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Research Article

UNDERSTANDING THE PHYSICAL PROPERTIES OF MULTIPURPOSE TREES: A COMPREHENSIVE ANALYSIS

[1]Settu Krishnamoorthi, [2*]Duraiswamy Suwethaasri, [3]Panneerselvam Kaviya

Department of Forest Products and Wildlife, Forest College and Research Institute, Mettupalayam – 641 301

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ABSTRACT

The study was conducted at the Forest College and Research Institute in Tamil Nadu, India, to characterize the physical properties of eight different tree species: *Tectona grandis*, *Swietenia macrophylla*, *Acrocarpusfraxinifolius*, *Artocarpus heterophyllus*, *Casuarina junghuhniana*, *Neolamarkiacadamba*, *Pterocarpus marsupium*, and *Melia dubia*. One-meter billets were collected from felled trees of each species, debarked, and cleaned for analysis. The samples were prepared according to the requirements for assessing various physical properties, including bulk and basic density, moisture content, specific gravity, and shrinkage and swelling. The results indicated that all eight species exhibited high moisture content and medium-range density. Understanding these physical properties is crucial for determining the suitability of these species for use in the timber and furniture industries.

Keywords: Multipurpose trees, Physical property, Density, Specific gravity.

INTRODUCTION

We depend on forests for our survival, from the air we breathe to the wood we use. Besides providing habitats for animals and livelihoods for humans, forests also offer watershed protection, prevent soil erosion and mitigate climate change. Yet, despite our dependence on forests, we are still allowing them to disappear. Over 2 billion people rely on forests. Forests provide us with shelter, livelihoods, water, food and fuel security. All these activities directly or indirectly involve forests (Somorin,2010). Looking at it beyond our narrow, human not to mention urban-perspective, forests provide habitats to diverse animal species. They are home to 80% of the world's terrestrial biodiversity, and they also form the source of livelihood for many different human settlements, including 60 million indigenous people. Forests are important in the livelihoods of local people in most developing countries. Local people depend on forests resources for various products such as fuel wood, construction materials, medicine, and food. Globally, it is estimated that between 1.095 billion and 1.745 billion people depend to varying degrees on forests for their livelihoods and about 200 million indigenous communities are almost fully dependent on forests. Moreover, 350 million people who live adjacent to dense forests depend on them for subsistence and income. It is estimated that 20-25% of rural peoples' income is obtained from environmental resources in developing countries and act as safety nets in periods of crisis or during seasonal food shortages.

According to the National Forest Policy 1952, 33% of the area of the country should be under forest with 60% cover in mountains and hilly regions and 20% in plains. This objective was reiterated in the National forest policy 1988 and also in the national Forestry commission report 2006. Only three Indian states meet the prescribed policy, while three more have the potential to do so, if their state wasteland area is afforested (Joshi *et al.*, 2011). Among the rest, a few states may achieve the 33% goal provided land conversion to tree cover is not hindered, and adequate resources are available at state level. The Planning Commission (XI Five-year Plan, 2007-12) has emphasized inclusion of other natural ecosystems (including treeless areas and trees outside forests) to forest cover.

The Indian National Forest Policy of 1988 emphasized the protective role of forests in maintaining ecological balance and environmental stability. The basic objectives that should govern the National Forest Policy were enlisted

*Corresponding Author: Settu Krishnamoorthi, Ph.D. Research Scholar, Department of Forest Products and Wildlife, Forest College and Research Institute, Mettupalayam – 641 301, Email: krishnamoorthik9725@gmail.com.

as follows:- (i) Maintenance of environmental stability through preservation and, where necessary, restoration of the ecological balance that has been adversely disturbed by serious depletion of the forests of the country. (ii) Conserving the natural heritage of the country by preserving the remaining natural forests with the vast variety of flora and fauna, which represent the remarkable biological diversity and genetic resources of the country. (iii) Checking soil erosion and denudation in the catchment areas of rivers, lakes and reservoirs in the interest of soil and water conservation, for mitigating floods and droughts (iv) Checking the extension of sand dunes in the desert areas of Rajasthan and along the coastal tracts. (v) Increasing substantially the forest/tree cover in the country through massive afforestation and social forestry programmes, especially on all denuded, degraded and unproductive lands. (vi) Meeting the requirements for fuel wood, fodder, minor forest produce and small timber of the rural and tribal populations. (vii) Increasing the productivity of forests to meet essential national needs. (viii) Encouraging efficient utilisation of forest produce and maximising substitution of wood. (ix) Creating a massive people's movement with the involvement of women (Siril *et al.,* 2023). This study was conducted to characterize the physical properties of multipurpose trees to reduce the pressure on natural forests.

MATERIALS AND METHODS

This study includes 8 species for physical property characterization i.e., *Swientenia macrophylla, Neolamarckia cadamba, Acrocarpus fraxinifolius, Artocarpus heterophullus, Melia dubia, Tectona grandis, Pterocarpus marsupium, Casuarina junghuhniana.*

Species Description

Swietenia macrophylla, commonly known as mahogany, Honduran mahogany, Honduras mahogany, or big-leaf mahogany is a species of plant in the Meliaceae family. Mahogany wood is strong and is usually a source for furniture, musical instruments, ships, doors, coffins, decors. The mahogany timber grown in these Asian plantations is the major source of international trade in genuine mahogany today (Krisnawati *et al*., 2011). *Neolamarckia cadamba*, flowers are used in perfumes. The tree is grown as an ornamental plant and for timber and paper-making (Devi *et al.,* 2023). *Acrocarpus fraxinifolius*, the pink cedar, a large deciduous emergent tree native to Bangladesh, Bhutan, China, India, Indonesia, Laos, Myanmar, Nepal and Thailand. The wood is used to produce pulp for paper but is rated as second-class for that purpose and is used for interior trim, paneling, furniture, and cabinet work (Suresh, K. 2009). *Artocarpus heterophyllus* (jackfruit) also known as the jack tree, is a species of tree in the fig, mulberry, and breadfruit family Moraceae. Jackfruit wood is widely used in the manufacture of furniture, doors and windows, in roof construction, and fish sauce barrels (Prakash *et al.,* 2009). *Melia dubia* commonly known as Malabar Neem, possess a medical properties and used in treatment of various ailments such cancer, Anti-diabetic, antitumour, anti-Inflammatory, antioxidant, antibacterial, anti viral and fungicidal properties. It is a good secondary timber and the most preferred species for plywood industry. The wood is also used for packing cases, ceiling planks, building purposes, agricultural implements, pencils, match boxes, splints, cattamarans, musical instruments and tea boxes as the wood is anti-termite by itself (Goswami *et al*., 2020). *Tectona grandis* (Teak) is a tropical hardwood tree species in the family Lamiaceae. Teak wood has a leather-like smell when it is freshly milled and is particularly valued for its durability and water resistance. The wood is used for boat building, exterior construction, veneer, furniture, carving, turnings, and other small wood projects (Palanisamy *et al.,* 2009). Indian kino, botanically known as *Pterocarpus marsupium*, leaves, bark, and gum were used for curing a number of ailments. Because of its medicinal properties, the plant species is cultivated for commercial purpose in many parts of the world. Be it for treating skin conditions or serving as an astringent, the herb is popular for its diverse health benefits. *P. marsupium* is a good timber species for making furniture, door, windows etc (Devgun *et al.,* 2009). *Casuarina junghuhniana* is an evergreen tree which can be used in rural construction as poles for house construction, electric poles and the masts of boats (Jayaraj, R.S.C.2010).

Methodology

The physical properties analyzed in this study includes moisture content, shrinkage and swelling, basic density, bulk density, and specific gravity (Haygreen & Bowyer, 1982).

Moisture content

100 g of wood were weighed and dried in an oven at 105°C for 8 Hrs. From the loss in weight, the moisture content was calculated using the following formula MC (%) = initial weight – final weight / initial weight *100 (Simpson &Tenwolde, 1999).

Shrinkage and Swelling

The amount of shrinkage and swelling that takes part as a product changes moisture content may be calculated by Shrinkage (%) = initial weight – final weight / initial weight *100, where final weight refers to oven dry weight whereas Swelling (%) = final weight- initial weight / initial weight*100, here final weight refers to green weight (after soaking in water for 48 hours) (Eckleman, C.A. 1998).

Basic Density

The basic density of each wood sample was found out by using the displacement method (Hay green and Bowyer1982) and the density was calculated using the following formula Basic Density = E2 \ F+G, where E2-Green weight (after soaking in water for 48 hours), F-Oven dry weight, G-Deflection of the needle in cm due to water displacement (Saranpaa,P.2003).

Bulk Density

Sample of chips were collected and their volumes were determined by placing them in a suitably graduated container The mass of these chips was determined The oven dry weight at particular volume is calculated based on moisture content of the chips i.e., Bulk density(kg/m^3) = m/V where, m-Oven dry weight of chips, V-Volume (Gendek *et al.,*2016).

Specific Gravity

Specific gravity is defined as the ratio of the density of a substance's over-density of water. The sample size was 2.5 cm × 2 cm × 2 cm. The specific gravity was calculated by the following formulae. $Gm = W_o / V_m \times D_w$, where W_o = Oven weight of the wood sample, V_m = Volume at same moisture content, D_w = Density of water (Williamson, G &Wiemann, M 2010).

RESULTS AND DISCUSSION

The study's findings, as presented in Table 1, provide a detailed comparison of the physical properties of eight different tree species. The results highlight significant variations in moisture content, swelling and shrinkage, density, and specific gravity among the species analyzed. Moisture Content: The study revealed that the moisture content varied widely across the species. *Artocarpus heterophyllus* (jackfruit) exhibited the highest moisture content at 23.47%, followed closely by *Pterocarpus marsupium* (kino) with a moisture content of 20.68%. These values indicate that jackfruit and kino have higher water retention compared to the other species tested. On the other hand, *Casuarina junghuhniana* (casuarina) recorded the lowest moisture content at 10.78%, suggesting that casuarina wood retains significantly less moisture than the other species. Swelling and Shrinkage: The results for swelling and shrinkage percentages also varied among the species. *Melia dubia* (melia) and *Pterocarpus marsupium* (kino) showed the highest percentages of swelling and shrinkage, at 73.71% and 16.19%, respectively. This indicates that these species experience more significant dimensional changes when exposed to moisture variations, which could affect their stability in applications where wood swelling and shrinkage are concerns. Conversely, the lowest swelling and shrinkage percentages were observed in *Swietenia macrophylla* (pink cedar) and *Tectona grandis* (teak), at 18.56% and 8.36%, respectively. This suggests that pink cedar and teak are more stable under varying moisture conditions, making them potentially more suitable for use in environments with fluctuating humidity.

Table 1. Physical properties of farm grown tree species.

S.No	Species	Moisture content (%)	Swelling (%)	Shrinkage (%)	Basic density (kg\m3)	Bulk density (kg\m3)	Specific gravity
1	*Tectona grandis*	11.01	22.29	8.36	527.1	652.8	0.6162
2	*Neolamarkiacadamba*	17.45	50.22	10.45	532.5	465.1	0.5112
3	*Melia dubia*	14.04	73.71	12.38	684.5	527.2	0.6375
4	*Acrocarpusfraxinifolius*	23.47	18.56	9.75	528.2	672.3	0.5325
5	*Pterocarpus marsupium*	20.68	23.28	16.19	482.2	487.7	0.6493
6	*Atrocarpus heterophyllus*	11.6	23.68	8.49	603.8	807.5	0.533
7	*Swietenia mahogany*	11.65	51.03	11.5	553.5	480	0.9344
8	*Casuarina junghuhniana*	10.78	45.86	11.11	635.6	632.1	0.75
	Mean	15.085	38.57875	11.02875	568.425	590.5875	0.6455125

Density: The study also examined the basic and bulk densities of the eight species. *Melia dubia* (melia) and *Artocarpus heterophyllus* (jackfruit) showed the highest basic density and bulk density, with values of 684.5 kg/m³ and 807.5 kg/m³, respectively. These densities suggest that melia and jackfruit are denser woods, which could be advantageous in applications requiring durable and strong materials. In contrast, the lowest densities were observed in *Pterocarpus marsupium* (kino) and *Neolamarkia cadamba* (kadamba), with basic density values of 482.2 kg/m³ and 465.1 kg/m³, respectively. These species' lower densities could indicate their suitability for applications where lighter wood is preferable. Specific Gravity: The specific gravity of the wood samples, which reflects their density relative to water, also showed notable differences among the species. The highest specific gravity was recorded for

Swietenia macrophylla (mahogany) at 0.934, indicating a relatively dense wood structure. This high specific gravity could make mahogany particularly suitable for furniture and other applications requiring hard, dense wood. In contrast, *Neolamarkia cadamba* (kadamba) had the lowest specific gravity at 0.511, suggesting it is a lighter wood, which might be preferred for applications where weight is a consideration. Overall, the study's findings provide valuable insights into the physical properties of these eight tree species. The variations in moisture content, swelling and shrinkage, density, and specific gravity highlight the diverse characteristics of these woods, which could inform their selection and use in various industrial applications, such as furniture making, construction, and other areas where specific wood properties are desired.

Wood is a hygroscopic material, meaning it has the natural ability to absorb or release moisture depending on the relative humidity (RH) of the surrounding air. This property of wood is crucial for understanding how it behaves in different environmental conditions. When the RH of the air increases, wood absorbs moisture from the environment and expands; conversely, when the RH decreases, wood releases moisture and contracts. This hygroscopic nature is a vital consideration for its application in various industries, as the acceptable moisture level in wood depends significantly on its intended final use and the average RH of the environment in which it will be utilized. For example, for wood products used indoors, common guidelines suggest that the moisture content should ideally range between 6% to 8% for wood flooring, 6% to 9% for furniture, and 9% to 14% for construction purposes (Asdrubali *et al*., 2017). The moisture content levels recorded in the study for different species *Tectona grandis* (11.01%), *Artocarpus heterophyllus* (11.6%), *Swietenia mahogany* (11.65%), and *Casuarina junghuhniana* (10.78%) align with these guidelines, indicating their suitability for use in furniture and construction industries where maintaining specific moisture levels is critical for durability and stability.

The concept of basic density in wood is another important physical characteristic that determines the relationship between the dry mass of the wood and its solid volume. Essentially, it measures how much dry wood weighs per unit volume. This metric is particularly significant because it directly influences the mechanical properties of wood, such as its tear resistance, compressive strength, and bending strength. Research by Srivaro *et al*. (2021) indicates that variations in basic density can account for approximately 70% to 80% of the variations in these strength parameters. This highlights the crucial role of wood density in determining the overall strength and performance of wood in practical applications. Zobel *et al*. (1995) further emphasized that a higher basic density is widely recognized as a key factor for assessing the strength of wood. From the current study, the highest wood density was recorded in *Melia dubia* at 684.5 kg/m³, suggesting that this species possesses a denser wood structure, which may be advantageous for applications requiring strong, durable wood.

Specific gravity is another vital parameter that provides insights into the physical properties of wood. It is particularly important for wood identification and quality assessment, as it reflects the density of the wood relative to water. A higher specific gravity generally indicates a denser, stronger wood, which is often preferred for certain applications. In the study, *Swietenia mahogany* exhibited the highest specific gravity of 0.9344, highlighting its potential suitability for applications that demand high-density wood, such as in high-quality furniture making and specialized construction. The physical properties of shrinking and swelling in wood are of great importance due to their impact on various aspects of wood utilization and performance. Wood's tendency to shrink and swell as its moisture content changes can affect its dimensional stability and, subsequently, its usability in applications such as joinery, fastening, flooring, and woodwork. Minimizing these dimensional changes is crucial for maximizing wood's performance, longevity, and usability in these applications. In this study, *Acrocarpusfraxinifolius* showed the minimum swelling percentage at 18.56%, indicating its stability and suitability for applications where dimensional stability is a critical requirement. On the other hand, *Pterocarpus marsupium* registered the maximum shrinkage percentage at 16.19%, which could affect its performance in environments with fluctuating humidity levels.

CONCLUSION

In summary, the study provides valuable insights into the physicochemical properties of different wood species, emphasizing the importance of parameters such as moisture content, density, specific gravity, and dimensional stability in determining their suitability for various industrial applications. Understanding these properties allows for better selection and use of wood species in furniture making, construction, and other sectors where wood quality is paramount.

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