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Research Article

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A Medium Density Fiberboard's Characteristics Based on Corn Stalk Fibers

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Abstract
The present study utilized corn stalk fiber for the production of medium density fiberboard (MDF), as it surpasses EN criteria in terms of internal bond, modulus of elasticity, and static bending throughout the manufacturing process. This study aimed to ascertain the impact of press temperature and maleic anhydride (MA) on the physical (thickness swelling, water and steam absorption, and internal bond) and mechanical (static bending, modulus of elasticity, and internal bond) properties of the boards. This study shown that, in comparison to other panel types for general purpose boards, all MDF panels constructed from Properties of Medium Density Fiberboard Based on Corn Stalk Fibers treated with MA at 190°C press temperature had the greatest values. Furthermore, at 190°C, treated fibers exhibited the least amount of steam absorption. In every treatment, the absorption of steam rose as the period grew from 12 to 125 hours. None of the six MDF boards exhibited any further steam absorption after 125 hours. Overall findings demonstrated the creation of MDF panels. The thickness swelling values, however, were worse-higher than necessary. This calls for more effort to be put into enhancing the particleboard made from Corn stalk's physical characteristics.

Keywords: MDF board, Dimension stability, Mechanical characteristics, Corn stalks.

Introduction

One kind of engineered wood product is called medium density fiberboard (MDF), which is created by compressing wood fibers, wax, and resin together with heat and pressure. MDF has a substantial market share in the wood composites business and has seen a sharp increase in manufacturing in recent years [1]. MDF is a great panel material to utilize as a substrate for thin overlays used indoors because it has several benefits, including a smoother surface and ease of machining [2]. Although a range of natural fibers can be used to make MDF, wood remains the most essential raw material due to its relative quantity and year-round availability [3]. However, the lack of wood is a result of the growing demand for forest resources for various purposes. Therefore, it is necessary to identify substitute raw materials or to fully utilize wood resources, such as pulp mill residues, annual plants, lumber and furniture plant residues, harvested residues, and recycled paper [4]. Corn stalks are among the most promising annual plant residual resources for making MDF because they can help maintain a balance between supply and demand. maize is a fibrous remnant of maize stalks left over after the crushing and extraction process. Corn is a common agricultural lignocellulosic waste. Globally, 597 million dry tons of corn stalk are produced each year.

Because of this biomass's ecological and regenerative qualities, there is increasing interest in using it to process innovative composites.

Indeed, major businesses including the automotive, construction, and packaging sectors have shown a great deal of interest in the creation of innovative composite materials packed with natural fibers [5]. When opposed to inorganic fibers, natural fibers have a few drawbacks, namely a propensity to clump during processing and a low level of moisture resistance. The main components of natural fibers are cellulose, hemicellulose, and lignin. Three hydroxyl (—OH) groups can be found in a D anhydroglucose, the fundamental building block of the cellulose macromolecule. The absorption of moisture is attributed to these hydroxyl groups [6].

For geotextiles, filters, sorbents, packaging, and nonstructural composites, fiber modification can be utilized to enhance the qualities of composites including natural and synthetic resources. The alteration of agro-fibers has been achieved through the use of many chemical reaction systems. Among these substances are anhydrides, including butyric, propionic, maleic, succinic, and phthalic anhydrides. Maleic anhydride (MA) use is interesting for producing MDF and particleboard that is environmentally friendly [7]. The -OH groups of the wood fiber and the MA groups interact chemically to significantly increase interfacial adhesion. Nevertheless, not all of the aforementioned issues such as aggregation, appearance, and water adsorption are typically resolved by such a modification. The current study examined how certain manufacturing parameters affected the characteristics of MDF panels composed of corn stalk fibers. Cutting the press cycle time is one of the key factors in lowering the end product's cost. Therefore, it was investigated how press temperature affected the physical (thickness swelling, water and steam absorption) and mechanical (static bending, modulus of elasticity, and internal bond) qualities of panels. Examining the mechanical and physical characteristics of panels that were treated with or without MA was one of the study's other goals.

Materials And Methods

Materials

The chemical composition, pulping behavior, bleaching, morphological characteristics, and physical strength characteristics of the maize stalk were evaluated. A nearby corn stalk mill provided the corn stalk. Table 1 lists the chemical composition and fiber shape of corn stalk fibers. These factors are crucial since they could affect the mechanical and physical.

Table 1: chemical component of Corn stalk and Fiber morphology.

Chemical components:	
Hemicellulose (%)	30-35
Lignin (%)	5-10
Cellulose (%)	15-20
Ash (%)	23
Fiber morphology:	
Length (mm)	1 – 1.5
Diameter (mm)	20

The dehydrated corn stalk was divided into particles ranging from 0.5 to 0.9 mm by screening and re-drying at 55 ºC. The mechanical pulping technique used in refiners created the fibers from corn stalks. MA ($C_4H_2O_3$) was employed as a grafting monomer to functionalize fibers due to the anhydride group's increased reactivity. The minimum amount of acetone needed to dissolve the 15% of MA (depending on the weight of the oven-dried fiber) was usually 5–6 mL for each gram of MA. To ensure that the MA was distributed evenly throughout the fibers, the MA solution and the fibers were completely combined. After the mixture was heated to 115 °C for 160 minutes, it was placed inside a fume hood to allow the acetone to evaporate. provided urea formaldehyde (UF) resin with a pH of 8 and a solid content of 65%. When making the MDF, no wax or other additives were used.

MDF Panel Fabrication

MDF panels were produced utilizing standardized processes that mimicked industrial manufacturing in the Department of Wood and Paper Science, RIFR, Indonesia. Prior to resin blending, corn stalk fibers were dried in a conventional oven to 3% (based on oven-dry weight) in order to prevent the MDF mat from becoming overly wet. After mixing the fibers by hand, they were put in a lab drum blender. Using a forming box, commercial liquid UF resin was applied to the fibers at a 15% (dry basis) concentration before being air-formed. The material was compacted in a pre-press without heat transfer following mat formation. After the prepressing process, the material was compressed for three minutes in a hydraulic press that was electrically heated to a maximum pressure of 40 kg/m^2. After that, the panels were compressed for four minutes using a single hot press at a pressure of 40 kg/cm^2. There were three different press temperature settings: 190, 200, and 210 ºC. Following the pressing process, every panel was cut to a final dimension of 500 x 500 x 8 mm3, with a density objective of 700 ± 0.01 kg/m^3. The study's experimental design is displayed in Table 2.

Mechanical characteristics and Dimensional Stability

The modulus of rupture (MOR), modulus of elasticity (MOE), internal bond strength (IB), and dimensional stability were measured in accordance with European standards. Nine specimens three from each of the three panels were utilized for each level and combination of press temperature and MA treatment to determine the mechanical and dimensional stability qualities. Before the mechanical assessments, at 23 ºC and 60% relative humidity (RH), the panels were conditioned.

Table 2: Experiments design.

Type of Board	MA (%)	Temperature(ºC)
A	15	190
B	15	200
C	15	210
D	0	190
E	0	200
F	0	210

The Instron Universal testing apparatus was utilized to ascertain the mechanical attributes. Measuring the growth in thickness of square test specimens immersed in water (23 ºC, pH 7) at 2 and 24 hours revealed the dimensional stability of the specimens, which had a nominal side length of 60 mm and were conditioned at 60% RH and 23 ºC.

Data Analysis

Every test's data were statistically examined. Analysis of variance and t-test were used to assess the impact of press temperature and MA treatment on the qualities of MDF panels in order to determine whether there was a significant difference between levels and factors. In order to determine whether groups were significantly different from other groups at a 97% and 99% confidence level, a comparison of the means using Duncan's multiple range test (DMRT) was conducted when the ANOVA revealed a significant difference among factors and levels. Tables 3 and 4 provide a summary of statistical evaluations of the mechanical and physical characteristics of MDF panels manufactured from corn stalk fiber. Figure 1 demonstrate how the addition of MA and press temperature affected the panels' mechanical and physical characteristics.

Mechanical Characteristics

At a probability threshold of 0.02 and 0.06, respectively, the statistical analysis demonstrated a significant impact of the MA treatment and press temperature on the MOR, MOE, and IB (Table 3). Indeed, once the fiber was treated with MA and the press temperature was raised to 200°C, an increase in the MOR, MOE, and IB was noted. The minimum standards for MOR and MOE of panels for general use and interior fitments, respectively, are 1600 N mm2 and EN standard 13. Table 4 shows that all of the panels' MOE and MOR were significantly higher than those needed for general purpose use. Tables 3 and 4 present the bending strength of the manufactured particleboards as determined by DMRT and the t-test.

Table 3: Statistical analysis of physical and mechanical properties of MDF produced with different variables.

Property	**MOR (N mm2)**	**MOE (N mm2)**	**IB (N mm2)**	**TS 2 h (N mm2)**	**TS 24 h (%)**	**WA 2 h (%)**	**WA 24 (%)**
(C.V.%)	6	4.22	24.3	14.44	8.76	14.45	8.83
MA	NS	**	NS	*	**	**	*
Press temp. (ºC)	NS	NS	NS	NS	NS		
MA and press	**	**	*	*	*	*	*

**Significant difference at the 1% level (p ≤ 0.01%), *Significant difference at the 6% level (p ≤ 0.06%). NS, Not significant.

Table 4: Duncan's Multiple range test of the MA treatment and press temperature.

Panel type Property	**I**	**II**	**III**	**IV**	**V**	**VI**
MOR (N mm^2)	28.3(B)	29.2(A)	28.7(B)	26.4(A)	25.7(C)	28.2(B)
MOE (N mm^2)	2237(B)	2611(A)	2288(B)	2195(B)	1894(C)	2167(B)
IB (N mm^2)	0.33(A)	0.23(C)	0.20(C)	0.18(C)	0.21(B)	0.21(B)
TS 2 h (%)	10.1(A)	10.2(A)	12.4(B)	12.6(B)	15.1(C)	12.3(B)
TS 24 h (%)	18.2(A)	19.1(A)	22.6(B)	22.8(B)	24.2(C)	22.5(B)
WA 2 h (%)	44.1(B)	38.4(A)	46.3(B)	52.7(C)	63.7(D)	50.3(C)
WA 24 h (%)	80.2(B)	74.6(A)	84.2(C)	86.5(C)	92.4(D)	85.3(C)

Values (A,B,C,D) having the same letter are not significantly different.

The MOR values for samples in groups I through VI were in line with EN 312-6 standard values. The MOR and MOE of the panels were generally improved by the modification process. The better interaction and stress transfer between the components is indicated by the MDF's increased mechanical characteristics as a result of chemical treatment. By pressing the MA-treated fibers at 200 ºC, the highest MOR and MOE strength values were achieved; raising the press temperature to 210 ºC resulted in a reduction. in terms of strength characteristics. Note that thermal breakdown of the fibers may be the cause of the MDF panels' reduced strength value at temperatures above 200 ºC. Corn stalk fiber components including hemicellulose start to deteriorate at 210 ºC [8]. At processing temperatures higher than 210 ºC, the thermal deterioration of the fibers also led to the generation of volatile compounds. Products that are porous and have poorer mechanical qualities and densities will result from this phenomena [9]. On the other hand, inadequate organoleptic qualities (such as color, smell, etc.) could make this degeneration macroscopically detectable.

Attempts have been undertaken to coat and/or graft the fibers with monomers in order to improve the thermal stability [10]. The range of IB data was 0.18-0.33 N mm2. 0.24 N mm2 is the minimum IB strength required for general use (EN 312-2). The test findings showed that all of the MDF manufactured, with the exception of panel type A, which had the highest values among the other specimen types for general purpose boards, did not meet the IB criterion of EN. The thermal deterioration of the fibers explains the significant negative influence of press temperature on internal bond strength. Conversely, MA treatment may enhance the MDF panels' IB characteristics.

Dimensional Stability

Figure 1 shows thickness swelling (TS) and water absorption (WA) of the MDF panels produced from treated with and without MA at three different press temperatures. Based on EN standard, MDF panel should have a maximum TS value of 8% and 15% for 2 and 24 h immersion, respectively.

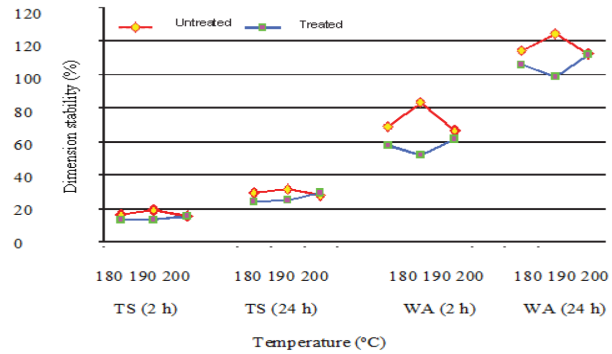

Figure 1: Effect of Press Temperature and MA treatments on Dimension stability

Average TS of the samples ranged from 18.2 to 24.2% for 24-h immersion. However, the Ts value 18.9% for panel A was close to the required level of TS of panels for general use. Average WA of the samples ranged from 74.6 to 94.2% for 24-h immersion (Figure 1). Panel B's water absorption was, nevertheless, significantly less than that of other MDF panels. Ester and hydrogen bonds are known to develop between MA treatment and the -OH groups in wood components. The reduction of free OH groups in wood lessens the material's susceptibility to water and, consequently to swelling [11].

Conclusions

In order to address the shortage of raw materials, the primary objective of the current work was to explore the potential use of corn stalk fibers in the production of MDF. The following outcomes were attained based on the MDF's mechanical and dimensional stability tests: All MA-treated panels outperformed untreated panels in terms of MOR and MOE for interior fittings, including furniture manufacturing applications, and their values were greater than those of the untreated panels. The panels' MOR and MOE improved as a result of the MA treatment. However, raising the press temperature significantly reduced IB strength and caused the fibers to degrade thermally. MDF panel mechanical and dimensional stability was generally significantly impacted by MA treatment and press temperature. After a 24-hour immersion, the panels' WA ranged from 74.6 to 94.2%, which is a relatively high value. The low dimensional stability of the panels can be attributed to the fact that no hydrophobic material was utilized in their manufacture. Compared to the corresponding untreated fibers, the MA-treated fibers exhibited reduced absorption of water and steam. After 125 hours, the trend of steam absorption in both treated and untreated samples becomes constant. It is possible to use corn stalk fiber as an additional fibrous material in MDF manufacture, according to the study's findings.

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