.32

Means in columns for each factor sharing the same letters are not significantly different at P>0.05.

Table(3):- Summary of AOVA Table for tree species

ANOVA summary *P* –values				
Species	0.001	0.001	0.288	0.352
Levels	0.066	0.000	0.402	0.326
Species*levels	0.731	0.009	0.758	0.435

Means in columns for each factor sharing the same letters are not significantly different at P>0.05.

Table(4):- Main effect with means± SD of physical and chemical properties

Species	**MC%**			**BD.**			**Lignin**			**H.V.**		
	Mean ±SD	Max	Min	Mean ±SD	Max	Min	Mean ±SD	Max	Min	mean±SD	Max	Min
E.camaldulensis	89.47± 5.2a	93.82	70	0.681±0.2a	0.95	0.37	30.43±6.44a	40	22.7	18.6±1.78a	20.4	15.1
M. azedarach	58.01± 3.51b	62.66	53.24	0.536±0.07b	0.611	0.42	26.73±7.01a	37.1	19	19.56±2.42a	23.4	17.32

Means in columns for each factor sharing the same letters are not significantly different at P>0.05.

Table(5):- Summary of AOVA Table for tree species

	ANOVA summary *P* –values			
Species	0.001	0.001	0.288	0.352
Levels	0.066	0.000	0.402	0.326
Species*levels	0.731	0.009	0.758	0.435

Means in columns for each factor sharing the same letters are not significantly different at P>0.05.

The correlation between physical and chemical properties

Person correlation analysis results (Table 4) show a strong and positive correlation between lignin and each heating value (r=0.742; p-value <0.01) and basic density (r=0.61; P-value<0.05). The outcome of lignin content correlation with heating value is similar to that found by(White 1987). Additionally, moisture content was positive correlation with basic density (r=0.576; p-value <0.05) Moreover, a positive correlation has been found between Lignin content and moisture content (r=0.615; P- value<0.05). Correlations between the rest of the parameters were very weak (p > 0.05) (Table 4).

Table(6):- Pearson Correlations between properties of trees

	B.D.(g/cm^3)	MC%	Lignin%
MC %	**0.576**		
	0.012		
Lignin%	**0.615**	**0.382**	
	0.007	**0.117**	
H.V.(MJ/KG)	**0.376**	**-0.112**	**0.742**
	0.124	**0.658**	**0.000**

CONCLUSION

In this research, physical and chemical properties of *Eucalyptus camaldulensis* and *Melia azedarach* were investigated and determined for woody biomass and these outcomes were compared with three different levels of tree crown. The following conclusions were obtained from this study:

1- The basic density value varies and showed significance between species and at different levels; it was increased from DBHLs to the up of the tree. In addition, its variation occurs through binary interaction with crown levels. Consequently, branch wood of both species might be used as a blending material in papermaking and glued plates because their wood is classified as heavy wood. As well as, moisture content was positive correlation with basic density and lignin content.

2- The person correlation results revealed that there were positive and strong relationships between lignin content and each of the heating value and basic density, which is a good indicator for utilization in woody biomass.

3- The amount of lignin in both species is high, and this specification led to an increase in their heating value, this indicator of the two species is suitable for the utilization of woody biomass as an energy source.

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پوخته

دار ئیکه ژ گرنکترین سەرچاوێت سروشتی, دشیان دایه وەکو تاکه گرنکترین سەرچاوه بهێته هژمارتن ل پاشەروژێ. دارا یوکالیپتوس و سەبەحبەح دهێته نیاسین ل هەرێما کوردستانێ وەکو دارێت جوانی یێ ل سەر جادا و دناڤا پارکاندا. فەکولین هاته ئەنجامدان ل سەر چەقێن هەردوو جورێن دارا ئو ل سەر ئاستێت جیواز د دارێ دا ب مەبەستا دیارکرنا زانیارییێن سەرەتایی یێن تایبەت ئو هەروەسا داکو ئەگەرێن ب کارئینانێ بهێنه دیارکرن ژبو وەبەرهێنانێ بو بایوماسی ل بازێرێ دهوکێ-هەرێما کوردستانا عێراقێ.نمونه ژ شەش دارا ژ هەر جورەکی و ل سەر سێ ئاستا (TL, ML, DBH) هاتنه وەرگرتن. تایبەت مەندییت فیزیاوی ب شێوەکێ بەرچاڤ کاریگەری ل سەر ئاستێت جیواز هەبوو (p<0.05), و بەرزترین بها ل ئاستێ DBH دا هاتنه دیتن ب بەراوردی دگەل ئاستێت دیتر ژبو رێژا شەهێ و تیراتییا بنەرەتی. بهایێ تیراتیا بنەرەتی ئو رێژا شەهێ ژ (0.681گم/سم3) (89.46%) د دارا یوکالیپتوسێ دا بو (0.536گم/سم3) (58.01%) د دارا سەبەحبەحێ دا بوو. هیچ جێوازییەکا بەرچاڤ د رێژا لگنینی وبهایێ گەرمکرنێ ب درێژاهیا ئاستێ تاجا دارا دا نەهاتە دیتن. تایبەتمەندییت فیزیاوی د هەردوو جورا دا ئو ل سەر ئاستێت جیواز کاریگەری ل سەر چەقان هەبوو, ددەمەکیدا تایبەتمەندییت کیمیاوی جێوازییەکا کێم هەبوو ب درێژاهیا تاجی. پشت بەستن ب تایبەتمەندییت فیزیاوی, دشیان داییە چەقێن ڤان دارا بهێنه ب کارئینان د گەلەك پێشەسازییت کارێ داری دا. پشت بەستن ب تایبەتمەندییت کیمیاوی و بهایێ گەرمکرنێ, دشیان داییە چەقێن ڤان دارا بهێنه ب کارئینان بو ب دەستڤەئینانا باشترین سەرچاوە ژ بو ب کارئینانین چالاك د وەبەرهێنان بایوماسێ دارێدا.

الخلاصة

يعتبر الخشب من اعظم الموارد الطبيعية, يمكن اعتباره بانه المورد الطبيعي الوحيد الاكثر اهمية في المستقبل. تم ادخال كل من شجرة اليوكاليبتوس والسبحبح الى اقليم كوردستان وزرعت كأشجار زينة في الشوارع والحدائق. تم إجراء دراسة على خشب الاغصان من أجل معرفة خصائصه الأساسية على طول المستويات المختلفة في الشجرة وإبراز استخداماته المحتملة في دهوك - إقليم كردستان العراق. تم جمع عينات من ستة أشجار ومن ثلاثة مستويات في التاج (DBH و ML و TL). في كلا النوعين ، تأثرت الخصائص الفيزيائية معنويا باختلاف مستويات الأشجار (p < 0.05) ، وقد وجدت أعلى قيمة في مستوى DBH مقارنة بالمستويات الأخرى للكثافة الأساسية ومحتوى الرطوبة. تراوحت قيمة الكثافة الأساسية ومحتوى الرطوبة من (0.681 جم / سم ^{3}) (89.46٪) في شجرة اليوكاليبتوس إلى (0.536 جم / سم ^{3}) (58.01٪) في شجرة السبحبح. لم يتم العثور على فروقات ذات دلالة إحصائية في محتوى اللجنين وقيمة التسخين على طول مستويات تاج الشجرة. تتأثر الخصائص الفيزيائية لكتا النوعين باخلاف مستوى الفروع ، في حين أن الخصائص الكيميائية لها اختلاف طفيف على طول تاج الأشجار. بناءً على خصائصها الفيزيائية ، يمكن استخدام اغصانهما في العديد من الصناعات الخشبية. اعتمادًا على الخصائص الكيميائية وقيمة التسخين ، يمكن استخدام هذا الفروع للحصول على أفضل الموارد للاستخدام الفعال في الاستثمارللكتلة الحيوية الخشبية.