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Comparative Evaluation of Physical and Mechanical Properties in the Radial Positions of Coconut (*Cocos nucifera*) Timber

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

This study evaluated the variation of the physical and mechanical properties within coconut timber's radial position (dermal, sub-dermal, core). Properties were studied on the 55-year-old coconut palm from KAU coconut farm Vellanikkara, in Thrissur, district Kerala. The density of coconut timber at the radial positions was 862.3 kg m^{-3}, 670.8 kg m^{-3} and 287.9 kg m^{-3}, respectively, for the dermal, sub-dermal, and core positions. The average moisture content of coconut timber in the dermal, sub-dermal, and core positions was 15.7 %, 16.6 %, and 17.5 %, respectively. Compressive strength parallel to the grain at the three radial positions such as dermal, sub-dermal, and core is 32764.77 kg cm^{-2}, 25591 kg cm^{-2}, 7532.35 kg cm^{-2}, respectively, and the compressive strength perpendicular to the grain was found as 46712.42 kg cm^{-2}, 39233.3 kg cm^{-2}, 22353.04 kg cm^{-2}. Hardness measured at the side and ends of the dermal position is 1207.612 kg and 767.65 kg, respectively. In the sub-dermal position, 1035.7 kg and 750.88 kg, respectively. The core position is 252.34 kg and 359.31 kg, respectively.

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1. INTRODUCTION

The coconut palm (*Cocos nucifera*) is the most important tropical crop under *Arecaceae.* Because of the multi-purpose use of coconut palm is often called the "Tree of life." Coconut palm is the most cultivable crop in almost all areas of the Kerala region. It bears food, fuel, cosmetics, and building materials and has many other uses. In Kerala, coconut is the inevitable ingredient in foods. Due to the high strength properties of coconut timber, it is used as structural components such as housing components like trusses, purlins, walls, joists, doors, and window frames [1].

The timber of the coconut palm is called "porcupine wood" and has a nice-looking, fragmented appearance. Coconut wood has proven to be comparable to conventional wood in durability, sturdiness, and versatility, often at a considerably lower cost [2]. Using coconut wood as a substitute material for building construction could reduce the cost of housing units.

Physical properties are the key factor in selecting coconut timber for various uses such as furniture, building materials, cabinet making, construction of the frame, bridge, sporting goods, measuring instruments, musical instruments, particle boards, decorative surfaces, insulating media, etc. [3]. Based on the density of the coconut timber, it can be used for loading and non–loaded structural components. Low-density timber is mainly used for non-loading structures, and high-density timbers are used for load-bearing materials [4,2].

Mechanical properties resist external forces (static or dynamic load) Sekhar et al. [5]; Panshin and De Zeeuw [6]. These properties are essential in considering the timbers for structural and construction purposes.

As the coconut is the major crop in Kerala and the neighboring state, Tamil Nadu's large plantations of the coconut palm are transformed into residential areas that require cutting and efficient utilization of this fallen trunk. Under the pilot project by Coconut Development Board, Kerala has announced a replanting and rejuvenation program. It is aimed to remove the senile and diseased plants by planting new ones. Efficient disposal of fallen trunks is by converting them into sealable wood products, and it also is an additional source of income for new growers [2]. Thus the information of properties makes it more advanced to use coconut timber as wood products. So, the study aims to determine timber's physical and mechanical properties to assess the coconut timber for structural purposes.

2. MATERIALS AND METHODS

Coconut palm was collected from the KAU coconut farm of Vellanikkara, Thrissur dist. Kerala. Sample trees were 55 years old and free from knots and other imperfections.

2.1 Density

According to IS 1708: 1986 (ISI, 1986) the required sample size for density was 6 cm x 2 cm x 2 cm and for moisture content determination was 2.5 cm x 2 cm x 2 cm. These cut specimens were made by using a plain saw.

A set of six samples were taken from the three radial positions to examine the variations.

The samples were kept oven-dry in a hot air oven for 103 ± 2 °C. Oven-dried samples were weighed with an accuracy of 0.001 g in a weighing balance.

- Density was calculated as the following equation.

$$\text{Density} = \frac{W}{V} \quad (1)$$

Where,

W= oven-dry weight, kg
V= Volume of the sample at test, m^3

2.2 Moisture Content

- The percentage of moisture content was calculated as the following equation.

$$\frac{w1}{w1-w0} \text{x } 100 \quad (2)$$

Where,

w_1 - Weight of sample at test in g
w_0 - oven dry weight of sample in g

2.3 Mechanical Properties

Mechanical properties such as compressive strength (parallel and perpendicular to the grain) and hardness were tested using an automatic Universal Testing Machine (UTM- Shimadzu 100 KN). These tests were conducted at the central wood testing laboratory, The Rubber Board, Kottayam.

According to IS 1708: 1986 (ISI, 1986), the sample size required for various mechanical properties testing is as follows. Compressive strength parallel to the grain (8 cm x 2 cm x 2 cm), Compressive strength perpendicular to grain (10 cm x 2 cm x 2 cm), and Hardness test (15 cm x 5 cm x 5 cm).

3. RESULTS AND DISCUSSION

3.1 Density

The density at the three radial positions varies greatly (Fig. 1). The highest mean density was at the dermal position (862.27 kg m^{-3}) and the lowest at the core (central) position (287.94 kg m^{-3}) (Table 1).

3.2 Moisture Content

The moisture content was different among the radial position (Fig. 2). The moisture content ranges from 15.7 % to 17.5 % (Table 1). The highest moisture content was at the central core position; thus, it is unsuitable for making load-bearing structural components. There is a significant moisture content variation among the three radial positions of coconut timber.

3.3 Mechanical Properties

3.3.1 Compressive strength

The palm's compressive strength (parallel to the grain and perpendicular to the grain) varies within the radial position. The highest strength is in the dermal position in both cases, i.e., 32764.77 kg cm^{-2} (Table 2) and 46712.42 kg cm^{-2} (Table 3). Figs. 4 & 5 shows the variation of compressive stress (parallel and perpendicular to the grain) between the radial positions.

Table 1. Density and moisture content variation at three radial positions

Sl. no	Radial position	Density (kg m^{-3})	Moisture content %
1	Dermal	862.27 (25.59)	15.559 (0252)
2	Sub-Dermal	670.75 (87.88)	16.58 (0.198)
3	Core	287.94 (14.89)	17.28 (0.432)

Note: Values in the parenthesis show standard deviation,
Significant within radial positions at 5% level

3.3.2 Hardness

The resistance to the indentation (hardness) is more for the dermal position (1207.61 kg, 767.65 kg) and is lesser for the core position (252.587 kg, 359.31 kg) on both sides and ends of coconut timber (Table 4).

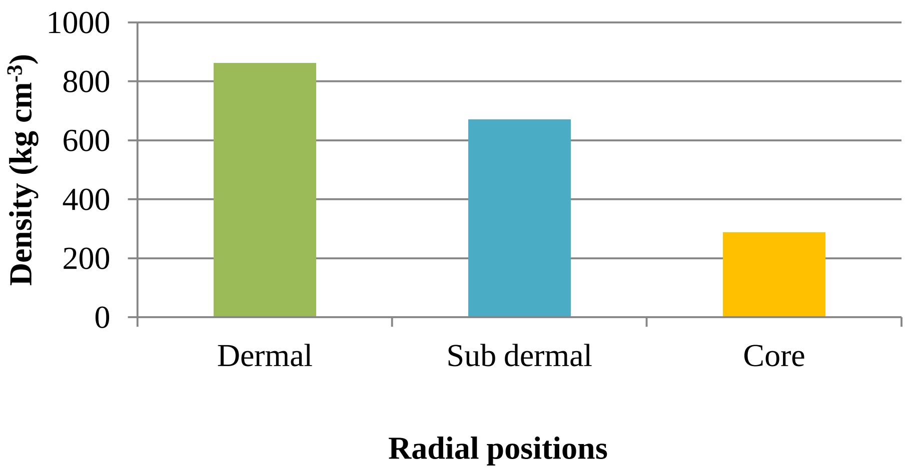

Fig. 1. Density variation at three radial positions

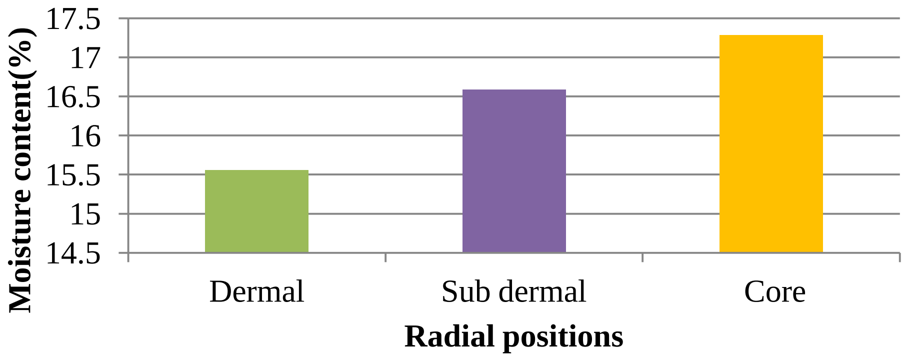

Fig. 2. Moisture content variation at three radial positions

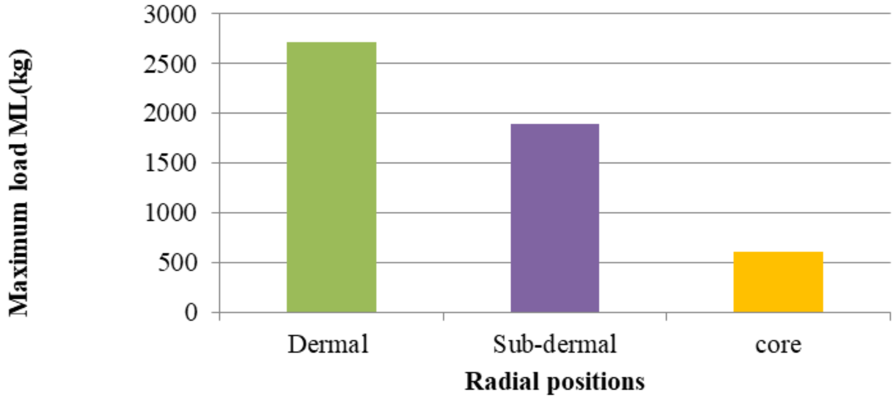

Fig. 3. Variations of ML for compression parallel to the grain between the three radial positions

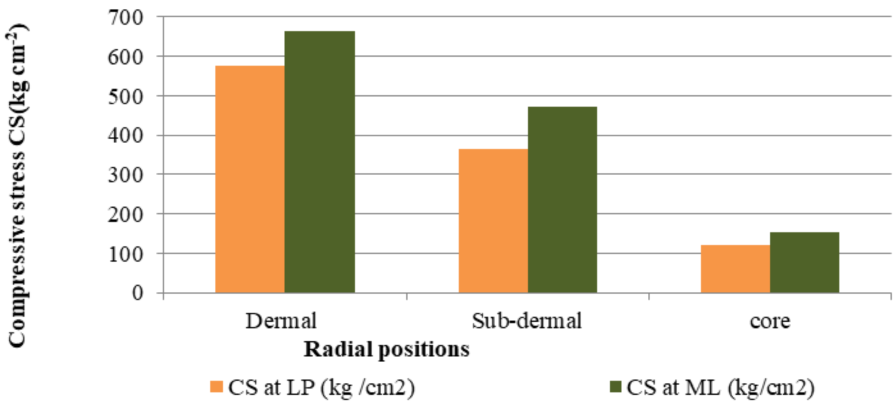

Fig. 4. Compression perpendicular to the grain in between radial position of coconut timber

3.4 Discussion

This study was conducted to evaluate and compare the physical and mechanical properties of coconut timber at three radial positions (dermal, sub-dermal, and core). Coconut timber has reminiscent appearance to conventional woods. And it has high strength characteristics. The timber can be used for high load bearing structures such as constructional purposes. Physical properties like density and moisture content varies in the radial positions dermal portion has higher density (862.3 kg m^{-3}), and lower moisture content (15.7 %). Mechanical properties like compressive strength parallel and perpendicular to the grain also determined to know how much is the strength of coconut timber [7,8]. The most hardness and strength is at dermal portion than the other two radial position. The compressive strength parallel and perpendicular to the grain are 32764.77 kg-cm^{-2} and 46712.42 kg-cm^{-2}, respectively and the hardness of dermal portion is 1207.612 kg, and 767.65 kg respectively. This results indicate that dermal portion is most suitable for the construction purposes such as load bearing structures.

Table 2. Compression parallel to the grain in between the radial position

Sl. No	Radial position	Compressive stress (CS) at limit of proportionality (kg cm^{-2})	Compressive stress (CS) at maximum load (ML) (kg cm^{-2})	Modulus of elasticity (MOE) (kg cm^{-2})	Maximum load (ML) kg
1	Dermal	576.3 (15.5)	668.98 (21.42)	32764.77 (5539.46)	2706.7 (86.71)
2	Sub-Dermal	364 (62.59)	470.65 (59.48)	25591 (5691.85	1885 (238.58)
3	Core	119.18 (27.25)	152.07 (40.8)	7532.35 (208.96)	612.58 (166.1)

Note: Values in the parenthesis show standard deviation, Significant within radial positions at 5% level

Table 3. Compression perpendicular to the grain in between the radial position

Sl. No	Radial position	Compressive stress (CS) at limit of proportionality (kg cm^{-2})	Compressive stress (CS) at 2.5 mm (kg cm^{-2})	Modulus of elasticity (MOE) (kg cm^{-2})	Load at 2.5 mm kg
1	Dermal	557.54 (90.92)	718.64 (137.68)	46712.42 (1035.34)	2878.42 (550.92)
2	Sub-dermal	40128 (64.5)	519.02 (70.59)	39233.3 (2973.41)	2078.2 (282.59)
3	Core	286.2 (34.95)	342.42 (42.67)	22353..04 (2032.8)	1372.96 (171.21)

Note: Values in the parenthesis show standard deviation, Significant within radial positions at 5% level

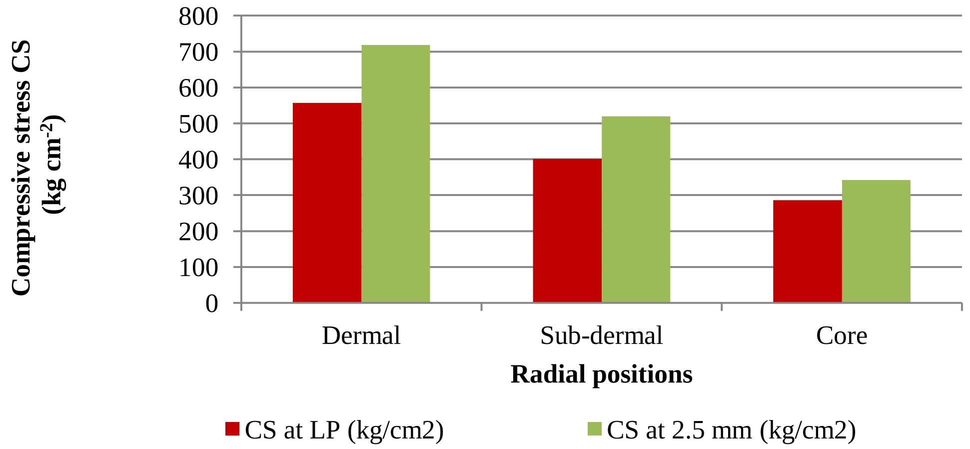

Fig. 5. Compressive stress perpendicular to the grain in between radial positions

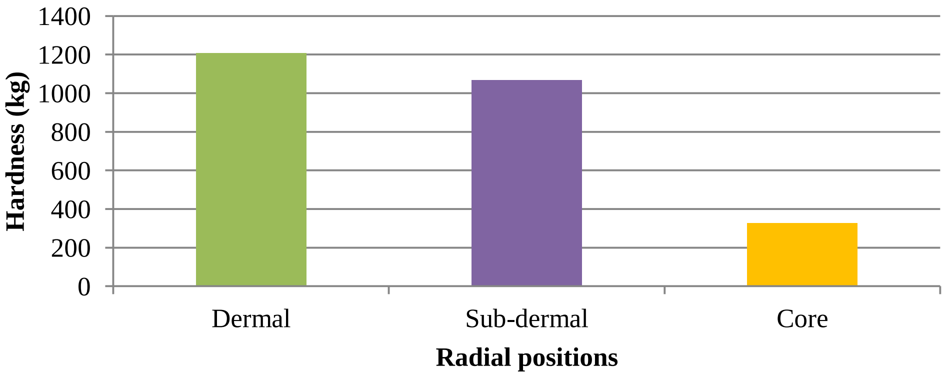

Fig. 6. Hardness at the sides of radial position

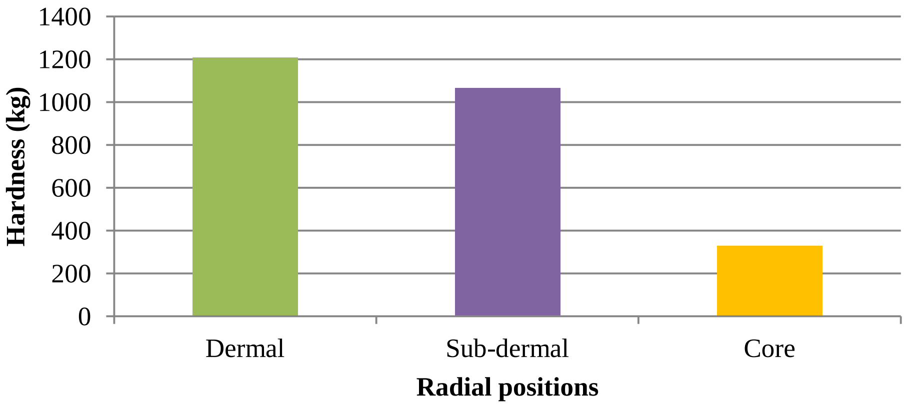

Fig. 7. Hardness at the ends of radial position

Table 4. Hardness at the radial position

Sl. no	Radial position	Hardness	
		Side (kg)	End (kg)
1	Dermal	1207.612 (82.746)	767.65 (224.69)
2	Sub-dermal	1035.7 (61.782)	750.88 (78.43)
3	Core	252.587 (164.69)	359.31 (50.65)

Note: Values in the parenthesis show standard deviation,
Significant within radial positions at 5% level

4. CONCLUSION

The following detail are concluded results from the current study of evaluation of physical and mechanical properties of coconut timber. The density of coconut timber at the radial positions (dermal, sub-dermal, and core) was 862.3 kg m^{-3}, 670.8 kg m^{-3} and 287.9 kg m^{-3}, respectively. The moisture content measured 15.7 %, 16.6 %, and 17.5 %. Compressive strength parallel to the grain was 32764.77 kg-cm^{-2}, 25591 kg cm^{-2}, 7532.35 kg-cm^{-2} and compressive strength perpendicular to the grain was found to be 46712.42 kg-cm^{-2}, 39233.3 kg-cm^{-2}, 22353.04 kg-cm^{-2}. Hardness at side and end of three radial position are as follows, for dermal position (1207.612 kg, 767.65 kg), sub-dermal (1035.7 kg, 750.88 kg), core (359.31 kg). Further studies are required to find out other properties. This study focuses on the usage of coconut timber for structural purposes.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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