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Application of African Couchgrass in Manufacturing of Medium Density Fiberboard

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Abstract: Worldwide, the medium density fiberboard (MDF) materials have been extensively used for furniture as well as a normal building material. The MDF production is based on wood materials that are obtained from the tree cutting, and this process may conduct to gradual deforestation. Different works have shown the advantages of using other renewable biomass sources for MDF manufacturing. This study aimed at assessing the potential of using the African couchgrass, as one of worldwide available grass, and which has been one of the most worrying weeds for agriculture areas. The test with the manufactured MDF checked such material properties like density, moisture content, water absorption, and thickness swelling. The established results were 727.143 kg/m^3, 5.81%, 9.18%, and 7.6% respectively. All those results are in the range of standard values recommended by ASTM D1037, and they give optimism for the application of couchgrass in the manufacturing of MDF. This new material was planned to be used as a partition component. Therefore, further studies should evaluate other important properties, like fire and sound resistance, while a proposal for potential replacement of the used industrial wood glue is also welcome.

Keywords: African couchgrass, density, medium density fiberboard, thickness swelling, water absorption.

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1. Introduction

Medium-density fiberboard (MDF) as the engineered wood invention is formed by breaking down softwood into wood fibers, normally in a deliberator, while combining it with wax and resin and forming panels under application of high temperature and pressure. Its name is drawn from the difference in densities of fiberboard. It is a similar material to plywood but made up of separated fibers and not wood veneers. MDF typically has a density of 600-800 kg/m^3, in contrast to particle board (160 - 450 kg/m^3) and to high-density fiberboard (500 - 1450 kg/m^3). Similar manufacturing processes are considered during the production of all types of fiberboard. The MDF production has been divisive especially because of the application of formaldehyde resins and all related health risks; thus other resins are being considered. Another challenge is the use of wood as raw materials that are conducting to the environmental degradation resulting from deforestation. Further, the currently manufactured MDF has been not much affordable, due to the limitation of the local manufacturing industry level. This study is, therefore, aiming at analyzing the possibility of using the African couchgrass (presented further in the study as “couchgrass”), as replacement of natural tree in making new MDF, so that not only the MDF cost is reduced, but also the environmental degradation is limited. Couchgrass (*Digitaria scalarum*), as one of the harmful weed of the world, is widely scattered in Rwanda. It is a creeping, recurrent grass with long, slender, branching rhizomes that form a dense mat beneath the soil surface and at the same time the most upsetting weed in the crops of Rwanda, especially for some crops like coffee, bananas, beans, tea, etc. Grave mechanical damage can take place when trying to remove rhizomes entwined in crop roots using hoe (REMA, 2011). An example of green and dry couchgrass is presented in Fig. 1.

While above-ground couchgrass might look just like any other grass, below ground is a different story. It forms a dense network of wiry roots and rhizomes that spread quickly and colonizes lawns and garden plants in beds and borders. Besides that negative impact to agriculture, the couchgrass does not offer any use in the economic development field, and once it is removed, it is just burnt. However, its structure leaves to think that the respective fibres would be strong enough to be used with other components and make a potential composite material.

(a) Green form

(b) Dry form

Fig. 1. Couchgrass forms

This experimental study seeks the answer to the following main question: Can the couchgrass be used in the manufacturing of an adequate MDF, and consequently enhance the environment protection? Therefore, the main objective was the assessment of couchgrass as a potential material for the manufacturing of MDF that would contribute to reduction of the deforestation and provide new and affordable material. Among others, specific objectives were the following: Analysis of properties of MDF components, assessment of the properties of couchgrass, and manufacturing of MDF using couchgrass and testing to establish the key properties. The produced MDF was checked for performance through its density, moisture content, water absorption, and thickness swelling. These properties are sufficient for this new material planned to be used as a partition component. However, without technical limitations such properties like fire and sound resistance would have been checked as well.

2. Literature Review

Investigations about MDF manufacturing and its properties have been considered in different authors' works and good results were availed. According to different background information, results from laboratory experiments seem to indicate that fiberboard can be made from almost any lignocellulosic raw material, but wood is still the most important constitutive material because of its comparative large quantity and continuous availability (Suchsland and Woodson, 1987). In their study, Akgül et al. (2017) demonstrated how diverse sources of biomas may be used as substitute raw material for MDF production. However, the use of renewable biomas in the manufacturing of MDF does not always offer improved results with comparison to those made using ordinary softwood fibers, even if it has shown a very promising tendency (Ye et al., 2007). Akgül et al. (2010) proved that the panels produced using exclusively corn stalk could meet the required standards, and its properties improved while increasing the pine fiber ratio. Mechanical properties of wood fiber MDF boards were found to be slightly higher than those of straw and straw wood fiber mixture MDF boards (Eroğlu et al., 2001). The use of bagasse fibers in MDF panels showed that some properties exceeded the EN standards, except the thickness swelling values which were higher than requirements (Ashori et al., 2009). Physical and mechanical properties for MDF manufactured applying other types of wood and resins are also assessed in the works of Da Silva et al. (2013) and Marinhoa et al. (2013) respectively, and important findings are established. There were other studies (Bektas et al., 2005; Taghiyari et al., 2016; etc), which were very relevant to the analysis of properties, either of particleboards or fiberboards made using specific and wood or under other effects, and good results in line with standards were established. All works related to this study and not underlined here are also recognized.

From the above overview, it is easily seen that no study yet neither about the use of couchgrass, nor about due consideration of environment aspect while manufacturing the MDF panels.

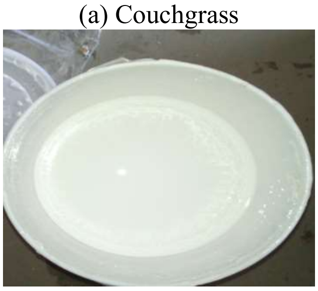
3. Materials and Methods

The method applied in this study was based on the documentation for sufficient background, collection of raw materials and their preparation, as well as the manufacturing and testing of MDF materials for density, moisture content, water absorption, and thickness swelling. The size of the produced MDF was selected based on its proposed use as a partition component inside the building.

3.1. Raw Materials

The materials used in manufacturing of the new MDF were dry couchgrass (couch rhizomes) and wooden glue. The natural couchgrass was collected from north province of the country, in the agricultural site of Ntarabana sector, allocated in Rulindo district. It was then cleaned with pure water, exposed to the sun`s temperature until it got dry, grinded using adequate machine, and finally cut into fibers using paper cutter. The used wooden glue was purchased from local market in Kigali City. Both materials are presented in Fig. 2.

(a) Couchgrass



(b) Wooden glue

Fig. 2. New MDF materials

3.2. MDF Preparation Tools and Methods

Dried couch grass was cut into standard fibers' size of 7 mm using the paper cutter. The process is presented in Fig. 3a.

(a) Cutting

(b) Grinding

(c) Used formwork

Fig. 3. Couchgrass preparation

The refining process was done by using ordinary grain milling/grinding machines to produce fine couchgrass particles (powder). The grinding machine is presented in Fig. 3b. The formwork used was made in wood with 200 mm × 100 mm × 12 mm size, in such a way that it was plane, smooth and adjustable in the corner to facilitate its removal without damaging the fresh product (Fig. 3c). Other manual tools used were a ***bucket*** as a mixed container, a ***steel rod*** for mixing, a ***pestle*** for compacting, and a ***steel roller*** for leveling purposes. The production process of MDF from coachgrass and wooden glue was 100% manual. The thickness of 12 mm for the MDF was selected based on the standards and market requirements. The weight batching method was adopted for this study. The measured samples of couchgrass and wood glue are presented in Fig. 4. The mixing process is presented in Fig. 5.

(a) Couchgrass

(b) Wood glue

Fig. 4. Samples measuring

(a) At the beginning

(b) Final mix

Fig. 5. Mixing process

The molding is laid on a plane table, fixed by using nails, and then oiled on its internal surface to prevent its bonding with glue. The prepared mixture was filled into a mold in layers of 4 mm and each of them was followed by compaction. It is advised to use appropriate placing tools or protective hand gloves to prevent the glue from sticking on the body. The molding process is presented in Fig. 6.

Fig. 6. Molding process

The final compaction was followed by the leveling process to ensure the fresh mixture is as denser and cohesive as possible, and the product is on the same level, respectively. The compaction and leveling process is presented in Fig. 7.

(a) Compaction

(b) Leveling

Fig. 7. Manufacturing process

After removal of the formwork (demolding) the fresh MDF was placed at low temperature. The cooling and drying process were conducted in sunny conditions (sun drying). After the MDF was dried, the last finishing operation was done for preventing moisture content and increasing the aesthetical appearance. Both unfinished and finished new MDF are presented in Fig. 8.

(a) Unfinished product

(b) Finished product

Fig. 8. New MDF

3.3. New MDF Testing Procedure

The new MDF panel was tested in order to assess its performance characteristics. The following are the selected tests for the evaluation of the designed and manufactured board. All tests and calculations were conducted following ASTM D1037.

3.3.1. Moisture content and density

Specific gravity (or density) and moisture content determination are mandatory on each test sample and are calculated from the dimensions and weight of the specimen at the time of the test. The specimen drying in the oven is conducted at 217 ± 4 °F (103 ± 2 °C) until approximately constant sample weight is attained. The moisture content is then calculated using the Eq. (1).

$$M = 100[(W - F)/F] \tag{1}$$

where:

M = moisture content, %;

W = initial weight, and;

F = final weight when oven-dry.

The density of a substance is its mass per unit volume and designated by the symbol ρ. It is in general based on the oven-dried weight, which is achieved after drying a specimen at 103 ± 2 °C until a constant weight is attained. In this study, the sample was first dried under normal condition of temperature and humidity for 28 days, and then was put under oven condition at the temperature of 103 ± 2 °C. The density value normally is calculated using the Eq. (2).

$$\rho = \frac{f}{lwt} \tag{2}$$

where:

ρ = density, kg/m^3;

f = dried sample weight (kg);

l = length of sample (m);

w = width of sample (m);

t = thickness of sample (m).

For some industries, while referring to a panel product the specific gravity, which is the ratio of the density of a material compared to the density of water, is mostly used.

3.3.2. Water absorption and thickness swelling

These two properties of building boards are expressed in percent for the sample after a single continuous submersion time of 24 hours. As per the procedure, two sets of measurements are required, the initial and the final (after the 24 hours of submersion period). The test sample must be 12 by 12 in (305 by 305 mm) in size, or 6 by 6 in (152 by 152 mm) in size with all four edges smoothly and squarely trimmed. The sample shall be subjected as nearly as deemed practical to constant weight and moisture content in a conditioning chamber kept at a relative humidity of 65 ± 1% and a temperature of 68 ± 6 °F (20 ± 3 °C).

The water absorption is calculated using the following Eq. (3).

$$w = \left[\frac{Ww - Wi}{Wi}\right] x100 \quad (3)$$

where:

w = water absorption in %;

W_w = wet weight;

W_i = initial weight.

The thickness swelling is expressed like the percentage of the original thickness. The following mathematical expression in Eq. (4) is used for calculation:

$$Tsw = \left[\frac{Tw - Ti}{Ti}\right] x100 \quad (4)$$

where:

T_{sw} = thickness swelling in %;

T_w = wet thickness;

T_i = initial thickness.

The thickness swelling is very important, especially when the composite board is kept in contact with water or moisture for long periods.

4. Results and Discussion

As stated in section 3, the molded specimen was 200 × 100 × 12 mm in length, width, and depth, respectively. The required size for different test specimen has been cut from the above-molded specimen.

4.1. Moisture Content

The weight variation results recorded at an oven temperature of 103 ± 2 °C are presented in Table 1, while the corresponding graph is given in Fig. 9.

Table 1. Weight variation results

S/N	Weight (g) /Hour						Remark
	0 hr	1 hr	2 hrs	3 hrs	4 hrs	5 hrs	
1	109.22	105.97	104.31	103.97	103.43	103.28	As time increases, the weight decreases until it becomes constant
2	108.36	105.34	103.69	103.01	102.63	102.63	
3	102.41	98.98	97.33	96.88	96.57	96.50	
Average	106.66	103.43	101.78	101.29	100.87	100.80	

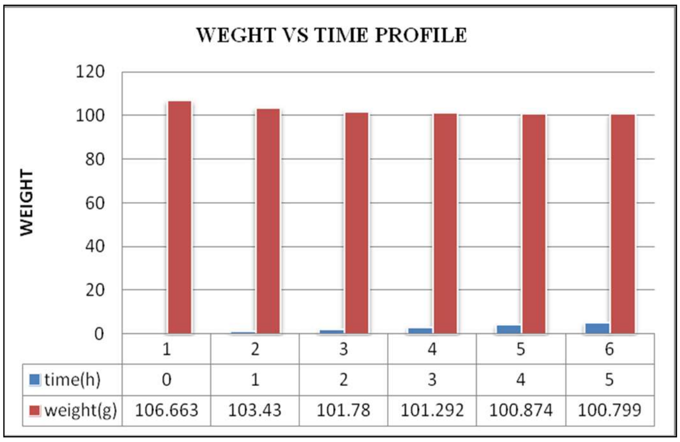


Fig. 9. Weight profile

The moisture content shall be calculated by applying the Eq. (1) presented earlier.

M =100[106.663g-100.799 g]/ 100.799g =5.81%

The above result is in the range recommended by ASTM D1037 standard which states that the moisture content should vary between 0 to 20%.

4.2. Density Test Results

The density results calculated using the Eq. (2), discussed above in section 3, for the samples dried under normal and oven temperature conditions are presented in Table 2 and Table 3, respectively. The density values for the specimen dried under oven conditions are used to draw the graphic given in Fig. 10.

Based on the above results the density of the designed MDF is 727.143 kg/m^3 and it is sitting in the range of 640 to 800 kg/m^3 recommended by ASTM D1037.

Table 2. Density variation table during 28 days

S/N	Density (kg/m^3)				Remark
	7 days	14 days	21 days	28 days	
1	960.4	823.8	800	787.9	As time increases density decreases, until a constant weight is reached
2	952.4	809.2	795	781.7	
3	863.8	751.3	742	738.8	
Average	932.2	794.7	779	769.4	

Table 3. Density variation based on oven temperature at 103 ± 2 °C

S/N	Density (kg/m^3) /hr						Remark
	0 hr	1 hr	2 hrs	3 hrs	4 hrs	5 hrs	As time increases, the density decreases, until a constant weight is reached
1	788	764	753	750	746	745	
2	782	760	748	743	740	740	
3	739	714	702	699	697	696	
Average	769.4	746.1	734.2	730.7	727.7	727.143	

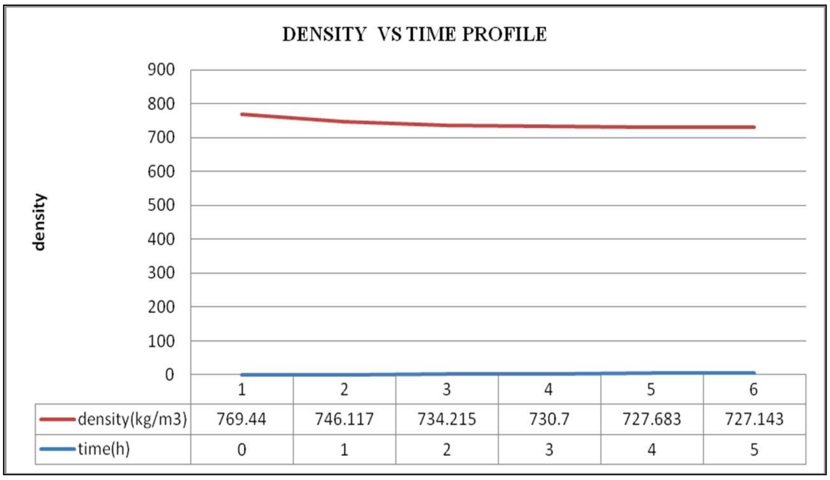


Fig. 10. Density vs time profile

4.3. Water Absorption and Thickness Swelling

About ***the water absorption***, it is observed that the amount of water absorbed by MDF sample is reduced with the increase of wood glue and fine particle of couchgrass. The specimen weighing results are presented in Table 4, while water absorption is calculated using the Eq. (3) presented in section 3.

Table 4. Weight before and after 24 hours of sample submersion

Specimen	Before 24 hours (g)	After 24 hours (g)
1	77.6	84.8
2	77.3	84.5
3	77.1	83.9
Average Weight	77.33	84.4

Water absorption, w = [(84.4g-773g)/ 77.3g] ×100 =9.18%

The above result is in line with standards as the absorption of an MDF and all other fiberboards should not be more than 10%.

About ***the thickness swelling***, let consider the thickness variation results presented in Table 5, and determine the thickness swelling using the Eq. (4), also discussed in section 3.

Table 5. Thickness variation during sample submersion

Specimen	Before 24 hours (mm)	After 24 hours (mm)
1	12	12.1
2	12	12.09
3	12	12.04
Average depth	12	12.077

The thickness swelling, T_{sw} = [(12.077 mm - 12 mm)/ 12 mm] ×100=7.6%, what is less than 10% as well.

The above results show that the new MDF meets the standard requirements as the water absorption and thickness swelling should not be greater than 10% (Surface & Panel Buyer Guide, 2014). Therefore, this manufactured new MDF is good and it can be used inside the building as a partition element used under normal conditions of humidity and temperature.

5. Conclusion

The purpose of this study was to assess the properties of the African couchgrass as a potential MDF constitutive material. It has been observed that the use of wood as raw materials was not an environment-friendly process, and the material cost was still not affordable at the market on one side. The couchgrass is locally available in Rwanda, and has been one of the most worrying weeds for agriculture areas, while still without any positive use on the other side. With reference to many previous studies which have shown the advantages of using other renewable biomass sources for MDF manufacturing, this study proposed the use of that African couchgrass for the manufacturing of a new MDF. The assessment of the prepared material was conducted through the arrangement of some tests for checking relevant properties. The results showed that the performance of the new MDF was good. The density of the new designed MDF was 727.143 kg/m^3 while the moisture content was 5.81%, which are both in the range of recommended values by ASTM D1037, recommended to be between 640 - 800 kg/m^3 and 0 - 20% for the density and the moisture content, respectively. Further, the water absorption and thickness swelling were determined as 9.18% and 7.6% respectively which are also in line with standards as those values should not be more than 10%. The above results give optimism for the application of couchgrass in the manufacturing of MDF, and it is suggested that a more modern technique for couchgrass preparation, rather than manual work, would offer even better results. Further studies may be welcome before this new material is widely used, for evaluation of other properties like soundproofing, load-bearing capacity, fire resistance, as well as for potential replacement of the used industrial wood glue.

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