Annals of Warsaw University of Life Sciences - SGGW
Forestry and Wood Technology № 116, 2021: 28-38
(Ann. WULS - SGGW, For. and Wood Technol. 116, 2021: 28-38)

Investigation of selected properties of the black elder wood (*Sambucus nigra* L.)

PAWEŁ KOZAKIEWICZ[1], MARCIN DADON[2], MONIKA MARCHWICKA[1]

[1]Department of Wood Science and Wood Preservation, Institue of Wood Sciences and Furniture, Warsaw University of Life Sciences – SGGW, 166 Nowoursynowska St., 02-787 Warsaw, Poland
[2]Faculty of Wood Technology, Warsaw University of Life Sciences-SGGW, Poland

Abstract: *Investigation of selected properties of the black elder wood (Sambucus nigra L.).* The work has defined the selected chemical, physical and mechanical properties of the black elder wood, such as content of non-structural substances, shrinkage and density, speed of sound propagation, dynamic modulus of elasticity, acoustic resistance and sound attenuation, modulus of elasticity, bending strength, compressive strength, Brinell hardness, cold and hot-water extractives content and pH of hot-water extract. The black elder wood is hard and moderately shrinking. Mechanical properties are reduced by going from the pith to the perimeter, which is most likely affected by the increasing twist of the fibres. The distance from the pith also affects the acoustic properties and the size of the shrinkage, while the density remains constant.

Keywords: black elder wood, non-structural substances, density, shrinkage, acoustic properties, modulus of elasticity, bending strength, compressive strength, hardness

INTRODUCTION

The black elder wood (*Sambucus nigra* L.) occurs in almost all of Europe, and northern Africa and south-western Asia [Atkinson M.D and Antkinson E., 2002]. In Poland, it grows throughout the country in both forests and open spaces. This species grows fast on fertile, humid, nitrogen-rich, loose soils. It is typically a large, spreading shrub (regrowing at the base) or a small tree with a sloping and often twisted trunk, reaching a height up to 10 meters and a diameter in the stump up to 40 cm [Amann 2007]. Other common names for this species include elder, elderberry, European elder, European elderberry, and European black elderberry.

The black elder wood is mainly known as a bioactive plant with food and pharmaceutical applications [Młynarczyk, Walkowiak-Tomczak, Łysiak 2018]. According to the above authors, black elder fruits are a rich source of antioxidant compounds and natural pigments used in the food industry. Simultaneously, extracts from different parts of the plant (flowers, fruits) show antioxidant activity and have medicinal potential, which has been used for a long time in folk, traditional medicine (including bark). The black elder wood has been used as an inflammatory, antipyretic and diuretic. In recent years, it has also been found to have antibacterial, antiviral, antidepressant, anticancer and hypoglycemic effects, as well as lowering the concentration of fats and lipids in the body. At the same time, parts of this plant contain toxic substances among others cyanoglycosides [Kaack and Austed 1998, Porter and Bode 2017, Młynarczyk, Walkowiak-Tomczak, Łysiak 2018, Güzelmeric et al. 2021].

The macroscopic appearance and microscopic structure of the wood [e.g. Clément et al. 1975, Schoch et al. 2004, Merev et al. 2005] are well described. The wood has a diffuse-porous structure and a hartwood. The wood pattern is poor and consists of weakly outlined annual rings and medium-sized medullary rays. The colour is monotonous, pastel, yellowish-white. Fresh wood emits a rather characteristic sour smell, which quickly disappears. Common defects are spiral grain and internal rot. The longitudinal section is composed of thin-walled fibres, vessels occurring individually and in tangentially arranged groupings of up to 6, and apotracheal parenchyma. Heterogeneous, medullary rays are medium in size, mostly 3 cells in width and

10 to 30 cell layers high. Despite its common occurrence, the properties of the black elder wood are poorly known, but many of its specific uses are pointed out. The black elder wood was used to make many traditional, wind musical instruments [Chętnik 1983]:

(a) in Kurpie and Masuria, they included (original Polish names): the pipe (fujarka), the clarinet (klarnet), the flute (rusoszka z piórkiem, dutka i flet),

b) in the Carpathians mountains they included (original Polish and Slovakian names): the herdings pipe (fujara pasterska, dvojacka i koncovka).

This wood was also used to make small utility items such as plugs, tools for patching nets and combs. The black elder dowels were used to instal fence rails. Small boards or branches were used to make canopies over cemetery crosses. Historically, in England, hollow, hollowed-out (coreless) black elder branches were blown through to light a fire, and during World War II, it was used to make charcoal [Chabowska-Dąbek, 2015]. The soft core from young black elder shoots was used by watchmakers to clean and regulate delicate watch mechanisms [Metcalfe 1948]. It was also used in physics laboratories for experiments with electricity [Chabowska-Dąbek, 2015]. In grapevine plantations, the black elder poles were used to support plants [Pokorný 1996].

The aim of this study was to investigate the selected chemical, physical and mechanical properties of the black elder wood (*Sambucus nigra* L.).

MATERIAL AND METHODS

The wood for the study was obtained from a magnificent black elder tree aged 30 years. It was 7 m high, with a trunk diameter of 30 cm at the butt end (Figure 1). The tree grew in Wełdkówko village (the administrative district of Gmina Tychowo, the West Pomeranian Voivodeship) on the edge of the forest. After cutting down the tree and limbing the branches, the trunk was divided into several rollers, which were subjected to a natural drying process. After the wood had dried to an air-dry state, samples were cut for individual determinations of physical and mechanical properties and small particles were obtained for chemical determinations.

The determination of wood moisture content by the dry-weight method was performed according to ISO 13061-1:2014, and the density by the stereometric method according to ISO 13061-2:2014. Measurements of linear shrinkage were performed according to ISO 13061-13:2016, and measurements of volumetric shrinkage were performed according to ISO 13061-14:2016.

Cold and hot-water extractives content in black elder wood were performed according to Tappi Test Method T 207 cm-08 after 48 and 3 hours, respectively. The value of pH of water extracts was measured by ELMETRON company pH meter model CP-551. Water extracts were obtained after the determination of hot-water extractives content. Extractives were tested at room temperature.

The study of acoustic properties of wood was carried out according to the original methodology on the ultrasonic material tester UMT 01 (transition method using cylindrical ultrasonic heads with a frequency of 100 kHz). The tester settings selected and verified in previous studies (e.g., Zawadzka and Kozakiewicz 2019, Hadinata and Kozakiewicz 2020) were as follows: 40 dB gain, signal transmission at pulse mode at 12 Hz. The ultrasound was passed parallel to the fibres using a polyacrylic gel as a coupling substance (the gel was coated on the fronts of the samples where the heads were placed). After the measurements were made and the time of ultrasound passage along the black elder wood fibres was read, the following quantities were calculated:

$$c_{||} = \frac{L}{t}$$

where: $c_{||}$ - velocity of the longitudinal ultrasound waves along fibers [m/s],
L – black elder sample length [m],
$t = t_1 - t_0$ – real time of the passing through of the longitudinal wave [s],
t_1 - time of the passing through of the wave read from the computer screen [s],
t_0 – zero time (lag time) t_o =4,24μs [s].

$$E_{II} = c_{II}^2 \cdot g \cdot \frac{(1+\mu_o)\cdot(1-2\cdot\mu_o)}{(1-\mu_o)}$$

where: E_{II} - dynamic (sonic) modulus of elasticity along fibres [GPa],
g – density of wood [kg/m^3],
μ_o - reduced Poisson's ratio (μ_o =0,3) [-].

$$Z = \sqrt{\rho} c_{\|}$$

where: Z – ultrasound wave resistant [kN·s/m³].

$$T = \frac{5 \cdot 10^{-8} \sqrt{\frac{c_{\|}}{\rho}}}{\rho}$$

where: T – damping of ultrasound radiation [m^4/s·kg].

a) b)

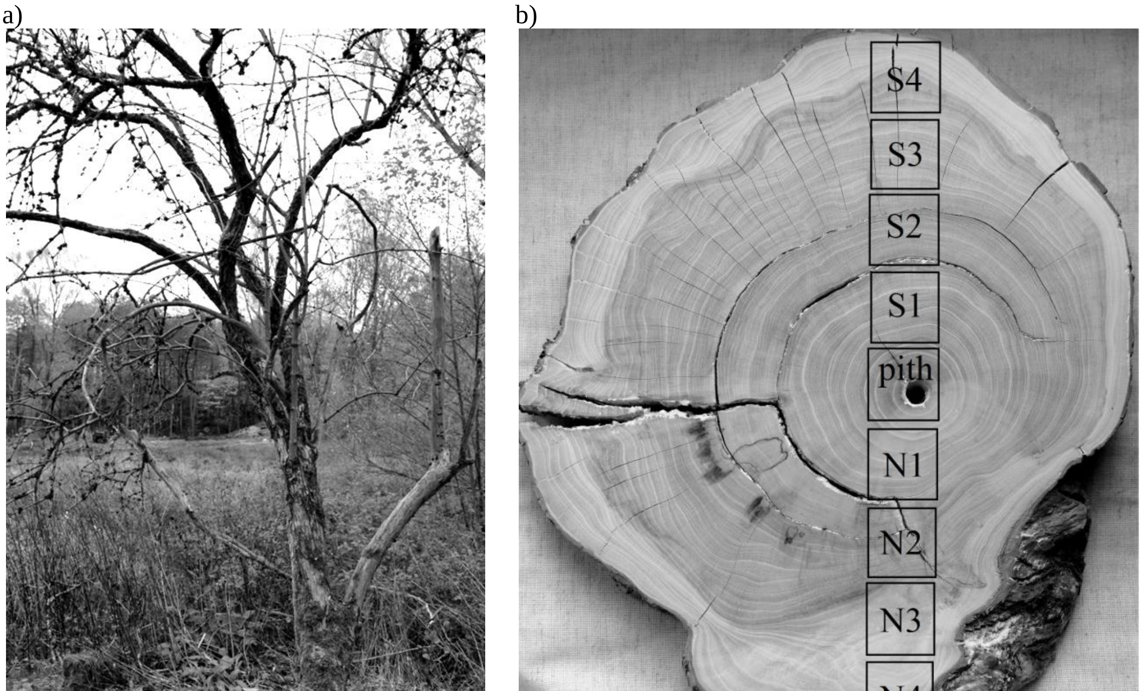

Figure 1. Material collected for the study: a) the black elder tree, b) the cross-section of bottom of the trunk

The bending strength (MOR) and the static elastic modulus (MOE) of the black elder wood were tested taking into account the recommendations of ISO 13061-3 and ISO 13061-4:2014. The tests were carried out on an INSTRON testing machine. The machine was operated using Instron's Series IX/s software. After entering the sample data, the strength and flexural modulus were automatically calculated after bending. The appearance of the broken samples after bending was analyzed according to ASTM D 143-94:2000.

Compressive strength testing was performed based on the specifications of ISO 13061-17:2017. Tests were performed in analogy to bending, including appearance analysis after test according to ASTM D 143-94:2000.

The Brinell hardness test of the black elder wood was carried out following ISO 13061-12:2017. The Brinell hardness of the black elder wood was measured using an indenter in the form of a steel ball of a 10 mm diameter and with a load of 980.6 N for 15 s. The hardness was tested on the tangential and radial section as well as on the transverse section (in the last case also divided into sapwood and heartwood).

RESULTS AND DISCUSSION

The results of the black elder wood properties are presented in Table 1. Most of them were carried out as part of the engineering work of Dadon [2019]. The absolute moisture content was at an average of 11.6%. After seasoning in terms of moisture content, the material was homogeneous (air-dry condition). The average air-dry density of the black elder wood was 689 kg/m^3, which according to Krzysik [1978] is qualified as moderately heavy wood. Concerning density, the examined wood was also a homogeneous material (low coefficient of variation equal to 7.0%).

Table 1. Selected properties of black elder wood.

Tested wood property	Average value	Standard deviation σ	Coefficient of variation V [%]
Density in the air-dry state [kg/m^3]	689	49	7.0
Total unit shrinkage along fibres [%]	0.25	0.05	21.7
Total unit shrinkage in radial direction [%]	5.1	0.3	5.8
Total unit shrinkage in tangential direction [%]	10.0	0.44	4.4
Total unit volumetric shrinkage [%]	15.0	2.1	19.9
pH [-]	5.2	0.0	0.0
Cold-water extractives [%]	3.1	0.1	3.7
Hot-water extractives [%]	3.7	0.1	2.7
Velocity of longitudinal waves [m/s]	3925	507	12.9
Dynamic modulus of elasticity [GPa]	7.73	1.68	21,8
Acoustic resistance [kN·s/m^3]	1619	86	5,3
Attenuation by radiation [m/s·kg]	$2.17\cdot10^{-10}$	$0,25\cdot10^{-10}$	11,5
Static bending strength [MPa]	74.7	11.5	15,4
Static modulus of elasticity [MPa]	6060	1356	22
Compressive strength along the fibers [MPa]	44.7	5.5	12,2
Brinell hardness on transverse section [MPa]	66	7.5	11
Brinell hardness on radial section [MPa]	37	2.5	7
Brinell hardness on tangential section [MPa]	38	4.6	12

The high coefficient of variation of shrinkage in the longitudinal direction (21.7%) is due to the presence in black elder wood of a fibre twist, which gradually increases from the core to the butt-end, reaching a maximum fibre inclination of 10°, relative to the stem axis. The ratio of tangential to radial shrinkage is approximately 2. There is typical anisotropy of shrinkage in black elder wood noted in wood from temperate climate zones [Kozakiewicz 2012]. The average value of volume shrinkage is 15%, which indicates moderately shrinkable wood. The above-mentioned characteristics indicate that black elder wood is not easy to dry without developing defects in the form of strong deformations and cracks, which is confirmed by observations made on the material obtained for this study.

PH of hot-water extracts was 5.2 with 0.0 standard deviation and also 0.0 coefficient of variation. For wood extracts, different pH values were obtained by other researchers depending on species, the wood-water ratio, method of obtaining extracts and others. The range of these values is on average from 4 to 6 [Geffert et al.2019]. Cold and hot-water extracts content was 3.1 and 3.7 %, respectively. The hot-water extractives content is slightly higher than cold-water extractives content. The cold-water extract contains mostly inorganic compounds, tannins, gums, sugars, and colouring matter, while hot-water extracts remove also starches [Pettersen 1984; Prosiński 1984; Walker 2006]. Hot-water is more effective in removing extractives.

The measured average value of the velocity of longitudinal waves (3925 m/s) is typical for temperate zone wood (from 3700 to about 4890 m/s) [Kozakiewicz 2012]. The average velocity of longitudinal waves in black elder wood is very similar to the velocity of longitudinal waves for sycamore wood (3826 m/s) [Kollmann 1951]. The average dynamic modulus of elasticity of black elder wood (7.76 GPa) is low, comparable to that of lime wood (7.26 GPa) [Kollmann 1951].

The Brinell hardness determined on the transverse section (average 66 [MPa]) is almost twice as high as the hardness determined on the tangential and radial section (average 38 [MPa]). The black elder wood (according to Morath classification) is classified as very hard wood. Additionally, the transverse section of the wood was used to check whether the hardness of the sapwood zone differed from that of the heartwood. The sapwood showed a lower average hardness (62 MPa) than the heartwood (69 MPa), which according to Krzysik [1978] may be caused by the lack of living cells in the heartwood and the saturation of this zone of the wood with heartwood compounds [Krzysik 1978].

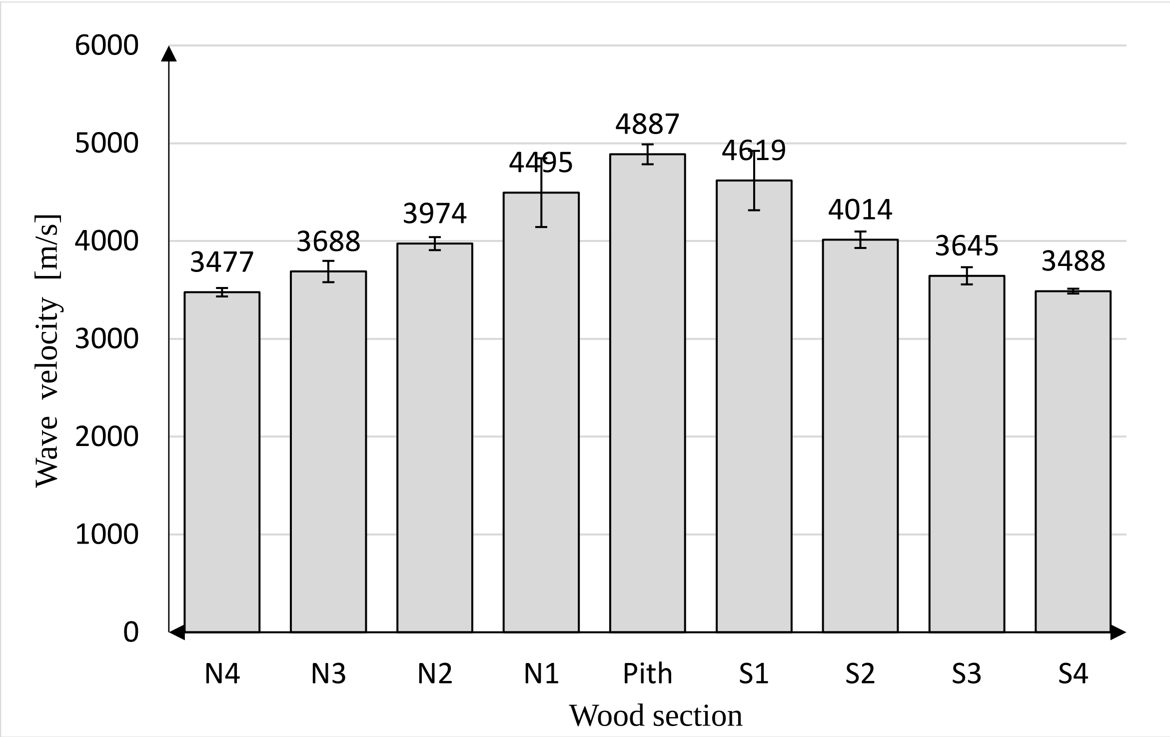

Figure 2. The dependence of the longitudinal wave velocity on the distance of the wood from the core

In addition to determining the mean values of particular features, for the selected properties their variation in the stem transverse section was also tested (from core to circumference). The investigated values of wave velocity [m/s] decrease significantly with increasing distance from the core (Figure 2). The dynamic modulus of elasticity shows an analogous tendency (Figure 3). This is most probably due to the presence of increasing fibre twist. The inclination (twist) of the fibres increases from 0° at the core to approximately 10° at the circumference.

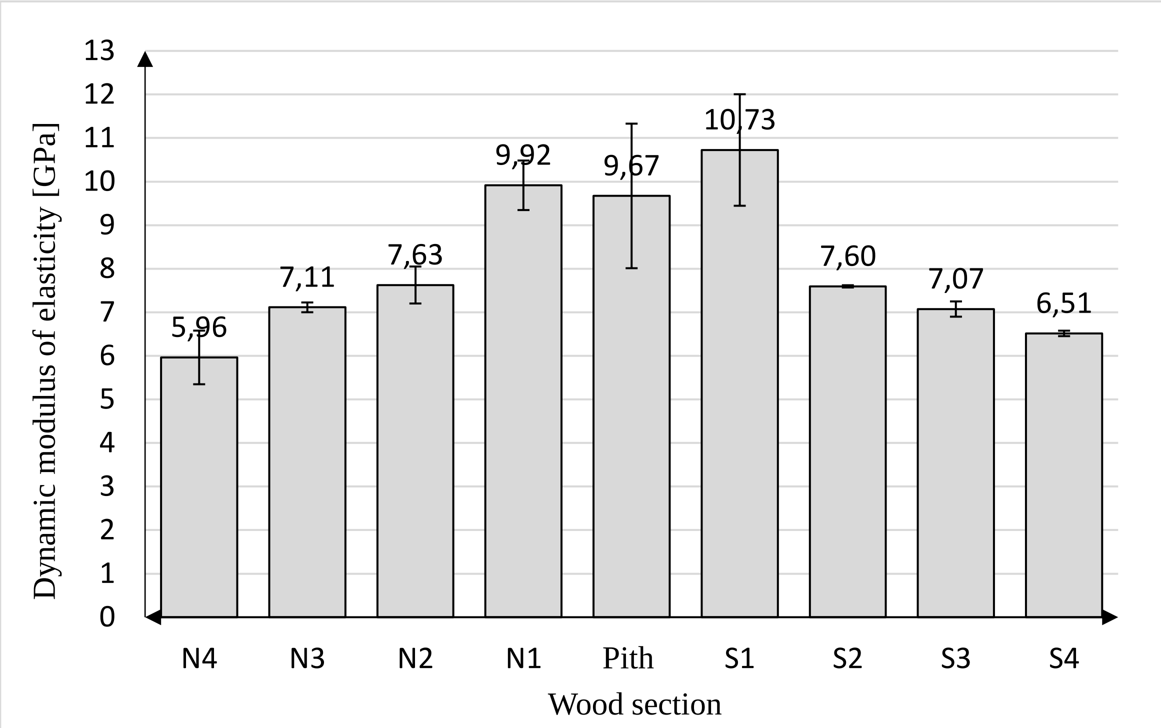

Figure 3. The dependence of the dynamic modulus of elasticity on the distance of the samples from the core

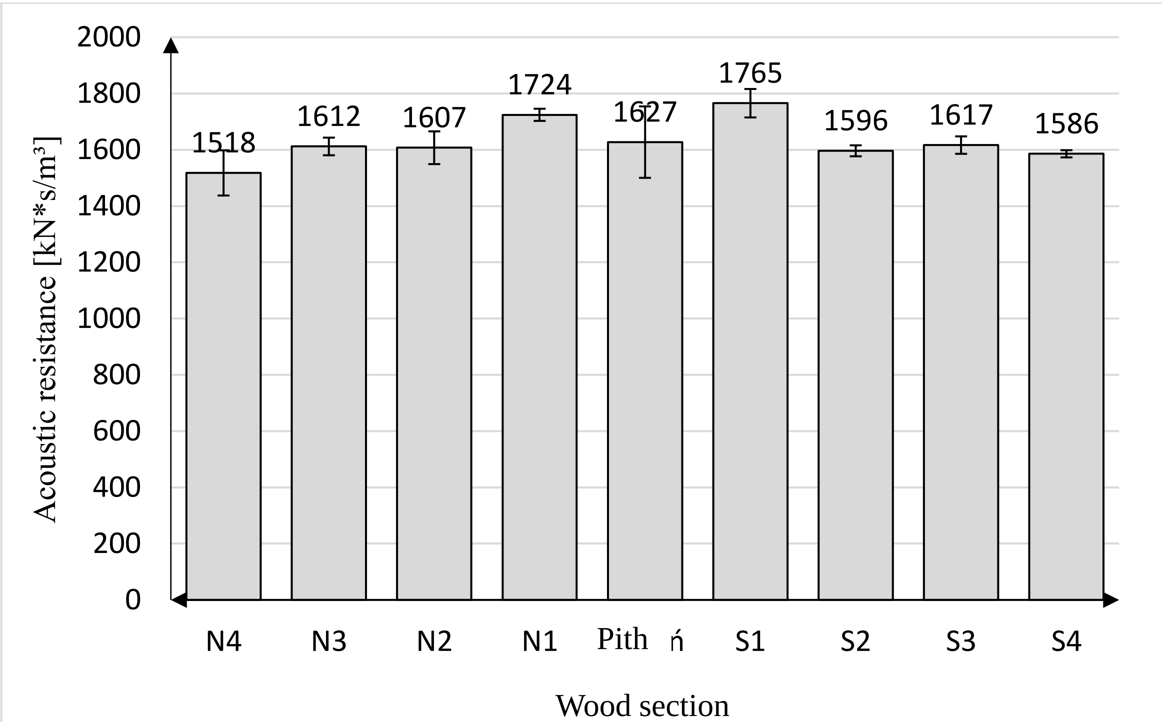

Figure 4. The dependence of the acoustic resistance on the distance of the wood from the core

The dependence of the acoustic resistance on the distance of the black elder wood from the core is shown in Figure 4. The black elder wood that was closer to the core has a slightly higher acoustic resistance than the wood at a greater distance, while the acoustic resistance of the samples containing the core is also slightly lower.

Figure 5 shows the dependence of attenuation by radiation on the distance of the samples from the core. This attenuation is the highest in samples containing the core and remains at a similar level in the others.

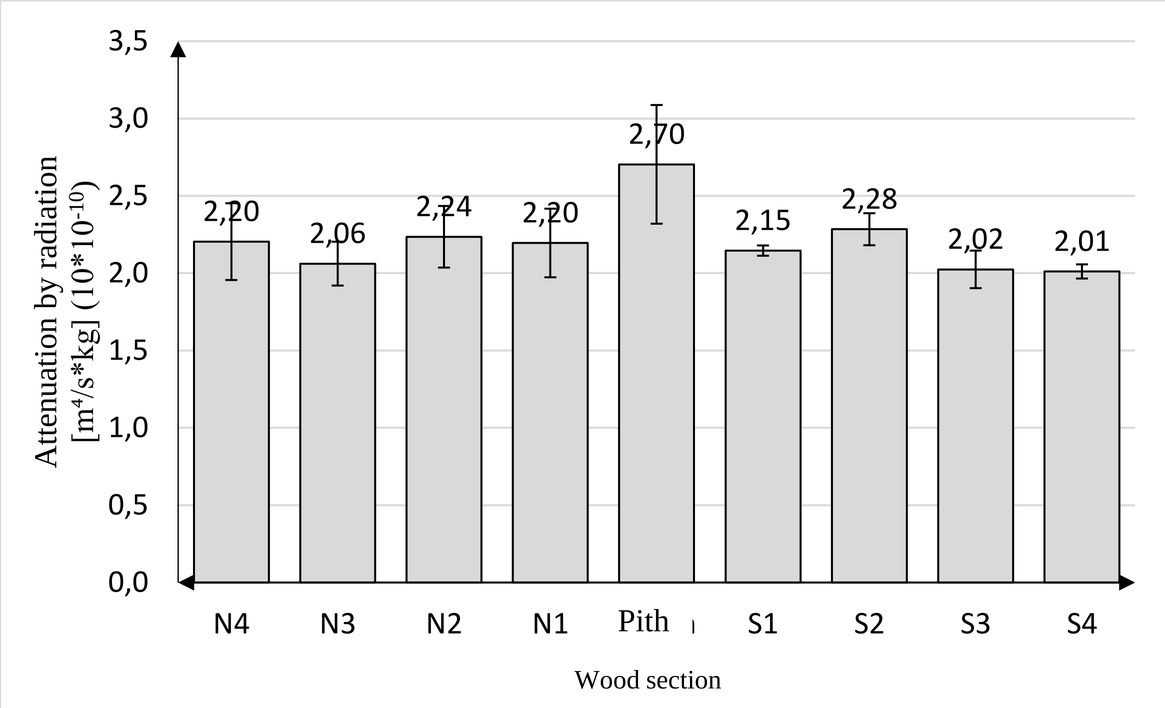

Figure 5. The dependence of the attenuation by radiation on the distance of the samples from the core

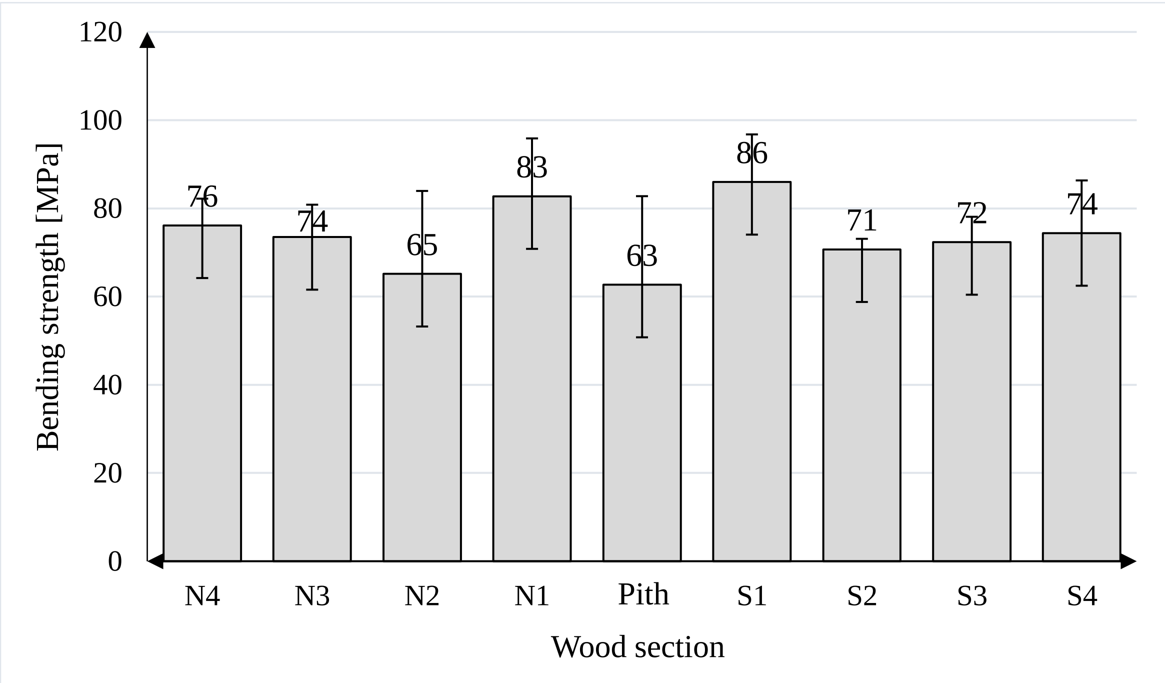

Figure 6. The dependence of the bending strength on the distance of the samples from the core

Wood with low acoustic resistance and high attenuation by radiation is a material predestined for amplifying sounds - the making of musical instruments [Kozakiewicz 2012]. In this context, the former use of small black elder wood branches for making the pipe instruments (polish – fujarka) is not surprising [Chętnik 1983].

The static bending strength of black elder wood is highest in samples cut from near the core, which is shown in Figure 6. It can also be observed that the further the wood is from the core, the value of the static modulus of elasticity decreases significantly. It is shown in Figure 7 (analogous to the dynamic modulus of elasticity (Figure 3)). It is caused by the described twist of the fibres. This is the opposite of the effect observed e.g. in coniferous species (e.g. Zawadzka and Kozakiewicz 2019), where modulus and mechanical properties increase with distance from the core.

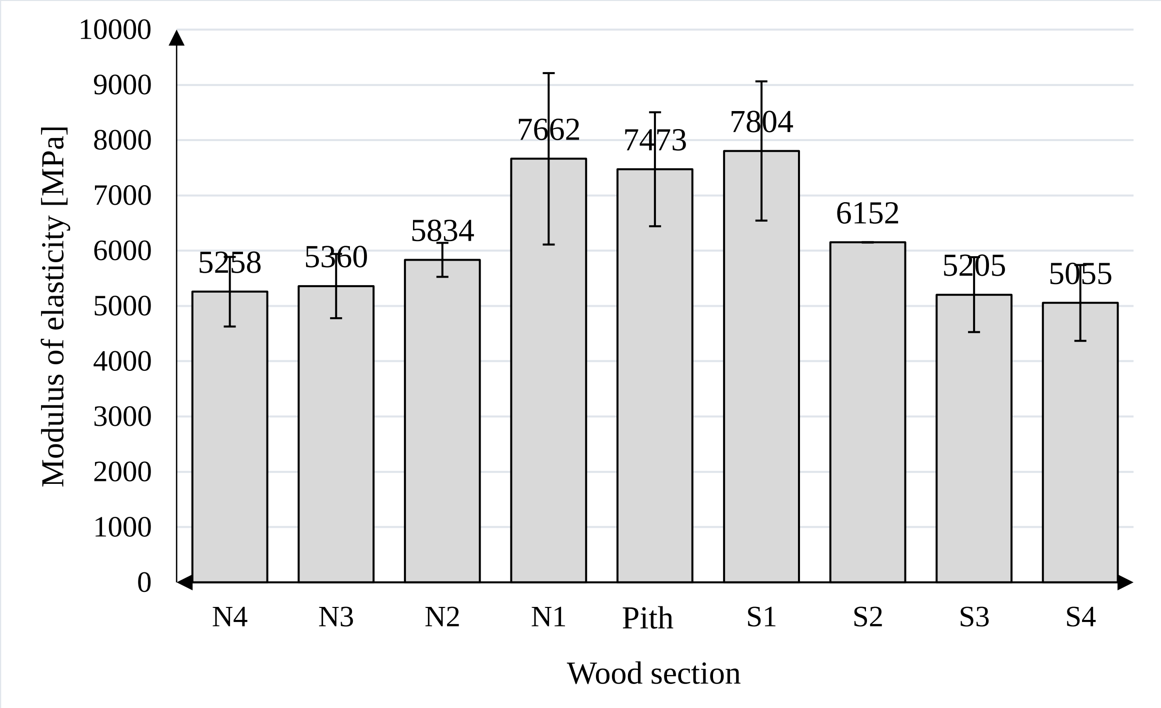

Figure 7. The dependence of the modulus of elasticity on the distance of the wood from the core

The slightly lower bending strength and the slightly lower modulus of elasticity in the samples containing the core are also noticeable in the studied material. This element, consisting of thin-walled, short and mechanically weak parenchyma cells, has a negative effect on the above-mentioned wood characteristics. Overall, the modulus of elasticity of black elder wood is low.

The samples subjected to the static bending test were dominated by "straight tensile scrap" and "oblique fracture scrap" (according to ASTM D 143-94:2000). A scrap with an oblique crack is typical in wood with an irregular grain pattern. In the samples containing the core, delamination i.e. detachment of wood tissue from the core and cracking of parts of the sidewalls of the samples occurred - a clear weakening effect of the wide core.

The compressive strength of wood along the fibres shows a directly proportional dependence on density, shown in Figure 8. This dependence is not strong but significant, with a correlation coefficient R of 0.631.

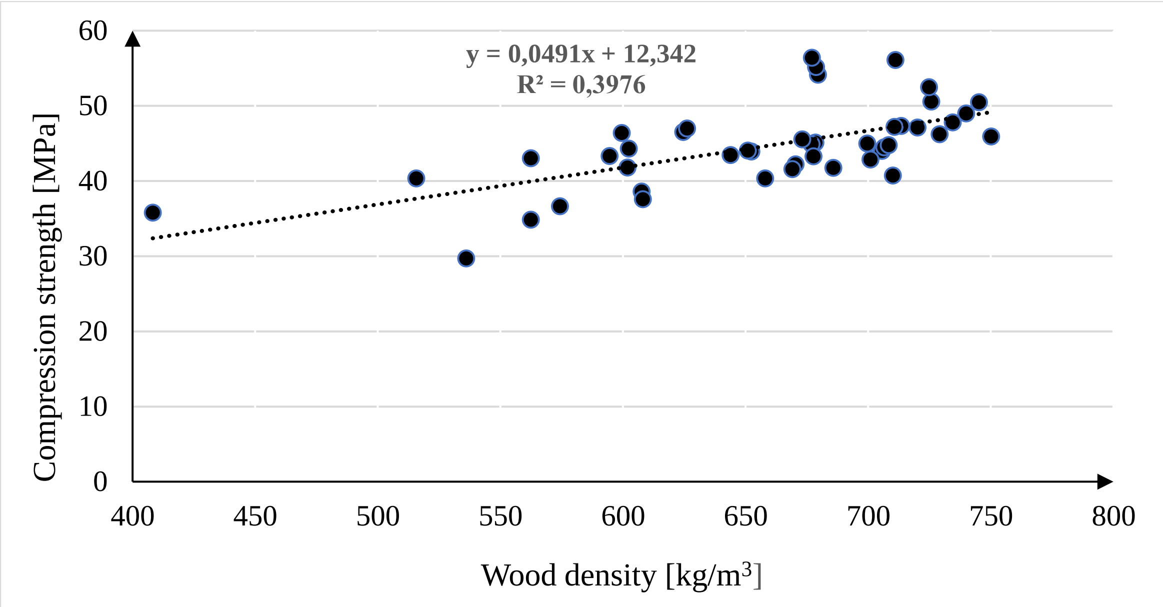

Figure 8. The dependence between compressive strength and density of wood

A shear-type crush was revealed in all compressed samples. The scrap lines on the tangential sections ran obliquely at an angle of about 15 - 25° to the longitudinal axis of the sample [ASTM D 143-94:2000]. This is a typical image of damage to dry wood of medium density [Kozakiewicz 2010].

CONCLUSIONS

Based on the conducted study of selected properties of black elder wood, the following conclusions were formed:

1. The black elder wood in the air-dry state has an average density of 688 kg/m^3. This value corresponds to the range for moderately heavy wood. At the same time, it is a moderately shrinkable wood with a typical shrinkage anisotropy of 2.
2. The black elder wood showed a pH of 5.2, extract test. This value is within the range reported in the literature for different wood species. Higher content of extractives was removed with hot-water (3.7 %) than with cold-water (3.1 %).
3. The black elder wood shows a low dynamic modulus of elasticity and high attenuation to radiation ($2.20 \cdot 10^{-10}$ $m^4/s \cdot kg$) and low acoustic resistance (1518 $kN \cdot s/m^3$) especially in samples collected closer to the circumference of the original trunk.
4. The average static bending strength was 74.7 MPa and the modulus of elasticity at bending was 6.1 GPa. The highest bending strength and modulus of elasticity at bending in black elder wood were shown by the older wood, located next to the core. The static modulus of elasticity decreases similarly to the dynamic modulus of elasticity with the distance from the core.
5. The compressive strength along the fibres of black elder wood (mean: 44.7 MPa) is average for deciduous species. The compressive strength along the fibres shows a directly proportional relationship with density.
6. In the bent samples of black elder wood, the most common occurrence was 'tensile scrap' and 'oblique scrap' (the last is related to the presence of angled fibres). In all samples subjected to compression testing along the fibres, the scrap lines run obliquely at an angle of 15 - 25° to the longitudinal axis of the sample.
7. The Brinell hardness tests on the transverse section showed that the black elder wood is classified as hard. At the same time, this wood shows half the hardness on longitudinal sections. The heartwood is harder than the sapwood.

REFERENCES

1. Amann G., 2009: Drzewa i krzewy. Flora i fauna lasów. MULTICO Oficyna Wydawnicza. Warszawa.
2. Atkinson M.D., Atkinson E., 2002: *Sambucus nigra* L. Journal of Ecology, vol. 90, no. 5, 2002, pp. 895–923. JSTOR, www.jstor.org/stable/3072258.
3. ASTM D 143-94:2000 Standard test methods for small clear specimens of timber.
4. Chabowska-Dąbek B., 2015: Krzewy – czarny bez, publikacja on-line na stronie: http://dzienniklesny.pl/przyroda/krzewy-bez-czarny/ (04.07.2019).
5. Chętnik A., 1983: Instrumenty muzyczne na Kurpiach i Mazurach. Wydawnictwo „Pojezierze". Olsztyn.
6. Clément J., Yvonne T., Danièle D., 1975: Atlas d'anatomie des bois des angiospermes: essences feuillues. Centre Technique du Bois. Paris.
7. Dadon M., 2019: Badanie wybranych cech mechanicznych i akustycznych drewna czarnego bzu. Praca inżynierska na kierunku - technologia drewna wykonana pod kierunkiem dr hab. inż. Paweł Kozakiewicza, prof. SGGW w Katedrze Nauki o Drewnie i Ochrony Drewna.
8. Geffert A., Geffertova J., Dudiak M., 2019: Direct Method of Measuring the pH Value of Wood, Forests, 10, 852.
9. Güzelmeriç E., Çelik C., Şen N.B., Oçkun M.A., Yeşilada E., 2021: Duali/quantitative research on Sambucus nigra L. fruits. J Res Pharm. 2021: 25 (3): 238-248.
10. Hadinata M.E, Kozakiewicz P., 2020: An investigation of selected properties of teak wood from 9-year-old plantation forest in Indonesia. Annals of Warsaw University of Life Sciences – SGGW No. 110, 2020:61-72 DOI: 10.5604/01.3001.0014.3929
11. ISO 13061-1:2014 Physical and mechanical properties of wood – Test methods for small clear wood specimens. Part 1: Determination of moisture content for physical and mechanical tests.
12. ISO 13061-12:2017 Physical and mechanical properties of wood -- Test methods for small clear wood specimens - Part 12: Determination of static hardness.
13. ISO 13061-13:2016 Physical and mechanical properties of wood -- Test methods for small clear wood specimens - Part 13: Determination of radial and tangential shrinkage.
14. ISO 13061-14:2016 Physical and mechanical properties of wood -- Test methods for small clear wood specimens - Part 14: Determination of volumetric shrinkage.
15. ISO 13061-2:2014 Physical and mechanical properties of wood – Test methods for small clear wood specimens. Part 2: Determination of density for physical and mechanical tests.
16. ISO 13061-3:2014 Physical and mechanical properties of wood - Test methods for small clear wood specimens - Part 3: Determination of ultimate strength in static bending..
17. ISO 13061-4:2014 Physical and mechanical properties of wood - Test methods for small clear wood specimens - Part 4: Determination of modulus of elasticity in static bending.
18. ISO 13061-17:2017 Physical and mechanical properties of wood -- Test methods for small clear wood specimens - Part 17: Determination of ultimate stress in compression parallel to grain.
19. Johnson O., 2009: Przewodnik Collinsa – Drzewa. MULTICO Oficyna Wydawnicza. Warszawa.
20. Kaack, K., Austed, T., 1998: Interaction of vitamin C and flavonoids in elderberry (Sambucus nigra L.) during juice processing. Plant Foods Hum Nutr **52,** 187–198 https://doi.org/10.1023/A:1008069422202
21. Kollmann F., 1951: Technologie des Holzes und der Holzwerkstoffe, Tom 1. Wydanie 2. Wydawnictwo Springer Verlag, Berlin.
22. Kozakiewicz P., 2010: Wpływ temperatury i wilgotności na wytrzymałość na ściskanie wzdłuż włókien wybranych rodzajów drewna o zróżnicowanej gęstości i budowie

anatomicznej. Trzysta siedemdziesiąta pozycja serii - Rozprawy Naukowe i Monografie. Wydawnictwo SGGW. Warszawa.
23. Kozakiewicz P., 2012: Fizyka drewna w teorii i zadaniach. Wydanie IV zmienione. Wydawnictwo SGGW. Warszawa.
24. Krzysik F., 1978: Nauka o drewnie. Wydawnictwo PWN. Warszawa.
25. Merev N., Gerçek Z., Serdar B., Ersen Bak F., Birtürk T., 2005: Wood anatomy of some Turkish plants with special reference to performed ray cells. Turk. J. Bot. 29, 269-281.
26. Metcalfe C.R., 1948: The elder tree (*Sambucus nigra* L.) as a source of pith, pegwood and charcoal, with some notes on the structure of the wood. Kew Bulletin. Vol. 3, No. 2 (1948), pp. 163-171.
27. Młynarczyk K., Walkowiak-Tomczak D., Grzegorz P.Łysiak G.P., 2018: Bioactive properties of *Sambucus nigra* L. as a functional ingredient for food and pharmaceutical industry. Journal of Functional Foods. Volume 40, January 2018, 377-390, https://doi.org/10.1016/j.jff.2017.11.025
28. Pettersen R.C., 1984: The chemical composition of wood. w: Rowell R.M. (ed.) The chemistry of solid wood. Advences in chemistry series 207. American Chemical Society, Washington, DC.
29. Pokorný J., 1992: Drzewa znane i mniej znane. Polska Oficyna Wydawnicza „BGW". Warszawa.
30. Porter R.S., Bode R.F., 2017: A review of the antiviral properties of black elder (*Sambucus nigra* L.) products. Phytotherapy Research. DOI: 10.1002/ptr.5782
31. Prosiński S., 1984: Chemia drewna. Państwowe Wydawnictwo Rolnicze i Leśne, Warszawa.
32. Schoch W., Heller I., Schweingruber F.H., Kienast F., 2004: Wood anatomy of central European Species. Online version: www.woodanatomy.ch
33. Tappi Test Method T 207 cm-08, 2008: Water solubility of wood and pulp.
34. Walker J.C.F., 2006: Basic wood chemistry and cell wall ultrastructure. In: Primary Wood Processing. Springer, Dordrecht.
35. Zawadzka K., Kozakiewicz P., 2019: The radial variation of the selected physical and mechanical properties of Norway spruce (*Picea abies* (L.) H. Karst) wood from the provenance area in Głuchów. Annals of Warsaw University of Life Sciences – SGGW, Forestry and Wood Technology No 105, 2019: 133-143.

Streszczenie: *Badanie wybranych właściwości drewna czarnego bzu (Sambucus nigra L.).* Bez czarny to pospolity gatunek rośliny drzewiastej występującej w całej Europie, o dobrze rozpoznanych właściwościach kwiatów i owoców, ale o słabo poznanych właściwościach drewna. W pracy zostały określone właściwości mechaniczne drewna czarnego bzu (*Sambucus nigra* L.), takie jak: twardość Brinella na przekrojach wzdłużnych i przekroju poprzecznym, moduł sprężystości, wytrzymałość na zginanie, wytrzymałość na ściskanie wzdłuż włókien a także właściwości akustyczne takie jak: prędkość rozchodzenia się dźwięku, soniczny moduł sprężystości, oporność akustyczna i tłumienie dźwięku, podstawowe właściwości fizyczne: liniowy jednostkowy skurcz całkowity i gęstość, oraz wybrane właściwości chemiczne: zawartość substancji ekstrakcyjnych w zimnej i gorącej wodzie oraz pH ekstraktu w gorącej wodzie. Drewno bzu czarnego jest twarde i średnio kurczliwe. Część właściwości fizycznych i mechanicznych zmniejsza się idąc od rdzenia do obwodu, na co najprawdopodobniej wpływa wzrastający skręt włókien. Odległość od rdzenia ma również wpływ na właściwości akustyczne oraz wielkość skurczu, natomiast gęstość utrzymuje się na stałym poziomie.

Corresponding author:

Paweł Kozakiewicz (e-mail: pawel_kozakiewicz@sggw.edu.pl)
Department of Wood Sciences and Wood Preservation
Institute of Wood Sciences and Furniture
Warsaw University of Life Sciences – SGGW
166 Nowoursynowska St.,02-787 Warsaw