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Water Absorption Behavior of *Bombax ceiba* after Exposing to Various Levels of Relative Humidity

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ABSTRACT

Wood is a hygroscopic material having the tendency to absorb and desorbs moisture with respect to atmospheric relative humidity and temperature. To study the moisture absorption behavior, wood specimens were exposed to varied levels of relative humidity in control environment at ambient temperature. Wood specimens were exposed to 75%, 55%, 43% and 33% relative humidity in desiccators for over 350 hrs. Weight percent gain, density and volume change of the specimens were recorded with respect to time. The mean density of the samples was 0.45 kg/m^3.Weight percent gain (WPG) increased went on increasing as the specimens were exposed for longer duration. Highest WPG was observed in case of 75% relative humidity and lowest at 33% relative humidity 22.45 and 5.27% respectively. Good relationship was observed with WPG and density.

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INTRODUCTION

Study of moisture absorption behavior is an integral part of any product development from lingo-cellulosic material like wood and bamboo. Ligno-cellulosic material has the tendency to interact with external moisture available in the ambient air, due to which wood either gains weight and swells (Fredriksson 2019). Absorbed moisture in wood is a cause of concern and potential parameter for fungal growth on wood. Wood being hygroscopic in nature, it tries to come in equal levels of humidity or moisture present in wood during its service life. In the process wood either swells or shrinks. This loss or gain in weight because of moisture movements in wood gives a typical sorption isotherm (Tremblay *et al*. 1996).

Information on physical properties such as dimensional stability, swelling of wood, response of wood with respect to relative humidity levels are vital to maximize value addition on wood products (Shukla and Kamdem 2009). Dimensional stability of wood varies with species, density, direction of measurement, relative humidity, temperature, chemical composition in terms of lignin, microfibril angle, type and amount of extractives (Mantanis *et al.* 1994, Hernandez 2007). Dimensional stability of wood will adversely affect its performances, especially when wood is used in furniture (Cetera *et al.* 2019).

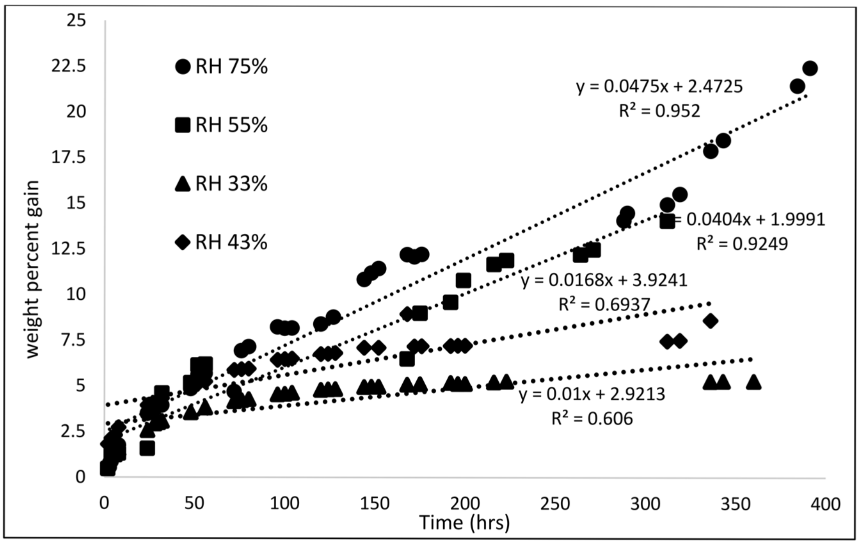

Fig. 1. Effect of different RH% on weight gain %.

Timber/wood of *Bombax ceiba* is a medium to low density wood. Wood is very much durable in submerged conditions hence used for small boats and catamarans. Apart from, it is also used for manufacturing of plywood, match boxes and sticks, scabbards. *Bombax ceiba* wood is cheaper compared to other hardwoods of medium to low density. It could serve as inexpensive replacement to existing conventional hard and softwoods. However, its softness and high biodegradable nature restrict its use (Saha *et al.* 2016). The objective of this research work was to observe the change in weight of wood specimens exposed to relative humidity at ambient temperature.

MATERIALS AND METHODS

Air dried and defect free, heartwood specimens of *Bombax ceiba* were sourced and cut into dimensions measuring 20 mm in width, 20 mm in thickness and 60 mm in length, according to IS 1708 Part II. Prior to exposing wood specimens to varied levels of relative humidity, they were oven dried and initial moisture content was recorded. At ambient temperature of 30 ± 2°C samples were exposed to 33, 43, 55 and 75%. The relative humidity was achieved by using selected saturated salt solution in desiccators as given in the Table 1. 10 wood specimens exposed to each RH%, were removed from the desiccators periodically and weighed to accuracy of 0.001g. Weight percent gain (WPG) was calculated using the given formula (equation 1). Density of the specimens is calculated based on oven dry weight of the samples.

Table 1. saturated salt solutions used to obtain RH% at ambient temperature.

Salt	RH%
Magnesium chloride	33 ± 2
Potassium carbonate	43 ± 2
Sodium dicromate	55 ± 2
Sodium chloride	75 ± 2

$$WPG = \frac{(W_0 - W_1)}{W_1} \times 100 \quad \text{eq. 1}$$

Where W_0, is periodical weight of specimen and W_1, is initial weight. WPG data was recorded for more than 350 hrs. The porosity of the wood specimens was calculated by the given equation 2 (Bowyer *et al.* 2007), Table 2.

Table 2. Basic properties of the specimens.

Density	Porosity
0.45 ± 0.033	69.55 ± 2.21

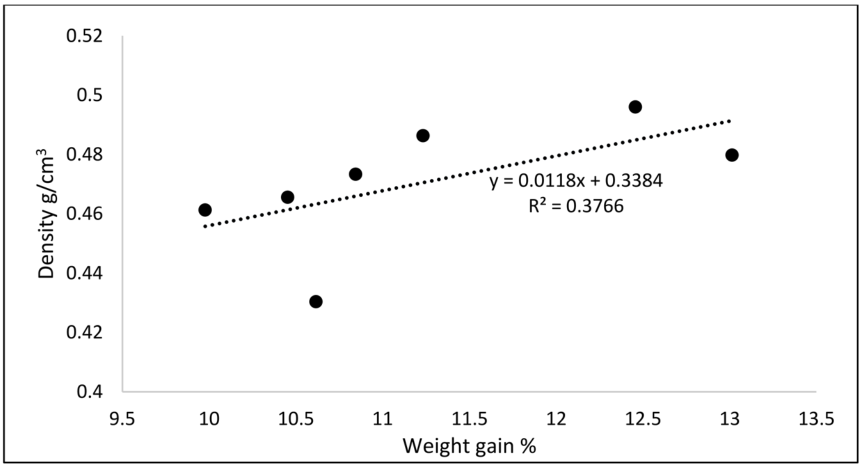

Fig. 2. Correlation between density and weight gain at 33% RH.

P (%) = (1–d/1.5) × 100 eq. 2

Where, d is oven dry specific gravity of the samples and 1.5 is the constant specific gravity of cell wall of lingo-cellulosic material.

RESULTS AND DISCUSSION

Fig. 1 shows the effect of different relative humidity percentages on weight gain of solid wood samples of *Bombax ceiba*. As one can observed from the figure that wood has gained highest weight when it was exposed to 75% RH at the end of more than 350 hrs. The lowest weight through-out the duration of the experiment was observed at 33% RH. At 75% RH maximum weight gain observed was 22.45% compared with initial weight of the oven dry sample. At 55% RH maximum weight gain observed was 14.06%, followed by wood exposed at 43% RH and lowest at 33% RH, with weight gain of 8.6 and 5.27% respectively. Wood is hygroscopic material. It adsorbs moisture upon exposure to weather conditions. Wood behaves differently at different levels of relative humidity. Oven dried wood specimen when it was exposed to higher relative (75%) humidity in a desiccators, it started gaining moisture, and it resulted in weight gain compared to initial dry weight. The same observations were observed when dried specimens were kept in desiccators having relative humidity of 33, 43, and 55%. Wood has cellulose, hemicelluloses, lignin and other extractives content. The higher the relative humidity, the greater the concentration gradient for the moisture diffusion in the material (Shi and Gardner 2006). Hence, in case of high RH% the

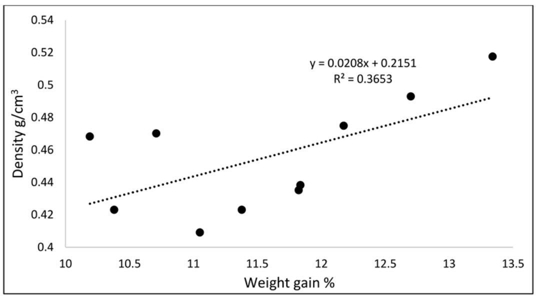

Fig. 3. Correlation between density and weight gain at 43% RH.

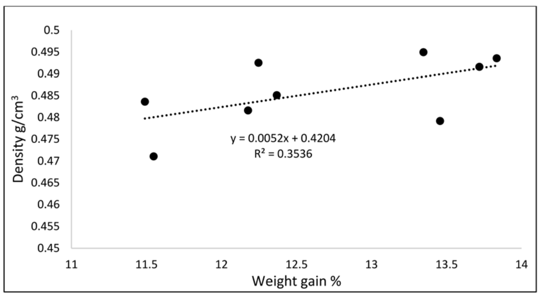

Fig. 4. Correlation between density and weight gain at 55% RH.

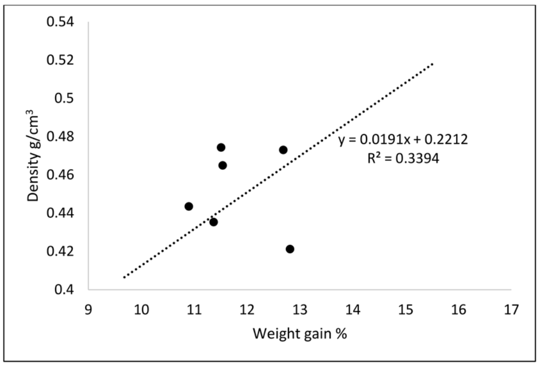

Fig. 5. Correlation between density and weight gain at 75% RH.

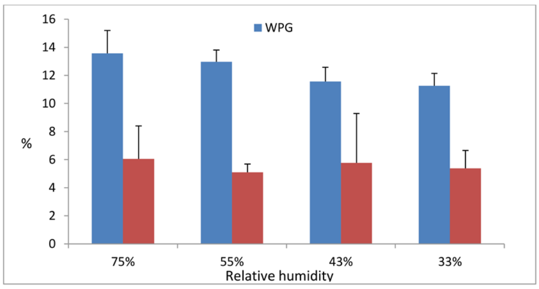

Fig. 6. Percentage change in volume and weight gain at saturation.

rate of moisture absorption is also higher than the lower RH%. The linear increase in weight because of moisture absorption in agreement with Zhang *et al.* (2016) and Tumuluru (2014).

In the Figs. 2—5 we can see the good linear correlation between the density of the wood and weight percentage gain at the end of more than 350 hrs exposure to respective RH%. In each case we can observe that, with slight increase in the density WPG has also increased. This may be due to the fact that the as the density of wood increases, more the amount woody mass accumulated per unit area. In the end, hydroxyl groups available for hydrogen bonding with external ambient relative humidity will be more. Moreover, since the wood is hygroscopic in nature, wood itself tries to come in equilibrium with ambient atmospheric humidity or the moisture present in the air. In this case wood tried to come in equilibrium with set RH% of 33, 43, 55 and 75%.

The Fig. 6 shows the WPG of the wood samples at the end of 350 hrs of exposure to wooden respective relative humidity percentages. When the samples have saturated themselves that means at this point, wood has come in equilibrium with atmospheric moisture.

CONCLUSION

The specimens were exposed to varied levels of relative humidity and repetitive readings of increase in weight were recorded. The highest weight percent gain was observed when samples were kept in 75% RH and rate of absorption of moisture is the as seen from the graphs. Sudden exposure of oven dry samples to high RH% environment may have triggered the hygroscopic behavior of wood and moisture absorption took place at higher rates. At lower RH% the samples, have saturated themselves quickly and rate of absorption is less than higher RH%. The linear increase the weight percent gain was observed in all the cases.

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