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Mechanical Properties of Medium Density Fibreboard Made from Admixture of Date Palm Branches and Bahan Wood in Several Commercial Trials

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ABSTRACT. The combination of wood and non-wood resources to produce wood composite products has become popular due to increased awareness of circular business practices. A commercial trial of medium density fiberboard (MDF) was carried out using a mixture of 50% date palm branches and 50% Bahan wood with six trials. The density of the MDF produced in the ranged of 663.33 kg/m^3 to 706.00 kg/m^3. This study investigates the effect of batch trial on modulus of elasticity (MOE), modulus of rupture (MOR) and internal bonding (IB) of the MDF. All the trial boards meet the minimum requirement of MOE (2000 MPa) except for trial no.2 (1997.33 MPa). For MOR value, only trial no. 3 met the minimum requirement of 23 MPa. Meanwhile, the majority of the MDF boards produced in this study did not meet the minimum requirement for IB. The findings revealed that some trial boards failed to meet the minimum MOR, MOE, and IB requirements. There was a significant positive correlation between density and MOR ($r = 0.706$) and MOE ($r = 0.514$), implying that the MOR and MOE of MDF board increased as density increased. A significant negative correlation ($r = 0.495$) was found between density and IB, indicating that IB decreased as board density increased. As a result, it was recommended that the MDF have a density of at least 706 kg/m^3 in order to meet the standard's minimum requirements.

Key words: Medium density fiberboard, Date palm, Bahan wood, Admixture materials, Density

INTRODUCTION

Lesser known and fast-growing tree biomass became popular in wood composite industry as alternative materials. Bahan (*Populus euphratica* Olivier) wood, also known as Euphrates poplar, is a tree native to the Middle East, southern Russia, India, and China. It is found in Pakistan in hot arid areas along river courses or where there is subsurface water. Woody portion of Bahan tree can be used for fuelwood or plywood. Meanwhile, its leaves can be used as fodder for sheep, goats, and camels, and its twigs can be chewed and used for teeth cleaning (Agroforestry Database 4.0, 2009). However, as a native species in Pakistan, the Bahan tree is underutilised due to its small log diameter. Meanwhile, as one of the world's largest producers and exporters of dates, the date palm (*Phoenix dactylifera* L.) is Pakistan's third most important fruit crop after citrus and mango (Abul-Soad et al., 2015). It has an estimation of 95,000 ha cultivation area in Pakistan in the year of 2012 (FAO, 2014). Both of these lignocellulosic materials could serve as a good alternative for a wide range of wood-based products.

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Medium density fiberboard (MDF) has been known to be made from date palm fronds and trunks (Jaber et al., 2016). Adam et al. (2018) produced MDF from date palm rachises and discovered that its strength performance is comparable to that of sugarcane bagasse-based MDF. More importantly, the use of date palm rachises can reduce the cost of storing and transporting sugarcane bagasse. Another study found that date palm pruning residues could be used as a raw material in the production of MDF (Hosseinkhani et al., 2015). The study's findings were encouraging, with MDF made from date palm pruning residues possessing strength properties that met the requirements specified in EN standards. Meanwhile, Bahan wood is a promising source of fibre for fine paper, packing paper, newsprint, and other paper grades (Orwa et al., 2009). According to Yadav et al. (2022), bahan wood is a potential source of high-quality pulp. However, in many countries, Bahan wood is still an unfertilized poplar species.

Several researchers have tested the feasibility of medium density fiberboard made from the admixture of two lignocellulosic materials. Harmaen et al. (2013) created MDF from empty fruit bunches (EFB) and rubberwood fibres. The results showed that the addition of EFB fibres reduced the strength performance of the MDF. However, when maintained at 30% EFB fibre loading, the resulting MDF has comparable performance to 100% rubberwood. Saharudin et al. (2020) produced fiberboard from co-refined rubberwood and kenaf core fibres and found that density is more important in determining fiberboard strength. However, one of the drawbacks of species admixture is that the bending strength of wood composites is lower than that of composites made of single species (Xu & Suchsland, 1998). This is because fibres with a lower density are more likely to float to the top of the mixing tank, absorbing a greater amount of resin than heavier fibres.

While date palm has long been recognised for its potential as a good fibre source for MDF production, Bahan wood has never been reported to be used in MDF production. Its suitability has yet to be determined. Therefore, the purpose of this study was to create MDF using a mixture of date palm branches and Bahan wood and to investigate the strength performance of the MDF.

METHODOLOGY

The fibers from admixture date palm branches and Bahan wood were refined using refiner before mixing it with wax and resin. A bonding agent or resin is used to coat the surface of the fibers. The fibers were dried and then formed into mats, which are finally hot pressed to form homogeneous board. The methodology for producing MDF from admixture date palm branches and Bahan wood (50%:50%) is presented in Figure 1. The MDF was obtained from a factory. Six MDF boards were obtained from a total of six trials, with each board from every trial.

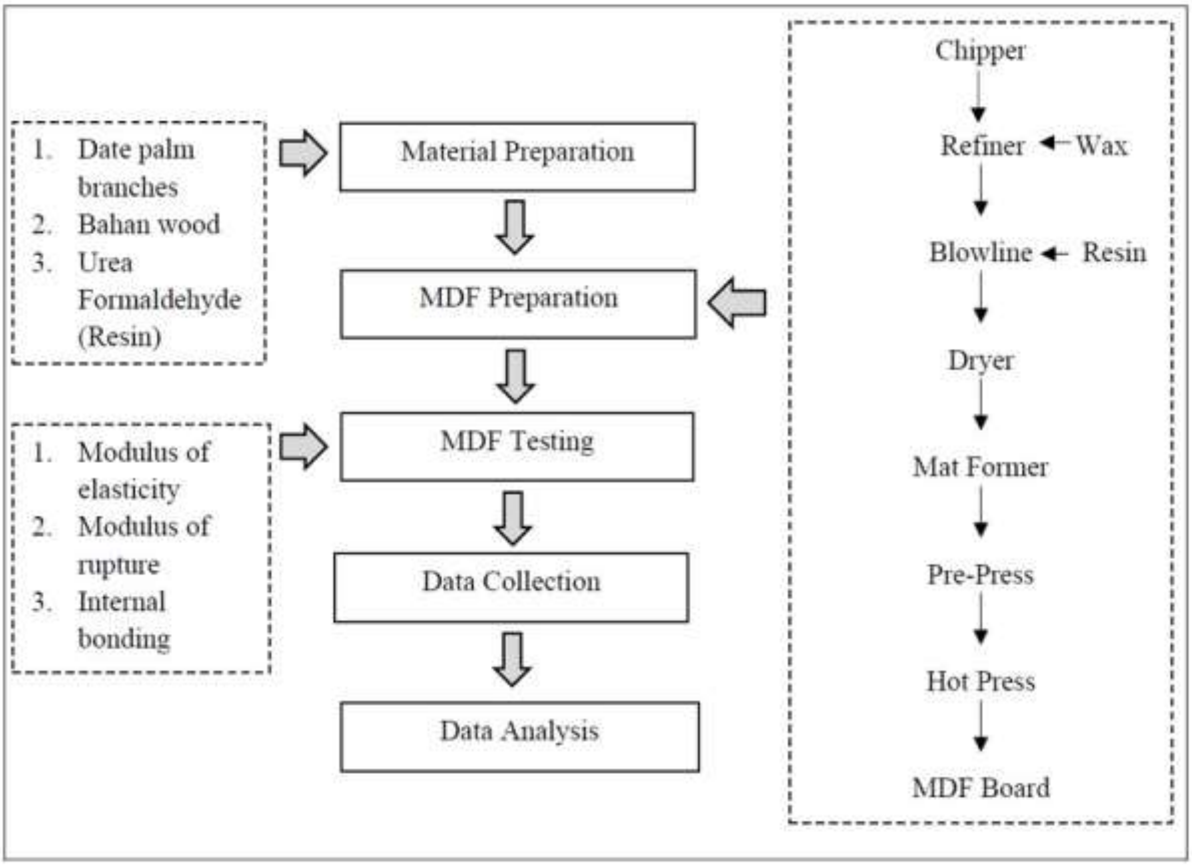

Figure 1. Methodology for producing MDF from admixture date palm branches and Bahan wood

The samples obtained underwent preparation, testing, and analysis following a specific standard. The mechanical properties of MDF, including modulus of elasticity (MOE), modulus of rupture (MOR), and internal bonding (IB), were tested according to the standards of EN310 and EN319.

RESULTS AND DISCUSSION

Table 1 shows the mean value of the MOR, MOE and IB strength of the MDF produced in this study. During the six trials, the density of the MDF produced ranged from 663.33 kg/m^3 to 706.00 kg/m^3. Similarly, the MOR of the MDF ranged from 18.01 MPa to 23.54 MPa. MOE values in the meantime ranged from 1997.33 MPa to 2204.04 MPa. It should be noted that the MDF with the highest density had the highest MOR and MOE value, and vice versa. The IB strength of the MDF, on the other hand, ranged from 0.39 MPa to 0.60 MPa. With the exception of trial no. 2, all of the trial boards' MOE values exceeded the minimum requirement of 2000 MPa. In terms of MOR, only MDF from Trial No. 3 met the minimum requirement of 23 MPa. However, the majority of the MDF boards produced in this study did not meet the minimum IB requirement of 0.55 MPa.

Table 1. Mechanical properties of medium density fiberboard produced (N=6 per trial)

Trial	Density (kg/m^3)	Modulus of rupture (MPa)	Modulus of elasticity (MPa)	Internal bonding (MPa)
1	674.83	19.25	2006.96	0.60
2	663.33	18.01	1997.33	0.52
3	706.00	23.54	2204.04	0.39
4	693.50	21.33	2183.56	0.50
5	684.50	22.47	2219.26	0.52
6	675.00	21.41	2204.02	0.56

Because the density of the MDF had a significant impact on the mechanical strength of the MDF boards, a density versus mechanical strength of MDF graph was plotted and is shown in Figure 2-4.

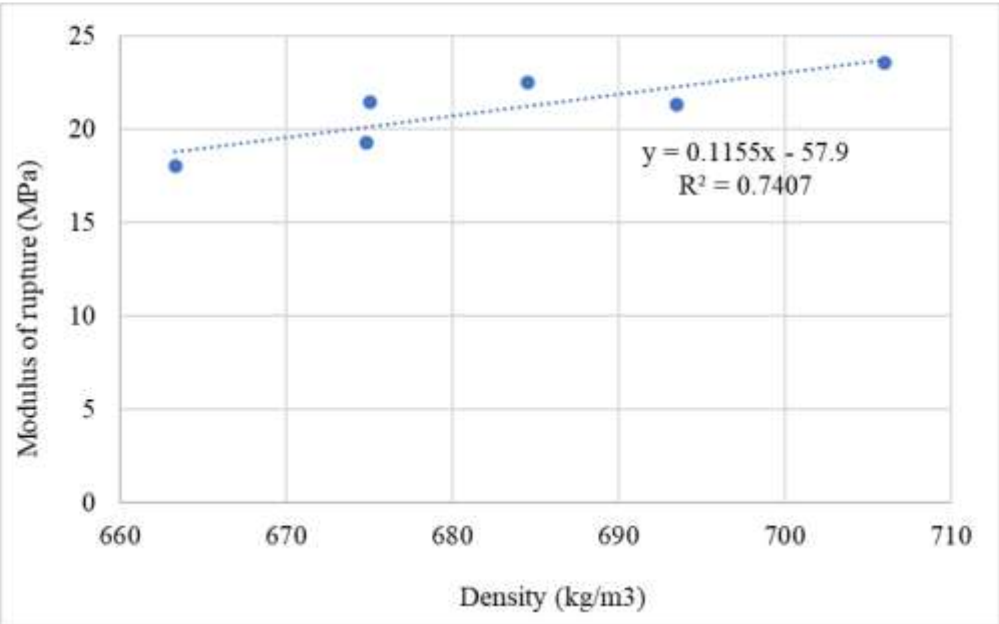

Figure 2. Relation between density and modulus of rupture of the MDF board

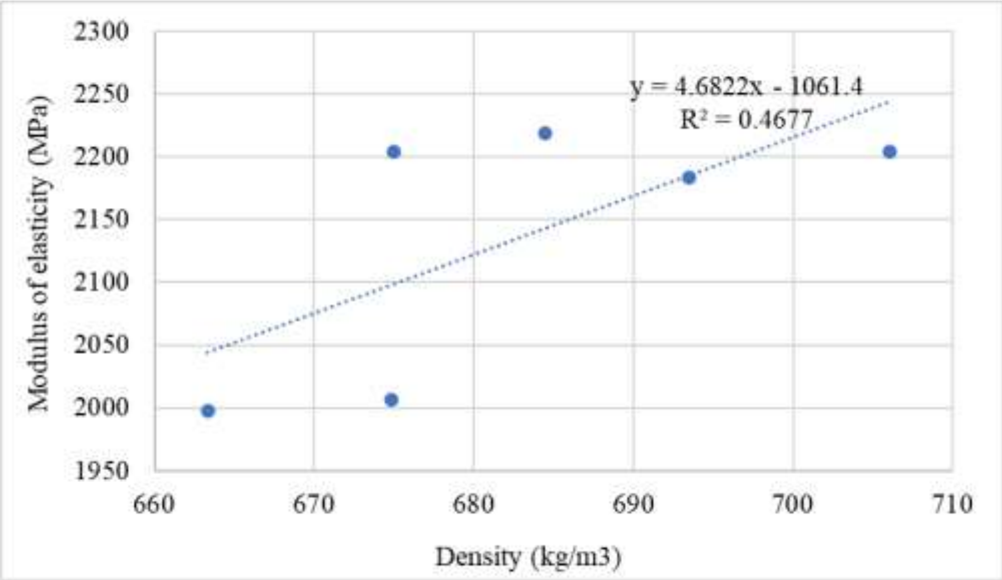

Figure 3. Relation between density and modulus of elasticity of the MDF board

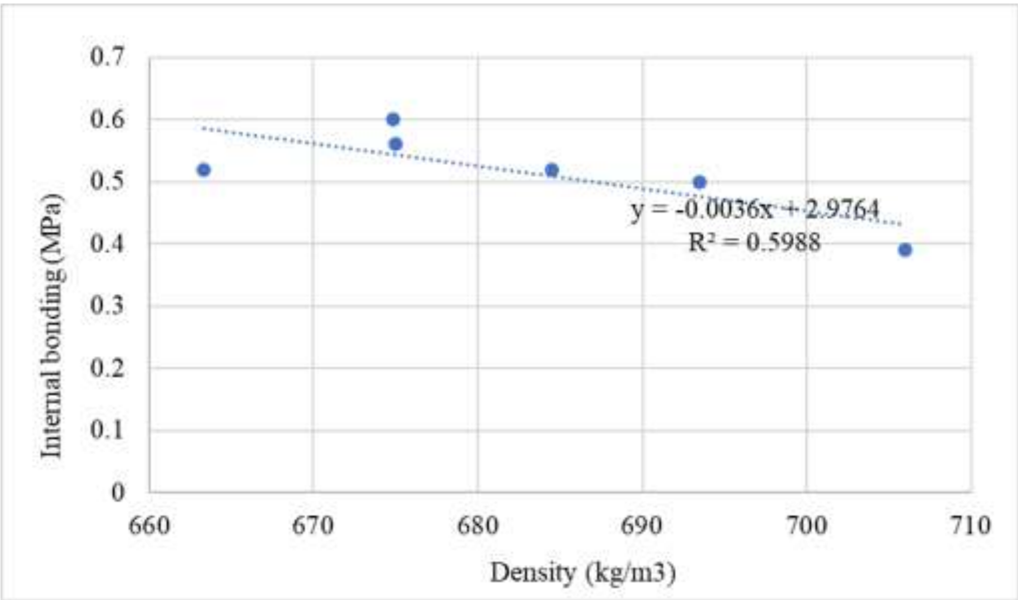

Figure 4. Relation between density and internal bonding strength of the MDF board

A positive correlation was found between density and MOR (Figure 2) and MOE (Figure 3), while a negative correlation was found between density and IB (Figure 4). The density versus MOR coefficient of determination (R^2) is high, at 0.74, indicating that the MOR of the MDF boards is highly dependent on the board density. Meanwhile, the effects of density are less pronounced, as evidenced by the low R^2 value of 0.47. Interestingly, the IB strength of the MDF boards decreased as board density increased, and the correlation is moderately strong (R^2 = 0.6).

The correlations between MOR and MOE can be expressed as in equations below:

$$MOR = 0.115D – 57.9 \qquad (1)$$

$$MOE = 4.6882D – 1061.4 \qquad (2)$$

According to the equations above, increasing the density from 700 to 800 kg/m^3 could result in a 50% increase in MOR and a 21% increase in MOE. To meet the MOR minimum requirement of 23 MPa, the MDF board must have a minimum density of 704 kg/m^3. As a result, it is recommended that the density of MDF made from Bahan wood and date palm branches be kept above this value, preferably 710-720 kg/m^3.

The correlations between density and mechanical strength attributes (MOR, MOE, and IB) of MDF produced in this study are summarised in Table 2. There was a significant positive correlation between density and MOR ($r = 0.706$) and MOE ($r = 0.514$), implying that the MOR and MOE of MDF board increased as density increased. MDF bending strength was influenced positively by density, particularly MOR. A significant negative correlation ($r = 0.495$) was found between density and IB, indicating that IB decreased as board density increased.

Table 2. Relationships between density and the modulus of rupture (MOR), modulus of elasticity (MOE) and internal bonding (IB)

	Ratio	MOR	MOE	IB
Density	Pearson Correlation	0.706**	0.514**	-0.495**
	Sig. (2-tailed)	0.000	0.001	0.002

CONCLUSION

In this study, MDF was successfully manufactured using a mixture of 50% date palm branches and 50% Bahan wood. The findings revealed that some trial boards failed to meet the minimum MOR, MOE, and IB requirements. The density of the MDF had a significant impact on its mechanical strength. As a result, it was recommended that the MDF have a density of at least 706 kg/m^3 in order to meet the standard's minimum requirements.

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AUTHOR CONTRIBUTIONS

Mohd Za'im Mohd Nor: Data collection, writing original draft**. Nurrohana Ahmad:** Methodology, supervision. **Nur Sakinah Mohamed Tamat:** Data analysis, writing-review and editing. **Salim Ayoab:** Methodology, Resources. **Wan Mohd Nazri Wan Abdul Rahman:** Conceptualization, supervision, writing-review and editing.

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DATA AVAILABILITY

Not applicable.

COMPETING INTEREST

The authors declare that there are no competing interests.

COMPLIANCE OF ETHICAL STANDARDS

Not applicable.

SUPPLEMENTARY MATERIALS

Not applicable.

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