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# INFLUENCE OF HOT-PRESSING TEMPERATURE ON PROPERTIES OF ECO-FRIENDLY DRY-PROCESS FIBREBORDS WITH LIGNOSULFONATE ADHESIVE

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## ABSTRACT

A major challenge for the producers of wood-based panels is to achieve formaldehyde emissions at wood levels. For that purpose, various types of lignin have emerged as particularly promising substitutes for the traditionally used urea-formaldehyde resins.

Lignosulfonates are a by-product of the production of cellulose by the sulphite method. They are practically harmless to human health. The main functional groups of lignosulfonates are the hydroxyl groups and the connection with fibres is mainly through hydrogen bonds. To form these bonds, in addition to the surface with active hydroxyl groups, the temperature of hot-pressing is also essential.

This paper presents a study on the effect of hot-pressing temperature on the properties of eco-friendly dry-process fibreboards. As an adhesive was used calcium lignosulfonate in a content of 10% to absolutely dry fibres. In the experiment, the hot-pressing temperature varied from 150 to 200° C, with increments of 10° C. The main physical and mechanical properties of the panels were determined. On this basis, an analysis was made. It was found that the properties of dry-process fibreboards with only lignosulfonate as a binder are significantly affected by the temperature of hot-pressing, because of which the hot-pressing temperature should be at least 190°C.

**Key words:** eco-friendly dry-process fibreboards, calcium lignosulfonate, hot-pressing temperature.

## INTRODUCTION

The industry for the production of the wood-based panel is one of the fastest-growing industries worldwide (FAO; Neykov, N et al. 2018; Neykov, N. et al. 2017). The production of fibreboards and in particular the production of dry-process fibreboards has a significant, almost 30%, share in this industry (FAO; Neykov, N. et al. 2020). Because of the new regulations and the introduction of emission classes $E_0$ and super-$E_0$, the main challenge for this industry is the reduction of formaldehyde emissions from the panels (Popovic, M et al 2020; Athanassiadou, E. 2017; Brezin, V. and Antov, P. 2015; Carvalho, L. et al. 2012; Doosthoseini K. et al 2010). A solution to the problem can be sought by partially or completely replacement of formaldehyde resins with other binders (Dunky, M. 2020; Sepahvand, S et al. 2018; Tisserat, B. et al. 2019; Solt, P et al. 2019) or modifications of traditionally used formaldehyde resin (Pizzi, A. et al. 2020; Tudor, E.M. et al 2020; Ružiak, I. et al. 2017).

Wood-based panels with low emissions of formaldehyde could be produced with pMDI (Pizzi, A. 2003; Frazier C.E. 2003). However, this type of binder is used by a limited number of plants worldwide. The use of pMDI requires a modification of the technology for the production of wood-based panels and increases the cost of production (Hornus, M et al. 2020). Another suitable replacement for formaldehyde resins is with bio-based, green, binders (Nordström, E. et al. 2017; Yotov, N. et al. 2017). The bio-based binders include the different types of lignin (Dunky, 2020; Hemmilä, V et al. 2017; Saražin, J. et al. 2021), tannins (Pizzi, A. 2019), soy-based adhesives (Ghahri, S. and Pizzi, A. 2018; Ghahri, S. et al. 2018), starch (Antov, P et. al.2020 a).

The use of bio-based binders will lead to the maximum utilization of natural resources and residual products from other industries. Lignosulfonates belong to the group of these types of binders. Since the main reagent groups of lignosulfonates are the hydroxyl groups (Dimitrescu L. et al. 2017), which form hydrogen bonds, they are particularly suitable for use in the production of fibreboards.

There are successful studies for both partial and complete replacement of formaldehyde resins with lignosulfonates (Antov, P et al. 2019; Savov, V et al. 2019; Hemmilä, V et al. 2019; Savov, V. and Mihajlova, J. 2017a; Savov, V. and Mihajlova, J. 2017b). However, a significant disadvantage of lignosulfonates is the poor water-resistance of the panels produced with them (Antov, P et al. 2020b). The leaching of lignosulfonates from the panel is in strong correlation with the temperature of hot-pressing (Savov, V and Antov, P. 2020).

The hot-pressing regime is essential for the properties of all wood-based panels, including fibreboards, and the hot-pressing temperature is of major importance in it (Gul W., et al. 2017; Khayal Os. 2019 Igaz, R. et al. 2016).

This research aims to study the effect of hot-pressing temperature on the properties of eco-friendly dry-process fibreboards bonded with calcium lignosulfonate.

## MATERIALS AND METHODS

For the experiments was used industrially produced wood-fibre mass. The pulp was produced in "Welde-Bulgaria" by the "Asplund" thermo-mechanical method and was composed of hardwood tree species – beech (*Fagus sylvatica*, L.) and Turkish oak (*Quercus cerris*, L.) in a ratio of 2:1. The moisture content of the pulp was 11% and the bulk density was 31 $kg.m^{-3}$. As an adhesive was used calcium lignosulfonate. The calcium lignosulfonate used had the following characteristics: calcium – up to 6%; reduced sugars – 7%; ash content – 14%; dry content – 93%; acidic factor in 10% solution – pH = $4.3 \pm 0.8$; bulk density – 550 $kg.m^{-3}$. The content of lignosulfonate was 10% relative to the absolutely dry wood fibres. The target thickness of the fibreboards was 6 mm at a target density of 920 $kg.m^{-3}$. Dry-process fibreboards with these parameters are most often industrially produced for use as the core of laminated wood flooring or thin structural elements.

To be determined the influence of hot-pressing temperature on properties of eco-friendly dry-process fibreboards the hot-pressing temperature varied from 150 to 200ºC. The step of variation was 10ºC. For the improvement of the distribution of lignosulfonate in fibreboards, it was introduced into the pulp as a solution with a concentration of 30%. Wood fibres were mixed in a high-speed glue blender (850 $min^{-1}$). The injection was through a nozzle with a diameter of 1.5 mm at a pressure of 0.6 MPa. The calcium lignosulfonate was introduced for 50 s and then the pulp and lignosulfonate were stirred for a further 3 minutes.

For the hot-pressing was used laboratory press PMS ST 100, Italy. A standard three-stage hot-pressing cycle was applied. The regime of hot-pressing was as follows: $1^{st}$ stage was 20% of the entire cycle and the specific pressure was 3.0 MPa; 2nd stage was at a specific pressure of 1.2 MPa and was maintained for 30% of an entire cycle; the specific pressure in 3rd stage was 0.6 MPa and the duration was 50% of the entire cycle. The purpose of the first stage is to compress the material. Then, because of the mat deaeration, the pressure is reduced, but it is still kept relatively high to accelerate the heating of materials. In the third stage, the final separation of the vapor-gas mixtures is carried out. The press factor was 90 s.mm$^{-1}$. The properties of the fibreboards were determined by the requirements of the relevant EN standards (EN 310, EN 317, EN 323). For each property were used 8 test pieces. The results for the physical and mechanical properties of the panels were processed by the methods of variation statistics.

## RESULTS AND DISCUSSION

The density of eco-friendly fibreboards with lignosulfonate adhesive varied from 821 to 939 kg.m$^{-3}$, Figure 1.

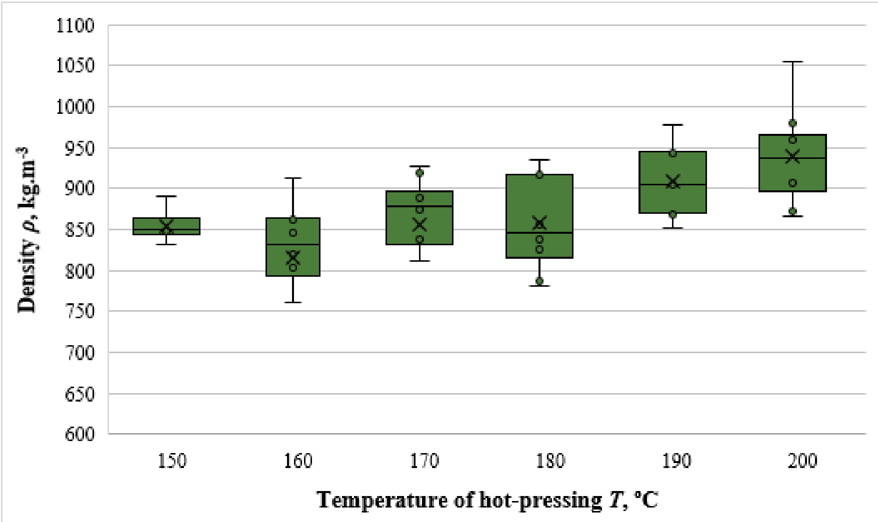


**Figure 1: Influence of hot-pressing temperature on the density of eco-friendly fibreboards**

The target density of the fibreboards from 920 kg.m$^{-3}$ was obtained only by the panels produced at hot-pressing temperatures of 190 and 200ºC. The thickness of these two panels was respectively 5.7 and 5.6 mm. Even at a panel produced at a temperature of 180° C, an increase in thickness to a value of 6.4 mm was observed, and the density decrease. The decrease in the density of the fibreboards produced at hot-pressing temperatures of 160 and 150º C was significant. The density of these two panels was 110 kg.m$^{-3}$ lower than the density of the panel produced at a hot-pressing temperature of 200º C. The thickness of the panel produced at a temperature of 150° reached 7.2 mm. Therefore, for the conditions of the experiment, at hot-pressing temperatures less than 190°C, in fibreboards only with the participation of lignosulfonate as an adhesive, creating bonds between fibres is insufficient in number and strength which resulted in decompression of the panels. For the conditions of the experiment, at temperatures below 190°C, the connections of the fibre elements with the lignosulfonate were not stable, whereupon some decompression of the panels occurs.

The bending strength of eco-friendly fibreboards, at the different hot-pressing temperatures, varied from 7.7 to 45 N.mm$^{-2}$, Figure 2.

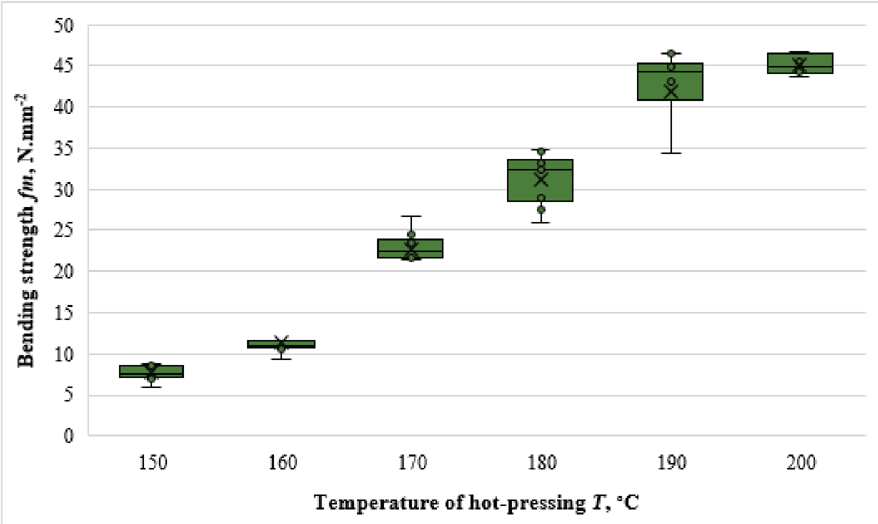


**Figure 2: Influence of hot-pressing temperature on bending strength of eco-friendly fibreboards**

With the increase of the hot-pressing temperature from 150 to 200º, the bending strength of fibreboards bonded with lignosulfonate increased by 5.8 times. Therefore, concerning this property of the panels, the hot-pressing temperature is a factor with a very strong influence. Panels produced at hot-pressing temperatures of 190 and 200°C had similar bending strength. Concerning this property, these panels meet the requirements for the highest strength class, namely for fibreboards with increased load resistance for load-bearing structures. At a hot-pressing temperature of 180ºC, the panes meet the requirements for the bending strength of fibreboards for general purposes. The remaining panels, produced at temperatures below 180ºC, do not meet the requirements of the standard for this property (EN 622-5).

With the increases of hot-pressing temperature from 160 to 190ºC, a significant increase in bending strength was observed. The bending strength of fibreboards produced at temperatures of 150 and 160ºC was similar and it was significantly, three times, lower than required by the standard. Again, an explanation can be sought here with the insufficient amount of bonds between the lignosulfonate and the wood fibres at hot-pressing temperatures below 190°C.

The results for water absorption of fibreboards with lignosulfonate adhesive are showing that the hot-pressing temperature is also a factor with a very strong influence on this property. For the conditions of the experiment with increasing hot-pressing temperature from150 to 200ºC the water absorption of the panels decreased from 116 to 50%, Figure 3.

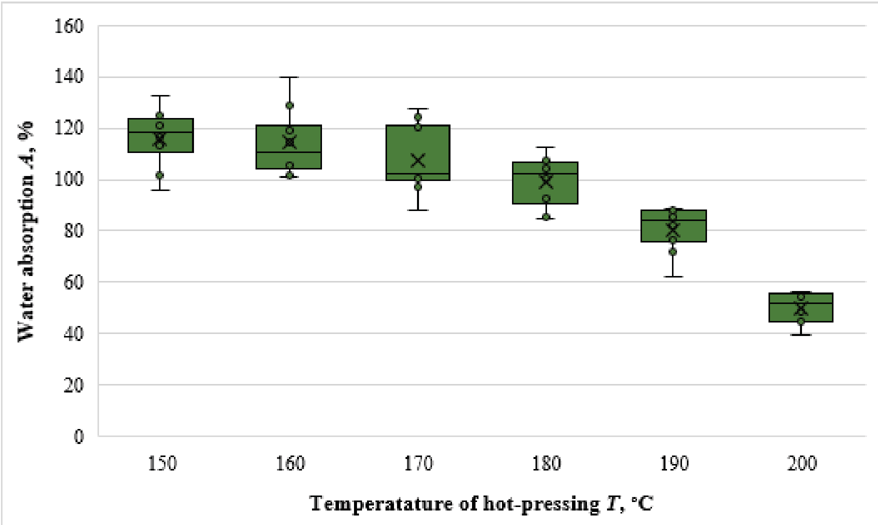


**Figure 3: Influence of hot-pressing temperature on water absorption of eco-friendly fibreboards**

In this property of eco-friendly fibreboards was observed even improvement when hot-pressing temperature increased from 180 to 200º. In contrast to bending strength, water absorption increased by 30% or relative deterioration by nearly 60% as the temperature decreased from 200 to 190°C. The relative deterioration of the property with a decrease in hot-pressing temperature from 190 to 180ºC is 20%. At temperatures of 170, 160, and 150º were observed similar values for the water absorption. Therefore, and concerning this property, the pressing temperature should not be below 190ºC. An explanation of the unsatisfactory values of the water absorption of the panels at temperatures below 190°C can be sought with the partial decompression of the fibreboards and with the leaching of lignosulfonate. Further researches are needed to be detailed described the leaching of lignosulfonate.

The thickness swelling of fibreboards with lignosulfonate adhesives, under the conditions of the experiment, varied from 33 to 13%, Figure 4.

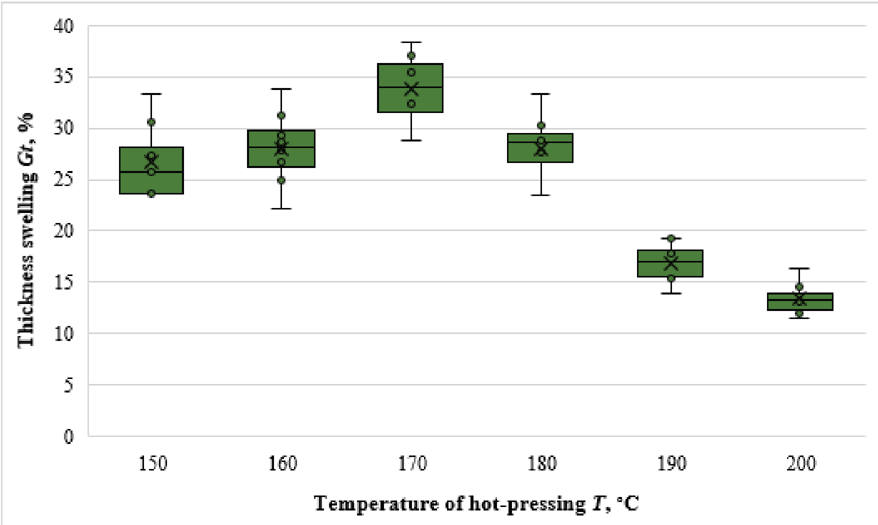


**Figure 4: Influence of hot-pressing temperature on thickness swelling of eco-friendly fibreboards**

The optimal value for swelling in thickness from 13% was observed in fibreboards produced at a hot-pressing temperature of 200º C. This panel as well as the panel obtained at a hot-pressing temperature of 190º C meets the requirements for use in humid conditions (EN 622-5). The deterioration in the property is very significant when the temperature of hot-pressing is lowered to 180ºC. After that the thickness swelling of panels had similar values. An explanation for this p can be found in the fact that although the panels produced at temperatures below 180ºC absorbed more water, the bonds in them were smaller, the pore space was larger and because of that, they had relatively less swelling in thickness.

## CONCLUSIONS

As a result of the study for the effect of hot-pressing temperature on the properties of eco-friendly dry-process fibreboards with lignosulfonate as a binder, it was found that the temperature of hot pressing is a key factor for the quality of the panels. At temperatures below 190ºC was observed decompression of fibreboard, i.e. the connections between wood fibres were not stable. At temperatures below 170ºC, the panels do not meet the standardization requirements in terms of bending strength, and although fibreboards produced at a temperature of 180ºC meet the requirements for bending strength, there was a very significant decrease in this property with decreasing temperature below 190ºC. Water absorption and swelling in thickness deteriorate significantly, i.e. increase with decreasing of hot-pressing temperature below 190ºC.

As a result of the study, it was established that can be successfully produced eco-friendly dry-process fibreboards with calcium lignosulfonate as an adhesive, but for this purpose, the temperature of hot-pressing should be at least 190ºC.

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