New insulation fiberboards from sunflower cake with improved thermal and mechanical properties

Philippe Evon, Justine Vinet, Matthieu Rigal, Laurent Labonne, Luc Rigal

New insulation fiberboards from sunflower cake with improved thermal and mechanical properties

Philippe Evon[1,2,a], **Justine Vinet**[1,2], **Matthieu Rigal**[1,2], **Laurent Labonne**[1,2], **Luc Rigal**[1,2]

[1] *University of Toulouse, INP, Laboratory of Agro-Industrial Chemistry, ENSIACET, 4 Allée Emile Monso, BP 44362, 31030 Toulouse Cedex 4, France*
[2] *University of Toulouse, INRA, Laboratory of Agro-Industrial Chemistry, 31030 Toulouse Cedex 4, France*
[a] *E-mail address (corresponding author): Philippe.Evon@ensiacet.fr*

Introduction

Biorefinery of sunflower (*Helianthus annuus* L.) whole plant can be conducted in a co-rotating Clextral BC 45 (France) twin-screw extruder [1]. Such a thermo-mechanical fractionation generates a cake. The cake is largely composed of ligno-cellulosic fibers (more than 50%). Actually, it is a lixiviated matter where soluble molecules (proteins, pectins) and lipids are partly removed. At the same time, molecules from plant skeleton are not extracted.

New valorizations of the cake as a mixture of ligno-cellulosic fibers and proteins can be considered. As a natural composite, it is successfully processed into dense boards by thermo-pressing [1, 2]. Proteins ensure the agromaterial cohesion, and fibers entanglement also acts like reinforcement. Thermal insulation fiberboards can be also produced [3]. But, their ability for thermal insulation of buildings would have to be improved.

This study aimed to manufacture by pressing at ambient temperature new insulation fiberboards with improved thermal and mechanical properties by adding to the cake different natural binders at different contents. The influence of molding conditions on board density, mechanical properties (flexural properties and Shore D surface hardness) and heat insulation properties was examined. Molding conditions included binder type (starch, casein or gelatine) and binder content (10%, 15%, 20% and 25%).

Experimental

The starting material was a slightly deoiled cake (17.4% oil content), and fibers represented 51.6% of its dry matter. The natural binder was dissolved in 500 g water and then mixed manually to the cake (250 g). The mixture was molded inside an aluminium mold using a hydraulic press. Pressure applied and molding time were 0.9 kgf/cm^2 and 30 s, respectively. Insulation boards produced were 150 mm × 150 mm square boards. They were dried at 80 °C using a ventilated oven to eliminate water added for binder dissolution and then equilibrated in a climatic chamber (60% RH, 25 °C) for three weeks before any analyses.

Results and discussion

All fiberboards produced were cohesive mixtures of a natural binder and ligno-cellulosic fibers, acting respectively as binder and reinforcing fillers, in what could be considered as a natural composite. Molding conditions greatly affected board density and thus the mechanical and heat insulation properties (Table 1). Board density increased with increasingly binder content, rising from 338.3 to 375.3 kg/m^3 with starch, from 266.1 to 439.0 kg/m^3 with casein and from 254.9 to 315.1 kg/m^3 with gelatine. The mechanical properties increased at the same time. As an example, mechanical properties of casein-based boards varied from 30.4 to 1477.7 kPa for flexural strength at break, from 0.8 to 34.4 MPa for elastic modulus, and from 6.7 to 20.3° for Shore D surface hardness. Conversely, heat insulation properties improved with decreasing board density, and the lowest thermal conductivity was obtained for each natural binder tested with the least dense fiberboard. As an example, for the casein-based boards, it was only 67.6 mW/m K at 25 °C for a 10% binder content and it reached 84.8 mW/m K for a 25% binder content. The best compromise between mechanical properties (347.0 kPa flexural strength at break, 9.5 MPa elastic modulus, and 18.9° Shore D surface hardness), and heat insulation properties (77.6 mW/m K thermal conductivity at 25 °C) was the 20% binder content starch-based board (board S3). The corresponding board density was medium (357.9 kg/m^3). Because of its promising heat insulation properties, this new fiberboard could be positioned on walls and ceilings for thermal insulation of buildings. The bulk cake also revealed very low thermal conductivity (only 62.0 mW/m K at 25 °C) due to its very low bulk density (198.0 kg/m^3). It could be used as loose fill in the attics of houses.

Table 1 *Mechanical and heat insulation properties of the twelve fiberboards manufactured*

Board number	S1	S2	S3	S4	C1	C2	C3	C4	G1	G2	G3	G4
Molding conditions												
Binder type	S	S	S	S	C	C	C	C	G	G	G	G
Binder content (%)	10	15	20	25	10	15	20	25	10	15	20	25
Mechanical properties (standards NF EN 310 for flexural properties and NF EN ISO 868 for surface hardness)												
t (mm)	34.8	37.1	38.7	40.6	38.3	37.3	35.8	35.5	37.2	38.5	39.9	39.6
d (kg/m^3)	338.3	346.4	357.9	375.3	266.1	339.6	394.5	439.0	254.9	270.8	280.9	315.1
σ_f (kPa)	184.6	256.9	347.0	604.4	30.4	176.3	987.0	1477.7	10.2	10.2	14.9	55.9
E_f (MPa)	7.0	9.9	9.5	12.9	0.8	4.8	25.6	34.4	0.3	0.5	0.5	1.8
Shore D (°)	14.5	15.5	18.9	24.6	6.7	13.0	17.9	20.3	4.8	13.8	16.8	27.4
Heat insulation properties at 25 °C (standard ISO 8302 08-91)												
λ (mW/m K)	74.4	75.7	77.6	83.4	67.6	72.1	79.1	84.8	64.0	69.5	71.0	73.1
R (m^2 K/W)	0.468	0.490	0.499	0.487	0.567	0.517	0.452	0.418	0.582	0.554	0.562	0.542

S, starch; C, casein; G, gelatine. – t, board thickness; d, board density; σ_f, flexural strength at break; E_f, elastic modulus. – λ, thermal conductivity; R, thermal resistance.

Conclusion

New insulation fiberboards from sunflower cake with improved thermal and mechanical properties were produced by pressing at ambient temperature. Best compromise between mechanical and heat insulation properties was a starch-based board with 20% binder content. Because of its promising heat insulation properties, this new fiberboard could be positioned on walls and ceilings for thermal insulation of buildings. The bulk cake could also be used as loose fill in the attics of houses.

References

1. Evon P, Vandenbossche V, Pontalier PY, Rigal L. The twin-screw extrusion technology, an original and powerful solution for the biorefinery of sunflower whole plant. Ol Corps gras Li 2010;17(6):404-417.
2. Evon P, Vandenbossche V, Rigal L. Manufacturing of renewable and biodegradable fiberboards from cake generated during biorefinery of sunflower whole plant in twin-screw extruder: influence of thermo-pressing conditions. Polym Degrad Stabil 2010;97(10):1940-1947.
3. Evon P, Vandenbossche V, Pontalier PY, Rigal L. New thermal insulation fiberboards from cake generated during biorefinery of sunflower whole plant in a twin-screw extruder. Ind Crops Prod 2014;52:354-362.