Use of wood characteristics in Identification of selected *Terminalia species* growing in Sri Lanka

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Abstract

250 timber species are being used by the timber industry in Sri Lanka and among them building constructors, furniture manufacturers and wood fabricators are the main consumers. Identification of the trees become very difficult once felled and processed and therefore macroscopic/ microscopic features and physical properties of timber become important. Timber identification is necessary for right use of timber and to check on fraud in timber trading as some timber traders deceive customers by mixing low value timber with high quality ones.

Five timber species of *Terminalia* namely *T. arjuna* (Kumbuk), *T. bellirica* (Bulu), *T. catappa* (Kottamba), *T. chebula* (Aralu) and *T. parviflora* (Hampalanda) of the family of Combretaceae were studied anatomically in search of sufficient features to separate one *Terminalia sp* from the other. Due to the resemblance of wood structure of five *Terminalia spp,* examination of the transverse sections of wood with a hand lens (×25) does not provide adequate reliable information to differentiate one species from the other for identification. Hence Transverse section (T.S.), radial longitudinal section (R.L.T.) and tangential longitudinal section (T.L.S.) were obtained using the microtome for the anatomical examination.

In this study, some important wood anatomical and non-anatomical features were studied according to IAWA (1989). It was found that all *Terminalia spp* had diffuse porous wood having vessels mainly solitary and occasionally in 2-3 of radial multiples. Mean vessel diameter and vessel diameter range were recorded respectively as 241µm and 172-331µm in *T. arjuna*, 169µm and 107-204µm in *T. bellirica*, 240µm and 169-309µm in *T. catappa*, 115µm and 68-175µm in *T. chebula* and 124µm and 75-159µm in *T. parviflora*. Mean vessel frequency were observed as 3 per mm^2 in *T. arjuna*, 4 per mm^2 in *T. bellirica*, 3 per mm^2 in *T. catappa*, 6 per mm^2 in *T. chebula* and 5 per mm^2 in *T. parviflora*. Mean rays frequency, mean ray height and mean ray width were found respectively as 9 per mm, 206µm, 24µm in *T. arjuna*, 11 per mm, 283µm, 24µm in *T. bellirica*, 8 per mm, 280µm, 25µm in *T. catappa*, 13 per mm, 239µm, 31µm in *T. chebula* and 10 per mm, 235µm, 30 µm in *T. parviflora*. Ray cell arrangement is mostly uniseriate and occasionally biseriate in *T. bellirica, T. parviflora* and *T. arjuna*. Ray cell arrangement is mostly multiseriate and occasionally uniseriate in *T. catappa* while *T. chebula* has uniseriate ray cell arrangement.

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Different type of axial parenchyma types were found in each *Terminalia* species. *T. bellirica* had axial parenchyma band (more than three cells wide). *T. parviflora* and *T. catappa* had aliform/vasicentric type axial parenchyma which can be differentiated from confluent parenchyma type in *T. chebula*. Vasicentric (halo) parenchyma types were found mainly in *T. arjuna*. Finally, it can be concluded that ray cell arrangement and axial parenchyma types can be used together as baseline to distinguish *Terminalia spp* in Sri Lanka for the purpose of timber identification.

Keywords: Terminallia, wood structure, wood identification, xylem vessels, parenchyma

1. Introduction

Terminalia is a pan tropical genus accommodating about 200 species (McGaw et al., 2001). The genus *Terminalia* is the second largest genus in the Combretaceae which is distributed throughout the tropical and sub-tropical region of the world. The name *Terminalia* derives from its Latin name (terminalis=end) in accordance of the position of the leaves, which are crowded at the ends of shoots (Lamb and Ntima, 1971; Rogers and Verotta, 1996). *Terminalia spp* range from small and medium sized shrubs or trees to large deciduous forest trees, ranging in height from 1.5 to 75 m tall (Lebrum and Stork 1991; Schmidt et al., 2002). *Terminalia* trees are planted in several countries in the tropics as a source of high quality solid timber for fine carpentry, joinery, building, flooring, plywood manufactures (Schmidt et al., 2002; Smith et al., 2004).

The present investigation was carried out on five species of *Terminalia* namely *T. arjuna* (Kumbuk), *T. bellirica* (Bulu), *T. catappa* (Kottamba), *T. chebula* (Aralu) and *T. parviflora* (Hampalanda). This study mainly focused on variation of wood anatomy, specific gravity, wood texture and heartwood colour in search of anatomical features of any diagnostic importance for the identification of *Terminalia species*. These five *Terminalia spp* have been categorised in different classes in State Timber Corporation's timber classification based on timber demand and its wood properties. *T. arjuna* and *T. bellirica* have been classified as special class and second class timber respectively. Other *Terminalia spp* like *T. catappa* and *T. chebula* were categorised under lower classes. The five *Terminalia* species studied in this research work found some similar characteristics such as wood external appearance, some gross features and wood specific gravity. Due to these reasons, authenticity of *Terminalia* species is questionable when marketing logs or sawn timber. Therefore the identification of these species by means of anatomical and other wood properties is imperative exercise to minimise various kinds of fraud taking place in timber industry.

In addition this information is useful in timber utilisation aspect. Jane (1967) recommended that the aspect of variation in wood structure is of practical importance in the industrial sense. He intended to draw the attention of wood anatomists engaged in wood quality study to look at the question of variability in wood structure. The structural features and variations in those features are related to properties and end uses. Cell size and proportion and arrangement of the various types of elements and tissues, for example, tracheid, vessels, fibers, and parenchyma and of early wood and late wood, vertical elements and ray tissues determine the grain and figure. Cell diameter in relation to cell wall thickness and the proportion of thin walled to thick walled cells determine density which is closely correlated to mechanical strength, machining and working properties and yield in pulping. The texture is concerned with the size of the wood element which depends mainly on the size of the vessel and the

size of the rays. Texture is a compromise between vessel size and ray size. Specific gravity which is the best single criterion of the strength of a piece of wood was also determined in order to make use in timber identification process.

Due to the above reasons, the present study was conducted (i) to examine the variation of wood anatomical features of the five *Terminalia* species and (ii) to determine the specific gravity, wood color and wood texture of these five species.

2. Materials and Methods

Fresh timber disk with five cm thickness was cut at breast height of the mature tree in the field. A radial wood strip was cut from each disk and divided into upper and lower strips. One was used for the investigation of anatomical characteristics and the other for the measurement of specific gravity and heartwood colour. Authentic timber samples of the five *Terminalia spp* were collected from the Research Division of State Timber Corporation (STC) along with fresh wood samples. The collected specimens from two sources mentioned above, were anatomically compared with each other for confirmation of the identity.

2.1 Determination of wood specific gravity

A radial strip cut from each disk was used for the measurement of specific gravity. Specific gravity was determined on the basis of oven-dry weight and green volume. Specific gravity of *Terminalia* species studied were grouped into three categories as basic specific gravity low (≤ 0.40), basic specific gravity medium (0.40-0.75) and basic specific gravity high (≥0.75).

2.2 Wood color

Wood samples containing both heartwood and sapwood were used to determine wood color according to IAWA (1989) category No. 197 to 202 by naked eye. Heartwood color is categorised mainly into three groups namely (i) basically brown or shade of brown (ii) red or shade of red (iii) yellow or shade of yellow. Visible differentiation of heartwood color from sapwood was also studied.

2.3 Anatomical characteristics

A radial strip taken from the pith to bark was used for the investigation of anatomical characteristics. So that the wood samples were boiled in water for about two hours to soften them. Each wood sample was then shaped and sized into wood block of 2×2×3cm. Transverse, radial and tangential sections at the range of 10-15 μm thickness were obtained at the laboratory by using a sledge microtome (Model Leica SM2000 R). Permanent slides of wood tissues were prepared after dehydrated and stained in safranin. Sections were mounted using Canada balsam using standard procedure.

Microscopic observations of each slide were made for qualitative and quantitative analysis of parameters under the light microscope at 4×10 magnifications. Measurements on wood anatomical features were taken after photomicrographs of each slide were made by Olympus microscope and Micrometrics SE Premium 4 soft ware available in Research division of STC.

Characters of wood anatomy for comparative anatomy were selected with the idea to use these parameters in timber identification with hand lens. Vessel porosity, growth ring, vessel shape, vessel grouping, vessel arrangement were studied under the light microscope. Mean Tangential vessel

diameter, vessel tangential diameter range and vessel frequency were then measured. Measurement of vessel frequency was based on 10 counts in an area of 25mm^2 field of view. Range of ray height, mean ray height, ray width and ray frequency were also studied. The measurement of ray frequency was based on 10 counts in a linear distance of 5mm field of view. The Terminology and measurements were taken according to IAWA Committee (1989). Visibility of vessels and rays on transverse section was also done with naked eye. These findings were grouped into fairly visible, just visible and not visible categories.

2.4 Identification of wood texture

Mean vessel tangential diameter, ray width and ray height were measured for this purpose from which the average tangential diameter of the vessel (µm) was used to determine wood texture. Although, vessel size is primarily responsible for texture, coarse texture may ensure from large rays alone in a wood with large rays and vessels of moderate size or small size. The Table 1 and ray information given in Table 4 are helpful to indicate roughly the basis of classification used in this study.

Table 1: Classification of wood texture.

Type of wood texture	**Average tangential vessel diameter (µm)**
Fine textured	Less than 100 microns
Medium textured	100 to 200 microns
Coarse textured	More than 200 microns

3 Results and Discussion

3.1 Heartwood and sapwood color of Terminalia spp

The sapwood from heartwood was easily distinguished in all the *Terminalia* species used in this study. The colour of heartwood varied from yellow to brown in selected species. All the selected five *Terminalia* species can be grouped into two categories according to heart wood colour. The yellow or shade of yellow colour heartwood was found only in *T. bellirica*. *T. arjuna*, *T. catappa*, *T. chebula* and *T. parviflora* bare brown or shade of brown heartwood. Sap wood of *T. parviflora* was found as white to grey in colour. Hence *T. bellirica* can be distinguished from other *Terminalia* spp on the basis of heartwood colour. Therefore heartwood color along with sapwood color can be used for the identification of *Terminalia spp*.

3.2 Wood texture

T. arjuna, *T. catappa* and *T. parviflora* coarse wood texture and other species studied such as *T. chebula* and *T. bellirica* are medium textured wood. According to Pearson and Brown (1981) the other elements, especially where mass in zonate bands (parenchyma, fibers) must be taken into consideration to categorise wood texture.

3.3 Specific gravity

Specific gravity determined in five species varied from 0.82 for *T. arjuna* to 0.63 for *T. chebula* (Table 2). *T. arjuna* showed the highest mean specific gravity of 0.82, followed by *T. parviflora* (0.70), *T. catappa* (0.69), *T. bellirica* (0.66) and *T. chebula* (0.63).

Five *Terminalia spp* studied can be grouped into two groups according to IAWA specific gravity classification, Only *T. arjuna* was identified as high density wood. *T. parviflora* (0.7), *T. catappa* (0.69), *T. bellirica* (0.66) and *T. chebula* (0.63) were identified as medium density wood. IAWA specific gravity classification of IAWA is too broad to differentiate the *Terminalia* species from each other because four *Terminalia spp* fall into one specific gravity category. However, in the case of *Terminalia* species verification process, specific gravity may be used as a parameter.

Table 2: Variation of mean specific gravity, wood colour and wood texture in five *Terminalia* species.

Species	Specific gravity Kg/ m^3 at 12% m.c.	Color of heartwood (HW) and sapwood (SW)	Texture
Terminalia arjuna	0.820-high density	HW colour darker than SW colour. HW basically brown or shades of brown	Coarse
Terminalia bellirica	0.660- medium density	HW colour darker than SW colour. HW basically yellow or shades of yellow	Medium
Terminalia catappa	0.690- medium density	HW colour darker than SW colour. HW basically brown or shades of brown	Coarse
Terminalia chebula	0.630-medium density	HW colour darker than SW colour. HW basically brown or shades of brown	Medium
Terminalia parviflora	0.700-medium density	HW colour darker than SW colour. SW is white to grey. HW basically brown or shades of brown	Coarse

3.4 Anatomical properties

Vessels

The anatomical features of *Terminalia* species were shown in Figure 1, 2 and Table 3, 4. All selected species were diffuse-porous and growth ring boundaries were indistinct or absent except for *T. arjuna* which had inconspicuous distinct growth ring boundaries. Vessels of all species were oval/round shape and majority was solitary and in radial rows of 2-3. Vessel frequency in 25 mm^2 area varied as 163 in *T. chebula* to 70 in *T. catappa* (Table 3). Mean minimum vessel diameter and mean maximum vessel diameter were found as 96 µm in *T. chebula* and 241 µm in *T. arjuna*.

Vessels of *T. chebula* were not visible to naked eye. However, the vessels of *T. arjuna*, *T. bellirica* and *T. catappa* were easily visible at normal reading distance while *T. parviflora* is just visible to naked eye (Table 3). This information can be used to distinguish *T. chebula* from other four species investigated. Size of vessel is practicably useful anatomical property when timber is identified by a hand lens. Ruwanpathirana (2002) found that vessel frequency and vessel size vary in radial direction from pith to bark in *E. grandis*. Therefore this variation may effect to result of comparative wood anatomy if wood samples were not taken in a consistent manner in radial direction.

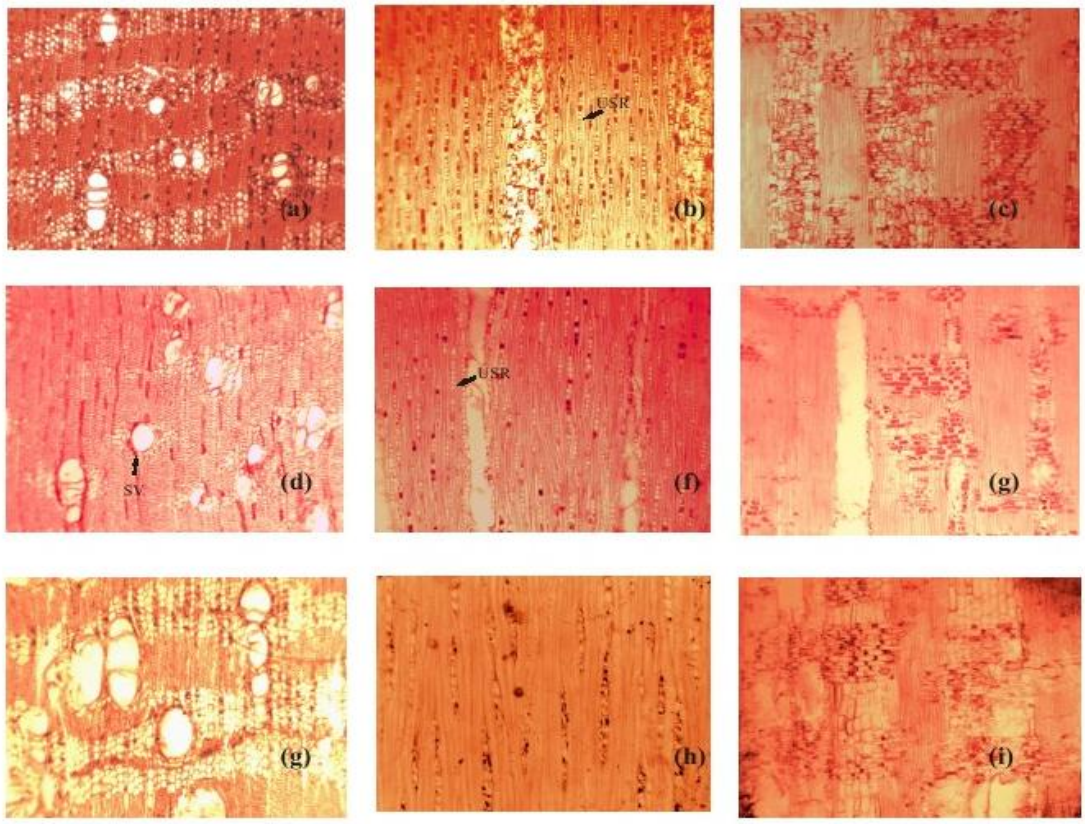

Figure 1: Wood anatomical features of the Genus *Terminalia.* (a) cross section, (b) tangential longitudinal section, (c) radial longitudinal section of *T. chebula*; (d) cross section, (e) tangential longitudinal section, (f) radial longitudinal section of *T. parviflora*; (g) cross section, (h) tangential longitudinal section, (i) radial longitudinal section of *T. belirica*.

Axial parenchyma

Variations of axial parenchyma cells show significant difference among the selected species. More than three cells wide band of axial parenchyma was observed in *T. bellirica*. Aliform and confluent axial parenchyma was found in *T. arjuna*, *T. catappa* and *T. chebula*. *T. parviflora* shows the vasicentric and alifom axial parenchyma. This variation of axial parenchyma is imperative to differentiate *Terminalia* species in the process of timber identification. *T. parviflora* can be separated from other species because it does not have confluent or banded axial parenchyma and *T. bellirica* can be distinguished from other *Terminalia* species because it is having banded axial parenchyma bands.

Rays

Rays were not visible to naked eye and the width of rays is less than half width of the vessel in all the selected *Terminalia* species. Ray cells are procumbent in all the species. Among the all the studied species, uniseriate rays and rays which are mostly multiseriate, were found respectively in *T. chebula* and *T. catappa*. Other *Terminalia* species namely *T. arjuna*, *T. bellirica* (Bulu) and *T.*

parviflora had mostly uniseriate and rarely bi-seriate. This ray characteristic can be used to differentiate *T. chebula* and *T. catappa* from other *Terminalia* species.

Ray frequency per 5mm varied from 45 in *T. arjuna* to 65 in *T. chebula*. Mean ray width varied from 23µm in *T. arjuna* to 31µm in *T. chebula*. This indicates that difference between ray widths within the five species is not enough for timber identification. Variation of mean ray height from 206 µm to 300 µm was found in *T. arjuna* and *T. parviflora* respectively. When analyzing this results, it is understandable that mean ray height, mean ray width and ray frequency cannot be used comfortably for timber identification. (Figure 1, 2 and Table 4).

Table 3: Variation of growth ring, vessel porosity, vessel arrangement, vessel grouping, vessel shape, vessel deposit, vessel diameter range, mean vessel tangential diameter and axial parenchyma in five *Terminalia* species.

Species	Growth ring, vessel porosity, vessel arrangement, vessel grouping, vessel shape and vessel deposit.	Vessel diameter range (mean vessel diameter)-µm	Vessels in 25mm²	Axial parenchyma
Terminalia arjuna	Growth ring boundary distinct but inconspicuous, diffuse –porous, Diagonal and / or radial rows of 2-4 (mostly 2-3) and majority exclusively solitary ,Oval shape and tyloses common	172-331 (241) easily visible at normal reading distance.	74	Axial parenchyma vasicentric (mainly), aliform and confluent
Terminalia bellirica	Growth ring boundary indistinct or absent, diffuse –porous, the majority solitary and in radial rows of 2-4 (mostly 2-3), Oval shape. Occasional brownish-yellow gum present.	107-204 (169) Easily visible at normal reading distance.	92	Axial parenchyma, aliform, confluent and mostly bands more than thee cells wide.
Terminalia catappa	Growth ring boundary indistinct or absent, diffuse –porous, the majority solitary and in short radial rows of 2-4 (mostly 2-3). Oval shape and Occasional brownish-yellow gum present.	169-309 (240) easily visible at normal reading distance	70	Axial parenchyma vasicentric, aliform and occasionally confluent.
Terminalia chebula	Growth ring boundary indistinct or absent, diffuse –porous, the majority solitary and in short radial rows of 2-4 (mostly 2-3). Oval shape and Occasional yellowish brown gum present.	68-126 (96) Not visible to naked eye	163	Axial parenchyma aliform and mostly confluent.
Terminalia parviflora	Growth ring boundary indistinct or absent, diffuse –porous, the most solitary and in short radial rows of 2-3 occasionally. Oval/round shape.	75-159 (124) Just visible to naked eye	135	Axial parenchyma vasicentric and aliform.

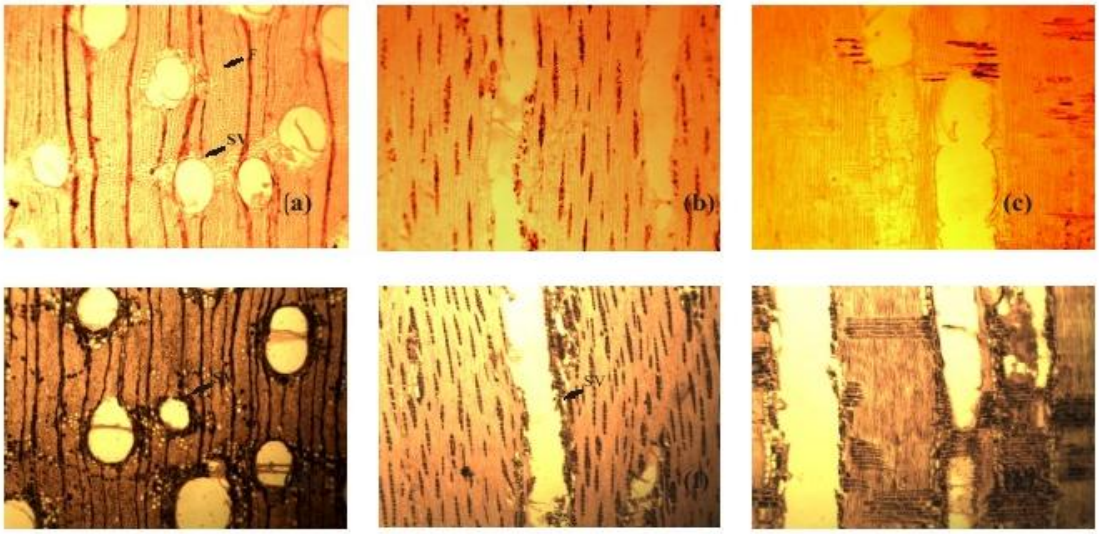

Figure 2: Wood anatomical features of the Genus *Terminalia.* (a) cross section, (b) tangential longitudinal section, (c) radial longitudinal section of *T. catappa*; (d) cross section, (e) tangential longitudinal section, (f) radial longitudinal section of *T. arjuna*.

Table 4: Variation of ray width, ray width range (µm), mean ray width (µm), ray height range (µm), mean ray height (µm), rays per 5mm for five *Terminalia* species.

Species	Ray width (µm)	Ray width range & mean width (µm)	Ray height range& mean height (µm)	Rays per 5 mm
Terminalia arjuna	Not visible to naked eye. Less than half width of the pore. Ray mostly uniseriate, rarely bi-seriate.	13-36 (23)	75-448 (206)	45
Terminalia bellirica	Not visible to naked eye .Less than half width of the pore. Ray mostly uniseriate and rarely biseriate.	13-42 (30)	166-440 (265)	55
Terminalia catappa	Not visible to naked eye. Less than half the width of the pore. Mostly multiseriate.	9-39 (23)	217-374 (291)	40
Terminalia chebula	Not visible to naked eye. Less than half width of the pore. Uniseriate.	19-46 (31)	114-491 (239)	65
Terminalia parviflora	Not visible to naked eye .Less than half width of the pore. Ray mostly uniseriate and rarely biseriate.	20-44 (30)	139-357 (300)	50

4. Conclusion

Among the studied anatomical properties, ray cell arrangement and axial parenchyma type showed comparative differences within studied *Terminalia spp*. Ray cell arrangement was mostly uniseriate and occasionally biseriate in *T. bellirica*, *T. parviflora* and *T. arjuna.* Ray cell arrangement is mostly multiseriate and occasionally uniseriate in *T. catappa. T. chebula* has uniseriate ray cell arrangement. Therefore *T. chebula* and *T. catappa* can be distinguished.

Different types of axial parenchyma types were found in each *Terminalia* species from which the prominent type of axial parenchyma was identified from each species as follows. *T. bellirica* had axial parenchyma band (more than three cells wide). *T. parviflora* and *T. catappa* had aliform/vasicentric type axial parenchyma which can be differentiated from confluent parenchyma type in *T. chebula*. Vasicentric (halo) parenchyma types were mainly found in *T. arjuna*. Other than ray and parenchyma cells, vessel diameter can be used to differentiate *T. arjuna* (Larger vessel) from *T. parviflora*. Finally, it can be concluded that ray cell arrangement, axial parenchyma types and in addition vessel diameter can be used together as baseline information to distinguish *Terminalia spp* in Sri Lanka for the purpose of timber identification.

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