ONLINE ISSN 2069-7430
ISSN-L 1841-4737
PRO LIGNO
www.proligno.ro
Vol. 13 N° 4 2017
pp. 247-251

INFLUENCE OF THE CONTENT OF LIGNOSULFONATE ON PHYSICAL PROPERTIES OF MEDIUM DENSITY FIBERBOARD

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Abstract:

One of the essential shortcomings in the production of MDF is the existence of formaldehyde emissions from boards. This could be overcome by replacement of the currently used synthetic binders. Lignin is a natural binder in wood. Globally, at laboratory level, there are numerous studies on the use of enzyme lignin as a binder for MDF. In these studies were observed some significant shortcomings that could be overcome with the use of lignosulfonates.

In this article is presented a study on the influence of the content of lignosulfonate in the composition of MDF made from hardwood tree species on their physical properties. The boards were produced with only 5% content of urea-formaldehyde resin and alteration in the content of calcium lignosulfonate from 0 to 20%.

The approximating functions for the influence of the content of lignosulfonate on physical properties of MDF were derived. On that base is made analysis with proper conclusions and recommendation for optimal content of calcium lignosulfonate in the composition of fiberboard.

Key words: *MDF; urea-formaldehyde resin; formaldehyde emission; calcium lignosulfonate.*

INTRODUCTION

As a material fiberboard is characterized by significantly better physical and mechanical properties in comparison with particleboards. Therefore, worldwide production of fiberboard is greater than the production of particleboard (FAO). It should be said that the increase in the production volume of fiberboard is mainly due to the increased production of Medium Density Fiberboard (MDF), which occupy a total of 78% of the overall production. This trend is also characteristic for Europe, production of wet processed fiberboard is replaced with a dry processed one. The advantages of the production by a dry method, in comparison with a wet, principally is in the ability to produce boards with a thickness greater than 8 mm and with two facial surfaces. However, there is one very important advantage of wet processed fiberboard, which is that they are eco-friendly. It means that in those boards there is practically no free formaldehyde. This determines the key feature for improving the technology for the production of MDF, a particular reduction or even replacing of traditionally used synthetic binders (urea-formaldehyde, melamine-formaldehyde, phenol-formaldehyde resins, etc.) and thus reducing the emissions of free formaldehyde from boards.

Interests in this field are attempts, though still in the laboratory stage, to be produced MDF by adding enzyme lignin, which acts as a binder for the boards (Zouh et al.). In this way were obtained eco-friendly, nontoxic, boards. A team of Spain (Mancera et al.) conducted similar studies. The content of enzymatic lignin was increased to 20%. In this case have been reported very good results, as the bending strength of the boards has reached more than $50N.mm^{-2}$, and swelling in thickness is less than 2%. Nevertheless, it should be stressed that the produced boards are with density more then $1300kg.m^{-3}$.

A team from Malaysia (Nasir et al.) with the addition of up to 30% enzyme lignin in fiberboard composition obtained in laboratory conditions MDF, conforms to the requirements of active standards (EN 622-5).

In all cited above studies there are several major drawbacks. The enzyme lignin is difficult for production and its price is high. Therefore, application of enzyme lignin as a binder will significantly increase the cost of MDF production. The lignin is not water-soluble and is used in the boards as an amorphous solid, which leads to major difficulties from a technological point of view. For the activation of the enzyme lignin is required increased temperature of hot-pressing and extended duration of the process.

Partially these shortcomings can be overcome by the use of lignosulphonate as a binder for MDF. Lignosulfonate take precedence over hydrolysis or enzymatic hydrolysis lignin that it is water-soluble and can be imported in the form of solutions in pulp mass. They are a waste product from the production of sulphate cellulose. At present, lignosulfonates are used in the woodworking industry primarily as a binder conferring additional mechanical stability of the pellets.

MATERIALS AND METHODS

The main goal of this study is to be determined the influence of the content of calcium lignosulfonate in the composition of MDF on their physical properties. To be fulfilled this goal in laboratory conditions they were produced MDF containing urea-formaldehyde resin of 5% and with variation in the content of calcium lignosulfonate from 0 to 20% with increment of 5%. The boards were produced with a density 850kg.m-3. For the production of MDF in laboratory conditions was used thermo-mechanical pulp of common tree species in Bulgaria – total content of beech (*Fagus silvatica* L) and cerris oak (*Quercuss cerris* L) of 80% and 20% content of poplar (*Populus alba* L). Wood fiber mass was with moisture content of 11%.

It was used calcium lignosulfonate with characteristic as follow: calcium – up to 6%; reduced sugars – up to 7%; dry content – 93%; acid factor in a 10% solution - pH = 4,3 ± 0,8; bulk density – 550kg.m^{-3}.

In order to more uniform distribution and easier activation of the calcium lignosulfonate it is inserted into the pulp in the form of a solution having a concentration of 30%, Fig.1.

Fig. 1.
Calcium lignosulfonate.

The physical properties of MDF were determined by standard methods (EN 316; EN 317; EN 323). For each property were used in eight test specimens per board. And main statistical parameters (average, standard deviation, probability) were calculated.

The data were processed by the methods of regression analyze and it was displayed approximating function to the influence of the content of calcium lignosulfonate on the MDF properties.

On the basis of experimental data obtained by means of measurements, the values of the approximating function for different values of the argument were determined. This problem is successfully solved by using the least squares method, with regression equation of the type:

$$\hat{Y} = \sum_{i=0}^{k} b_i f(\tilde{x}) = b^T f(\tilde{x}) \qquad (1)$$

where: $b^T = (b_0, b_{1,} \ldots, b_k)$ is a (k + 1)-dimensional vector of the unknown coefficients in the equation;

$\hat{y}$ – the predicted value of the output quantity;

$f^T(\tilde{x}) = [f_0(\tilde{x}), \ldots, f_x(\tilde{x})]$ is a (k + 1)-dimensional function of the vector of input variables $\tilde{x}$ being derived.

In the case of the least squares method, the polynomial of best root-mean-square approximation of given degree coincides with the interpolation polynomial.

As a criterion for approximation accuracy, the coefficient of determination is used (Trichkov 2015):

$$R^2 = 1 - \frac{\sum_{i=1}^{N} (y_i - \hat{y})^2}{\sum_{i=1}^{N} (y_i - \bar{y})^2} \qquad (2)$$

RESULTS AND DISCUSSION

The summarized results for the properties of MDF, with different participation of lignosulfonate are presented in Table. 1.

Table 1

Experimental results for physical and mechanical properties of MDF

Board №	Content of calcium lignosulfonate *Px*, %	Density ρ, kg.m^{-3}			Swelling in thicknesses *Gt*,%			Water absorption *A*,%		
		Average	STDV	*P*-value	Average	STDV	*P*-value	Average	STDV	*P*-value
1	0	843.96	89.05	0.037	53.76	7.14	0.047	88.01	10.94	0.044
2	5	845.98	44.97	0.019	45.23	5.86	0.046	76.63	3.86	0.018
3	10	836.18	31.17	0.013	41.88	5.18	0.044	72.47	6.93	0.039
4	15	839.19	68.46	0.029	23.04	2.94	0.045	63.14	4.82	0.027
5	20	844.45	66.28	0.028	22.25	3.06	0.049	61.16	6.44	0.037

Analysis of experimental results for water absorption of MDF

The dependence of water absorption of MDF of the content of lignosulfonate over a range of variation of 0 to 20%, is described by the equation of the regression, approximating function, of the type:

$$\hat{A} = 87.67 - 2.12.P_x + 0.04.P_x^2 \text{ [\%]} \quad (3)$$

where: $\hat{A}$ is the predicted value for water absorption, %;
Px – content of calcium lignosulfonate in MDF, %.

The equation is characterized by the coefficient of determination R^2 = 0.98.

Fig. 2 illustrates the variation of water absorption of MDF in function dependence from the content of lignosulfonate.

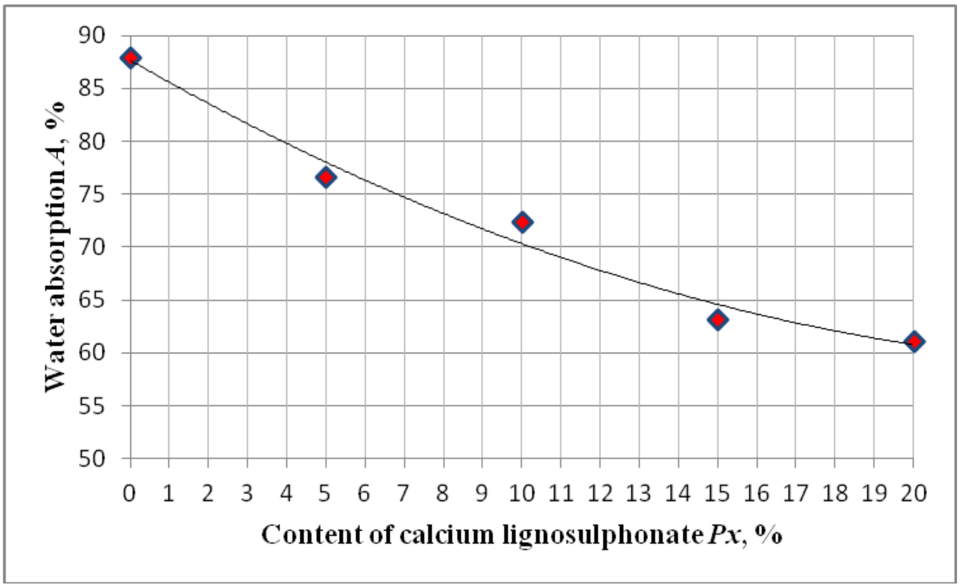

Fig. 2.
Variation of water absorption of MDF in dependence from the content of calcium lignosulfonate.

In the property water absorption is observed improvement with increasing the content of lignosulfonate from 0% to 20%, respectively, the value of the property is 88% at 0% content of lignosulfonate and 61% at 20% content of lignosulfonate in MDF.

There are two major declines in the values of the water absorption with the addition of 5% lignosulfonate, and with an increase the content of lignosulfonate from 10% to 15%. Values of the water absorption at 15% and 20% content of lignosulfonate are commensurate.

Analysis of the experimental results for swelling in thickness of MDF

The dependence of the swelling of MDF in thickness of the content of lignosulfonate over a range of variation of 0 to 20%, is described by the equation of the regression, approximating function, of the type:

$$\hat{G}_t = 54.27 - 1.70.P_x \text{ [\%]}, \quad (4)$$

where: $\hat{G}t$ is predicted value for swelling in thicknesses, %;
Px – content of calcium lignosulfonate in MDF, %.

The equation is characterized by the coefficient of determination $R^2 = 0.92$.

Figure 3 illustrates the variation of swelling in thicknesses of MDF in function dependence from the content of lignosulfonate.

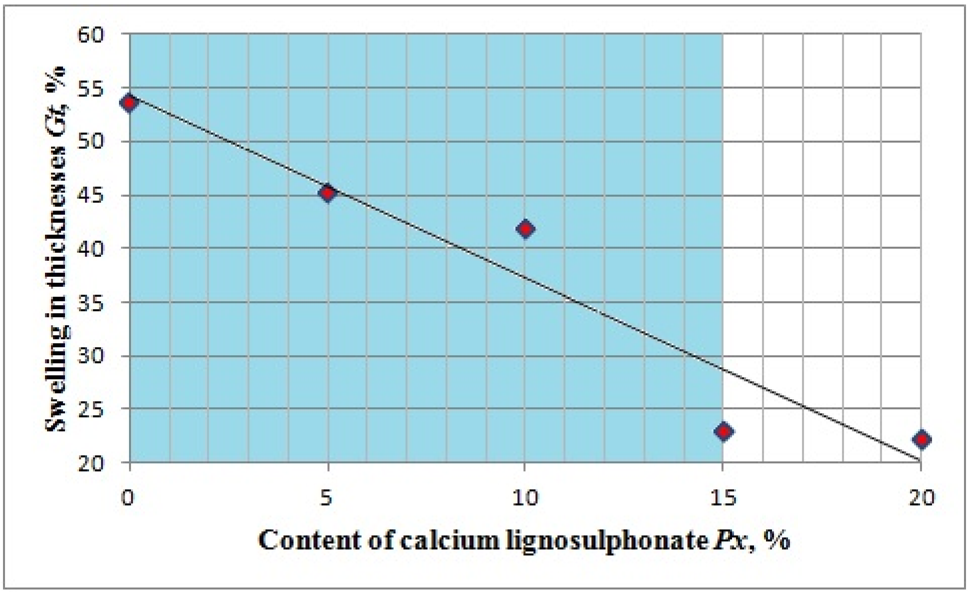

Fig. 3.
Variation of swelling in thicknesses of MDF in dependence from the content of calcium lignosulfonate.

With increasing the content of lignosulfonate from 0% to 20% swelling in thicknesses is improved, i.e. is reduced. It is not observed inflection point. In general, with the addition of lignosulfonate, swelling in thickness of MDF is reduced from 54% to 22% or the improvement of the property is exactly twice. This indicates that there is a lot of potential for the use of lignosulfonate in MDF intended for environment with high humidity.

The most significant improvement in the property was observed with an increase in the content of lignosulfonate from 10% to 15%. With increasing the content of lignosulfonate from 15% to 20%, there was no significant improvement in swelling in thickness of MDF.

Under the conditions of the experiment MDF does not meet the requirements for for use in humid conditions (EN 622-5).

On Fig. 2 with light blue is marked the area where MDF does not meet the requirements for swelling in thicknesses for use in a dry conditions. The requirements for the swelling in thicknesses are implemented under a lignosulfonate content of 15% or more. Therefore, the recommended content of lignosulfonate, wherein content of the urea-formaldehyde resin from 5% in MDF, is from 15 to 16%. In that content of calcium lignosulfonate are achieved requirements for MDF for load-bearing boards and use in dry conditions.

CONCLUSIONS

As a result of the conducted study on the influence of the participation of lignosulfonate in composition of MDF on its physical properties, can be made the following conclusions:

1) The addition of lignosulfonate in the composition of MDF leads to improvement, respectively, lowering the water absorption and swelling in thickness of the boards.
2) The most significant improvement of these properties is observed with increasing of the content of lignosulfonate by ten to fifteen percent;

3) It is not justified from a technological and economic standpoint to increase the content of lignosulfonate up to 20%.
4) MDF containing calcium lignosulfonate from fifteen to sixteen percent meet the requirements for load-bearing boards and are used in dry conditions and those boards are with only 5% content of urea-formaldehyde resin.

In conclusion, the use of calcium lignosulfonate is the perspective method for replacing the currently applied synthetic binders in MDF. This would make it possible to be reduced harmful emissions of the boards. Research in this area should be intensified by study of the influence of factors such as temperature and duration of hot-pressing, concentration of the lignosulfonate solution etc.

ACKNOWLEDGEMENT
This paper is supported by Scientific Research Sector of University of Forestry, Sofia, Bulgaria.

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