Scope of Medium density fiberboard (MDF) from water hyacinth (*Eichhornia crassipes*)

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Abstract: **In this study medium density fiberboard (MDF) were manufactured from water hyacinth (*Eichornia crassipes*), the world's worst aquatic weeds. The produced fiberboard showed better performance in case of physical and mechanical properties and satisfied ANSI, IS, AS/NZS standards. The thickness swelling and water absorption of the board were 48.41% and 71.03% respectively. Modulus of elasticity (MOE) and Modulus of rupture (MOR) of the board were 3135 MPa and 31.25 MPa respectively. It seemed that the water hyacinth fiberboard may be a cheap, durable and sustainable material that can substitute timber and also reveal a new path of wise utilization of these aggressive weeds simultaneously.**

Keywords: **Absorption, density, fiberboard, moisture, strength.**

I. INTRODUCTION

In Bangladesh water hyacinth is known as tagar, shaola locally. It is one of the world's worst aquatic weeds. It has a lot of negative impact like blockage of fishing grounds, transport routes, eliminate native aquatics plants, reduce the gas exchange capacity of the surface water and increase in waterborne diseases [1, 2]. Besides the management and removal of the weeds are expensive [3]. In spite of these negative effects it has some beneficial use like- use as animal fodder, compost and mulch product, fuel, rope making, household ornamental purpose etc. Under favorable conditions water hyacinth can achieve a growth rate of 17.5 metric tons per hectare per day [4]. It is doubling its population every 5–15days and producing up to 140 million daughter plants annually [5, 6]. Sometimes it is used in fodder or producing compost manure. But this proportion is very little and has generally no commercial use. So a vast portion of water hyacinth remains unused, rather it creates different problems for the water body. For this reason water hyacinth can play a vital role for a vast source of lingo-cellulosic material especially in Bangladesh.

The growing demand for wood based panels has led to declining wood resources and encourage us to find new resources as an alternative to wood. The use of other renewable resources such as agricultural residues in the production of composite panel (i.e. fiber boards and particleboards) has recently been considered attractive both from the economic and environmental point of view [7]. One of the principal advantages using natural fibers is given by the widespread availability of fibers, their low cost, low weight, biodegradability, co-neutral renewable nature, and good mechanical properties [8]. The chemical compositions of water hyacinth are as Cellulose (25%), Hemicellulose (35%), Ash (20%), and Lignin (10%). Its fiber length is 1.53 mm [9] and cell wall thickness 1.6 µm [10]. The water hyacinth fiber shows satisfactory physical properties, such as relatively high tensile strength and stiffness, which indicate its prospect as a promising fiber material. Here, holocellulose portion is 60%, it is not a small amount. Due to lack of wise utilization these vast portions of biomass remain unused or wasted generally. This point was very much vital for us to carry out the study. The aims of this study were to show the potentiality of water hyacinth fibers as an alternative raw material for fiber board manufacturing.

II. MATERIAL AND METHOD

Green water hyacinth was collected from Khulna University campus (22° 48' 0" N and 89° 33' 0" E), Khulna, Bangladesh. For this collection bigger size one was preferred for the easy transportation and handling. Then root and leaves portion was discarded and only the petiol of the leaves of water hyacinth was taken to wash and cut into desired size by chips as 1.0-1.15 inches manually. Then fresh water hyacinth chips were dried in the sun. These dry chips were used to cook with 20% sodium hydroxide solution for 4 hours in 120-140°C temperature in a digester to separate the fiber nicely. These cooked chips were blended to separate the fiber and finally this fiber was washed in water to remove the sodium hydroxide solution clearly. These separated fibers were kept in the oven machine at 101-103℃ temperature for 24 hours to quick and even dry.

Urea formaldehyde (UF) resin was mixed with fibers manually at 20% of the weight of fibers. The glued fibers were then kept on a steel sheet to make a mat of fibers. The mat was (25 mm) five times more than the of the target fiber board (5mm). This mat was then inserted into the hot press machine for pressing. The temperature was raised to a maximum of about 140˚c after proceeding 10 minutes. The pressure was 2 MPa and continued for 7 minutes with an increasing temperature. Then the board was kept 30 minutes for cooling and keeping the same pressure, so that the board may balance with environmental condition.

After the manufacturing of the board, the edges of the board were trimmed with the fixed type circular saw. This board was then cut into standard sizes according to ASTMD-1037 standard to test the different properties. The physical and mechanical properties were tested according to the procedures defined in the American standard for Medium Density fiberboard (ANSI), Indian Standard (IS) and Australian/ New Zealand Standard (AS/NZS).

Analysis of Data

All the data, produced during the laboratory tests for characterization of physical and mechanical properties of each type of fiberboard, which were analyzed by using Microsoft Office Excel 2007; SAS (Statistical Analysis System) software and SPSS (Statistical Package of Social Survey) software to analyze the data.

III. RESULT AND DISCUSSION

The physical properties

There is a significant difference of physical properties (Density, moisture content, water absorption and thickness swelling) among different types of fiber board. In describing these properties of boards, here we considered 5 mm water hyacinth fiberboard as (S_5) and 5 mm medium density fiberboard collected from market as (S_m). The result and discussion of physical properties among different types of fiber board are explained below.

Density

It was found that the density of water hyacinth board (S_5) and medium density market board were 780 kg/m^3 and 750 kg/m^3 respectively. Fiberboard of water hyacinth (S_5) was satisfy all the standard of medium density fiberboard (MDF). Fiberboard of water hyacinth (S_5) was denser than market fiberboard (S_m) which is lower than the fiberboard made from giant bamboo (801 kg/m^3, 837 kg/m^3,837 kg/m^3, 814kg/m^3) [11] and similar to the fiberboard manufactured from *Pinus Elliottii* Wood (750 kg/m^3, 800 kg/m^3) [12].

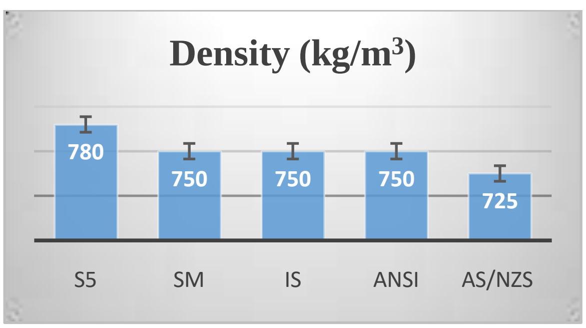

Fig 1: Density and standard of MDF: Water hyacinth fiberboard (S_5), market fiberboard (S_m), Indian Standard (IS), American National Standard (ANSI), Australian/ New Zealand Standard (AS/NZS)

Medium density fiberboard has a density between 650-800 kg/m^3 and can be produced both with and without wax and sizing agents [13, 14]. So it found that water hyacinth board (S_5) (780 kg/m^3) fulfil the standard which are very close to the banana (*Musa sapientum*) stem MDF and mid rib of banana leaf MDF 780 and 740 kg/m^3 [15]. Where the density of Jute (*Corchorus olitorius* L.) coarse and fine (JCF), dhaincha (*Sesbania cannabina* Retz.) coarse and fine(DCF), jute fine(JF) and dhaincha fine (DF) was respectively 930, 950, 860 and 920 kg/m^3 [16]. Also the findings of water hyacinth board (S_5) (780 kg/m^3) was similar to untreated rice straw (*Oryza Sativa* L.) (790 kg/m^3) and lower than the hot water treated board (910 kg/m^3) [17].

Moisture content

Moisture content is a vital physical property that causes change of other physical and mechanical properties of the boards. From the test the moisture content was 10.28% for water hyacinth fiberboard (S_5) and 10.03 % for market fiberboard (S_m). From Fig-2, found that, the calculated moisture content of water hyacinth fiberboards (10.28%) were alike to different standard of MDF.

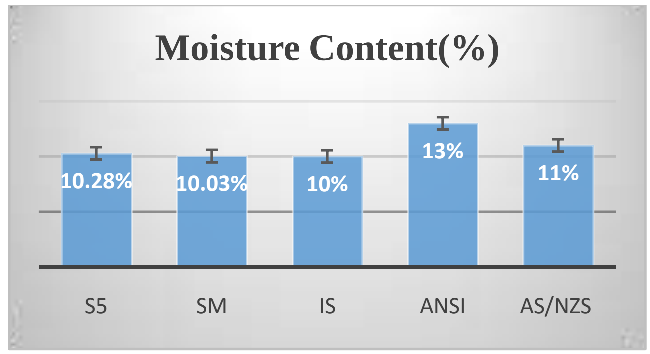

Fig 2: Moisture content (%) and standard of different MDF: Water hyacinth fiberboard (S_5), market fiberboard (S_m), Indian Standard (IS), American National Standard (ANSI), Australian/ New Zealand Standard (AS/NZS)

The moisture content of water hyacinth fiberboards (10.28%) was very close to the moisture content of JCF, DCF, JF and DF 10, 9.30, 9.55 and 7.85% respectively [16]. It also similar to the untreated fiberboard (12.29%) and treated fiberboard (9.4%) of rice straw (*Oryza Sativa* L.) [17].

Thickness Swelling

In this study, the thickness swelling of water hyacinth fiberboard (S_5) and market board (S_m) were 48.41% and 25.15% respectively after 24 hours soaking period in the cold water (Fig-3). It is known that TS tends to increase with increasing board density because of the swelling of the wood itself and the release of the compression stress from the pressing operation [18].

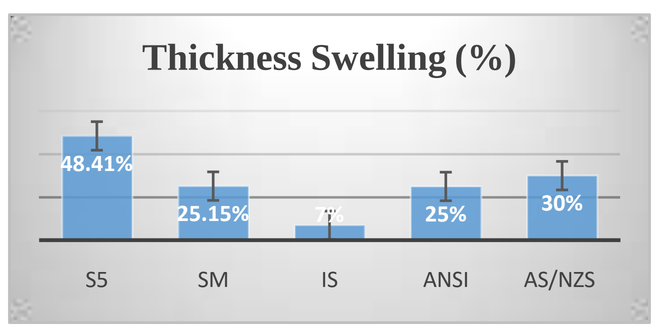

Fig 3: Thickness swelling (%) and standard of different MDF: Water hyacinth fiberboard (S_5), market fiberboard (S_m), Indian Standard (IS), American National Standard (ANSI), Australian/ New Zealand Standard (AS/NZS)

Calculated value (48.41%) was lower than the untreated fiberboard of rice straw (*Oryza Sativa* L.) (58.28%) and higher than the treated fiberboard of rice straw (40.76%) [17]. It was 31.90 and 40.50% respectively for bagasse and wheat straw MDF [19, 20]. Thickness swelling of water hyacinth fiberboard (48.41%) was very high compare to JCF (6.64%), DCF (17.91%), JF (11.53%) and DF (18.80%) [16]. and also higher from the fiberboard of banana stem (15.70%) and mid rib (16.65%) [15].

Water absorption

The water absorption of the water hyacinth fiberboard (S_5) and market fiberboard(S_m) were 71.03% and 45.25% respectively after 24 hours soaking period in cold water (Fig-4). According to the Indian Standard and ANSI, the standard value for thickness swelling for the fiberboard was (30% and 35% respectively). So, the thickness swelling of water hyacinth fiberboard (48.41%) was very high and could not satisfy the standard. Water absorption of water hyacinth fiberboard (71.03%) was very high compare to the fiberboard of banana stem (40.12 %) and mid rib of banana leaf (38.49%) [15]; JCF (18.81%), DCF (23.93%), JF (27.45%) and DF (26.35%) [16].

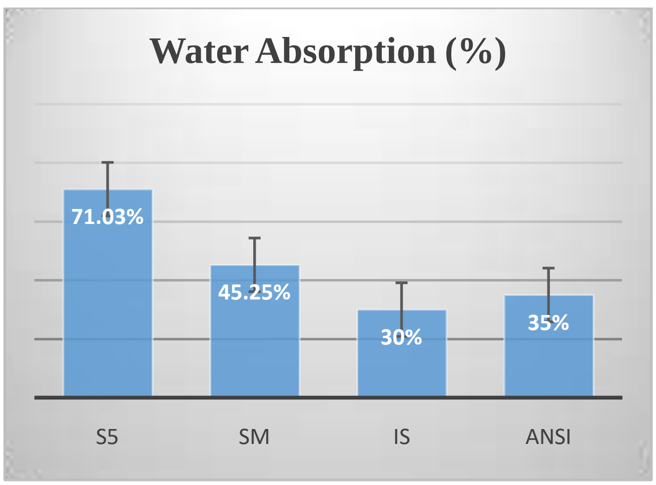

Fig 4: Water absorption (%) and standard of different MDF: Water hyacinth fiberboard (S_5), market fiberboard (S_m), Indian Standard (IS), American National Standard (ANSI)

The high cellulose content in water hyacinth fiber contributes to more water penetrating into the interface through the micro cracks induced by swelling of fibers [21]. George *et al*. [22] nhave reported that the hydrophilicity of the fibers can be reduced by a suitable chemical treatment. Calculated value (71.03%) was similar compare to bagasse MDF (76.40 %) [19] and lower than untreated fiberboard (154.21%) and treated fiberboard (109.4%) of rice straw (*Oryza Sativa* L.) [17].

Mechanical properties

Modulus of Rupture (MOR)

The modulus of rupture of two categories of fiberboard (S_5 and S_m) were 31.25 MPa and 31.15 MPa respectively (Fig-5). The MOR of water hyacinth fiberboard (S_5) was so higher than the fiberboards made from giant bamboo (9.38 MPa, 8.94 MPa, 10.78 MPa, and 11.10 MPa) [11]. But the MOE was lower than the fiberboard manufactured from *Pinus Elliottii* Wood of 8mm thickness (34.93Mpa, 36.66Mpa, 37.41Mpa) and 15mm thickness (32.25 MPa, 37.40MPa, 33.59MPa) [12] respectively and also banana stem (50.91MPa) and mid rib of banana leaf (45.30 MPa) [15].

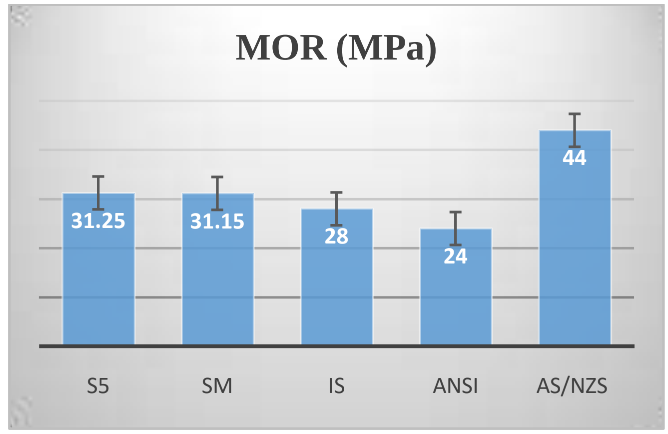

Fig 5: Modulus of Rupture (MPa) and standard of different MDF: Water hyacinth fiberboard (S5), market fiberboard (Sm), Indian Standard (IS), American National Standard (ANSI), Australian/ New Zealand Standard (AS/NZS)

According to ANSI A208.1–1993 [23], the MOR of standard particleboard is 16.50 to 23.50 MPa for high density grade, 11.00 to 16.50 MPa for medium density grade and 3.00 to 5.00 MPa for low density grade. According to IS: 3087-1985 [24] and British Standard BS: 5669 [25], the MOR of standard particleboard is 10.98 MPa and 13.80 MPa respectively. The MOR of water hyacinth fiberboard (S_5) was fulfill all the standard except AS/NZS standards for medium density fiberboard (Fig-5). The MOR was increased with the increasing of density and also depends on the raw materials used, the inherent properties of fiber and spatial arrangement of fibers [26]. Water hyacinth fiberboard (31.25 MPa) showed very high MOR than the standards and the untreated fiberboard (13.15MPa) and treated fiberboard (25.59 MPa) of rice straw (*Oryza Sativa* L.) [17]; straw (6.00 MPa) and flax (11.30MPa) MDF [20]; JCF (18.75MPa), DCF (24.01MPa), JF (12.14 MPa) and DF (15.04 MPa) [16].

Modulus of Elasticity (MOE)

The modulus of elasticity of two categories of fiberboards (S_5 and S_m) were 3135 MPa and 3115 MPa respectively (Fig-6) which were higher than the fiberboard made from giant bamboo (1219.18 MPa, 877.45 MPa, 1297.51 MPa, 1067.73 MPa) [11] but lower than the banana stem (3,939.25 MPa) and mid rib of banana leaf (3,606.17 MPa) MDF [15]. ANSI A208.1–1993 [23] described that the MOE of standard particleboard is 2400 to 2750 N/mm² for high density grade, 1725 to 2750 N/mm² for medium density grade and 550 to 1025 N/mm² for low density grade.

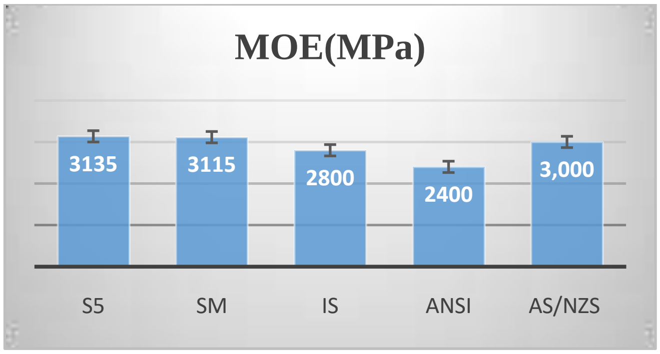

Fig 6: Modulus of Elasticity (MPa) and standard of different MDF: Water hyacinth fiberboard (S_5), market fiberboard (S_m), Indian Standard (IS), American National Standard (ANSI), Australian/ New Zealand Standard (AS/NZS)

From Fig-6, it unrevealed that the MOE of water hyacinth fiberboard (S_5) was higher that the IS, ANSI and AS/NZS standards. Density has positive effect on the MOE and it increases with the increasing of density [26]. The MOE of water hyacinth fiberboard was so high than untreated fiberboard (386.57 MPa) and treated fiberboard (1044.31 MPa) of rice straw (*Oryza Sativa* L.) [17], and JCF (2301.05 MPa), DCF (2960.85 MPa), JF (1038.17 MPa), and DF (1307.59 MPa) [16].

IV. CONCLUSION

This study investigated the potentiality of using water hyacinth as a raw material for the production of the Medium density Fiberboard (MDF) and its basic physical and mechanical properties. It appears that manufacturing of water hyacinth fiberboard (MDF) is technically feasible for various structural purposes. It has been observed that all the properties of the boards meet the requirements of the international standard like ANSI; ISO; AS/ NZS. In future, this fiberboard may be a cheap, durable and sustainable material that can substitute timber or wood products and also be a new path of wise utilization of these aggressive weeds simultaneously.

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