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ALIEN WOOD SPECIES FOR PARTICLEBOARDS

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Abstract:
Under the frame of Project APPLAUSE, we tested the possibility to use four alien/invasive wood species for particleboard production. For that purpose, black locust (Robinia pseudoacacia), honey locust (Gleditsia triacanthos), staghorn sumac (Rhus typhina) and tree of heaven (Ailanthus altissima) were used. Preparation of particles and particleboards was done in laboratory conditions. The properties of particleboards were influenced by the selection of wood species. Differences already appeared with the morphological characteristics of the particles. Best properties, in general, were obtained using staghorn sumac (highest bending strength and modulus of elasticity, relatively high internal bond and relatively low thickness swelling). Relatively good properties were also determined at particleboards made from tree of heaven (relatively high bending strength and modulus of elasticity, highest internal bond) and honey locust (low thickness swelling relatively high bending strength and modulus of elasticity), although some improvements needs to be made, with regard to the board composition and manufacturing process.

INTRODUCTION

The quest for wood raw material is constantly increasing, especially when low quality wood is in question. Therefore, wood-based panel producers, especially producers of particleboards, are under huge pressure, because they need a substantial amount of wooden raw material at affordable (low) price in order to keep relatively low price of product. Although particleboards are a good example of wood recycling, since they can use every kind of wood shape and size (from logs, towards sawmill residues and residues from woodworking facilities as well as reclaimed wood and wooden based furniture), the quality of particleboards strongly depends on the wood species used as well as on type of used wooden raw material (Buschbeck et al. 1961a, 1961b, Kehr 1962, Moslemi 1974, Niemz 1993, Schöberl 2000, Xu and Suchsland 1998, Barboutis & Philippou 2005, Medved 2007). The relation of wood species used, and particleboard quality is due its density, anatomical structure, morphological characteristics of obtained particles and their compressibility.

Last decades Europe faced overgrowing of alien/invasive wood species, especially in rural area. The overgrowing of alien wood species raised an interesting challenge, namely what can be done with those wood species. City of Ljubljana realized that problems, hence starting the project called Alien PLAnt SpEcies - from harmful to useful with citizens' led activities (acronym APPLAUSE). The project addresses unsolved questions regarding invasive alien plant species in terms of the zero-waste approach and circular economy. The project addresses issues in recognition of invasive non-native plants, their removal and potential processing into product or semi-products like panels. An efficient way to use alien wood species is to break them down into particles and fibres and use them for different wood-based composites such as wood-plastic composites, fibreboards and particleboards. And as mentioned before, for production of particleboards all types (from sawmill residues, shavings, chips towards round wood) can be used.

The aim of paper is to present the possibility to use some alien wood species for manufacturing of particleboards.

MATERIALS AND METHODS

For the purpose of investigation four alien wood species (Fig. 1) were used:
- black locust (*Robinia pseudoacacia*),

- honey locust (*Gleditsia triacanthos*),
- staghorn sumac (*Rhus typhina*) and
- tree of heaven (*Ailanthus altissima*).

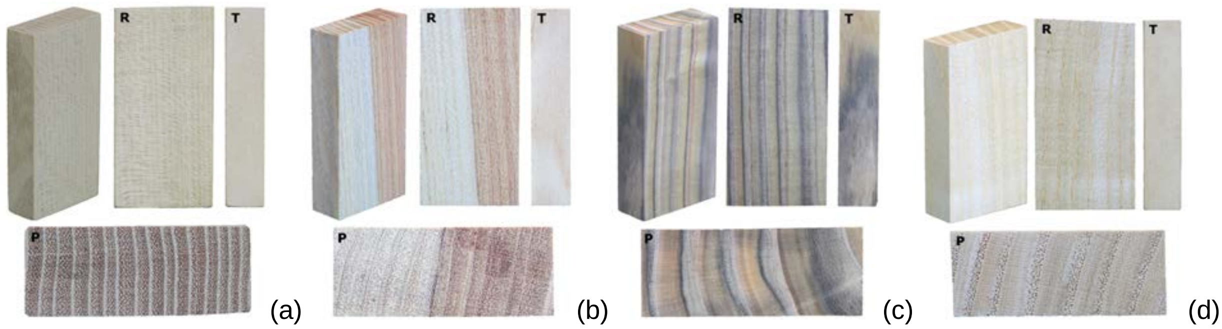

Fig. 1.
Macroscopic structure of wood species used in investigation (a) black locust, (b) honey locust, (c) staghorn sumac and (d) tree of heaven (P - cross, R - radial and T - tangential section). Image presents true colour and average texture of wood in all three sections (Merela et al. 2019).

The chips obtained from company Tisa, d.o.o. (Ljubljana, Slovenia) were break down into particles in a laboratory chipper. The average moisture content was 60±5%. Afterwards particles were sieved in order to separate particles appropriate for surface and those appropriate for core layer. The particles that remained on sieve with mesh size 1, 1.27 and 1.5mm were used as surface layer particles, while particles that remained on sieve with mesh size 2, 4 and 6.14mm were used as core layer. After screening particles were dried for 24 hours at 70°C.

Particles were manually blended and mixed with melamine-urea formaldehyde resin. Blending ratio for core layer particles was 6%, while blending ratio for surface layer particles was 10%. Resin was obtained from local producer Melamin d.d. (Kočevje, Slovenia), with solid content 58%. To the resin for core layer 3% of ammonium sulphate (20% water solution) was added as hardener. Particles were afterwards hand formed into mat with dimensions 500×500mm^2. Target density was 0.7g·cm^{-3}, while target thickness was 16mm. Thickness, during pressing, was controlled by thickness bars. Mat was pressed at 180°C and 3N·mm^{-2} for 4 minutes (closing, degassing and opening included). Panels were than left for 60 minutes at room conditions to cool down and afterwards stored at normal climate conditions (temperature 20±2°C and relative humidity 65±5%) for 14 days. Following properties were determined:

- thickness and density (EN 323: 1996),
- moisture content (EN 322: 1996),
- thickness swelling and water uptake (EN 317: 1996),
- internal bond (EN 319: 1996),
- bending strength and modulus of elasticity at bending (EN 310: 1996).

Thickness swelling and water uptake was determined after 2- and 24-hour immersion. From the results the resistance against water was calculated according to equation 1.

$$Rwater = \frac{WU_i}{TS_i} \qquad (1)$$

where:
- WU stands for water uptake in %
- TS stands for thickness swelling in %
- i stands for 2- or 24-hour immersion
- Rwater stands for resistance against water (% of water uptake needed to increase the thickness for 1%).

In addition to above mentioned panel properties we also analysed the size of particles and pH value. Particles for each layer were spread over the scanner surface in order to obtain particle image. Length, width, visible area and aspect ratio of particles was determined using Image J software. Aspect ratio is defined as ratio between particle length and particle width.

The pH value of particles was determined by Subramanian's method. Owen dried particles (25g) were placed into 800mL beaker with 250g of distilled water and left in water for 24 hours. The solution was than filtrated, followed by the determination of filtrate pH value.

RESULTS

The visual analysis of particles showed differences between wood species used (Fig. 2 and Fig. 3).

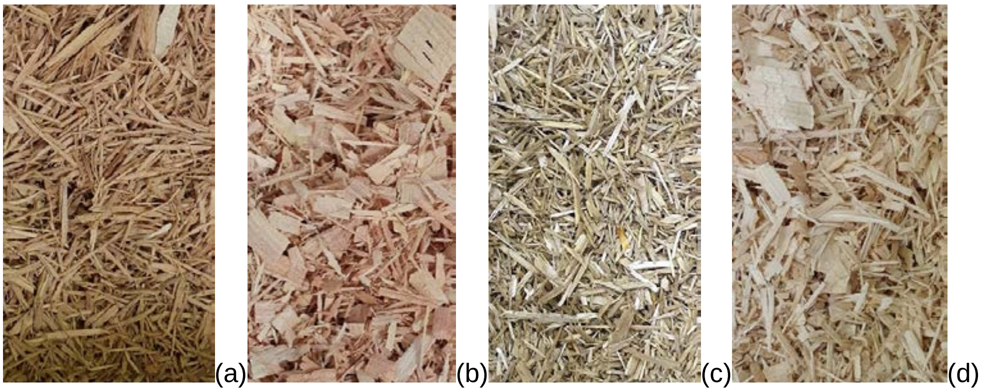

Fig. 2.

Core layer particles (a) black locust, (b) honey locust, (c) staghorn sumac and (d) tree of heaven.

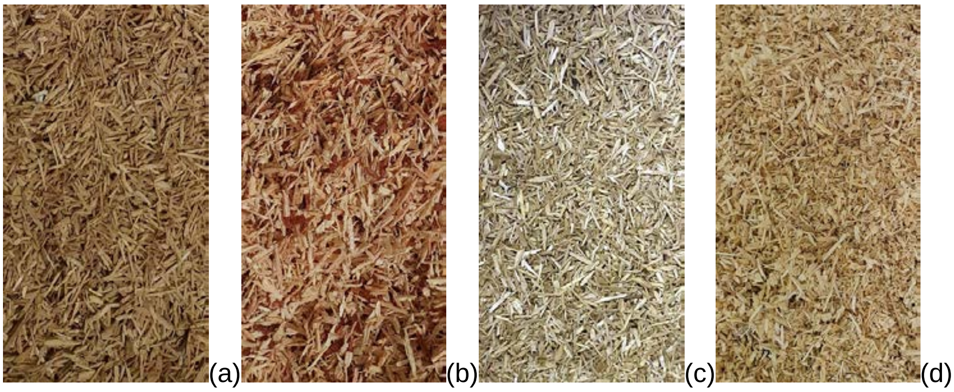

Fig. 3.

Core layer particles (a) black locust, (b) honey locust, (c) staghorn sumac and (d) tree of heaven.

The observations of visual analysis are supported by the data obtained by image analysis (Table 1 and Table 2).

Table 1

Core layer particle morphology results

	Density (Gorišek et al. 2019)	Area	Length	Width	Aspect ratio
	$g \cdot cm^{-3}$	mm^2	mm	mm	mm/mm
Black locust	0.678	20.21	12.82	2.23	7.10
Honey locust	0.641	99.32	23.84	5.78	6.98
Staghorn sumac	0.514	30.12	12.52	3.61	4.23
Tree of heaven	0.602	51.36	14.27	5.20	4.32

Table 2

Surface layer particle morphology results

	Density (Gorišek et al. 2019)	Area	Length	Width	Aspect ratio
	$g \cdot cm^{-3}$	mm^2	mm	mm	mm/mm
Black locust	0.678	3.83	4.62	1.15	5.12
Honey locust	0.641	2.73	3.43	1.13	3.83
Staghorn sumac	0.514	5.30	4.48	1.62	3.30
Tree of heaven	0.602	5.24	4.14	1.80	2.74

The particles from honey locust were on one side the biggest (core layer), but also the smallest (surface layer). Largest surface layer particles were obtained from staghorn sumac and tree of heaven. Smallest core layer particles were obtained at black locust. At core layer particles (up to density 0.65g·cm^{-3}) an increase in density resulted in area, length and width increase (Fig. 2), while black locust (having highest density) resulted in loves area and width and highest aspect ratio.

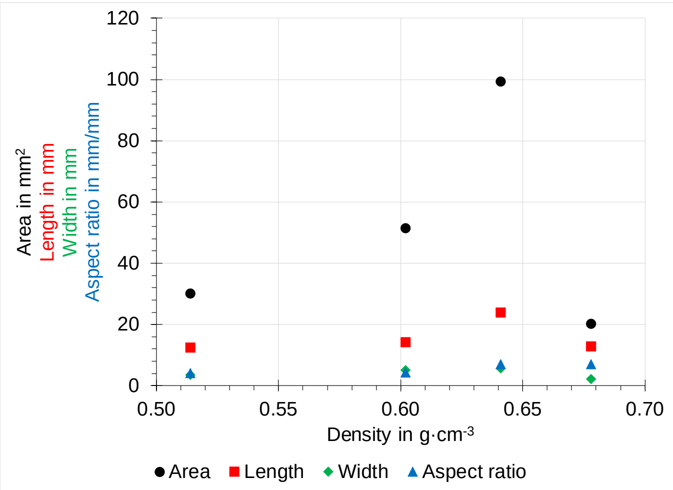

Fig. 4.
Morphological characteristics of core layer particles.

At smaller particles (surface layer) use of wood species with density bellow 0.61g·cm^{-3} resulted in particles with higher area, width and aspect ratio (Fig. 5). The increase in particle length with increasing density could be observed.

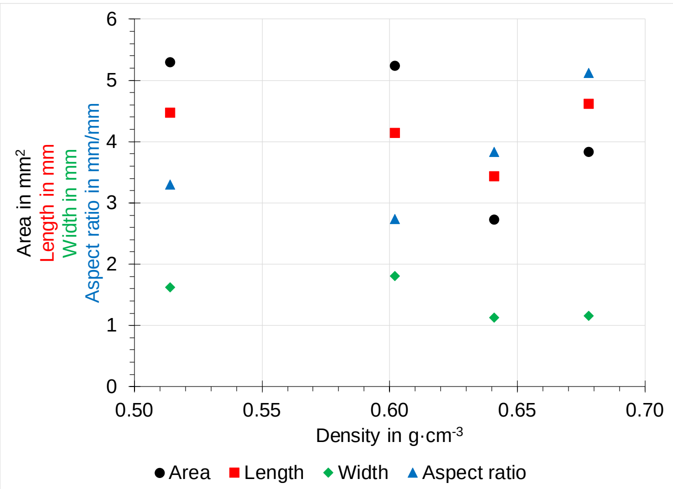

Fig. 5.
Morphological characteristics of surface layer particles.

The determination of pH value showed the highest pH value at particles made from tree of heaven (5.30), while pH value of other three gave the values 4.39 (honey locust), 4.43 (black locust) and 4.64 (staghorn sumac).

As was reported previously wood species used for production of particleboards plays important role. Differences can be observed already at thickness, density, moisture content and compaction ratio (Table 3).

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Vol. 15 N° 4 2019
pp. 220-227

Table 3

Thickness, density, moisture content and compaction ratio (value in bracket represents standard deviation value)

	Thickness	Density	Moisture content	Compaction ratio
	mm	g·cm^{-3}	%	
Black locust	15.93 (0.160)	0.555 (0.014)	8,83 (0.147)	0.82
Honey locust	16.78 (0.086)	0.707 (0.022)	8.52 (0.175)	1.10
Staghorn sumac	17.04 (0.064)	0,686 (0.017)	9,79 (0.199)	1.33
Tree of heaven	16,91 (0.080)	0.702 (0.057)	9.68 (0.226)	1.17

Internal bond strength was higher than it was observed at boards made from coniferous wood species, where it was 0.20N·mm^{-2} (Fig. 6).

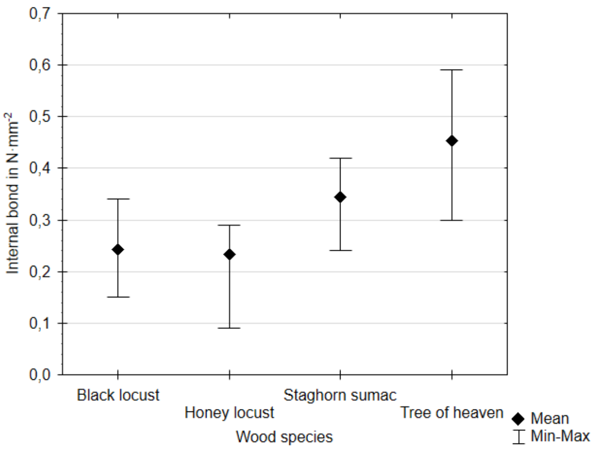

Fig. 6.
Internal bond strength regarding wood species used.

Highest internal bond values were determined at staghorn sumac and tree of heaven were calculated compaction ration (ratio between panel density and density of wood species) was relatively high (above 1.2). Higher compaction ratio means that less voids exist between particles, hence less week areas in panel, especially in core layer. Higher compaction ratio also means that distance between particles is smaller, hence bond between particles is more efficient. Although compaction is important, important factor in relation towards bond quality was the wood species pH value (Fig. 7).

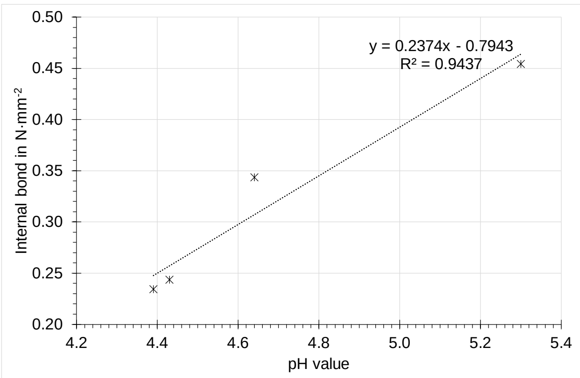

Fig. 7.
Internal bond strength regarding wood species pH value.

Bending strength and modulus of elasticity were also affected by the wood species used (Fig. 8) and compaction ratio (Fig. 9).

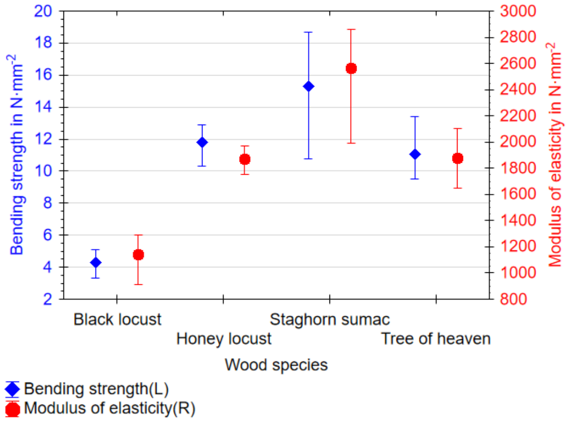

Fig. 8.
Bending strength and modulus of elasticity regarding wood species used.

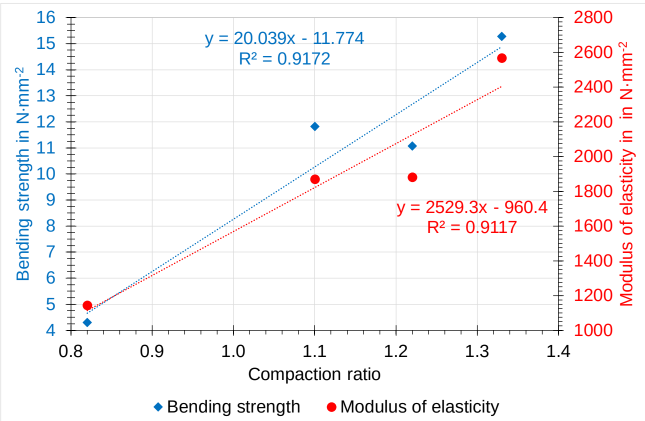

Fig. 9.
Bending strength and modulus of elasticity regarding compaction ratio.

As it was already determined by Moslemi (1974), Niemz (1993), Barboutis & Philippou (2005), Medved (2007), Fan et al. (2009)), wood species is important factor affecting the properties of particleboard. On one side the impact relates to size of particles that can be obtained from individual wood species and on other side it also depends on the particle resistance against compression. In presented research the increase in compression resulted in increase in bending strength and modulus of elasticity. As mentioned before higher compressibility means less voids between particles, smaller distance between particles hence higher resin efficiency. Comparing the results of bending strength and modulus of elasticity from alien wood species with results at panels from coniferous wood species shows lower values at alien wood species (bending strength at panel from coniferous wood species was 14.26N·mm^{-2}, while modulus of elasticity was 2831N·mm^{-2}.

Wood species is also important in relation towards exposure to water (Fig. 10).

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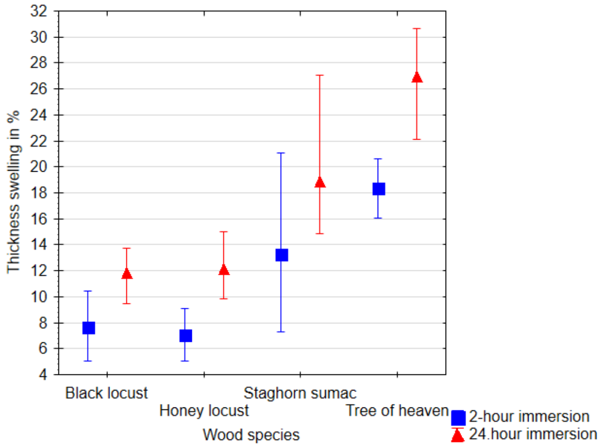

Fig. 10.
Thickness swelling regarding wood species used.

Although lowest swelling (after 2- and 24- hour immersion) was determined when particles from black locust were used their resistance against water is not the highest (it was 4.97). Highest water resistance was determined at honey locust (6.40). Resistance against water at staghorn sumac was 3.46 and at tree of heaven 2.85. Thickness swelling of panel from coniferous wood species was significantly higher. After 2-hour immersion it was 40.09%, and after 24-hour immersion 47.43%.

Statistical analysis (Tukey HSD teste at α=0.05) showed following results:

- Significant difference between board made from black locust and other tree wood species.
- At bending strength and modulus of elasticity, little or no statistically significant differences were observed at honey locust and tree of heaven.
- Little or no statistically significant differences, at internal bond, were determined at board made from black locust and honey locust. Similar was determined for thickness swelling.

CONCLUSIONS

Based on presented results following conclusions can be made:

- Morphological characteristic (area, length, width, aspect ratio) of particles depends on wood species used.
- Highest bending strength and modulus of elasticity was determined at staghorn sumac, while the lowest was determined at black locust.
- The lowest internal bond strength was at honey locust and the highest at tree of heaven.
- Panels from black locust and honey locust had the lowest thickness swelling, while the highest was determined at tree of heaven.
- Most suitable wood species is staghorn sumac, while at other some optimisation needs to be done.
- Boards made from alien wood species had higher internal bond than boards made from coniferous wood species under same conditions.
- Boards made from alien wood species had lower thickness swelling, bending strength and modulus of elasticity compared to board made from coniferous wood species under same conditions.

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