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The impact of the share of waste lignocellulosic biomass from apple orchards on the susceptibility to drilling of produced particleboards

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Abstract:
The impact of the share of waste lignocellulosic biomass from apple orchards on the susceptibility to drilling of produced particle boards. Every year, care cuts are carried out in the orchards, which result in a significant amount of waste. This waste is a valuable source of lignocellulosic material for particleboards production. As part of this study, the influence of the share of waste apple wood on the susceptibility to drilling of particleboards was investigated. Three-layer particle boards with share of lignocellulosic waste biomass from apple orchards (0%, 25%, 50% and 75%) and density level at 650 kg/m^3 and 550 kg/m^3 were made. The particleboards were examined for the axial force and torque that occurs during drilling. The highest value of the axial force during drilling was notice for particleboard without apple wood and a density of 650 kg/m^3. While the lowest axial force during drilling was recorded for particleboard with 50% share of apple wood and density of 550 kg/m^3. The obtained results allow to conclude that density of the produced particleboards and the share of apple wood waste have a statistically significant effect on the axial force during drilling. While the share of apple wood do not statistically affect the torque during drilling. In the case of the pressing unit pressure used in the particleboards production process, no statistically significant influence on the axial force and torque during drilling was found.

Keywords: drilling, particleboard, biomass, wood waste

INTRODUCTION

Agricultural biomass is a fraction of biodegradable products and byproducts. An example of such a type of biomass is every-year care cut in orchards. Even though amounts of agricultural biomass are significant, the problem is still underrated. Currently in Poland there are 370 000 ha of orchards within which more than 177 200 ha are apple orchards. 1 ha of such area can produce 3,5 tons of biomass each year. This means that, considering the whole orchard area in Poland, it is possible to produce 620 200 tons of biomass per year. (Habiera et al. 2018).

Recently, research on the use of agricultural residues in chipboard technology has become increasingly important. Research on the use of agricultural biomass concern: corn cobs (Sekaluvu i in. 2014, Banjo Akinyemi i in. 2016), sunflower husk (Klimek et al. 2016), hazelnut husk (Kowaluk and Kądziela 2014), and apple wood (Auriga et al. 2019) or plum wood (Auriga et al. 2021). Auriga et al. (2019) claim that particles obtained from apple wood waste can be used as an additive in three-layer particleboards with a density of 650 kg/m^3 manufactured by pressure at the level of 1.5 and 2.5 MPa. The authors showed that the boards made with the 75% share of apple wood meet at least the requirements of the EN312 standard for P1 boards.

Research on the use of alternative raw materials in the production of particleboards mainly concerns their mechanical and physical properties. While the research on machinability in this aspect is treated marginally. This is incomprehensible due to the fact that the susceptibility to machining allows determining the ease of processing particleboard into final products. Therefore, in the framework of this study, it was decided to determine the effect of apple wood waste addition on susceptibility to drill of particleboard.

MATERIALS AND METHODS

Materials

As part of the research, three-layer particleboard were made in two variants of the density 650 kg/m^3 and 550 kg/m^3 and four variants of the mass fraction of particles from waste apple wood in the core and face layers at 0%, 25%, 50% and 75%. The thickness of the particleboards was 16 mm, the degree of gluing of the face layers 10% and the core layer 8%. Share of face layers in boards was 35%. UF (Silekol 123) urea-formaldehyde resin was used as a adhesive. 10% ammonium sulfate was used as the hardener. The unit formulation of the adhesive was 50: 15: 1.5 parts by weight of resin, water and hardener, respectively.

The process of pressing was carried out on a one-shelf press with the temperature of 180°C, the maximum unit pressing pressure of 2.5MPa, pressing time 325s. The manufactured boards were seasoned in a normal climate (20 ± 2ºC, 65 ± 5% relative air humidity) for a period of 7 days.

Auriga at al. and Auriga et al. (2019) described process of boards manufacturing and their mechanical and physical parameters, some of that parameters are shown in table 1.

Table 1. Basic mechanical and physical properties of tested boards (Auriga at al. 2019[a] and Auriga et al. 2019[b])

Unit pressing pressure	Density	Share of apple wood	MOR	MOE	IB	TS24H
(MPa)	(kg/m^3)	(%)	(N/mm^2)	(N/mm^2)	(N/mm^2)	(%)
1.5	550	0	12.36	2107	0.31	20.3
		25	10.44	1832	0.31	20.5
		50	8.57	1425	0.24	22.3
		75	7.33	1166	0.26	20.5
	650	0	17.12	2756	0.53	23.9
		25	15.12	2389	0.44	25.4
		50	12.58	2062	0.41	24.2
		75	10.51	1772	0.42	25.7
2.5	550	0	12.82	2159	0.35	19.2
		25	10.59	1818	0.33	18.0
		50	8.50	1419	0.36	21.4
		75	6.78	1080	0.33	22.4
	650	0	18.32	3020	0.40	22.6
		25	17.54	2774	0.47	23.6
		50	14.03	2322	0.48	25.5
		75	11.81	1988	0.45	25.1

MOR – modulus of rapture; MOE – modulus of elasticity; IB – internal bound; TS24H – thickness swelling after 24 hour soaking in water

Methods

A Busellato Jet 130 CNC machining center (Casadei-Busellato, Thiene, Italy) was used to test the machinability of particleboards. The new 8 mm DPI single-edge polycrystalline diamond drill bit from Leitz (GmbH and Co. KG, Stuttgart, Germany) were used. The given drilling parameters were as follows: rotational speed 6,000 rpm, feed speed 1.2 m/min, feed per revolution 0.2 mm. In addition, the axial force and torque signals during drilling were recorded using a Kistler 9345A piezoelectric force sensor (Kistler Group, Winterthur, Switzerland). The sampling frequency was 12 kHz. Ten repetitions were made for each variant.

Statistical analyses

The statistical analysis of the results was carried out in the Statistica13. In order to show the relation between variables, the type of these relations and the impact of selected factors on variables (eg the impact of the share of apple wood waste on the properties of particle boards), a multivariate analysis of variance was used in the statistical analysis (α=0.05). In order to compare the significance of differences of the individual values, homogeneous groups were used based on the Tukey test (α=0.05).

RESULTS

The results obtained as part of the research allowed to conclude that the influence of the share of apple wood waste particles in particleboards on the value of the axial force is visible mainly in the case of boards with a density of 550 kg/m^3 (Figure 1). In the case of chipboards with a density of 550 kg/m^3 produced with the use of a unit pressing pressure of 1.5 MPa, the decrease in the axial force value during drilling is visible with an increase in the share of apple wood waste particles. It should be emphasized that this decrease is statistically significant for 50% and 75% share of apple wood waste in particleboards. In the case of particleboards with a density of 550 kg/m^3 produced with the use of a unit pressing pressure of 2.5MPa, the decrease in the axial force value with an increase in the share of apple wood waste is visible, however, the decrease remains statistically insignificant. Particleboards with a density of 650 kg/m^3 did not show statistically significant differences in the values of the axial forces depending on the share of apple wood.

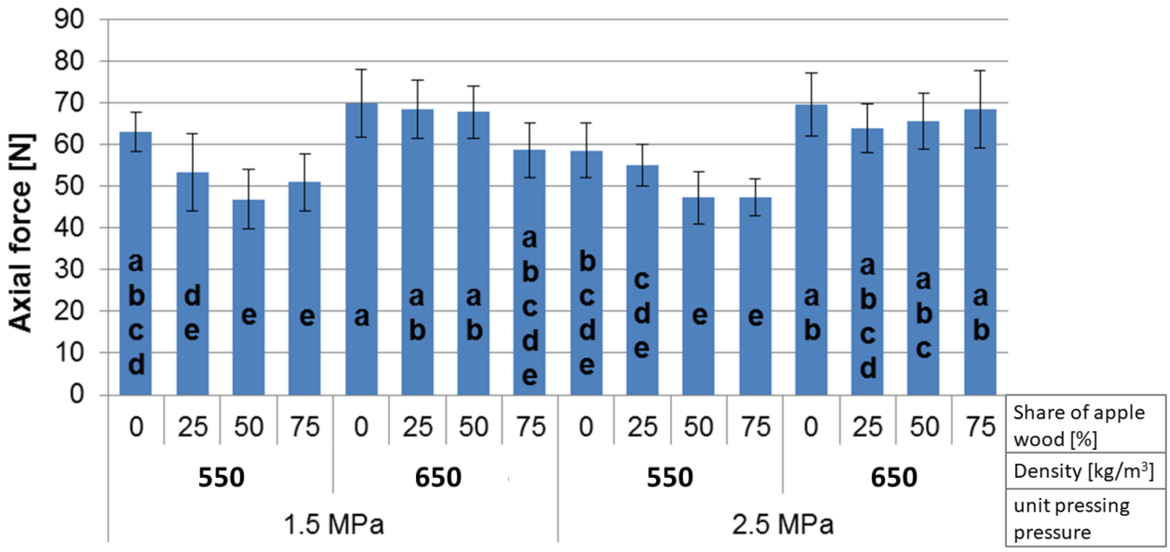

Figure 1. Axial force during drilling of the tested particleboards.
a,b,c… - homogeneous groups by Tukey's test.

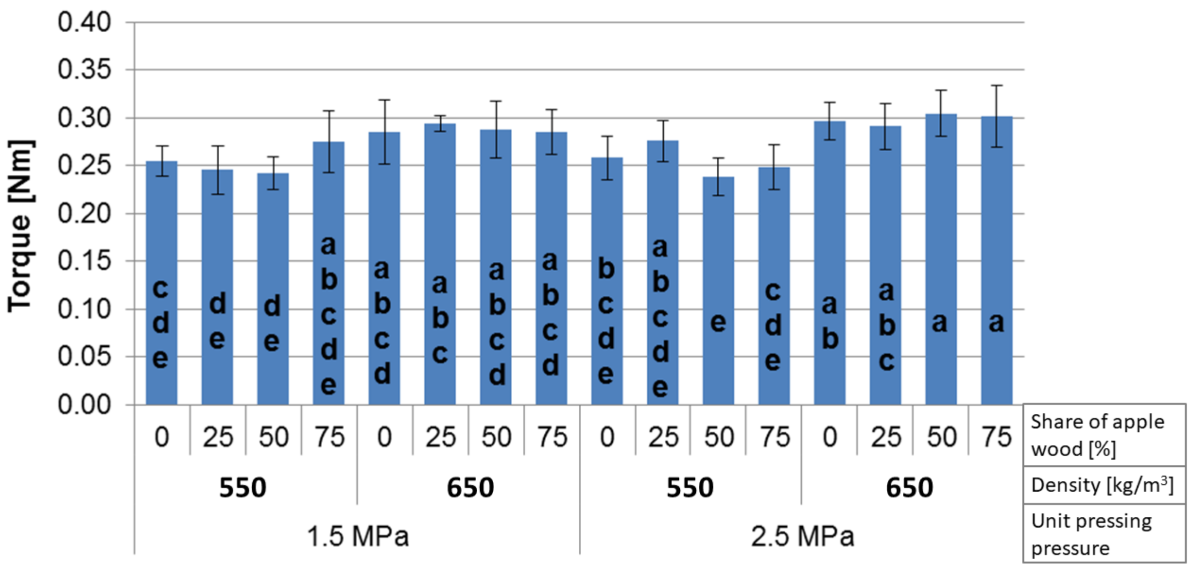

Figure 2. Torque during drilling of the tested particleboards.
a,b,c… - homogeneous groups by Tukey's test.

In the case of the torque value occurring during drilling, no unequivocal influence of the share of apple wood waste in particleboards was observed (Figure 2). Statistically significant differences appear only in the case of particleboards of different densities. The analysis of the variance of the obtained results confirms that the main factor influencing both the axial forces and the torque during drilling is the density of the manufactured particleboards (table 2.) The percentage influence for this factor was 42% for the axial force and 35% for the torque. Such a high influence of density on susceptibility of drill is confirmed in the literature. Wilkowski et al. (2009) report that density is the main factor determining the cutting resistance during mechanical processing of wood and wood-based materials.

It should also be noted that in the case of the axial force, the share of apple wood waste was also a statistically significant factor. However, the percentage impact for this factor was only 12% and was significantly lower than the percentage impact noted for the error (37%). This may indicate that the value of the axial force during drilling is influenced by other factors not included in this study. It should be noted that the share of apple wood in the case of torque during drilling was statistically insignificant.

The results of the conducted research also showed that the unit pressing pressure used in the particleboard production process does not statistically significantly affect the values of the axial force and torque during drilling.

Table 2. Analysis of variance for selected factors and interactions between factors affecting the drilling torque during drilling

Factor	Axial force		Torque	
	p	X	p	X
Share (S)	0.000	12.33	0.386	1.35
Density (D)	0.000	42.09	0.000	35.78
Specific pressing pressure (SPP)	0.753	0.03	0.197	0.74
Share*Density	0.016	3.48	0.150	2.38
Share*SPP	0.366	1.04	0.491	1.07
Density*SPP	0.372	0.26	0.264	0.55
Share*Density*SPP	0.029	3.02	0.024	4.29
Error		37.74		53.82

p – significant with α = 0.05; X – percentage of contribution

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CONCLUSION

1. The density of the produced particleboards and the share of apple wood waste have a statistically significant effect on the axial force during drilling. The particleboards with a density of 650 kg/m^3 showed a much smaller variation in the value of the axial force depending on the share of apple wood waste than the particleboards with a density of 550 kg/m^3.
2. The share of apple wood has a statistically significant effect on the axial force during drilling, however, it does not statistically affect the torque during drilling
3. The unit pressing pressure used in the particleboard production process does not have a statistically significant effect on the axial force and torque during drilling.

REFERENCES

AURIGA R., BORYSIUK P., GUMOWSKA A., SMULSKI, P., 2019[a]: Influence of apple wood waste from the annual care cut on the mechanical properties of particleboards. Annals of Warsaw University of Life Sciences - SGGW, Forestry and Wood Technology 105, 47-53. ISSN 1898-5912.

AURIGA R., BORYSIUK P., SMULSKI, P., 2019[b]: Drewno jabłoni pochodzące z rocznego cięcia pielęgnacyjnego jako dodatek surowcowy przy produkcji płyt wiórowych. Biuletyn Informacyjny OB-RPPD 1-2 (2021) 17-24 https://doi.org/10.32086/biuletyn.2019.02

AURIGA R., BORYSIUK P., MISIURA Z., 2021: Evaluation of the physical and mechanical properties of particle boards manufactured containing plum pruning waste. Biuletyn Informacyjny OB-RPPD 1-2 (2021) 5-11 https://doi.org/10.32086/biuletyn.2021.01

BANJO AKINYEMI A., AFOLAYAN J., OLUWATOBI E., 2016: Some properties of composite corn cob and sawdust particle boards. Construction and Building Materials 127, 436-441.

HABIERA K., LACH A., DYJAKON A. 2018. Metody zagospodarowania biomasy z sadów jabłoniowych w Polsce. XII, 138-152, ISBN 978-83-950719-2-8

KLIMEK P., MEINLSCHMIDT P., WIMMER R., PLINKE B., SCHRIP A., 2016: Using sunflower (Helianthus annuus L.), topinambour (Helianthus tuberosus L.) and cup-plant (Silphium perfoliatum L.) stalks as alternative raw materials for particleboards. Industrial Crops and Products 92, 157-164. https ://doi.org/10.1016/J.INDCROP.2016.08.004

KOWALUK G., KĄDZIELA J., 2014: Properties of particleboard produced with use of hazelnut shells. Annals Warsaw University of Life Sciences - SGGW. Forestry and Wood Technology 85, 131-134.

SEKALUVU L., TUMUTEGYEREIZE P., KIGGUNDU N., 2014: Investigation of factors affecting the production and properties of maize cob particleboards. Waste and Biomass Valorization 5, 27-32. https://doi.org/10.1007/s1264 9-013-9228-9

WILKOWSKI J., BORYSIUK P., GÓRSKI J., ŚMIETAŃSKA K., SZYMANOWSKI K., AURIGA R. 2014: Wybrane aspekty jakości obróbki skrawaniem płyt MDF. Biuletyn Informacyjny Ośrodka Badawczo-Rozwojowego Przemysłu Płyt Drewnopochodnych w Czarnej Wodzie, ISSN 0209-2190, Nr 1/2; s. 43-55

Streszczenie: *Wpływ udziału odpadowej biomasy lignocelulozowej z sadów jabłoniowych na podatność na wiercenie płyt wiórowych*. Każdego roku w sadach przeprowadzane są cięcia pielęgnacyjne, w wyniku, których powstaje znaczna ilość odpadów. Odpady te są cennym źródłem materiału lignocelulozowego do produkcji płyt wiórowych. W ramach pracy zbadano wpływ udziału drewna odpadowego jabłoni na podatność na wiercenie płyt wiórowych. Zbadano płyty wiórowe trójwarstwowe z udziałem lignocelulozowej biomasy odpadowej z sadów jabłoniowych (0%, 25%, 50% i 75%) oraz gęstością 650 kg/m^3 i 550 kg/m^3. Płyty wiórowe zostały przebadane pod kątem siły osiowej i momentu obrotowego występującego podczas wiercenia. Otrzymane wyniki pozwalają stwierdzić, że gęstość wytworzonych płyt wiórowych oraz udział odpadów z drewna jabłoni mają statystycznie istotny wpływ na siłę osiową podczas wiercenia. Przy czym najwyższą wartością siły osiowej podczas wiercenia charakteryzowały się płyty bez udziału drewna jabłoni oraz gęstości 650 kg/m^3. Natomiast najniższą siłą osiową podczas wiercenia płyty z 50% udziałem drewna jabłoni i gęstości 550 kg/m^3. Natomiast udział drewna jabłoni nie wpływa statystycznie na moment obrotowy podczas wiercenia. W przypadku jednostkowego ciśnienia prasowania stosowanego w procesie produkcji płyt wiórowych nie stwierdzono statystycznie istotnego wpływu na siłę osiową i moment obrotowy podczas wiercenia.

Słowa kluczowe: wiercenie, płyta wiórowa, biomasa, odpady drzewne

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