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INFLUENCE OF THE CONTENTS OF CORN STALKS AND PHENOL-FORMALDEHYDE RESIN ON SOME PHYSICAL AND MECHANICAL PROPERTIES OF VERY HARD FIBERBOARD

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Abstract

The main advantages of production of fiberboard are lowered requirements to wood raw material and possibility for utilization of lignocelluloses agricultural wastes in their composition. The negative impact of the higher content of hemicelluloses, minerals and wax in the non-wood lignocelluloses raw materials can be reduced by increase the contents of the binders.

In the report is presented study about complex influence of the content of corn stalks and phenol-formaldehyde resin on some physical and mechanical properties of very hard fiberboard.

For the purpose of the study are produced fiberboards in laboratory conditions in alternation of the content of corn stalks from ten to thirty percent and alternation of phenol-formaldehyde resin from eight to sixteen percent. Regression models for the influence of both factors are drawn and it is conducted an optimization of the results by the method of random search. On that base is done analysis and proper conclusions are made.

Key words: *very hard fiberboard, corn stalks, phenol-formaldehyde resin*

INTRODUCTION

In Bulgaria are made considerable number of studies on the possibility for utilization of residual lignocellulosic raw materials in the composition of fiberboard. These studies are aimed primarily at production of wet process and are not carried out recent studies concerning the effect on production by dry process and in particular those exploring the possibility of utilization of corn stems. The latter are a waste product of the crop that is widely used in our country.

In the dry process for production of fiberboard the adhesion connections have a central role in the formation of boards properties, such as when used in ambient conditions is preferred implementation of phenolformaldehyde resins with a view to a better strength and water resistance of board.

This underlines the relevance of the study related to determining the influence of the content of cornstalks and phenol-formaldehyde resin on the properties of the very hard fiberboard.

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MATERIALS AND METHODS

The purpose of the study is to determine the influence of content of cornstalks and phenol-formaldehyde resin on the performance of very hard fiberboard.

It will be produced fiberboards with 6 mm thickness, density of 950 kg.m^{-3} and resin content of 8, 12 and 16 %. As a binder it will be used Phenol-formaldehyde resin. The boards will be with content of pulp from cornstalks of 10, 20 and 30 %. The experimental plan is given in table one.

Table 1. Experimental plan

№	Content of cornstalks *Px*, %	Content of phenol-formaldehyde resin *p*, %	Content of cornstalks X_1 /encoded/	Content of phenol-formaldehyde resin X_2 /encoded/
1	10	8	-1	-1
2	10	16	-1	+1
3	30	8	+1	-1
4	30	16	+1	+1
5	10	12	-1	0
6	30	12	+1	0
7	20	8	0	-1
8	20	16	0	+1
9	20	12	0	0

The cornstalks are pulped on a hammer mill, and then screened and purified from the core, thus formed pass through sieve with a square mesh 3/3 mm, Fig. 1.

Fig. 1. Screening pulp (without thermal treatment) from corn stalks

The hot-pressing regime will be as following: in I stage specific pressure will be increased by 20 s to 3.0 MPa and will be maintained 20% of the entire cycle, after that, in II stage, evenly the pressure will be reduced for 10 s to 1.2 MPa and it will be maintained for 30% of the cycle, the III stage will be with pressure of 0.6 MPa and it will be 50% of the cycle. The temperature of hot pressing will be 180^{o}C.

The physical and mechanical properties of fiberboard will be determined in accordance with current European norms in that area.

Bringing out the regression models for influence of content of cornstalks and phenol-formaldehyde resin on properties of fiberboard will be carried out by standard methods using a D-optimal compositional plan of the type B_2.

The general appearance of the regression equation is as follows:

$$\hat{Y} = B_0 + B_1.X_1 + B_2X_2 + B_{12}X_1.X_2 + B_{11}X_1^2 + B_{22}X_2^2, \quad (1)$$

where $\hat{Y}$ is the predicted value for the given physical and mechanical property,
B_0 – free member;
B_1, B_2, B_{12}, B_{11}, B_{22} – coefficients of regression.

As a measure for accuracy of models will be used coefficient of determination - R^2, which will be examined for significance with F-criterial, the criterial of Fisher. In view of the advantages of using specialized software, the optimization will be carried out by the method of random search.

RESULTS AND DISCUSSION

The results for physical and mechanical properties of fiberboard are given in table 2..

Table 2. Results for physical and mechanical properties of fiberboard

№	Density ρ, kg.m^{-3}	Bending strength (MOR) f_m,N.mm^{-2}	Internal bond strength (IB) f_t, N.mm^{-2}	Swelling of thicknesses G_t, %	Water absorption A, %
1	947.36	29.30	0.98	23.91	75.86
2	949.50	44.59	0.88	14.54	53.65
3	950.00	28.40	0.70	23.03	67.46
4	948.75	35.64	0.54	14.92	48.43
5	950.88	40.22	0.90	16.82	58.80
6	917.50	31.37	0.56	16.39	51.47
7	947.25	29.90	0.65	23.04	62.19
8	927.13	38.42	0.56	14.08	49.92
9	929.25	35.38	0.59	14.26	57.04

The data are processed through the use of specialized software *QstatLab*, version 6.0. In the processing is set maximum accuracy of the model for this purpose is implemented stepwise regression. The regression models are in encoded and decoded form, with adjoining coefficients of determinations are given in tabular form. The regression coefficients in encoded form are given with capital letters, and in decoded – with small letters. All coefficients of determinations are significant.

Table 3. Coefficients for properties of boards in regression with content of cornstalks and content of phenol-formaldehyde

Property / Regression coefficients	Bending strength (MOR) f_m	Internal bond strength (IB) f_t,	Swelling of thicknesses G_t	Water absorption A
B_0/ b_0	35.66/ 2.75	0.720/ 0.997	55.78/ 128.63	15.83/ 58.32
B_1/ b_1	- 3.12/ 0.92	-0.158/ -0.021	-3.49/ -0.59	-0.10/ -0.13
B_2/ b_2	5.18/ 4.22	0.045/ 0.003	-8.92/ -8.35	-4.39/ -5.75
B_{12}/ b_{12}	-	0.016/ 0.0001	-	-
B_{11}/ b_{11}	- 1.28/ - 0.80	-	3.81/ 0.24	2.97/ 0.19
B_{22}/ b_{22}	- 2.02/ - 0.50	-	0.80/ 0.02	0.40/ 0.01
Coefficient of determination R^2	0,97	0.79	0.90	0.97

Figure 2 illustrates the change in bending strength of fiberboard in function depending on the content of phenol-formaldehyde resin and pulp of corn stalks.

Under the conditions of the experiment there is a change in the value of the indicator from 29 to 45 N.mm^{-2}.

The analysis of the regression model describing the effect of the content of corn stalks and a phenol-formaldehyde resin, shows that the effect of both examined factors is opposite. In a study range of alternation of factors more strongly influenced is the content of the resin.

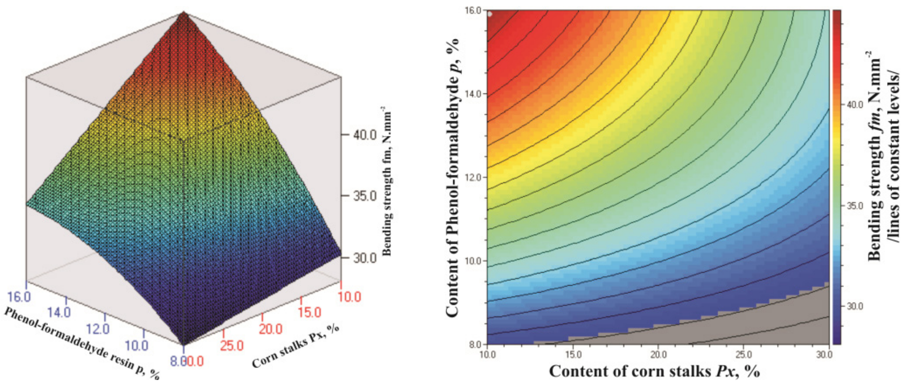

Fig. 2. Bending strength of fiberboard in correlation with content of corn stalks and phenol-formaldehyde resin

The functional dependence is from the second degree, as there was no inflection point. In the comparative characterization of the sub ranges it is reported a significant improvement in bending strength of boards by increasing the content of the phenol-formaldehyde resin from 8 to 10%. Then it is observed two falls in the gradient of the increase in strength, namely an increase of 10 to 14% of resin content and at least a relative improvement was observed with increase of resin content from 14 to 16%.

It can therefore be inferred the conclusion that increasing the content of phenol-formaldehyde resin over 14% is not technologically justified.

When analyzing the impact of the content of corn stalks on the bending strength of fiberboard is noted the negative impact of the increased amount of non-wood lignocellulosic raw-material. Dependence in the studies range of amending of the factor is linear. Many more pronounced is the deterioration of the property with increased content of corn stalks in upper border level (16%) of the contents of the binder.

At optimization is set functional limitation, to achieve the standard required bending strength of 30 $N.mm^{-2}$. The maximum value of bending strength from 43,9 $N.mm^{-2}$ is reported at 11.1% content of corn stalks and 15.9% content of phenol-formaldehyde resin. Analysis shows that the standard required bending strength of 30 $N.mm^{-2}$ can be achieved by increasing the content of corn stalks to 30%, in which case the content of the phenol-formaldehyde resin should be at least 9.2 %.

On Figure 3 is illustrated the change in internal bond strength of fiberboard in function depending on the content of corn stalks and phenol-formaldehyde resin.

Under the conditions of the experiment there is a change in the value of the studied properties from 0.54 to 0.98 $N.mm^{-2}$. In the studied range from amending the two factors the impact on the IB strength is described by a linear relationship. Comparing the direction of impact of the two factors it should be noted their diversely impact. It is observed deterioration, respectively decrease, of the properties by increasing the content corn stalks. Theoretically, this can be explained by the greater amount of hemicelluloses, respectively, the smaller quantity of cellulose in corn stalks from the composition compared to the wood, as well as by the presence of wax on the surface of the stalks.

The above mentioned reduces the active surface of the fibre elements as a direct consequence of this is the reduced amount of both adhesion and cohesion bonds in such boards.

The strength of the influence of the content of the corn stalks is greater than the strength of influence of the content of the phenol-formaldehyde resin. Weaker influence the content of the binder shows that even with its increase can not be fully offset the effect of reduced amount of cohesive bonds in the boards.

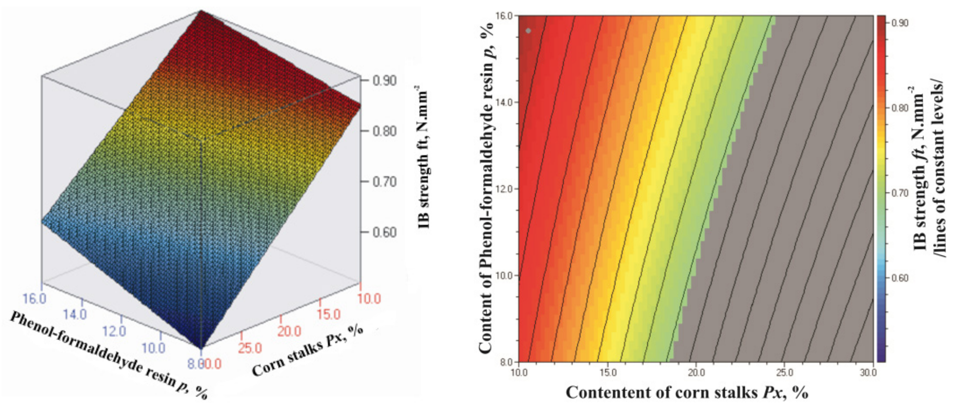

Fig. 3. IB strength of fiberboard in correlation with content of corn stalks and phenol-formaldehyde resin

At optimization is set functional limitation, to be achieved the standard required IB strength of 0.6 $N.mm^{-2}$. The maximal IB strength of 0.89 $N.mm^{-2}$ is achieved at 10.5% content of corn stalks and 15.7% content of phenol-formaldehyde resin.

The maximum content of corn stalks in which can be reached the required IB strength is 24%, in which case the content of the phenol-formaldehyde resin should be at least 16%. Therefore can be determined conclusion that is technologically unjustified increase in the content of corn stalks over 24%. In the 10% content of corn stalks the required value of the properties is obtained at the content of the binder of at least 11%.

Figure 4 illustrates the change of water absorption of fiberboard in function depending on the content of corn stalks and phenol-formaldehyde resin.

In the studied range of amending of the factors there is a change in the values of the property from 48 to 76%. The analysis of the regression model describing the effect of the content of corn stalks and a phenol-formaldehyde resin, showing that the effect of both examined factors is unidirectional.

As with increasing of the content of corn stalks is observed an improvement, reduction of water absorption with steady steps. The improvement of that property as a result of the increased content of corn stalks is due to the presence of wax on the surface of the stalks.

The dependence of water absorption by the content of the phenol-formaldehyde resin is described by equation of the second degree. The effect of this factor is significantly stronger than the effect of the content of corn stalks.

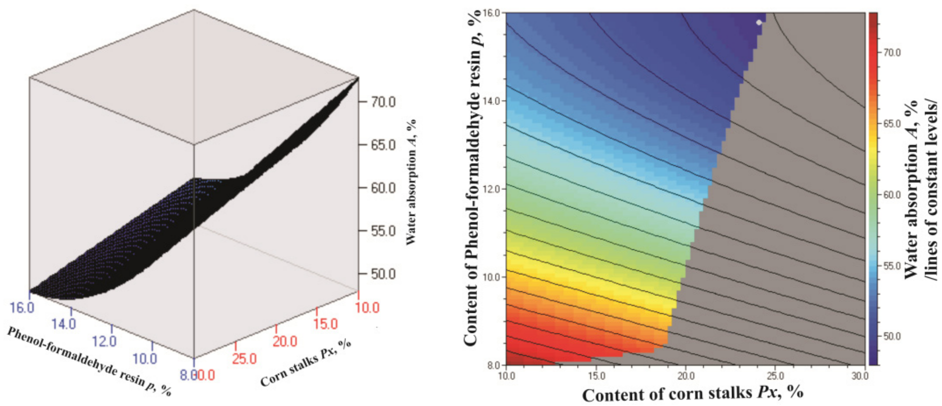

Fig. 4. Water absorption of fiberboard in correlation with content of corn stalks and phenol-formaldehyde resin

In the considered range is more powerful effect in increasing a phenol-formaldehyde resin from 8 to 14%, then there is a decrease in the rate of improvement decreases, a water absorption in the same increase in the content of the binder.

Since the property has not been standardized limitation is given to achieve the requirements for strength properties of the boards. The minimum amount of water absorption is reported at 24.1% content of corn stalks and 15.9% content of phenol-formaldehyde resin.

Figure 5 illustrates the change of swelling in thickness of fiberboards in function depending on the content of corn stalks and phenol-formaldehyde resin.

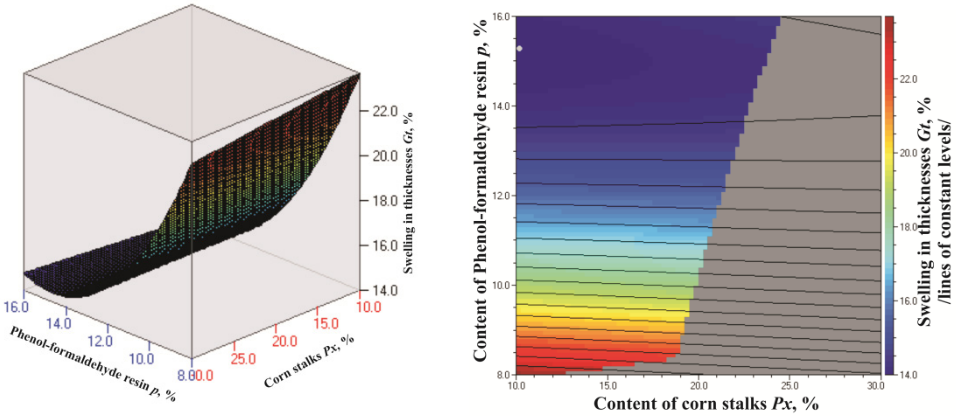

Fig. 5. Swelling in thicknesses of fiberboard in correlation with content of corn stalks and phenol-formaldehyde resin

In the variation of the factors there is a change in the values of research property of 14.3 to 23.9%. By increasing the content of the corn stalks and the content of the phenol-formaldehyde resin there is an improvement, respectively, reduction of swelling in the thickness of fiberboard. A highly effect is observed by the increase in resin content. This dependence is from the second degree and after passing the limit of 14% resin content is observed non-significant change in the value of research property. The dependence of swelling in thickness of the contents of corn stalks is linear, as seen steadily in decline, respectively improvement of the indicator with the increased content of stems.

Since all values of swelling in thickness are below the required from standard, in constructing the line of constant levels are set restrictions on its strength of boards. Minimum amount of swelling in thickness is reported at 10.2% content of corn stalks and 15.3% content of phenol-formaldehyde resin. In general, this can be explained by the interaction of the two factors and greater in absolute value deterioration of adhesive bonds with increasing content of corn stalks in the upper limits for the content of the phenol-formaldehyde resin.

As with relatively greater swelling of thicknesses of the fibers of the non-timber lignocellulose raw materials compared with that of the wood fibers, at the same values for the water absorption.

CONCLUSIONS

As a result of the studies and analysis of experimental results on the effect of the content of corn stalks and phenol-formaldehyde resin on the properties of very hard fiberboards can be made the following conclusions:

1) By increasing the content of corn stalks was observed deterioration of the strength properties of boards and an improvement in water-repellent properties, while with increasing the content of the phenol-formaldehyde resin was achieved an improvement in the strength and in water-repellent characteristics of the boards;

2) A strong influence on the bending strength of very hard fiberboard has the resin content; Dependence is of the second degree, with at least a relative improvement in the property was observed with increase of resin content of 14 to 16%;

3) The maximum value of bending strength of boards is achieved with 11.1% content of corn stalks and 15.9% phenol-formaldehyde resin content.

The standard required value of the property can be achieved by increasing the content of corn stalks to 30%, in which case the content of the phenol-formaldehyde resin should be at least 9.2%.

4) The effect of the content of corn stalks and the content of the phenol-formaldehyde resin on the IB strength is described by a linear relationship, as more strongly influenced by the content of the corn stalks.

5) The maximum IB strength is obtained in 10.5% content of corn stalks and 15.7% phenol-formaldehyde resin containing, as a maximum content of corn stalks in which can be reached the required IB strength was 24% where in the content of the phenol-formaldehyde resin is of 16%;

6) The minimum amount of water absorption is reported at 24.1% content of corn stalks and 15.9% content of phenol-formaldehyde resin.

7) The minimum value of the swelling in thickness is achieved at 10.2% content of corn stalks and 15.3% phenol-formaldehyde resin content, which may be explained by the interaction with a larger relative thickness swelling of the fibers of the non-timber lignocellulose materials in comparison with that of the wood fibers, at the same values for the water absorption.

8) The content of the corn stalks in the composition of very hard fiberboard should not exceed 24%, as is the technologically unjustified increase in content of phenol-formaldehyde resin over 14%.

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