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CROP BY-PRODUCTS CHARACTERIZATIONS AND VALORIZATION IN INSULATING MATERIAL: CASE OF CORN PITH AND SUNFLOWER PITH

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Abstract

The aim of this study is to investigate the potential of low-density thermal insulation materials obtained from corn pith or sunflower pith. This type of material is usually obtained by adding synthetic or natural binder. In this study, corn pith and sunflower pith are subsequently thermocompressed without the addition of binder. The addition of water coupled to thermocompression would allow the extraction of soluble compounds from the pith which acts as a binder within the material. Physical and biochemical characterizations were previously carried out on the two piths studied before implementation in materials. They highlight common properties, such as a low density as well as a capacity to control hygrometry explained by the predominant presence of a honeycomb structure. The presence of fibers traversing the corn pith observed by microscopy differs from the 100% alveolar structure of the sunflower pith. These differences impact the final properties of the particleboard.

Keywords

biochemical composition ; crop by-product ; thermal insulation ; water absorption ; bio-based material

1. Introduction

Buildings are responsible for approximately 40% of energy consumption and 36% of CO₂ emissions in the EU [1]. One of the most important challenges of future and existing buildings is the reduction of energy consumptions in all their life phases, from construction to demolition. The introduction of the concept of “sustainability” in the building sector gradually led to the production of insulation products made of recycled or natural material [2]. Several authors reported that bio-based insulation materials made from crop by-products are an interesting alternative to those obtained from fossil energy. They have lower thermal conductivity and density, are cheaper, available in abundance and environmentally friendly compared to conventional ones [3]. In this context, low-density particleboards were developed from a combination of crop by-products and natural binders to have potential application for ceiling panels, core materials, and bulletin boards [4].

The sunflower stalks are not at all valorized. They are left in the field after head harvesting. All the harvesting and industrial valorization chain must be carried out but this agricultural byproduct presents a very high potential of valorization for agromaterials [5]. About the corn stalks, the valorization chain

exists at industrial scale but new valorization ways can be considered [6]. The aim of this study was to manufacture and to characterize binderless particleboards made from sunflower or corn pith in order to contribute to the understanding of the structure-property relationships.

2. Material and Methods

2.1. Materials

This study is performed on two kinds of raw materials : sunflower pith came from the South-West of France and corn pith supplied by Cormo Enterprise and came from East of France. The sunflower pith is the internal part of sunflower stalks. It can be obtained after separation of the sunflower bark which forms the external part of the stalks [7]. The corn pith is the internal part of corn stalks. It can be obtained after separation of the corn bark which forms the external part of the stalks [6].

Different physical characterizations were performed (Figure 1) bulk density, specific density, obtained with a helium pycnometer method, and particle size distribution obtained by mechanical sieving. They were measured at dry state following the recommendations of the Rilem TC BBM [8].

Figure 1 : Physical characterizations of sunflower and corn piths batches used

	sunflower pith	corn pith																																																				
bulk density (Kg.m⁻³)	22,1 ± 0,1	15,0 ± 0,3																																																				
specific density (Kg.m⁻³)	1034 ± 16	1254 ± 24																																																				
particle size distribution	<table border="1"> <caption>Particle Size Distribution Data for Sunflower Pith</caption> <thead> <tr> <th>Sieve Size (µm)</th> <th>Percentage (%)</th> </tr> </thead> <tbody> <tr><td>16</td><td>0.0</td></tr> <tr><td>12.5</td><td>0.0</td></tr> <tr><td>10</td><td>0.0</td></tr> <tr><td>8</td><td>0.0</td></tr> <tr><td>6.3</td><td>0.0</td></tr> <tr><td>4</td><td>7.1</td></tr> <tr><td>2</td><td>23.8</td></tr> <tr><td>1</td><td>36.3</td></tr> <tr><td>0.5</td><td>20.4</td></tr> <tr><td>0.25</td><td>6.1</td></tr> <tr><td>0.1</td><td>0.0</td></tr> <tr><td>tamisat</td><td>0.0</td></tr> </tbody> </table>	Sieve Size (µm)	Percentage (%)	16	0.0	12.5	0.0	10	0.0	8	0.0	6.3	0.0	4	7.1	2	23.8	1	36.3	0.5	20.4	0.25	6.1	0.1	0.0	tamisat	0.0	<table border="1"> <caption>Particle Size Distribution Data for Corn Pith</caption> <thead> <tr> <th>Sieve Size (µm)</th> <th>Percentage (%)</th> </tr> </thead> <tbody> <tr><td>16</td><td>0.0</td></tr> <tr><td>12.5</td><td>0.0</td></tr> <tr><td>10</td><td>0.0</td></tr> <tr><td>8</td><td>0.0</td></tr> <tr><td>6.3</td><td>4.5</td></tr> <tr><td>4</td><td>26.9</td></tr> <tr><td>2</td><td>61.2</td></tr> <tr><td>1</td><td>4.7</td></tr> <tr><td>0.5</td><td>0.0</td></tr> <tr><td>0.25</td><td>0.0</td></tr> <tr><td>0.1</td><td>0.0</td></tr> <tr><td>tamisat</td><td>0.0</td></tr> </tbody> </table>	Sieve Size (µm)	Percentage (%)	16	0.0	12.5	0.0	10	0.0	8	0.0	6.3	4.5	4	26.9	2	61.2	1	4.7	0.5	0.0	0.25	0.0	0.1	0.0	tamisat	0.0
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SEM analysis permit to observe the honeycomb structure for both of piths, the presence of fibers traversing the corn pith and the number of pores in the sunflower pith higher than in the corn pith.

2.2. Method for biochemical characterization (Van Soest method)

The first extraction is realized with NDF (Neutral Detergent Fiber) solution, in the Fibertec™ 8000 Automated Fiber Analyzer to remove soluble cell contents. ADF (Acid Detergent Fiber) solution is used for the second extraction. The last extraction is realized with ADL (Acid Detergent Lignin) solution

which is 72% sulfuric acid. After each extraction, porous bags are rinsed in water, hed with acetone and dried overnight at 105°C. Then, the calcination of the samples at 480°C for 3 hours is done [9].

2.3. Water Absorption

Water absorption was measured following the recommendations of the Rilem TC BBM [8]. The measurement of water absorption consists in drying aggregates and then calculating their water content at different immersion times.

2.4. Particleboard manufacturing

Particleboards are made with particles of pith (sunflower or corn) without any binder addition. The quantity of matter used was calculated in order to obtain panels with different density between 25 to 100 kg.m⁻³. The pith particles blended with water (80% mass/vegetal particles mass) were thermocompressed during 45 minutes for the panel at 150°C. Chocks are utilized to stop the closure of the mold in order to obtain a fixed panel volume and so the target density. The size particleboard was 150*150*25 mm³.

2.5 Thermal Conductivity

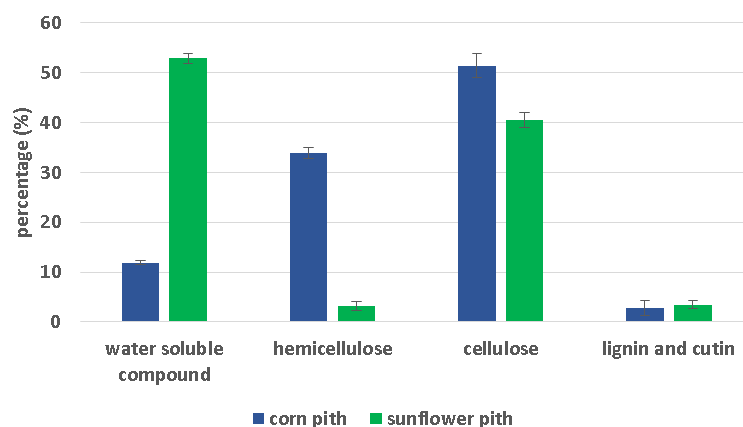
The thermal conductivity of the particleboards was measured with a Heat Flow Meter HFM 436 Lamda from Netzch. The sample size was 150*150*25 mm³. The measurements were performed in a steady state at 20°C with a temperature gradient between the hot and the cold plate of 20°C and repeated at least 3 times for each material.

3. Results and discussion

3.1. Piths characterizations

The content of water-soluble compounds, hemicellulose, cellulose and lignin, determined by the Van Soest method, from sunflower and corn piths, are shown in the figure 2.

Figure 2 : Biochemical composition of piths

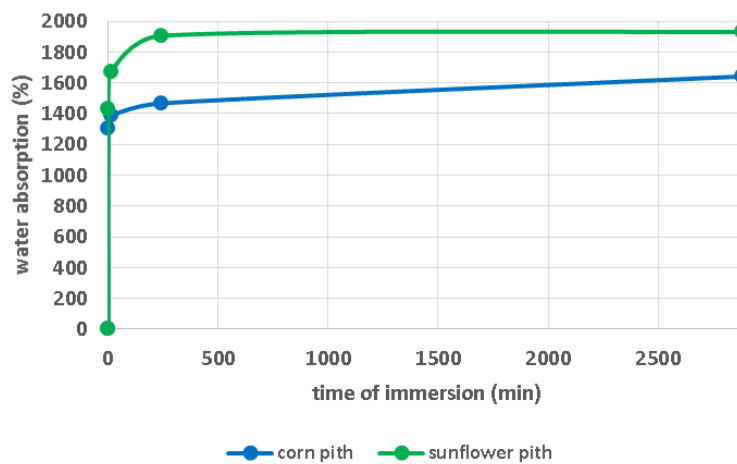


Large differences in the biochemical composition between both piths are evident. Corn pith has the highest cellulose content (51,4%). There was a significant difference in hemicellulose levels between sunflower pith (3,1%) and corn pith (33,9%). Sunflower pith has the highest soluble content (52,9%).Lignin content are near for both of piths.

The cellulose is present in all the different walls of plant cell, in the form of cellulose microfibrils (fiber-like strand). Cellulose microfibrils has a rigid structure, formed from many cellulose molecules, in order to create the strong support structure that allows agro-resources to stand upright. Between the cellulose microfibrils, hemicellulose forms a network and is the second component of plant cells. In the second wall, lignin, acts as a cement, has a supportive structural function and also protects the cellulose and hemicellulose [10]. The study of the biochemical composition and molecules in plant cell surface may help to better understand the impact of the chemical interaction between pith particles during the manufacturing process of particleboards.

The figure 3 presents the mass percentage of water absorbed versus immersion time in water.

Figure 3 : Water absorption of piths

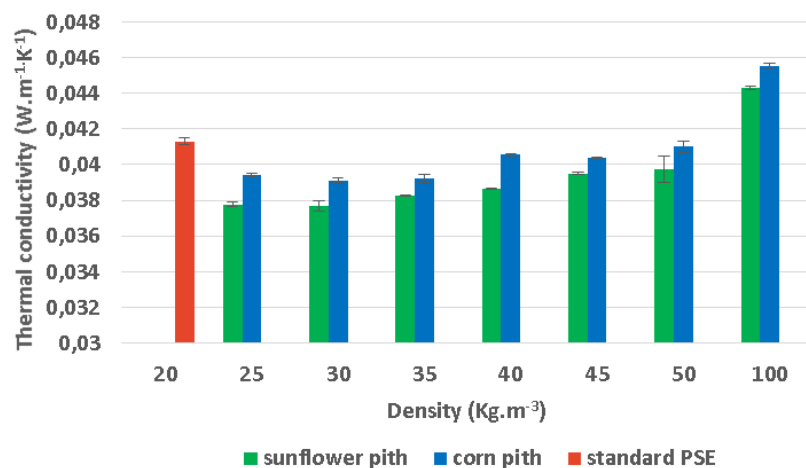


It can be seen in the figure 3 that both aggregates absorb most of their water over the 48 hour testing period in the first minute. The results were shown that the sunflower pith absorbs more water than the corn pith; after 48 hours the sunflower pith has absorbed about 1900 % of its own weight in water whereas the corn pith absorbed about 1600 %. Both of which are very high. The high porosity observed by SEM (figure 1) allows the aggregate to pump water using capillarity forces and also diffuse it. The lowest water absorption content for corn pith is explained by the presence of fibers in the honeycomb structure.

3.2. Insulation properties of particleboards

It seems interesting to realize a particleboard without binder because this corresponds to valorization only of the agroresource and its internal composition. In fact, it has been demonstrated that water-soluble compounds are responsible for the self-adhesion capacity of agro-resources during the thermomechanical steam treatment of binderless particleboards. Interesting compounds must be extracted from the vegetal matter thanks to vapor and then activated with heating to act as binder and then obtain cohesive particleboards [11]. The high absorption of water by both aggregates permits to access to the water-soluble compounds. As described previously, the vapor can be obtained by vaporization in the mold of the water previously blended with the vegetal particles. The binderless particleboards obtained in this study had sufficient strength to handle.

The figure 4 summarizes the thermal conductivity at different densities.

Figure 4 : Thermal conductivity of piths compared to PSE

Globally, the thermal conductivity increases with bulk density. All the studied panels present interesting thermal conductivities in comparison with classical polystyrene panel (standard PSE) which present a thermal conductivity of 0,041 W.m⁻¹.K⁻¹. For densities of particleboards between 25 to 50 Kg.m⁻³, thermal conductivities values are less than the standard PSE (0.038 to 0.040 W.m⁻¹.K⁻¹). Both piths present mainly a honeycomb structure with fine cavities full of air, the best insulator. The particleboards include two types of porosity: the internal porosity of the vegetal particleboards and the porosity induced by the arrangement of the particles in the panel, which is linked to the panel density.

The panels made of corn pith present a slightly higher thermal conductivity than these made of sunflower pith at the same panel density. At the same particleboard density, the internal porosity of the vegetal particles has a more important role in the material insulation capacity. This observation is confirmed by the difference between thermal conductivities of comparable panels made of sunflower pith or corn pith. The increasing of thermal conductivity is explained by the difference between specific densities and by the presence of fibers traversing the corn pith observed by SEM (figure 1).

3. Conclusion

In this paper, we have investigated the potential uses of sunflower pith and corn pith in low-density particleboards. The study of characterizations highlighted a large difference of biochemical compositions and an important water absorption capacity due to the high porosities. The results of the various experiments presented in the paper showed that sunflower and corn piths can be used with advantage in manufacturing particleboards without binder. Insulation properties of all particleboards studied are interesting, with thermal conductivities near to commercial reference. However, it is interesting to note that the difference of structure of both piths impact on the insulation properties.

Further research is still required to study other properties such as the mechanical ones, and to qualify the fire resistance.

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