USABILITY OF AGRICULTURAL RESIDUES OUT OF THE CORN HARVEST IN THE PANELPRODUCTION

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ABSTRACT:

Residues of the field – corn harvest , namely corn stalk (plant stem and leafs), the corn cob (the inner part of the corn cob) and the corn husks (leafs around the corn cob) are processed to particle, MDF and insulation boards in order to evaluate their usability for the panel production. The material was machined in a hammer mill or refiner and afterwards sieved before processed to panels. All materials were bonded with UF and PMDI. To evaluate the properties of the produced samples they were tested on internal bond, thickness swelling and thermal conductivity. All specimen with the target density of 650 kg / m^3 and bonded with PMDI passed the requirements P2 of the EN 312. Corn stalk fibers and their fines glued with UF also passed the P2 level. None of the manufactured boards reached the P3 level for thickness swelling. The measurement of the thermal conductivity showed for corn husks 0.051 W / mK and for corn stalk fibers 0.044 W / mK. The tests showed promising results for different applications of these residues in the panel industry.

1. INTRODUCTION

Corn (Zea mays L.) is beside wheat and rice one of the most important feedstock of the world, which is also planted in our temperate regions (*Figure 1.*). Corn produces a larger amount of lignocellulose raw material than rice or wheat and is in reality the most abundant in the world [1]. Considering of this fact and the huge amount of corn that is planted worldwide, there is a big potential for different applications. Nowadays corn is used in a wide range, as animal feed, raw material for the industry (starch production), bio – energy, bio – fuel as well as food for humans. Especially interesting for the panel industry and their production is the field – corn (starch production). At harvest, the grain itself is the part of interest, all the rest of the plant is left on the field as residue. In some cases they are used for producing energy, but not everywhere. This residues, namely corn stalk (plant stem and leafs), the corn cob (the inner part of the corn cob) and the corn husks (leafs around the corn cob) are a valuable lignocellulose raw material. Those raw materials where used in this work to evaluate their usability for the panel production. The main focus was on particle boards and MDF for furniture or construction and also the application for insulation purposes.

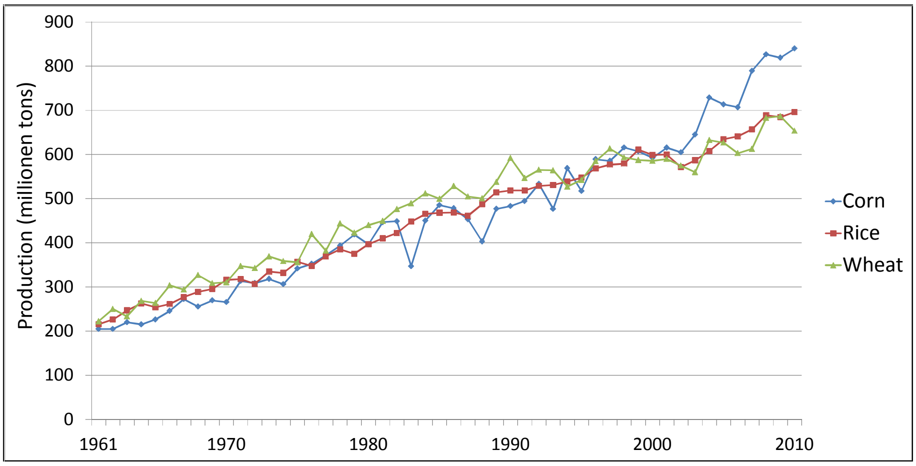

Figure 1: Development of the worldwide rice, wheat and corn production from 1961 – 2010 in million tons [2]

2. MATERIALS AND METHODS

The raw materials where prepared in different ways to cover a wide range of applications. To produce particle boards the raw material was processed in a hammer mill with two different screen sizes (4 mm and 5 mm). Fibers for the MDF (Medium Density Fiberboard) and the insulation board were machined in a laboratory Refiner, corn stalk was chosen for this method. Further, preparation methods were analysed with a laboratory sieve to compare the grading curves with the industrial standard. This was done with all raw materials, except the corn husks. In addition the hammer milled corn cob was wind sieved with a zick-zack wind sieve to remove the maize granules, which has a higher specific weight as the other fibrous material in the hammer milled part.

Urea Formaldehyde (UF) and Polymeric Methylenediphenyldiisocyanate (PMDI) where chosen as the binder for the production of the test panels. All panels, except the insulation boards, had the same pressing and gluing parameters. The resin content for UF was 12 % and for PMDI 6 % of the dry mass. A press temperature of 180°C and pressing time of 15 min was used for every pressing cycle. Target density of the normal boards was 650 kg / m^3. The insulation boards had a target density of 150 kg / m^3, manufacture out of both the corn husks and the corn stalk fibers. The corn husks were processed untreated and the glue content for both materials was 6 % PMDI, preheated in a high frequency press before pressing at 180°C to the final thickness of 40 mm.

To evaluate the usability of the material for the production of furniture panels used for furniture, construction or insulation, some parameters have to be proofed. All the panels with the target density 650 kg / m^3, representing particle boards and MDF, were tested on their IB (Internal Bond) and W (Water uptake, thickness swelling) according the standard EN 319 and EN 317. The thermal conductivity measurement was done according to the EN 12667.

2. RESULTS

In *Table 1* the design of experiment is summarised and complemented with the test results to give a complete overview on the realized research. The results of the IB tests are shown in *Figure 2*. The results of the PMDI bonded samples were better than those glued with UF. All trials with PMDI passed the P2 Norm of 0.45 N/mm^2 for panels. The boards manufactured out of corn husks (CH) were for both glue systems significantly lower compared to the other materials. Samples out of corn cob (CC) and corn stalk (CS) glued with UF did not reach the P2 level, with results of 0.32 N/mm^2 to 0.38 N/mm^2. Specimen out of CS fibers or fines of the fibers bonded with UF passed the requirements of P2 with 0.52 N/mm^2 and 0.66 N/mm^2.

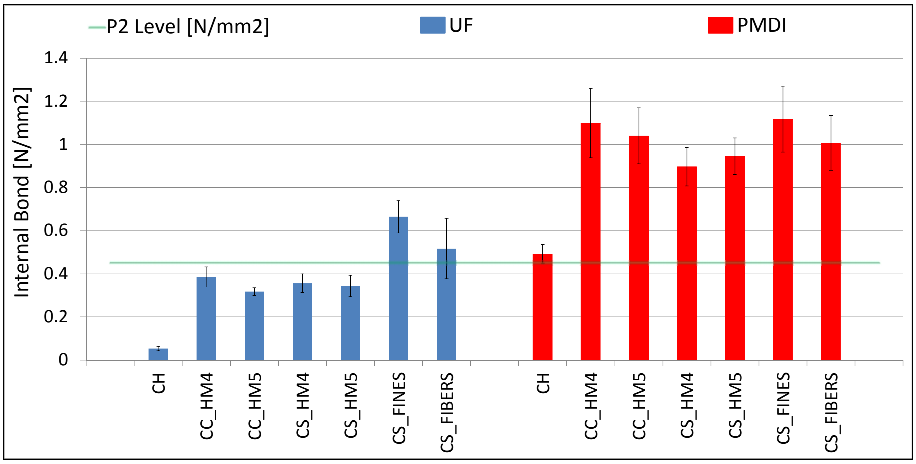

Figure 2: Results of the internal bond tests, panels out of corn husks (CH), corn cob (CC) and corn stalk (CS), in different fraction, hammer milled (HM) and fibers, and bonded with UF and PMDI.

The thickness swelling of all UF and PMDI bonded samples was too high to pass the requirements of P3, 16 %. Panels produced with CH and UF failed completely. CC samples with PMDI did not pass by 1 % with a test result of 17 %. A tendency of a lower thickness swelling when panels are bonded with PMDI instead of UF is identifable.

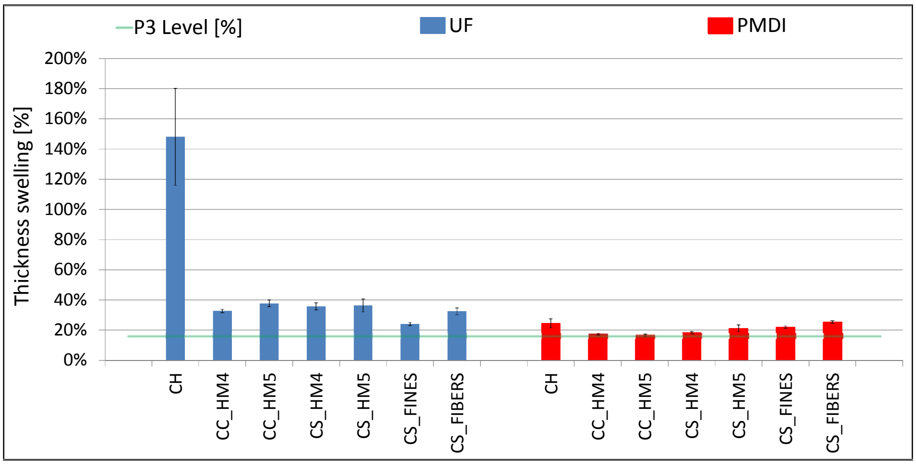

Figure 3: Results of thickness swelling tests, panels out of corn husks (CH), corn cob (CC) and corn stalk (CS), in different fraction, hammer milled (HM) and fibers, and bonded with UF and PMDI.

The measurements of the thermal conductivity showed for CH, a moisture content of 11.1 %, a density 160 kg / m^3, and a lambda of 0.051 W / mK. For the corn stalk fibers it was 0.044 W / mK with 140 kg / m^3 and 9.5 % moisture content.

2. DISCUSSION

As expected all specimen bonded with PMDI were meeting the standards for internal bond without any problem. The results of the UF bonded samples were surprisingly good; take into account all the problems that are mentioned in the literature caused by the waxy surface of annual plants [3-6]. It is shown that corn stalk machined in a refiner delivers fibers that can be bonded with UF. This year Wu, T.T. et al. published her work on producing biodegrable boards using corn straw and came to the conclusion that it is technically possible to process corn residues to a raw material usable in the board production [7].

The thickness swelling is not satisfying but could be solved with adding some hydrophobic additives to meet the requirements of the standards.

The thermal conductivity of the corn stalk fibers is comparable to wood fibers insulation boards with the same density.

Table 1: Design for the panel production and results.

Material	Preparation method	Particle size	Target density [kg/m³]	Glue system	Tests	Results
Corn Husks (CH)	-	Raw	650	UF 12%	IB	0.05 N/mm²
					W	148%
				PMDI 6%	IB	0.49 N/mm²
					W	25%
			150	PMDI 6%	TC	0.051 W/mK*
Corn Cob (CC)	Hammer mill 4mm	Wind sieved x>200µm	650	UF 12%	IB	0.38 N/mm²
					W	33%
				PMDI 6%	IB	1.1 N/mm²
					W	17%
	Hammer mill 5mm	Wind sieved x>200µm	650	UF 12%	IB	0.32 N/mm²
					W	38%
				PMDI 6%	IB	1.04 N/mm²
					W	17%
Corn Stalk (CS)	Hammer mill 4mm	x>200µm	650	UF 12%	IB	0.36 N/mm²
					W	36%
				PMDI 6%	IB	0.9 N/mm²
					W	18%
	Hammer mill 5mm	x>200µm	650	UF 12%	IB	0.34 N/mm²
					W	36%
				PMDI 6%	IB	0.95 N/mm²
					W	21%
	Refiner	2mm>x>200µm	650	UF 12%	IB	0.66 N/mm²
					W	24%
				PMDI 6%	IB	1.12 N/mm²
					W	22%
		x>2mm	650	UF 12%	IB	0.52 N/mm²
					W	32%
				PMDI 6%	IB	1.01 N/mm²
					W	25%
		x>2mm	150	PMDI 6%	TC	0.044 W/mK*

*moisture content of CH = 11.1 % and CS_FIBERS = 9.5 %, when measured.

3. CONCLUSION

Corn is a valuable resource with a potential in the tested fields of application. Even though not all tests were passed successful, the results are promising. The fact that all the panels were produced without any optimisation, for example particle sizes, moisture content, glue content, pressing time, pressing temperature and additives, make the results look even better. Of course there are still many open questions. How will the supply be solved? What about the storage? How to get the nutrients back to the field? What are the cost? Why should we change?

According to FAOSTAT (Food and Agricultural Organisation of the United Nations, Statistics) in Europe we had harvested 18.3 million hectares of field – corn in 2012 [2]. If we consider a yield of 2.5 tons dry mass per hectare of residues that could be processed we get 45 million tons of raw material readily available in Europe. If 50 % of it is already used or for animal feed, energy production or biofuel, so not process able, and calculating a yield of 50 % for preparing to usable particle or fibers, which is quiet low, we end up with ca. 11.5 tons of material. This multiplied by the density of 650 kg / m^3 would give a potential of 17.7 million m^3 of panels and represents one third of the European particle and MDF production of 45 million m^3 in 2012.

To use this potential of a lignocellulose resource further test need to be done to introduce the material to the panel industry as a reliable opportunity.

4. REFERENCES

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