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Engineering properties of wood under different drying methods

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Abstract

This project work focuses on the comparison of the engineering properties of *Pyrus communis* under solar and air-drying method. Green samples of the wood were dried simultaneously in both solar kiln and open air for 15 days. The daily moisture content reduction (%MC) under both drying conditions were observed and recorded. Mechanical tests (shear strength, compressive strength, hardness and tensile strength) were conducted. The results showed that open air-dried woods attained fibre saturation point (30-25%MC) within three days. Timbers dried in solar kiln attained lower %MC (12.9, 11.0, 14.3, 12.3) when compared to open-air dried samples (22.1, 18.5, 21.1, 17.1). For all the mechanical tests conducted, solar kiln dried timber had higher mechanical properties than the open air-dried woods.

Keywords: Wood; Drying; Engineering; *Pyrus communis*; Moisture content

1. Introduction

The high moisture content of freshly milled wood affects its properties, necessitating the reduction of the timber moisture content prior to its use. Moisture reduction from wood improves its mechanical properties such as hardness, shear strength, compressibility strength, tensile strength etc. Over the years, various moisture removal methods have been used, they include uncontrolled (air drying) and controlled (kilns) [1].

Drying is a process of removing moisture involving a simultaneous heat and mass transfer under the influence of air temperature, velocity and relative humidity [2]. Drying ensures the attainment of equilibrium moisture content of timber, thereby enhancing shelf life, value addition, volume reduction, workability, strength and quality enhancement [3,4]. In open-air or natural drying method, which takes a lot of drying time, drying is achieved under direct exposure of woods to ambient air, ambient temperature, relative humidity and natural wind. Solar kiln methods attain faster and more uniform drying in a controlled environment [5,6,7].

According to Miri Tari *et al.* [8], aside moisture removal, drying influences the internal drying strain and stresses and rate of cracks and checks. At high temperatures, mechanical properties are decreased, and defects increased [9]. Studies in the past have discussed the drying rate of local species, others investigated the effects of different wood drying types on physical and mechanical properties [1,8,10,11]. No previous study has been reported on the impact of drying methods on the engineering (mechanical and physical) properties of *Pyrus communis.* This paper reports on a study conducted to understand the effect of open air and solar kiln drying on the engineering properties (compressive strength, shear strength, tensile strength, and hardness) of a selected wood specie and recommend which is better.

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2. Material and methods

Freshly *pyrus communis* was gotten from Edemani in Nsukka, latitude 6.8°N, Nigeria. The timber was cut into 8 sample boards and labelled A-H. A-D was stacked in the solar kiln developed by [1] for solar drying while E-H was stacked outside for the air drying. Timber load was stacked between stickers of 25mm thickness and stacked at least 75 cm away from both top and bottom of the chamber to enable proper circulation of heated air as shown in Fig 1.

The moisture content and the mechanical tests were carried out using OHAUS Triple Beam Balance, Fisher Scientific Isotemp Oven Model 655F, Berkel weighing Balance NR139964, Vickers's hardness testing machine, Impact strength testing machine, Universal testing machine, Mass cylinder and Pendulum testing machine at the wood workshop section of the Department of Civil Engineering, University of Nigeria.

Figure 1 Wood stacked in the solar kiln and wood stacked in open air environment

2.1. Physical Properties (Moisture content)

These timber boards were representative of the slowest drying part (widest, thickest, highest moisture content and free of knots) [12] as reported in [1]. Using Eq. (1), the moisture content (MC) of each section was calculated and the average MC of the two sections was computed to obtain the initial MC of the sample board.

$$MC\% = \left(\frac{weight\ of\ wet\ section}{weight\ of\ oven\ dried\ section} - 1\right) X100 \qquad [1]$$

The wet sample boards were weighed within 5g accuracy and recorded. The average MC from Eq. 1 and 2 were used in estimated the oven-dry weight.

$$Estimated\ oven\ drying\ weight\ (g) = \frac{weight\ of\ sample\ board}{100+MC\%} \qquad [2]$$

The sample boards were reweighed daily and the MC for each day calculated using Eq. 3, the daily weight of each board and the MC(%) were recorded.

$$Current\ MC(\%) = \left(\frac{current\ weight\ of\ sample\ board}{Estimated\ oven\ dry\ weight} - 1\right) X100 \qquad [3]$$

2.2. Mechanical Properties

2.2.1. Shear strength

Shear strength of wood is the measure of its ability to resist internal slipping of one layer relative to another along the grain, and it is defined by the maximum load per shear plane area. The shear strength was conducted using universal testing machine as reported in Simpson [13], Mujumdar [14] and Uetimane [15]. The horizontal shear strength (N) was determined using Eq. 4.

$$Shear\ strength = \frac{Shearing\ force\ (F)}{Area\ sheared\ (A)} \qquad [4]$$

2.2.2. Tensile strength

A material's static strength is the resistance to permanent deformed. This kind of strength tends to prevent bending, twisting or denting of a material permanently in service. The tensile strength (TS) was determined as shown in Eq. (5).

$$Tensile\ strength = \frac{ultimate\ load\ (P)}{cross\ sectional\ area\ (A)} \qquad [5]$$

2.2.3. Hardness

Hardness is a characteristic of a material, not a fundamental physical property. It is defined as the resistance to indentation, and it is determined by measuring the permanent depth of the indentation. Indentation hardness obtained by measuring the depth or the area of the indentation using Vickers hardness test method as shown in Eq. (6).

$$HBN = \frac{2P}{\frac{2\pi}{D}(D^2\sqrt{D^2-d^2})} \qquad [6]$$

Where: HBN = Brinnel Hardness no, D = Brinnel bulb diameter (indenter), d = depth of indentation
P = constant axial load.

2.2.4. Compressibility strength

Compressive strength is the capacity of a material or structure to withstand loads tending to reduce its size. Compressive strength resists compression (being pushed together), the compressive strength of wood parallel to the grain is much higher than that perpendicular to the grain. Compressive strength was calculated using Eq. (7).

$$Compressibility\ strength = \frac{maximum\ load(kilo\ N)}{cross\ sectional\ area\ (M^2)} \qquad [7]$$

3. Results and discussion

3.1. Physical properties

After the oven-drying process and the simultaneous drying of the wood stacks in both open air and in solar kiln for 15 days, weights of all sample boards were obtained daily for calculation of the daily moisture content. Results of daily weight and %MC are shown in Tab.1 and Fig.2.

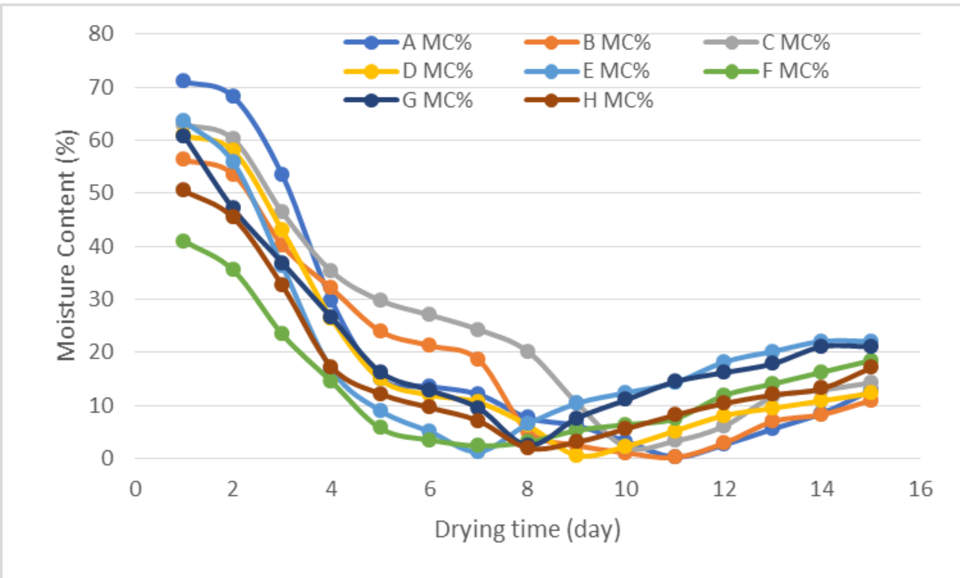

Figure 2 Graph of %MC samples A-H

Table 1 Weight and moisture content reading for the solar kiln (samples A – D) and air drying (samples E – H) methods

Sample Number		**Green Weight (kg)**	**Day**														
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
A	Weight	5.8	5.8	5.7	5.2	4.4	3.9	3.85	3.8	3.7	3.6	3.5	3.4	3.3	3.2	3.1	3.0
	MC%	71.1	71.1	68.2	53.4	29.8	15.1	13.6	12.1	7.69	6.2	3.25	0.3	2.6	5.6	8.55	12.9
B	Weight	5.8	5.8	5.7	5.2	4.9	4.6	4.5	4.4	3.9	3.8	3.75	3.7	3.6	3.45	3.4	3.3
	MC%	56.3	56.3	53.6	40.2	32.1	24.0	21.3	18.6	5.2	2.5	1.1	0.2	2.9	7.0	8.3	11.0
C	Weight	5.9	5.9	5.8	5.3	4.9	4.7	4.6	4.5	4.4	4.0	3.7	3.5	3.4	3.2	3.2	3.1
	MC%	63.0	63.0	60.2	46.4	35.3	29.8	27.1	24.3	20.2	10.5	2.2	3.3	6.1	11.6	12.9	14.3
D	Weight	5.6	5.6	5.5	5.0	4.4	4.0	3.9	3.85	3.7	3.5	3.40	3.3	3.2	3.15	3.10	3.05
	MC%	60.9	60.9	58.0	43.0	26.4	14.9	12.0	10.6	6.3	0.6	2.3	5.2	8.1	9.5	10.9	12.3
E	Weight	4.2	4.2	4.0	3.5	3.0	2.8	2.7	2.6	2.4	2.3	2.25	2.2	2.1	2.05	2.0	2.0
	MC%	63.6	63.6	55.8	36.3	16.8	9.03	5.1	1.3	6.5	10.4	12.4	14.3	18.2	20.2	22.1	22.1
F	Weight	6.4	6.4	6.2	5.6	5.2	4.8	4.7	4.65	4.4	4.3	4.25	4.2	4.0	3.9	3.8	3.7
	MC%	41.0	41.0	35.5	23.4	14.5	5.7	3.5	2.4	3.1	5.3	6.4	7.5	11.9	14.1	16.3	18.5
G	Weight	4.7	4.7	4.3	4.0	3.7	3.4	3.3	3.2	2.9	2.7	2.6	2.5	2.45	2.4	2.3	2.3
	MC%	60.8	60.8	47.1	36.9	26.6	16.3	12.9	9.5	2.5	7.6	11.05	14.5	16.2	17.9	21.1	21.1
H	Weight	5.9	5.9	5.7	5.2	4.6	4.4	4.3	4.2	4.0	3.8	3.7	3.6	3.5	3.45	3.4	3.3
	MC%	50.5	50.5	45.4	32.6	17.3	12.2	9.6	7.1	2.0	3.1	5.6	8.2	10.4	12.0	13.2	17.1

Sample A, B, C and D dried in the solar kiln and were compared to the open-air dried samples E, F, G and H for a period of 15 days as shown in graph in Fig. 2 below. It was seen that the %MC in sample E attained the fibre saturation point before the sample A. The fibre saturation point of sample A was attained on the third day, the drying rate was maintained till it reached the equilibrium moisture content of 12.0% which is remarkable as compared to 22.1% MC attained by air drying. Sample B was compared to sample F, it was seen that the moisture content in sample F attained the fibre saturation point before the sample B, but the fast rate of drying was not maintained unlike in the case of sample B, which attained the fibre saturation point and maintained its drying rate till it reached the equilibrium moisture content of 11.0% which is remarkable as compared to 18.5% MC attained by air drying.

Sample G attained the fibre saturation point before the sample C but could not maintain the fast-drying rate. But in the case of sample C it attained the fibre saturation point and was able to maintain its drying rate till it reached the equilibrium moisture content of 14.3% which is remarkable as compared to 21.1% EMC attained by air drying. Sample H attained the fibre saturation point before the sample D but could not maintain the fast-drying rate. But in the case of sample D it attained the fibre saturation point and was able to maintain its drying rate till it reached the equilibrium moisture content of 12.3% which is remarkable as compared to 17.1% EMC attained by air drying. The results of %MC in Table 1 and Fig. 2 showed similarity when compared with Helwa [16], which reported that timbers were dried for 17days attained 12.0%MC in solar kiln dryer and 20.0% under air drying condition.

3.2. Mechanical Test Results

The mechanical properties of wood are always in relationship with the percent moisture content [17]. In view of this, sample A (solar dried) and sample E (air dried) to 12.0%MC and 22.1%MC respectively, were compared as shown in Fig. 3a below and it was seen that the mechanical properties of sample A dried under the solar kiln showed more advance in properties with shear strength 137.20 N/mm^2, compressive strength 14.80N/mm^2, hardness 82.9N/mm^2 and tensile strength of 35.96N/mm^2 as compared to sample E dried under air with shear strength 135.84 N/mm^2 compressive strength 14.63N/mm^2 hardness 82.67N/mm^2 and tensile strength of 35.77N/mm^2.Sample C (solar dried) and sample G (Air dried) to 14.3%MC and 21.1 % MC respectively, were compared and showed in Fig. 3a that the mechanical properties of sample C dried under the solar kiln showed more advance in properties with shear strength 137.66 N/mm^2, compressive strength 14.83 N/mm^2, hardness 82.2 N/mm^2 and tensile strength of 36.34 N/mm^{2}as compared to sample G dried under air with shear strength 135.71N/mm^2 compressive strength 14.72 N/mm^2 hardness 81.71 N/mm^2 and tensile strength of 35.76 N/mm^2.

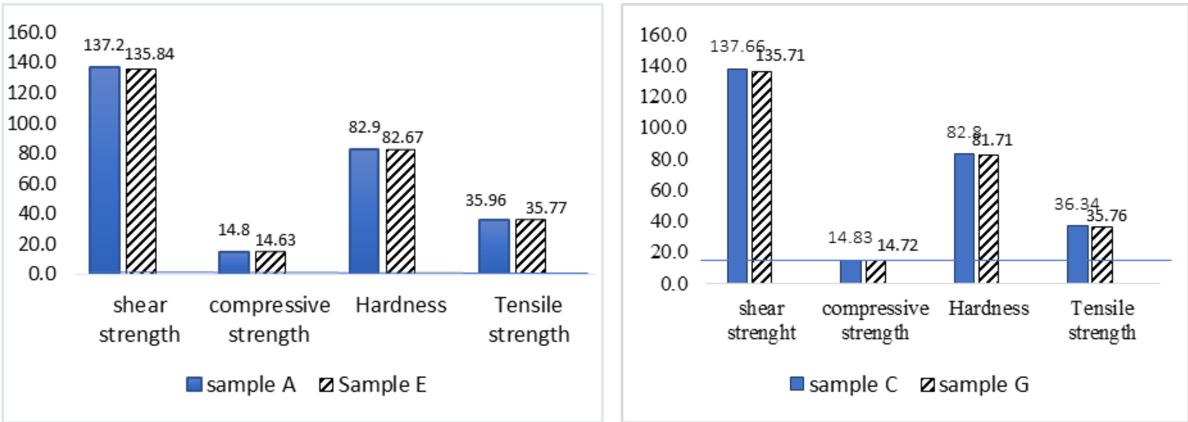

Figure 3a Mechanical Properties of Sample A and E; C and G

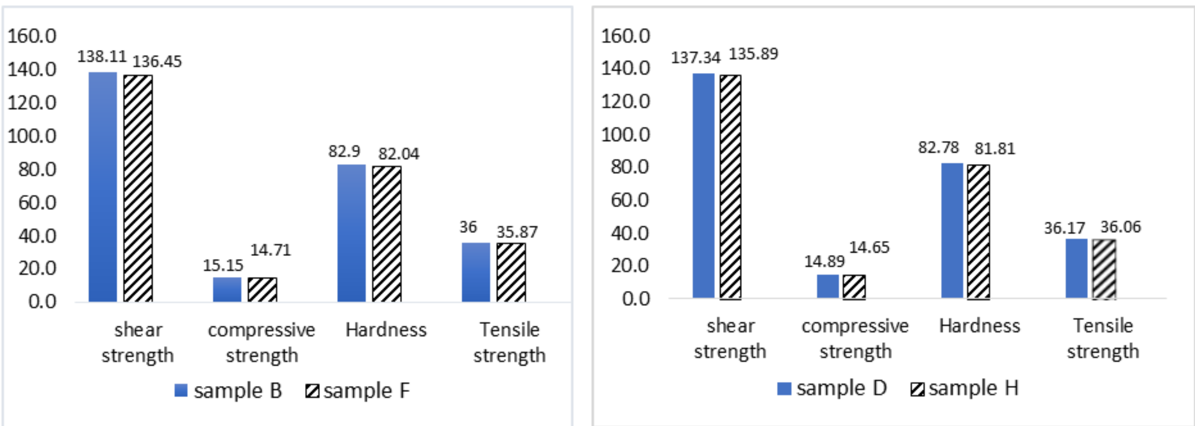

Figure 3b Mechanical Properties of Sample B and F; D and H

In comparing the mechanical properties of sample B (solar dried) with sample F (air dried) and sample D (solar dried) and sample H (air dried) with a moisture content of 11.0% and 18.5% and 12.3% and 17.1% respectively, as shown in Fig. 3b below, it can be observed that similar trends of higher mechanical properties in solar dried samples exists. This is in line with the reports of Uetimane [15] and Jacek et al. [17], which revealed that woods dried under controlled environment had higher mechanical properties.

4. Conclusion

This study evaluated the influence of open-air drying and solar kiln drying on the engineering properties of *Pyrus communis.* The open-air drying system attained fibre saturation point (25%-30% MC) faster than the solar kiln drier. Lower %MC was attained by the solar kiln dried timbers. The mechanical properties of the wood showed higher mechanical properties especially in the case of Sample B with the average hardness of 82.9N/mm^2, shear strength of 138.11N/mm^2, compressive strength of 15.15 N/mm^2, and tensile strength of 36.00N/mm^2. Lower mechanical properties were showed by the open-air dried. Better moisture reduction and improved mechanical properties of a woods dried in solar kiln, suggests that solar kiln drier enhanced the engineering properties of timbers when compared to the ones dried in the open air drying.

Compliance with ethical standards

Acknowledgments

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Disclosure of conflict of interest

The authors declare that there is no conflict of interest in the preparation and submission of this paper.

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