

## **Selected physical and mechanical properties of particleboards produced from lignocellulosic particles of black chokeberry (*Aronia melanocarpa* (Michx.) Elliott)**

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**Abstract:** *Selected physical and mechanical properties of particleboards produced from lignocellulosic particles of black chokeberry (*Aronia melanocarpa* (Michx.) Elliott).* The aim of the research was to confirm the possibility of using woody particles of black chokeberry (*Aronia melanocarpa* (Michx.) Elliott) stems as an alternative raw material in particleboard technology. As part of the work, particle boards from woody chokeberry particles were produced in laboratory conditions and selected physical and mechanical properties of the obtained boards were tested. The research confirmed that it is possible to manufacture boards for the furniture industry using lignocellulosic particles of black chokeberry (*Aronia melanocarpa* (Michx.) Elliott) meeting the requirements for P2 boards according to PN-EN 312.

*Keywords:* lignocellulosic raw material; black chokeberry; properties; particleboard; furniture

### INTRODUCTION

In the early 1700's, black chokeberry became famous as a landscape plant due to white flowers in spring, shiny and green leaves and black fruits in summer, as well as bright yellow-orange-red leaves in autumn. An additional advantage is the fact that the plant reproduces very easily and does not require excessive environmental conditions (Hardin 1973). Black chokeberry comes from North America and belong to the Rose family, moreover is a deciduous shrub with a height in the range of 0.9 to 3.7 m (Knudson 2009).

Apart from landscape aspects black chokeberry is most often associated with tart black fruit, which have many health benefits. *Aronia melanocarpa* belongs to the richest sources of polyphenols in the plant kingdom (Denev et al. 2018). These compounds have strong antioxidant activity and may reduce the risk of some civilization diseases as well inhibit the aging process (Kobus et al. 2019). Consumed in various forms help in the treatment of, for example, digestive and vascular diseases (Jurikova et al. 2017). Chokeberry is used to make jellies, jams, syrups, teas, wines and yoghurts. Chokeberry juice is a great dye and because of its taste, chokeberry juice is usually an addition to more aromatic juices, including apples (Brand 2010).

Due to the growing population, and thus, more and more consumerism, the demand for wood is increasing. It also involves intensive deforestation. To prevent this, it is worth looking for new sources of wood raw material that can be used as a substitute for wood, and their main advantage is that they grow faster than wood. Until now, alternative raw materials were sought and their use was made, such as the production of bamboo particleboards. Bamboo particles have a greater length-to-thickness ratio compared to conventional particles, but nevertheless, the boards produced meet the standards for P3 boards for interior furnishings. 10% sizing with UF resin was used for their production (Papadopoulos et al. 2004). The main advantage of bamboo lignocellulosic material is its intense growth, which ranges from 15 to 18 cm during the day, and reaches its maximum height in just half a year (Aminuddin and Abd. Latif 1991).

Another alternative in obtaining raw materials for the production of particleboard can be waste resulting from the annual care of fruit shrubs. In case, when these wastes are not removed at all, they contribute to the development of diseases and fungi. An example of such a raw material can be kiwi stalks from crops originating in the eastern Black Sea region of Turkey. Shredded kiwi stalks were used as the core of the particleboard and also as the face layers. The research showed that kiwi can be used for the production of particleboard, however, it is not an perfect material and requires further testing, because the obtained boards minimally met the standards for particleboard (Nemli et al. 2003). As part of the research, Kowaluk et al. (2019) produced three-layer particleboards using plum and apple shavings. Studies have shown that apple wood has a higher bulk density, which adversely affects the mechanical properties of the obtained boards. Nevertheless, the boards produced minimally met European standards. Until now, boards were also made of other alternative raw materials, such as: vine branches (Yeniocak et al. 2016), flax shive (Papadopoulos 2003), eggplant stalks (Guntekin and Karakus 2008), walnut shell (Pirayesh et al. 2012), kenaf (Juliana et al. 2012), wheat straw and corn pith (Wang and Sun 2002), pepper stalks (Oh and Yoo 2011), sugar beet pulp (Borysiuk et al. 2019), sorghum stalk (Khazaeian et al. 2015), tomato stalks (Taha et al. 2018), coffee husk and hulls (Bekalo and Reinhardt 2010), eucalyptus wood and coffee parchment (Scatolino et al. 2017), almond shell (Gürü et al. 2006), sunflower (Hoang et al. 2009), poppy stalks (Arslan and Sahin 2016) willow (Warmbier et al. 2013), Jerusalem artichoke (*Helianthus tuberosus*) (Klimek et al. 2016), sugarcane (Nadhari et al. 2020, Wang and Sun 2002), cereal straws (Grigoriou 1998) and raspberry stalks (Wronka and Kowaluk 2019).

Due to the different properties of lignocellulosic particles compared to industrial particles, each feature can be important and affect the final properties of manufactured panels, which is why the characteristics of lignocellulosic raw material are so important. Therefore, the aim of the research was to confirm the possibility of using woody particles of black chokeberry (*Aronia melanocarpa* (Michx.) Elliott) stems as an alternative raw material in particleboard technology.

## MATERIALS AND METHODS

### *Raw material and investigated panel preparation*

The investigated panels have been made from the lignocellulosic raw material: black chokeberry (*Aronia melanocarpa* (Michx.) Elliott).

The 6-years-old chokeberry stalks were mechanically shredded onto ca. 50 mm long chips, and these chips have been milled in laboratory 3 knife drum mill with outlet fitted with 6x12 mm<sup>2</sup> mesh to the form of particles. All the particles, have been dried to the MC about 5% and then were sorted to the fractions for core (8/2 mm mesh) and face (2/0.25 mm mesh) layer. The bulk density of each type of particles has been completed, where three repetitions of each particle type has been made.

A 16 mm – thick three layer particleboards, with face layers weight share of 32%, with several various content: 0, 10, 25, 50 and 100% (hereinafter called variants or panel types) with nominal density 650 kg/m<sup>3</sup>. with use urea – formaldehyde (UF) resin, were produced in laboratory conditions. The resination of particles was 12% and 10% for face and core layers, respectively. As a hardener an aqueous solution of (NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub> was used. Curing time of glue mass in 100°C was about 82 s. No hydrophobic agent was added during panels production. The pressing parameters were as follow: temperature 200°C, time factor 20 s/mm, maximum unit pressure 2.5 MPa.

As a reference, the industrial particles have been characterized and used to produce the panels in the laboratory conditions, as mentioned above.

All the tested panels have been conditioned prior the tests in 20°C/65% ambient air to constant mass.

#### *Mechanical properties testing*

In accordance with the European standard EN 310:1994, the following mechanical parameters of the manufactured boards were tested: bending strength (MOR) and modulus of elasticity during bending (MOE). The tensile strength was also investigated perpendicular to the plane of the board (internal bond, IB) according to EN 319:1993 and screw withdrawal resistance compliant with the PN-EN 320:2011. Prior to the test, the density of every single sample was measured. According to the results, the maximum measured difference between assumed and achieved density of produced panels was less than 5%. A 10 samples of each variant were used.

#### *Determination of swelling in thickness and water absorption after immersion in water*

To carry out the swelling (according to PN-EN 317:1999) and water absorption tests, 10 samples of each variant with dimensions of 50 x 50 mm<sup>2</sup> have been used. The samples were measured and weighed after 2 and 24 hours of soaking. During the same test, the thickness and mass of the samples have been measured, to estimate the thickness swelling and water absorption, respectively. In case of water absorption, the mass raise after soaking has been referred to initial mass.

#### *Density profile*

The density profile was tested on samples 50 x 50 x 16 mm<sup>3</sup>. Density profile test was performed on a X-Ray density profile analyzer DA-X (GreCon), the measurement method of which is based on X-rays. The sampling step was 0.02 mm. As many as three samples of each variant have been tested, and then results analyzed, and one representative profile of each variant has been used for further evaluation. Due to the symmetrical character of the density profiles, to achieve the better readability of the results, the profiles to the middle of the panel thickness have been displayed on the resulted plot.

#### *Statistical analysis*

The statistical significance of the average values between factors as well as levels, has been estimated by analysis of variance (ANOVA) and t-tests calculations ( $\alpha = 0.05$ ), Duncan test, where applicable, with use IBM SPSS statistic base (IBM, SPSS 20, Armonk, NY, USA).

## RESULTS

The graph below (fig. 1) shows the bulk density of black chokeberry compared to industrial particles. According to a common dependence, the raw material of wood - wood particles or fibers, which has a lower bulk density, is densified better than raw material with a higher bulk density. The obtained values may justify the obtained results of the density profile or the bending strength and modulus of elasticity, mentioned below. The statistically significant differences of the average values of bulk density have been confirmed between all the tested particle variants.

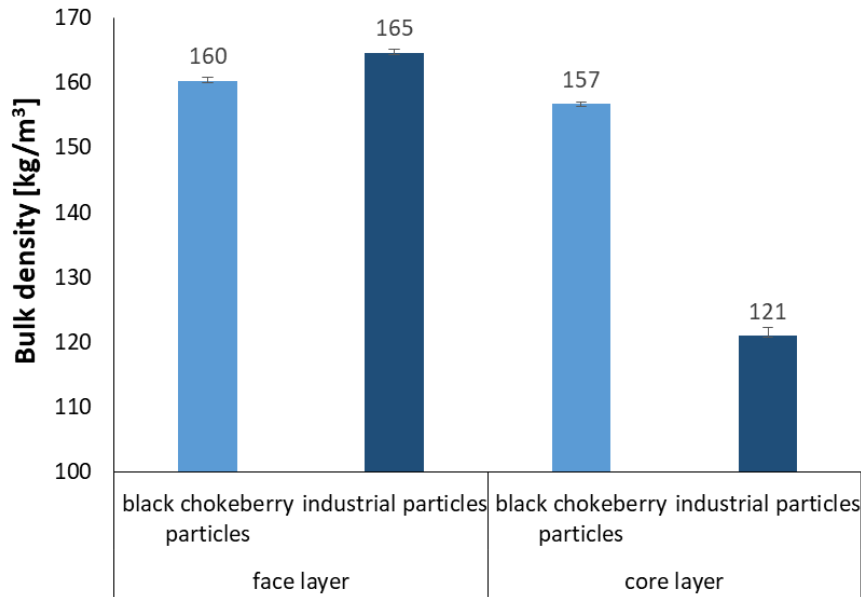


Fig. 1. The bulk density of investigated panels's particles

The diagram below (fig. 2) shows the influence of the proportion of black chokeberry particles on the bending strength of the boards produced. With an increase in the proportion of black chokeberry particles, the bending strength decreases. The reason for this may be the chokeberry particles bulk density. The high bulk density of the raw material in the face layers contributes to a lower layer density and thus to the weakening of the strength of the panels. The situation is similar in the case of apple wood panels, because with an increase in the share of wood particles obtained from waste apple wood, the static bending strength and the static bending modulus decrease (Auriga et al. 2019). Despite this, the results show that the chokeberry panels conforms the requirements of PN-EN 312 standard for P2 type panels. The statistically significant differences between MOR average values have been found between 0% and remaining panel type, as well as between 10 and 100% panels.

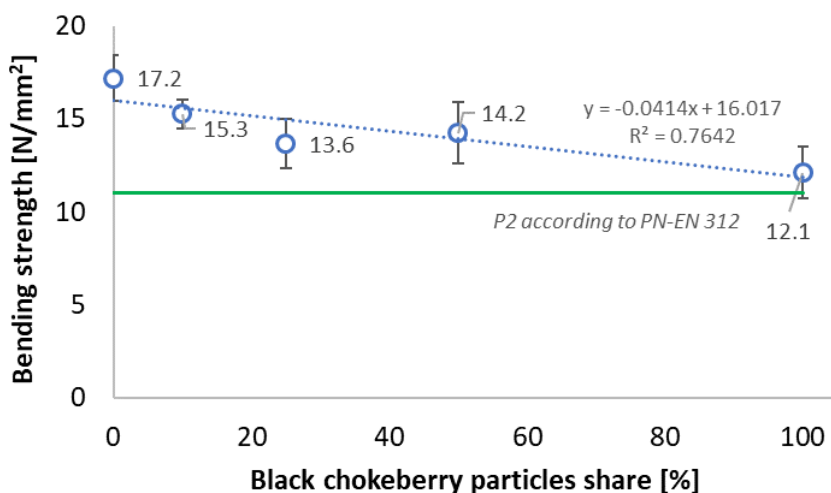


Fig. 2. Bending strenght of investigated panels

The graph (fig. 3) shows the obtained values for the modulus of elasticity of the obtained panels. In this case, the values of the elastic modulus decreases with increasing proportion of black chokeberry particles. It should be mentioned here, that, despite the MOE decreasing tendency with raising addition of chokeberry particles, even 100% chokeberry panels conforms the P2 type panel according to PN-EN 312 standard. The only statistically insignificant differences have been found between 25 and 50% panels.

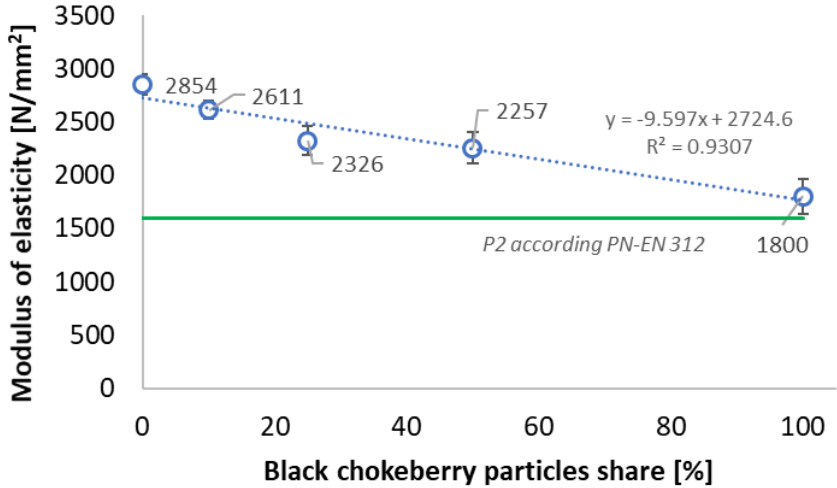


Fig. 3. Modulus of elasticity of investigated panels

The values of internal bond results of the tested panels have been displayed on fig. 4. As it is shown, the highest value of IB has been found for reference panel. When analyze the regression line, it can be concluded, that there is slight decrease of IB values with the chokeberry particles share increase. It should be also noted that all the tested panels have meet the requirements of PN-EN 312 standard for P2 type panels, and, even for the panel with the lowest reached IB strength, 0.80 N/mm<sup>2</sup>, this value exceeds the standard minimal requirements for over 130%. The statistically significant differences between the average values of IB have been found between 0% and remaining panels, as well as between 50% and remaining panels.

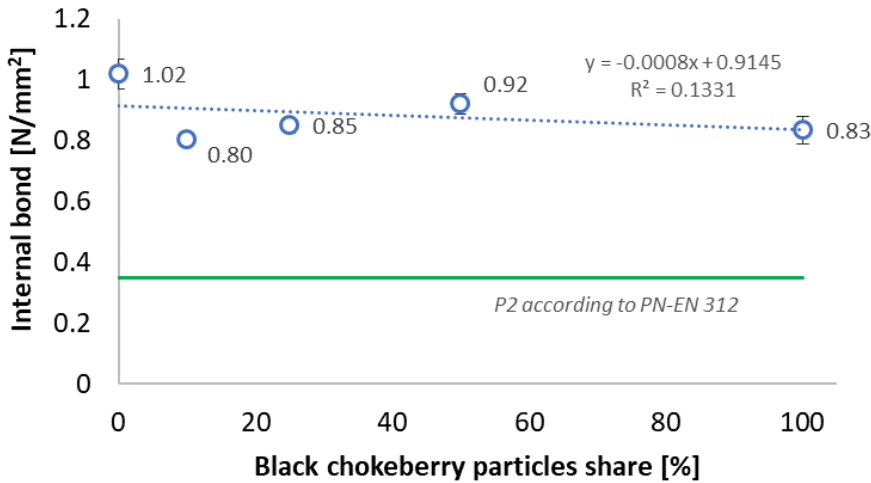


Fig. 4. Internal bond values of investigated panels

The attached graph (fig. 5) shows the thickness swelling results of the individual panel variants. The swelling decreases with the increasing proportion of chokeberry particles, this it does not meet the standards for P3 furniture boards intended for use in conditions with increased humidity. However, as it was mentioned in methodology paragraph, there was no hydrophobic agent added to the produced panels. The decreasing tendency of panels' thickness swelling with raising chokeberry particles content can be explained by higher bulk density of chokeberry in core layer (fig. 1). These particles, due to the higher bulk density in regard to industrial particles, have been compressed (densified) during pressing in lower ratio, thus, their reaction to water was less intensive. The only statistically insignificant differences for 2h soaking have been found between 50 and 100% panels, whereas, the only statistically significant differences between mean values of thickness swelling after 24h of soaking have been found for 100 and 0 and 10% panels.

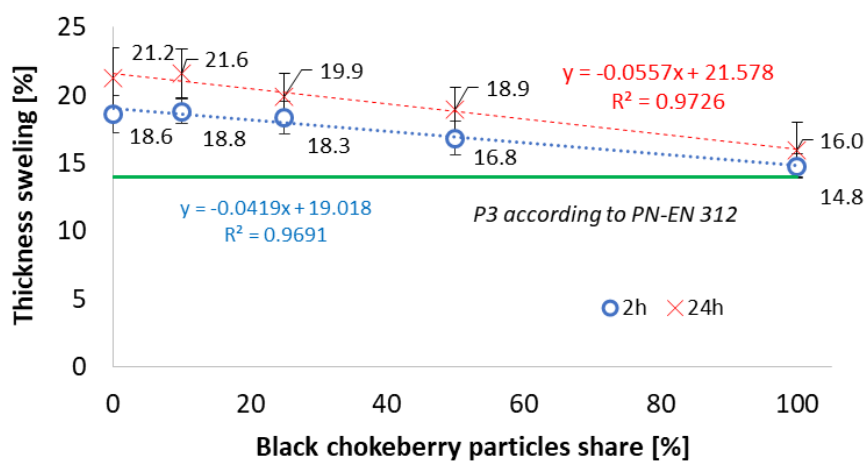


Fig. 5. Thickness swelling of investigated panels

The attached diagram (fig. 6) shows the water absorption of the manufactured boards, tested after 2 and 24 hours. From the graph it can be concluded that the black chokeberry reacts faster to water compared to the reference boards, but after 24 hours it absorbs less water than the board made of industrial particles. Deciduous trees have 5 times higher the ability to conduct water due to the presence of vessels with larger light, which facilitates the movement of water (Krzysik 1975). However, due to the fact that black chokeberry has a higher density (chokeberry density is comparable to that of fruit trees - 650 kg/m<sup>3</sup>) (Kowaluk et al. 2019), it absorbed a similar amount of water over a longer period of time as panels with a predominance of conventional raw material. The only statistically significant differences between the average values of water absorption have been found in case of 24h soaking, for 100 and 0 and 10% panels.

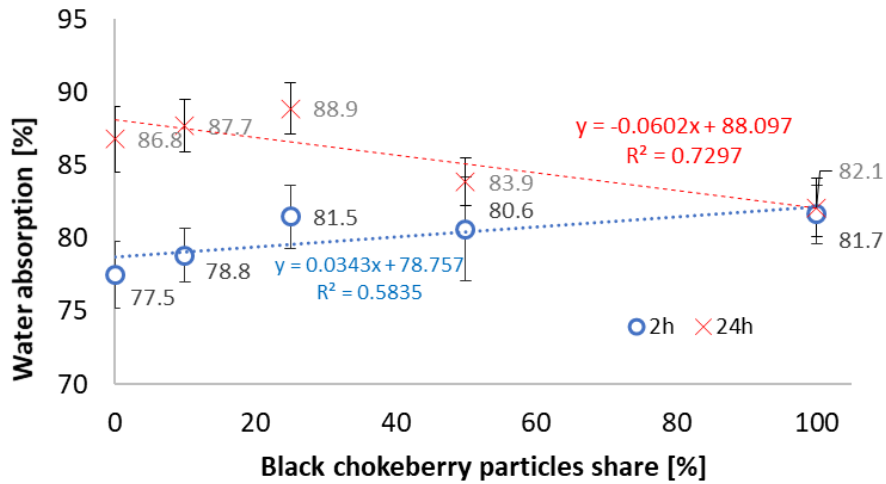


Fig. 6. Water absorption of investigated panels

The axial pull out strength of the screws of the tested boards is shown in fig. 7. The attached diagram shows that the resistance slightly decreases with the increase in the proportion of black chokeberry particles. For this reason, the worst parameters were obtained for a panel fully made of black chokeberry. No statistically significant differences of the obtained results of average values of screw withdrawal resistance have been found between the tested panels.

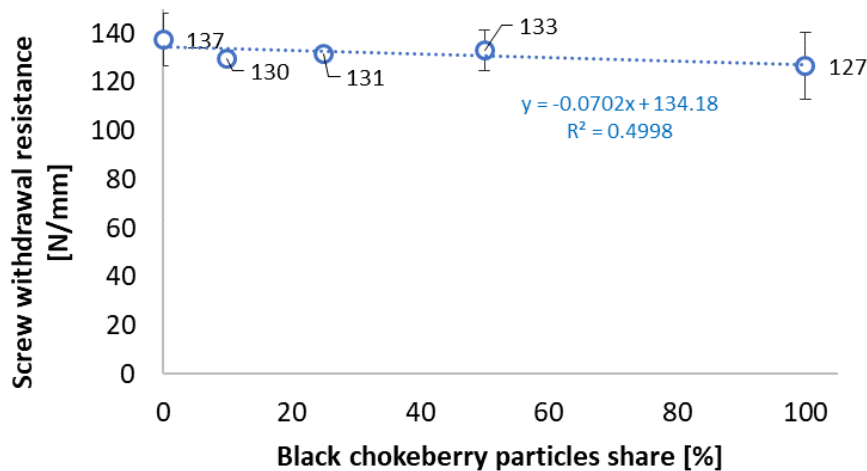


Fig. 7. Screw withdrawal resistance of the tested panels

Fig. 8 shows the density profile of the tested boards. The values in parenthesis show the mean values of the panels' density. The highest density can be observed for the face layers for variants 0 and 25%. The lowest density of the face layer was obtained for a panel made of 100% chokeberry particles. A similar relationship occurred in the case of the density profile of boards made with plum and apple particles (Kowaluk et al. 2019). On the other hand, in the core layers, the panels with a higher proportion of chokeberry particles - 50, 100% - obtained higher density.

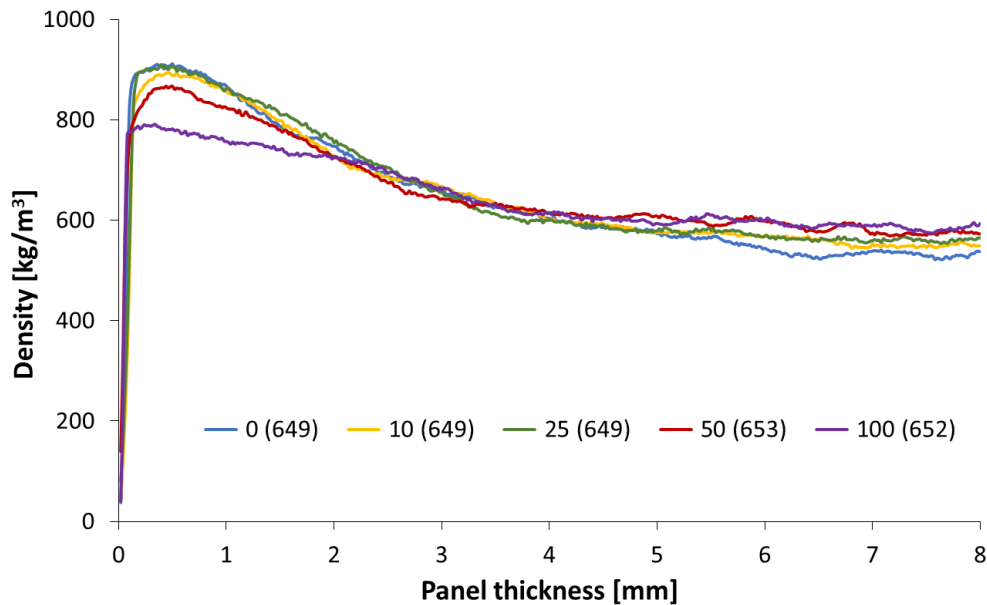


Fig. 8. Density profile of investigated panels

## CONCLUSIONS

Based on the research and analysis of the obtained results, the following conclusions were presented:

1. The bulk density of black chokeberry particles on the face layers is higher than that of industrial particles. The inverse relationship occurs in the case of particles on the core layers.
2. With an increase in the proportion of black chokeberry particles in the particleboard, the bending strength and modulus of elasticity decreases.
3. The internal bond slightly decreases with black chokeberry particles increase, however, the reached values of IB exceeds the minimal requirements of international standard for over 130%.
4. The swelling decreases with the increasing proportion of black chokeberry particles in the particleboard.
5. The water absorption test showed the increasing dynamics of water absorption for boards with a higher proportion of chokeberry particles, but in the long run they absorb less water than the reference boards.
6. There was no significant influence of the proportion of black chokeberry particles on the screw withdrawal resistance.
7. The differences between the maximum density in the outer layers and the minimum density of the inner layers decrease with the increase in the proportion of chokeberry particles.
8. It has been confirmed that the black chokeberry (*Aronia melanocarpa* (Michx.) Elliott) lignocellulosic particles can be valuable raw material for particleboards production.



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**Streszczenie:** Wybrane właściwości fizyczne i mechaniczne płyt wiórowych wytworzonych z cząstek lignocelulozowych aronii czarnej (*Aronia melanocarpa* (Michx.) Elliott). Badania miały na celu potwierdzenie możliwości wykorzystania zdrewniałych cząstek łądy aronii czarnej (*Aronia melanocarpa* (Michx.) Elliott) jako surowca alternatywnego w technologii płyt wiórowych. W ramach prac wytworzono w warunkach laboratoryjnych płyty wiórowe ze zdrewniałych cząstek aronii oraz zbadano wybrane właściwości fizyczne i mechaniczne otrzymanych płyt. Badania potwierdziły, że istnieje możliwość wytwarzania płyt z przeznaczeniem dla meblarstwa z wykorzystaniem cząstek lignocelulozowych aronii czarnej (*Aronia melanocarpa* (Michx.) Elliott) spełniających wymagania dla płyt typu P2 wg normy PN-EN 312.

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