

## ALKENYL SUCCINIC ANHYDRIDE AS A COMPOUND TO REDUCE WATER ABSORPTION IN THE PRODUCTION OF FIBERBOARD WITH PHENOL FORMALDEHYDE RESIN

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### ABSTRACT

*This study investigates the effect of alkenyl succinic anhydride (ASA) as an additive for improving the water resistance of wood fiberboard produced with urea-formaldehyde (UF) resin. The modulus of elasticity (MOE) showed a decreasing trend with increasing ASA content with reductions of 17 % to 35 % at 2 - 8 wt. % ASA, respectively, suggesting insufficient interfacial adhesion between the resin and ASA. However, at 10 wt. % ASA, no significant decrease in MOE was observed, indicating an improvement in crosslinking at higher additive levels. A similar trend was observed for bending strength (MOR), which decreased by an average of 1.77 - fold with increasing ASA content. In contrast, the addition of ASA significantly improved water - related properties. Water absorption decreased by up to 3 - fold and thickness swelling decreases 5 - fold.*

*Keywords:* wood fiberboard panels, hydrophobic agent, alkenyl succinic anhydride, surface modification.

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### INTRODUCTION

Wood fiberboards as medium - density fiberboard (MDF) and high - density fiberboard (HDF) are the most used wood products in the furniture and construction industries. Their popularity is attributed to their mechanical properties, low - cost production, homogeneous structure, and the possibility of utilizing various lignocellulosic raw materials and recycled fibers [1 - 3]. The global production of wood - based panels has increased significantly over the years, with MDF and HDF representing a substantial part of the total production of wood composites. The development of these materials is related to improvements in adhesive systems and manufacturing technologies [4].

Urea - formaldehyde (UF) resin is the most used adhesive in the production of wood fiberboards. UF resins are characterized by low - cost, fast - cure, high reactivity and good bonding performance during the hot - pressing process [1 - 4]. Due to these advantages UF adhesives remain the dominant binder for MDF

and HDF panel production in industrial conditions [5, 6]. However, UF resins also present certain drawbacks including relatively low moisture resistance and the potential release of formaldehyde emissions. These limitations have stimulated the development of modified resin systems and the use of various additives to improve panel performance [1 - 6].

To improve the water resistance of wood - based composites, various chemical additives and adhesive modifications have been investigated. These include lignin - based additives, bio - based modifiers and different water - repellent chemical additives. The additive can reduce water absorption and thickness swelling and improve the properties of fiberboard materials [1, 7].

Alkenyl succinic anhydride (ASA) has become the most important internal sizing agent for paper introduction in the 1960s. ASA is most used in the paper industry as an internal sizing agent that reduces the hydrophilicity of cellulose fibers and improves the water repellence of paper products [8]. Effect of ASA

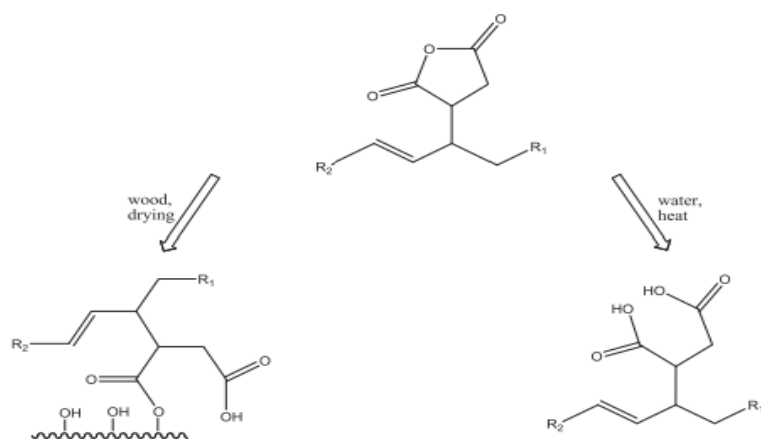


Fig. 1. Reaction pathways of ASA with wood compounds and water.

is generally attributed to a chemical reaction with the hydroxyl groups of fibers (Fig. 1). The molecule has an amphipathic character because of its polar anhydride group and the non - polar hydrocarbon chain with lengths of C14 - 20. While the partially positively charged carbonyl C - atoms can undergo an esterification with a hydroxyl group and anchors the molecule to the fiber surface, the hydrophobic entity points outwards by forming a hydrophobic layer on their surface. This leads to improved water repellence [9 - 11].

In recent years, increasing attention has been directed toward the use of bio - based resin and similar hydrophobic agents in the manufacturing of wood - based composites with enhanced moisture resistance. These additives can significantly reduce water absorption and thickness swelling while improving the mechanical properties of fiberboard panels. Furthermore, these additives may allow optimization of the adhesive content and reduction of formaldehyde emissions in wood - based panels [12 - 14].

The aim of this study is to investigate the effect of Alkenyl Succinic Anhydride as an additive on the water absorption and physical - mechanical properties of a fiberboard panel with urea - formaldehyde resin.

## EXPERIMENTAL

### Materials and methods

Industrially produced wood fibers from 60 % oak and 40 % beech were used for this study. The wooden

fibers are obtained in factory by Asplund method its dried to 7 % and is provided by factory Kronospan Bulgaria EOOD (Veliko Tarnovo, Bulgaria). The wood fibers are produced by thermomechanical method, for this method wood chips are mixed whit steam at pressure of 0.8 MPa and temperature of 170°C.

The adhesive formulation is made by mixing UF resin (64 % dry solids content and 1.16 molar ration), the resin is supplied by the factory Kastamonu Bulgaria AD (Gorno Sahrane, Bulgaria) and ASA product used in paper manufacturer for making paper moisture resist. ASA is provided by Kemira Globul, Finlandia

In the laboratory, the MDF panels will be whit dimensions of 400 mm × 400 mm × 6 mm and target density of 1000 kg.m<sup>-3</sup>. Thus, in this study to save the common industry practice, we tried to optimize the press factory by applying adhesive formulation of UF resin and five different additions levels (2 %, 4 %, 6 %, 8 % and 10 %) of ASA based on the dry weight of fibers. The UF resin was used at 10 % concentration.

The manufacturing parameters of the laboratory - produced MDF panels are given in Table 1.

One control panel bounded only whit 10 % UF resin based on the dry fibers and without ASA were fabricated. The control panel was used to evaluate the effect of adding ASA on the panel properties over moisture buffering and water absorption.

Wood fibers were mixed whit the adhesive in a high - speed laboratory blender whit needle - shaped paddles (prototype, University of Forestry, Bulgaria) at 800 min<sup>-1</sup>. The UF resin is mixed whit ASA and then is sprayed

Table 1. Manufacturing parameters of MDF panels made from industrial hardwood fibers bounded whit UF resin and ASA.

Adhesive Type	UF Resin content, %	ASA content, %
UF	10	0
UF + ASA	10	2
UF + ASA	10	4
UF + ASA	10	6
UF + ASA	10	8
UF + ASA	10	10

in the laboratory blender through a 1.5 mm nozzle. The hot - pressing process was performed in a single opening hydraulic press (Manni PMC ST 100, Italy). The temperature used for pressing it was 180°C. The press factor applied was 1 min mm<sup>-1</sup>. A three - stage pressing regime is applied whit the following pressure values: 2.0 MPa for 1 min, 1.2 MPa for 3 min and 0.4 MPa for 2 min. The pressing regime was selected from comparison whit previous studies involving MDF panels whit similar density and moisture content [4]. Following the hot pressing, the manufactured panels were conditioned for 24 h at a temperature of 20 ± 2°C and a humidity of 65 %. The pressing regime was selected in accordance whit the common industrial practice for production of industrial MDF panels.

The physical and mechanical properties of the laboratory - produced MDF panels were determined according to the standards EN 310, EN 317, EN 322 and EN 323. The mass of the specimen was measured by using a precision laboratory balance whit accuracy of 0.01 g. The dimensions of the test samples were measured using digital callipers whit accuracy of 0.01 mm. Water absorption and thickness swelling tests were made out by the weight method after 24 h of the immersion in water. The mechanical property tests were performed on a universal testing machine Zwick/Roell Z010 (Zwick/Roell GmbH, Ulm, Germany). For each property, twelve MDF test samples were used for testing.

## RESULTS AND DISCUSSION

All obtained fiberboard panels have average densities of 1010 - 1077 kg m<sup>-3</sup> (variation ± 2.8 %),

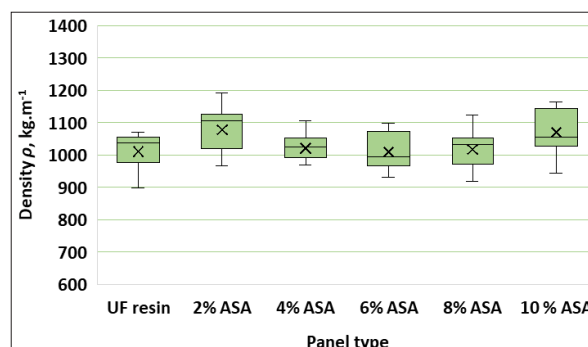


Fig. 2. Density of fiberboard panels with 10 wt. % urea - formaldehyde (UF) resin and varying proportions of alkenyl succinic anhydride (ASA) at concentrations of 2, 4, 6, 8 and 10 wt. % relative to dry fibers.

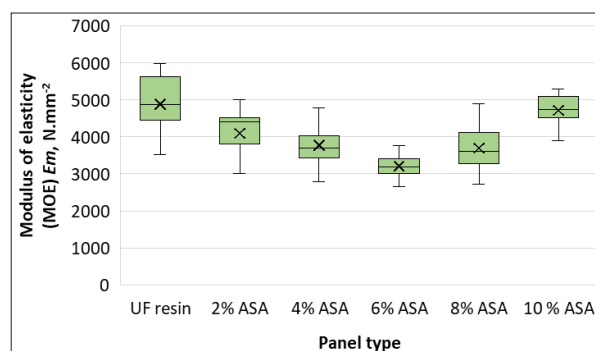


Fig. 3. Modulus of elasticity (MOE) of panels with varying concentration of alkenyl succinic anhydride (ASA).

indicating the applied press regime was effective in achieving the target density. This low variation suggests that differences in physical and mechanical properties are due to formulation, processing parameters, and added additive, rather than density deviations (Fig. 2).

The results of the modulus of elasticity (MOE) of the panel are presented in Fig. 3.

The MOE values of the fiberboard ranged from 3213 to 4879 N mm<sup>-2</sup>. A decreasing trend of MOE was observed with the addition of ASA. Accordingly, the MOE decreased by 17 % at 2 wt. % ASA, by 23 % at 4 wt. % ASA, by 25 % at 8 wt. % ASA and the lowest value by 35 % at 6 wt. % ASA. This behaviour can be explained by the fact that good adhesion between the resin and ASA was not achieved, suggesting the ASA acts more as a filler that reduces the adhesive properties of the resin. Increasing ASA content to 10 wt. % resulted

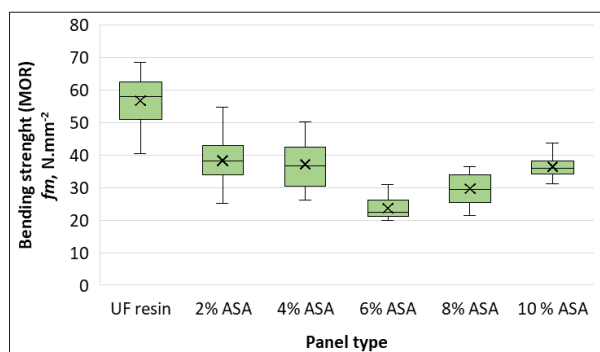


Fig. 4. Bending strength (MOR) of fiberboard panel with different concentrations of alkenyl succinic anhydride (ASA).

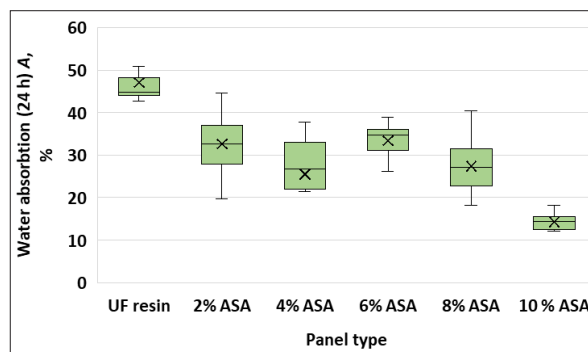


Fig. 5. Effect of alkenyl succinic anhydride (ASA) concentration on the water absorption (WA) of fiberboard panels.

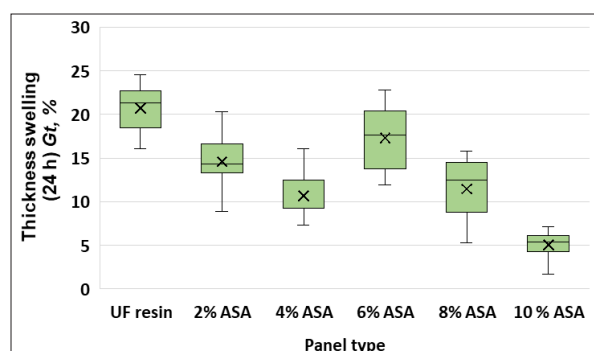


Fig. 6. Thickness swelling of panels with varying ASA concentration.

in a decrease in MOE by only 3 %, which indicates that crosslinking improves with increasing ASA content. However, the reduction in MOE, all values meet the minimum strength requirements.

The results of the Bending strength (MOR) test are presented in Fig. 4. With the increase of ASA content from 2 wt. % to 10 wt. %, the MOR value decreased by an average of 1.77 - fold. This trend is like the MOE, which confirms that there is no good adhesion between the resin and ASA.

Water absorption (WA) results of the laboratory obtained fiberboard panels are presented in Fig. 5.

A significant effect on water absorption is observed with the addition of ASA. At an additive content of 10 wt. %, up to a 68 % reduction in water absorption (3 - fold) is achieved. The results also show that even the use of 2 wt. % ASA leads to about a 30 % (1.45 - fold) improvement in water resist. Although the addition of ASA results in a decrease in the physical and mechanical

properties, the main reduction in water absorption makes ASA a potentially suitable additive to produce fiberboard panels with high water resistance. The improvement in water absorption properties is most likely due to the reaction of ASA with the free hydroxyl groups (-OH) of cellulose and lignin by its anhydride ring, forming a covalent ester bond. At the same time, the hydrophobic chains of ASA orient outward from the fiber surface, creating a thin hydrophobic layer that enhances water properties.

The data on thickness swelling are shown in Fig. 6.

The results for thickness swelling are like those for water absorption and clearly show that increasing the amount of ASA significantly improves swelling resistance. When 10 wt. % of the additive is used, a 5 - fold improvement is achieved compared to the UF sample. This significant improvement demonstrates the suitability of ASA as an additive for improving the water resistance of fiberboard panels.

## CONCLUSIONS

The possibility of using ASA as an additive to improve water absorption in the production of fiberboard panels with urea formaldehyde resin was investigated.

The results show lower physical and mechanical properties of the obtained panels, due to poor bonding between the resin and the ASA additive. However, the panels still meet the minimum strength requirements.

The modulus of elasticity remains unchanged at 10 wt. % ASA, indicating that the ASA has not hydrolysed. Moreover, at lower concentrations it plays the role of a filler rather than a crosslinking agent.

The water - resistant results show that even 2 wt. % of ASA improves this indicator. At a 10 wt. % charge of ASA, water absorption decreases 3 - fold, and thickness swelling decreases 5 - fold. This means ASA can be used to increase the water - resistant properties.

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### Authors' contributions

*S.P.: Conceptualization, methodology, experimental work, formal analysis, writing - original draft, preparation, visualization; G.I.: Methodology, experimental work, formal analysis, writing - review and editing, visualization;*

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