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# NEW RENEWABLE AND BIODEGRADABLE FIBERBOARDS FROM A CORIANDER PRESS CAKE

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## Introduction

Coriander (*Coriandrum sativum* L.) is an annual herb, commonly used as a condiment or a spice. The coriander fruits are particularly interesting as they contain both a vegetable oil and an essential oil, even if the latter is present in significantly smaller proportions. The main fatty acid in *Coriandrum sativum* vegetable oil is petroselinic acid. It forms a unique oleochemical with high potential for food, cosmetic and pharmaceutical industries. Moreover, vegetable oil from coriander fruits has recently been labeled as a novel food ingredient [1]. Therefore, the development of a new process for the extraction of coriander oil is a major challenge for the years to come.

Industrial oil extraction from coriander fruits is usually carried out by mechanical pressing with a single expeller press, followed by solvent extraction. Recently, mechanical pressing of coriander oil was also conducted successfully using a twin-screw extruder [2]. As mixtures of proteins and lignocellulosic fibers, the obtained press cakes can be considered as natural composites. Therefore, they could be transformed into biodegradable agromaterials through thermo-pressing [3-8].

This study aimed to evaluate the influence of the thermo-pressing conditions (mold temperature, applied pressure and molding time) on the mechanical properties, the thickness swelling and the water absorption of fiberboards made from a coriander press cake produced in a single-screw extruder.

## Results and discussion

New renewable and biodegradable fiberboards were manufactured from a coriander press cake by thermo-pressing. The press cake originated from the extraction of vegetable oil from coriander fruits of French origin through mechanical pressing, using an OMEGA 20 (France) single-screw extruder. Its residual oil content was 17.2% of the dry matter instead of 27.7% for the fruits, leading to an oil extraction yield of 47.6% during extrusion. As a mixture of proteins (18.2%) and lignocellulosic fibers (53.8% including cellulose, hemicelluloses and lignins), the press cake was a natural composite. It was crushed before thermo-pressing using an Electra F3 (France) hammer mill fitted with a 15 mm screen. After milling, it consisted of almost spherical particles with a mean diameter of around 170  $\mu\text{m}$  and its apparent and tapped densities were 0.416 and 0.482  $\text{g}/\text{cm}^3$ , respectively. Lastly, its thermogravimetric analysis (TGA) performed with a Shimadzu TGA-50 (Japan) analyzer revealed that no thermal degradation of the organic compounds in the press cake occurs before 225  $^{\circ}\text{C}$ .

A PEI (France) heated hydraulic press with 400 tons capacity was used for thermo-pressing. The square mold applied was 15 cm  $\times$  15 cm, and it was equipped with vents to allow the expression of part of the residual oil during molding. The moisture and the mass of the press cake at molding were 2.1% and 200 g, respectively, for all tested thermo-pressing conditions. These comprised 160-200  $^{\circ}\text{C}$  mold temperature, 24.5-49.0 MPa applied pressure and 60-180 s molding time. The eight fiberboards resulting from these thermo-pressing conditions (Table 1) were all cohesive, with proteins and fibers acting respectively as a natural binder and reinforcing fillers.

When comparing boards from trials 1, 2 and 7, the increase in mold temperature (from 160 to 200  $^{\circ}\text{C}$ ) led to a significant reduction in viscosity of the protein-based resin resulting in the progressive improvement of fiber wetting. This could explain why the board density and its mechanical properties increased as the mold temperature increased, the 200  $^{\circ}\text{C}$  mold temperature (trial 7) leading to the most resistant (1.30 board density, 11.3 MPa flexural strength at break, 2625 MPa elastic modulus, 1.26  $\text{kJ}/\text{m}^2$  resilience and 70.8 $^{\circ}$  surface hardness) and the least water-sensitive (51% thickness swelling and 33% water absorption) fiberboard.

For this optimal mold temperature, both the applied pressure and the molding time affected the board density, its mechanical properties, its thickness swelling and its water absorption. For the 60 s molding time (trials 3 to 5), the increase in the applied pressure resulted in an increased board density, enhanced mechanical properties and in a decreased water-sensitivity. Next to this, further improvement of the flexural properties, the surface hardness, the thickness swelling and the water absorption was obtained for the 180 s molding time with every tested condition of applied pressure (trials 6 to 8).

The best compromise between mechanical properties, thickness swelling and water absorption is represented by the board from trial 7 (Table 1). It was produced from the following thermo-pressing conditions: 200 °C mold temperature, 36.8 MPa applied pressure and 180 s molding time. Moreover, the pressure applied during molding resulted in the expression of part of the residual oil in the press cake. This led to a decrease in the residual oil content inside fiberboards (7.7% of the dry matter for trial 7) and to an increase in the total oil yield (from 47.6% after extrusion to 79.7% after thermo-pressing for trial 7).

**Table 1** – Thermo-pressing conditions, mechanical properties, thickness swelling (TS) and water absorption (WA) of the fiberboards manufactured.

Trial	1	2	3	4	5	6	7	8
Thermo-pressing conditions								
Temperature (°C)	160	180	200	200	200	200	200	200
Pressure (MPa)	36.8	36.8	24.5	36.8	49.0	24.5	36.8	49.0
Time (s)	180	180	60	60	60	180	180	180
Flexural properties (French standard NF EN 310) <sup>1</sup>								
t (mm)	6.36	6.20	6.52	6.24	6.11	6.15	5.93	6.00
d	1.27	1.28	1.24	1.27	1.28	1.29	1.30	1.29
F (N)	36.6	52.0	30.3	49.7	66.2	70.6	79.5	68.4
$\sigma_f$ (MPa)	4.5	6.8	3.6	6.4	8.9	9.3	11.3	9.5
$E_f$ (MPa)	929	1457	785	1418	1895	2141	2625	2074
Charpy impact strength at 23 °C (French standard NF EN ISO 179, unnotched test specimens) <sup>2</sup>								
W (mJ)	70	67	73	82	86	80	75	82
K (kJ/m <sup>2</sup> )	1.09	1.08	1.12	1.32	1.40	1.30	1.26	1.36
Surface hardness (French standard NF EN ISO 868)								
Shore D (°)	60.8	63.6	59.5	65.0	66.2	68.8	70.8	69.7
Thickness swelling and water absorption (French Standard NF EN 317) <sup>3</sup>								
TS (%)	157	160	148	137	124	69	51	42
WA (%)	167	112	173	71	67	39	33	42

<sup>1</sup> 30 mm specimen width and 100 mm grip separation. <sup>2</sup> 10 mm specimen width and 25 mm grip separation. <sup>3</sup> 50 mm × 50 mm samples. – t, thickness; d, density; F, breaking load;  $\sigma_f$ , flexural strength at break;  $E_f$ , elastic modulus. W, absorbed energy; K, resilience.

## Conclusion

In regard to the mechanical properties of the board 7 and its water-sensitivity, such a fiberboard would be applicable as inter-layer sheets for pallets, for the manufacture of containers or furniture, or in the building trade (floor under-layers, interior partitions or ceiling tiles). Moreover, thermo-pressing not only produces cohesive fiberboards, but also significantly increases the oil extraction efficiency.

## References

1. European Food Safety Authority (EFSA) *EFSA J.* **2013**, *11* (10), 3422.
2. E. Uitterhaegen; Q.H. Nguyen; K.A. Sampaio; C.V. Stevens; O. Merah; T. Talou; L. Rigal; Ph. Evon *J. Am. Oil Chem. Soc.* **under review**.
3. Ph. Evon; V. Vandebossche; P.Y. Pontalier; L. Rigal *Adv. Mater. Res.* **2010**, *112*, 63-72.
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- This study aimed to evaluate the influence of the thermo-pressing conditions (mold temperature, applied pressure and molding time) on the mechanical properties, the thickness swelling and the water absorption of fiberboards made from a coriander press cake produced in a single-screw extruder.

## Results and discussion

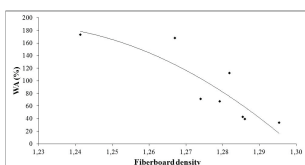
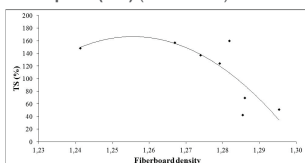
- New biodegradable fiberboards were manufactured from a coriander press cake by thermo-pressing.
- The press cake originated from the extraction of vegetable oil from coriander fruits of French origin through mechanical pressing, using an OMEGA 20 (France) single-screw extruder.
- Its residual oil content was 17.2% of the dry matter instead of 27.7% for the fruits, leading to an oil extraction yield of 47.6% during extrusion.
- As a mixture of proteins (18.2%) and lignocellulosic fibers (53.8%), the press cake was a natural composite.
- It was crushed before thermo-pressing using an Electra F3 (France) hammer mill fitted with a 15 mm screen.
- After milling, it consisted of almost spherical particles with a mean diameter of around 170  $\mu\text{m}$ .
- Its apparent and tapped densities were 0.416 and 0.482  $\text{g}/\text{cm}^3$ , respectively.
- Its TGA analysis revealed that no thermal degradation of the organic compounds occurs before 225  $^{\circ}\text{C}$ .

- A PEI (France) heated hydraulic press with 400 tons capacity was used for thermo-pressing.
- The square mold applied was 15 cm x 15 cm.
- It was equipped with vents to allow the expression of part of the residual oil during molding.
- The moisture and the mass of the press cake at molding were 2.1% and 200 g, respectively, for all tested thermo-pressing conditions (Table 1).
- The eight fiberboards resulting from these thermo-pressing conditions were all cohesive, with proteins and fibers acting respectively as a natural binder and reinforcing fillers.

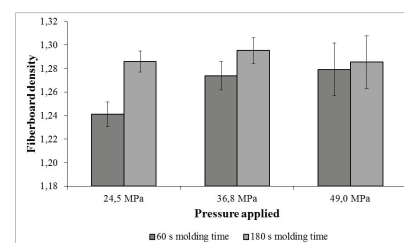
**Table 1.** Thermo-pressing conditions used for the manufacture of the eight fiberboards.

Trial	1	2	3	4	5	6	7	8
Mold temperature ( $^{\circ}\text{C}$ )	160	180	200	200	200	200	200	200
Applied pressure (MPa)	36.8	36.8	24.5	36.8	49.0	24.5	36.8	49.0
Molding time (s)	180	180	60	60	60	180	180	180

### Thickness swelling (TS) and water absorption (WA) (NF EN 317)

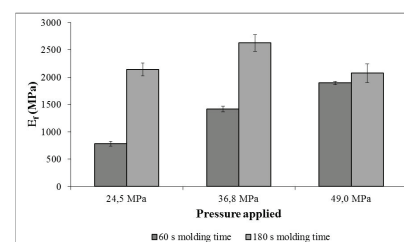
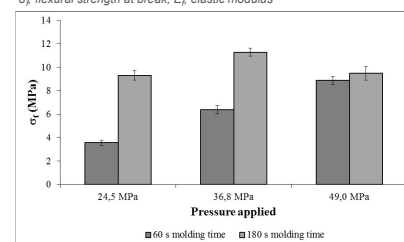


- When comparing boards from trials 1, 2 and 7, the increase in mold temperature (from 160 to 200  $^{\circ}\text{C}$ ) led to a reduction in viscosity of the protein-based resin resulting in the progressive improvement of fiber wetting.  
 **$\Rightarrow$  The 200  $^{\circ}\text{C}$  mold temperature (trial 7) led to the most resistant and the least water-sensitive fiberboard.**
- For this optimal mold temperature, the best compromise between mechanical properties (11.3 MPa flexural strength at break, 2.6 GPa elastic modulus and 70.8 $^{\circ}$  Shore D surface hardness), thickness swelling (51%) and water absorption (33%) was the board from trial 7 (Table 1 and Figures).  
 **$\Rightarrow$  Optimal molding conditions: 200  $^{\circ}\text{C}$  mold temperature, 36.8 MPa applied pressure and 180 s molding time.**
- Moreover, the pressure applied during molding resulted in the expression of part of the residual oil in the press cake.  
 **$\Rightarrow$  This led to:**
  - a decrease in the residual oil content inside fiberboards (7.7% of the dry matter for trial 7).
  - an increase in the total oil yield (from 47.6% after extrusion to 79.7% after thermo-pressing for trial 7).

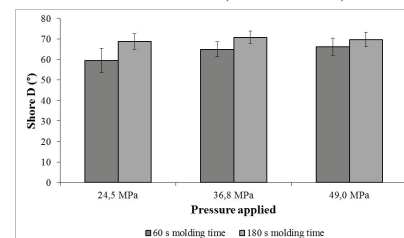


### Flexural properties (NF EN 310)

$\sigma_b$  flexural strength at break;  $E_s$  elastic modulus



### Shore D surface hardness (NF EN ISO 868)



## Conclusion

- In regard to the mechanical properties of the board 7 and its water-sensitivity, such a fiberboard would be applicable as inter-layer sheets for pallets, for the manufacture of containers or furniture, or in the building trade (floor under-layers, interior partitions or ceiling tiles).
- Moreover, thermo-pressing not only produces cohesive fiberboards, but also significantly increases the oil extraction efficiency.

## REFERENCES

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