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Wood Density of Ten Native Trees and Shrubs and Its Possible Relation with a Few Wood Chemical Compositions

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Abstract

The present study was undertaken in Forest Science Faculty, Universidad de Nuevo Leon, Mexico on variability of Wood density and its possible relation to few wood chemical composition and wood fiber cell structure anatomy. The results reveal that among 10 specie studied, there exist a large variation in wood density (0.51 to 1.09), and few wood chemical composition such % carbón (37.14 to 44.07), nitrogen (9.18 to 19.22), sulphur (31.45 to 33/82), lignin (15/28 to 24.35), hemicellulose (19.94 to 27.36%), and % cellulose (33.69 to 45.92). In general, though there was no clear relationship between wood density and other chemical composition of wood. It was observed that the species having moderate to high wood density contained >40% carbón, >30% sulphur and >40% cellulose and more or less 20% lignin. It seems that carbón, sulphur, cellulose and lignin content contribute to greater density. The wood fiber cell with wall lignification seems to be related to higher wood density.

Keywords

Wood Density, Wood Chemical Composition, Cellulose, Lignin, Carbón Concentration, Variability

1. Introduction

Wood density is an important wood quality parameter in carbon cycle research and offers resistance in the trees against wind, storms, cavitation of xylem vessels, and other environmental stresses. The wood density of tropical

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tree species is determined in units of oven dry weight in grams per cubic centimeter of green volume. It varied from 0.5 to 0.8 g/cm^3 [1]. Few research findings are mentioned herein on wood density and factors affecting it. A study was undertaken [2] on wood density and fibre length of *Eucalyptus grandis* grown in Kerala, India in trees of four age groups (3, 5, 7, and 9 yr). The average basic density was 495 kg/m^3 at 3 yr revealing a no significant increase from 3 to 9 yr, whereas 5-yr-old trees had a significantly lower value. Density did not show significant differences but it differed significantly between the locations. The woof fibres were found to be longer in one location where the trees had a faster growth. It is well confirmed that wood-specific gravity is an important component of the biomass estimations [3] [4]. Wood density predicts life-history strategies of tree species, owing to the fact that it is closely related to tree growth rates [5]. On the other hand, wood density is positively related to drought resistance in tropical trees [6]-[8]. High wood density is positively correlated with xylem wall enforcement, which in turn reduces cavitation risk due to strong tensions during periods of drought [6]. It was reported [9] that the wood density of tree species in Neotropical forests was a taxonomically conserved trait, whereby variation in wood density was mainly explained by the wood density at generic level. Several studies on wood density have documented that community-level wood density varies considerably among Neotropical forests [9]-[11] and therefore it is considered a predictive variable in large-scale tropical biomass estimation protocols [9] [12], [13]. It is reported [11] that wood density across 59 Amazonian plots and four Neotropical forests, respectively, is negatively associated with soil fertility. In this respect at a broader scale, [10] (1988) undertook comparative study of North American and South American communities, and observed a positive correlation between wood density and mean annual precipitation. On the contrary, it was reported [14] that the variation in mean wood density within Guyana did not show correlation with either precipitation or soil fertility, whereas in Mexico, [15] found that mean wood density showed a negative correlation with precipitation. All these studies discuss contrasting trends in the regional and environmental variability of wood density, although they are based on a limited number of study sites or are restricted to one region of the Neotropics. Density is correlated with cavitationresistance. Wood density is safety factor against implosion of xylem to avoid collapse. It is investigated in [6]. A study was undertakent [16] on the relation between transport capacity and wood density and wood anatomy with leaf photosynthetic traits in two low land Panamanian forest. Leaf specific hydrauic conductivity of the upper branches showed positive corelation with the maximum rates of net CO_2 assimilation per unit leaf area and stomatal conductivity. Maximum leaf hydraulic conductivity showed stronger correlation with net CO_2 assimilation. This suggests that allocation to photosynthetic potential is proportional to maximum water transport. Branch wood density was negatively correlated with wood water storage and wood water potential. Wood density also constraints physiological functions.

A study was undertaken [17] on regional and phylogenetic variation of wood density across 2456 neotropical trees species. According to them, wood density is a crucial variable in carbon accounting programs of both secondary and old-growth tropical forests. Wood density is also the best single descriptor of wood: it correlates with numerous morphological, mechanical, physiological, and ecological properties. This reveals that genus-level means give reliable approximations of values of species, except in a few hypervariable genera. They also studied the evolutionary shifts in wood density occurring in the phylogeny of seed plants using a composite phylogenetic tree. Major changes occurred at deep nodes (Eurosid 1), and also in more recent divergences (for instance in the Rhamnoids, Simaroubaceae, and Anacardiaceae). Their unprecedented wood density data set yields consistent guidelines for estimating wood densities when species-level information is lacking and should significantly reduce error in Central and South American carbon accounting programs.

Wood density plays a key role in ecological strategies and life history variation in woody plants, but very little is known about its anatomical basis in shrubs [18]. They quantified the relationships between wood density, anatomy, and climate in 61 shrub species from eight field sites along latitudinal belts between 31 and 35 in North and South America. Measurements included cell dimensions, transverse areas of each xylem cell type and percentage contact between different cell types and vessels.

In the face of literatures available on various factors affecting wood density, a preliminary study is undertaken to find possible relation with few wood chemical composition and wood fiber characteristics.

2. Materials and Methods

Guadalupe Bárcenas Pazos and Raymundo Dávalos Sotelo (2015) (23) made a review on the importance of lignin. Temperate hardwood species, both from México and the United States undergo a greater shrinkage percentage than tropical hardwoods and softwoods from both countries. The three-dimensional stiffness of lignin, greater than that of the other chemical constituents of the cell wall, along with its low higroscopicity, relimit the movements due to changes in moisture content. Regression analyses to determine the influence of specific gravity and lignin content were analyzed. It is concluded that both have a marked importance. Specific gravity shows to be the most important variable, although the influence of lignin is also significant. It is remarked that it is necessary to carry out experimental studies on the effect of these variables on dimensional changes, along with that of other important variables, such as extractives and ray volume.

In earlier study we determined wood density of 37 woody species of Northeastern Mexico, out of which we selected 3 species with high density, 3 species with moderate density and 3 low density.

Wood samples of each species were grounded in a Thomas Willey mill (Thomas Scientific Apparatus, Model 3383) using a N˚60 (1 mm × 1 mm) mesh these were sieved, and stored in labeled plastic containers. Samples by triplicate were subjected to chemical analysis. The neutral detergent fibre (NDF), acid detergent fibre (ADF) and detergent fibre lignin (ADL) contents were determined by methods described by [19] VanSoest *et al*. (1991). Hemicellulose (NDF-ADF) and cellulose (ADF-lignin) were obtained by difference.

3. Results and Discussion

The Wood density variations and chemical composition of 10 woody species are shown in **Table 1**.

Wood density being an important parameter contributes to Wood quality. Various workers reported variation in Wood density in various species in the world [1] [2] [4] [6] [17] [20]. We also observed in the present study a large variation in Wood density. It is observed that among 9 species studied there existed a large variation in wood density which varied from (0.51 to 1.09), % carbón (37.14 to 44.07), nitrogen (9.18 to 19.22), sulphur (31.04 to 33.82), lignin (15.28 to 24.35), hemicellulose (19.94 to 27.36%), and % cellulose (33.69 to 45.92). In general, though there was no clear relationship between wood density and other chemical composition of Wood. We observed the species having moderate to high wood density contained >40% carbón, >30% sulphur and >40% cellulose and more or less 20% lignin. It seems that carbón, sulphur, cellulose and lignin content contribute to greater density. We do not observe clear cut relationship between lignin content with that in hard Wood. Wood fibre cells having lignified cell wall (being lignocellulose) contribute to density and strength to the Wood. The species having high wood density viz. *Fraxinus greggii*, *Acacia shaffneri*, *Helietta parviflora* contained in total 60% cellulose and lignin and 40% carbón store revealing that apart from cellulose, and lignin carbón probably contribute to Wood density.

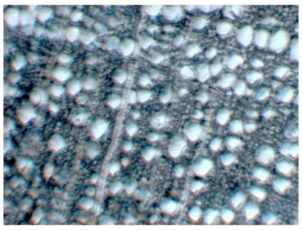
It has been interpreted by [21] that Wood anatomy could predict Wood quality and its utility. We wanted to verify this in the present study. We wanted to know whether Wood anatomical features could predict Wood density and Wood quality interpreted by [21]. It is observed that tree species having high Wood density have compact Wood tissue with thick walled Wood fibres as observed in the case of *Hellieta parviflora* shown below.

Table 1. Variability in wood density (g/cm^3), % of carbón, nitrogen,sulphur, lignin, hemicellulose, and cellulose in ten Woody species.

Scientific name	Wood density g/cm^3	%C	%N	%S	%NDF	%ADF	%Lignin	%Hemi-cellulose	%Cellulose	%Fibres
Cordia boissieri	0.620 ± 0.048	38.55 ± 0.38	11.69 ± 0.68	33.05 ± 0.48	81.5 ± 2.81	61.56 ± 1.84	24.359 ± 1.327	19.942 ± 1.029	37.337 ± 1.661	81.638
Helietta parvifolia	**0.999 ± 0.170**	**41.24 ± 0.83**	11.07 ± 0.73	32.53 ± 0.76	81.15 ± 0.94	60.73 ± 0.72	**20.396 ± 1.317**	20.418 ± 0.575	**40.527 ± 1.174**	81.341
Amyris madrensis	**1.017 ± 0.130**	**42.00 ± 0.03**	10.155 ± 0.12	31.6 ± 0.47	81.17 ± 1.07	55.43 ± 0.40	15.283 ± 0.254	25.741 ± 0.703	**40.290 ± 0.494**	81.314
Diospyros texana	0.642 ± 0.055	39.87 ± 1.39	16.96 ± 1.12	32.485 ± 2.18	86.01 ± 2.30	62.15 ± 1.07	18.705 ± 1.179	23.858 ± 1.249	43.587 ± 0.545	86.15
Karwinskia humboldtiana	**0.885 ± 0.080**	39.325 ± 0.67	13.42 ± 0.08	32.34 ± 0.00	82.57 ± 0.74	60.02 ± 0.58	21.933 ± 0.404	22.554 ± 0.417	38.275 ± 0.655	82.762
Acacia farnesiana	0.808 ± 0.090	37.14 ± 0.41	14.325 ± 1.18	31.2 ± 0.10	74.86 ± 0.63	50.89 ± 1.02	17.310 ± 0.482	23.971 ± 0.435	33.697 ± 1.248	74.978
Acacia shaffneri	**1.096 ± 0.059**	**40.22 ± 0.31**	9.18 ± 0.74	31.04 ± 0.86	83.01 ± 1.43	60.16 ± 0.83	**19.047 ± 0.347**	22.845 ± 0.785	**41.209 ± 0.506**	83.101
Forestiera angustifolia	0.634 ± 0.033	41.81 ± 0.06	11.95 ± 0.06	32.945 ± 1.08	86.12 ± 2.50	63.88 ± 2.59	20.716 ± 0.737	22.246 ± 0.346	43.279 ± 1.853	86.241
Croton suaveolens	**0.912 ± 0.137**	**44.075 ± 0.45**	19.22 ± 0.75	33.825 ± 0.59	88.89 ± 2.96	61.52 ± 1.12	**19.511 ± 1.200**	27.3697 ± 2.063	**42.177 ± 0.640**	89.0577
Salix lasiolepis	0.514 ± 0.042	42.415 ± 1.03	13.36 ± 0.68	31.45 ± 1.73	85.14 ± 1.94	63.56 ± 1.57	17.848 ± 0.940	21.584 ± 0.580	45.924 ± 1.853	85.356

Helietta parviflora

Wood fiber cell



Transverse section of wood

We also observed that both *Acacia shaffneri* and *Fraxinus greggii* having high Wood density have thick walled fibre cell and narrow lumen.

Acacia shaffneri

Wood fiber cell

Fraxinu greggii

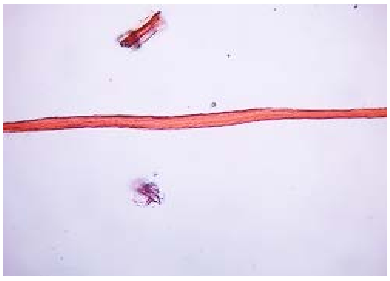
Wood fibre cell

On the contrary in the case of soft wood *Salix humboldtiana*, *Forestieria angustifolia* and *Cordia boissieri*, the Wood tissue is loose and fibre cells are thin walled with broad lumen as shown below.

SOFT WOOD

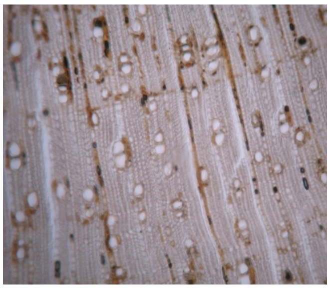
Salix humboldtiana Willd

Transverse section



Fiber cell 40×

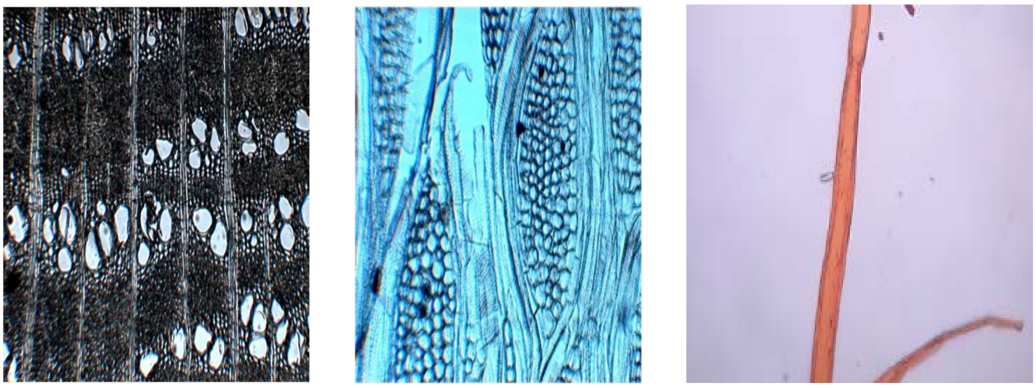
Forestiera angustifolia Torr.



Transverse section

Fibre cell 40×

Cordia boissieri



Transverse section Tangential section Fiber cell 40×

It is observed the species having high Wood density (*Acacia shaffneri*, *Fraxinusgreggii*, *Helietaparviflora*) possess compact Wood with thick walled fibre cells, thick walled cell wall and narrow lumen compared to soft wood having loose wood tissue, thin fibre cell wall viz. *Salix humboldtiana*, *Forestieria angustifolia*, *Cordia boissieri*. This needs to be confirmed in future study.

4. Conclusion

The present study has clearly shown that the chemical composition of the woody tree species varies. This variability in the percent carbon content, ligin, sulphur and hemicellulose may govern the variability in the wood density of the species also as these form the major weight in determining the oven dry weight of the species during the determination of wood density. It was observed that the species in high density had lignified fibre cell wall and compact wood. It has been observed that this variability in the chemical composition is also likely to determine the fiber lumen width and the density of the fibres. This hypotheses needs further confirmation. This needs to be confirmed with a large number of species.

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