Research Article
Araştırma Makalesi
DOI: 10.24011/barofd.382428

Bartın Orman Fakultesi Dergisi,
20 (1): 81-86
16 Nisan/April 2018

Journal of Bartin Faculty of Forestry
p-ISSN :1302-0943
e-ISSN :1308-5875

Use of Screening Machine Wastes for Manufacturing of Particleboard Composite

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Abstract

In this study, fast grown *Ailanthus Altissima* (Mill.) Swingle wood and screening machine wastes occurred during the particleboard manufacturing were used for particleboard manufacturing. The purpose of this study is to determine the effects of screening machine wastes (dust and rude particles) usage on the mechanical (modulus of rupture, modulus of elasticity and internal bond strength), physical (thickness swelling) and surface quality (roughness), and formaldehyde emission of particleboard. 10% dust usage positively affected the surface roughness, thickness swelling, and mechanical properties of particleboard panels. 20 % dust usage did not statistically affect the mechanical strength properties, surface roughness, and formaldehyde emission. Thickness swelling of the panels was improved by using 20% dust. Increasing dust usage to 30% caused poorer the mechanical strength properties and surface smoothness. 10% rude particle usage did not statistically influence the quality properties of particleboard. Increasing rude particle usage from 10% to 20 % and 30% negatively influenced the mechanical resistance properties and thickness swelling of the particleboards. The results showed that fast grown *Ailanthus Altissima* (Mill.) Swingle wood can be used particleboard manufacturing. Dust (in surface and core layers) and rude particles (in core layer) usage should not exceed 20% and 10 %, respectively.

Keywords: *Ailanthus Altissima* (Mill.) Swingle, dust, particleboard, quality properties, rude particles, screening machine wastes

Yongalevha Üretimi İçin Elek Makinesi Atıklarının Kullanımı

Öz

Bu çalışmada, yongalevha üretiminde hızlı büyüyen bir tür olan *Ailanthus Altissima* (Mill.) Swingle odunu ve yongaların elenmesinde oluşan atıklar kullanılmıştır kullanılmıştır. Bu çalışmanın amacı elek makinası atıklarının kullanımının (toz ve kaba yonga) yongalevhanın mekanik (eğilme direnci, elastikiyet modülü ve çekme direnci), fiziksel (kalınlığına şişme) ve yüzey kalitesi (pürüzlülük) ve formaldehit emisyonu üzerine etkilerini belirlemektir. % 10 toz kullanımı yüzey pürüzlülüğü, kalınlığına şişme ve mekanik özellikleri pozitif yönde etkilemiştir. % 20 toz kullanımı mekanik direnç özellikleri, yüzey pürüzlülüğü ve formaldehit emisyonunu istatistiksel olarak etkilememiştir. Panellerin kalınlığına şişme değerleri % 20 toz kullanımı ile iyileşmiştir. Toz kullanımının % 30'a çıkması ile mekanik direnç özellikleri ve yüzey düzgünlüğü da zayıf olmasına neden olmuştur. % 10 kaba yonga kullanımı yongalevhanın kalite özelliklerini istatistiksel olarak etkilememiştir. Kaba yonga kullanımının % 10'dan % 20 ve % 30'a çıkarılması yongalevhaların mekanik direnç özellikleri ve kalınlığına şişme değerlerini negatif yönde etkilemiştir. Sonuçlar hızlı büyüyen bir tür olan *Ailanthus Altissima* (Mill.) Swingle odununun yongalevha üretiminde kullanılabileceğini göstermiştir. Toz (dış ve orta tabaka) ve kaba yonga kullanımı (orta tabaka) sırasıyla % 20 ve % 10'u aşmamalıdır.

Anahtar Kelimeler: *Ailanthus Altissima* (Mill.) Swingle, toz, yongalevha, kalite özellikleri, kaba yongalar, elek makinesi atıkları.

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Geliş (Received) : 22.01.2018
Kabul (Accepted) : 21.02.2018
Basım (Published) : 16.04.2018

1. Introduction

New studies have increased due to technological improvements (Sogutlu and Dongel, 2007; Zor, et al., 2016). Particleboard is a wood based panel composite manufactured by pressing of particles of wood or other ligno-cellulosic fibrous materials with the addition of a adhesive under pressure and temperature. Typical applications of particleboard are furniture, floor underlayment, cabinets, housing, shelving, vanities, bulletin boards, structural sheathing, electronic game consoles, table tennis, sliding doors, pool tables, lock blocks, displays, speakers, counter tops, stair treads, paneling, kitchen worktops, interior signs, wall and ceiling panels, packing materials, insulators, educational establishments, building and other industrial product applications (Rokiah, et al., 1987; Wang and Sun, 2002; Wang, et al., 2008).

Decreasing forestlands and amount of raw material, forest fires have caused new studies to ensure more efficient use of trees. Social demands, environmental movemement, recycling trends, green movement lead to the continuous effort of finding new raw materials and wastes as an alternative wood (Yang et al., 2007). Works have been showed on many alternative raw materials and wastes such as sunflower, topinambour and cup-plant stalks (Klimak, et al., 2016), coir fiber and waste banana stem fiber (Wang and Hu, 2016), tree pruning wastes (Nasser, et al., 2016), sugarcane bagasse (Oliveria, et al., 2016), tetra-pak and polyethylene waste (Bekhta, et al., 2016), corn stalk rinds (He, et al., 2016), vine prunings (Yeniocak, et al., 2016), canola straws (Kord, et al., 2016), cotton stalks (Nazerian, et al., 2016), flax and hemp fiber (Sam-Brew and Smith, 2015), rice straw (Kurokochi and Sato, 2015), poppy husk (Keskin, et al., 2015), peanut shell and coconut husk fiber green (Cravo, et al., 2015), maize cob (Scatoloni, et al., 2015), branch wood (Rios, et al., 2015), sorghum stalk fibers (Khazaeian, et al., 2015), hardwood sawmill residue (Gamage and Setunda, 2015), and yerba mate pruning residues (Carvalho, et al., 2015).

The purpose of our study was to investigate the effects of using chip screening machine wastes on the quality properties of particleboard.

2. Materials and Methods

Five *Ailanthus Altissima* (Mill.) Swingle trees were taken from a forest in Trabzon. 14 years old trees were chosen and their diameters were determined as 18 cm. The bark was raised from logs before chipping process. After the trimming process of the foliage, a flaker was used to chip the trees. Then, the chips were converted to smaller pieces with help of a hammer mill and dried to reach 3% moisture content of the pieces. After that, the pieces were categorized into two layers with help of screening machine: the core and face layers. Dusts passed a 0.5 mm opening and rude particles unpassed the 3.0 mm opening were collected for adding them to particles in standard dimensions. In the following step, a pneumatic spray gun was used for resin application. Taking as a reference of oven dry particle weight, core particles are prepared using 10% urea formaldehyde adhesive with a solid content of 65% while 12% was chosen for surface particles. For all prepared samples, a shelling ratio of 0.40 was set. As a hardener, ammonium sulfate, which has concentration of 25%, was added into the urea formaldehyde resin by about 1% of the solid resin amount. At a temperature of 150°C using a pressure of 2.5 N/mm^2 for 6 min, mats were pressed to make experimental panels (1.2 cm thickness and 0.75 g/cm^3 average target density) in a 55 x 60 cm frame. Following all these processes, 14 experimental panels were produced containing 2 panels for each type of particleboard (see Table 1).

The conditioned room was set to a relative humidity of 65% and a temperature of 20 °C to keep the particleboards until they reached equilibrium moisture. Mechanical properties- modulus of rupture (MOR), modulus of elasticity (MOE) and internal bonding (IB)- and physical property- thickness swelling (TS)- of the panels were determined according to European standards (EN 310, 1993; EN 317, 1993; EN 319, 1993) respectively. Thirty experimental samples were used for each type of property. Formaldehyde emission (FE) was determined in keeping with perforator method based on EN 120-1 standard (EN 120-1, 1993). Three samples were used for determining FE.

The samples were sanded to use them in the surface roughness tests. The surface qualities were measured by employing a fine stylus profilometer (Mitutoyo SJ-301). For the surface roughness measurements, ten experimental samples were processed from each panel types. Following quantities of roughness, characterized by ISO 4287 standard, were considered to utilize the board surface: maximum peak-to-valley height (R_y), mean peak-to-valley height (R_z), and average roughness (R_a) (ISO, 1987).

ANOVA (analysis of variance) was performed to evaluate the effects of dust and rude particle usage on the quality properties of the particleboards. İmportant differences between the average values of each type of particleboard were determined employing Newman-Keuls test. The experimental design is indicated in Table1.

Table 1. Schematic of the study.

Panel types	Dust usage * (%)	Rude particle usage** (%)
A	0	0
B	10	0
C	20	0
D	30	0
E	0	10
F	0	20
G	0	30

Note: * Added to total outer and core layers weight of the panels, ** Added to only total core layer weight of the panels.

3. Results and Discussion

The properties of physical and mechanical, formaldehyde emission, and surface roughness of the particleboards are presented in Table 2-4, respectively.

Table 2. Mechanical strength of particleboards

Panel types	MOR (N/mm^2)	MOE (N/mm^2)	IB (N/mm^2)
A	15.49 (2.85) a A	2278.99 (194.86) a A	0.517 (0.054) a A
B	17.29 (2.81) b	2439.82 (191.83) b	0.565 (0.037) b
C	15.34 (2.14) a	2269.25 (172.24) a	0.509 (0.040) a
D	12.88 (2.87) c	2156.38 (169.27) c	0.421 (0.021) c
E	15.20 (2.80) A	2174.82 (186.94) A	0.505 (0.049) A
F	13.47 (1.65) B	2045.46 (209.87) B	0.451 (0.022) B
G	11.93 (2.98) C	1910.61 (240.15) C	0.354 (0.044) C

Note: Statistical differences at 95% confidence level (standard deviations). Each letter corresponds to different level of statistical differences.

Table 3. Thickness swelling and formaldehyde emission of particleboards

Panel types	TS * (%)	TS ** (%)	FE (mg CH_2O)
A	13.65 (1.19) a A	24.96 (0.56) a A	7.28 (0.12) a A
B	12.98 (1.25) b	23.68 (0.41) b	7.21 (0.11) a
C	12.01 (1.14) c	22.23 (0.60) c	7.34 (0.15) a
D	10.85 (1.06) d	20.65 (0.33) d	7.37 (0.07) a
E	13.89 (1.12) A	25.23 (0.58) A	7.33 (0.14) A
F	15.76 (0.86) B	27.19 (0.99) B	7.37 (0.13) A
G	17.58 (1.33) C	29.13 (1.10) C	7.40 (0.12) A

Note: Statistical differences at 95% confidence level (standard deviations). Each letter corresponds to different level of statistical differences. *: after 2 hours sinking, **: after 24 hours sinking.

Table 4. Average surface roughness of the particleboards

Panel types	R_a (µm)	R_y (µm)	R_z (µm)
A	5.54 (1.30) a A	41.85 (6.96) a A	26.27 (4.40) a A
B	4.55 (1.13) b	36.03 (7.72) b	22.46 (6.70) b
C	5.74 (1.74) a	42.35 (8.41) a	26.34 (5.27) a
D	7.09 (1.52) c	50.26 (9.01) c	32.15 (4.94) c
E	6.01 (1.33) A	42.78 (11.38) A	26.59 (7.12) A
F	6.05 (1.29) A	42.87 (10.97) A	26.71 (6.84) A
G	6.11 (1.37) A	42.91 (10.03) A	26.79 (6.79) A

Note: Statistical differences at 95% confidence level (standard deviations). Each letter corresponds to different level of statistical differences.

12.5 N/mm^2 and 13 N/mm^2 are the minimum conditions of the panel rupture modulus for general uses and interior fitments, respectively, while the minimum modulus of elasticity for interior fitment (including furniture) is 1800 N/mm^2 based on EN 312 (2010) standard. All panels satisfied the minimum MOE requirement for interior fitments (including furniture). Panel type G did not have the required level of MOR for general uses and furniture manufacturing. Named panel types in the tables had the essential levels of MOR for general uses and interior fitments. Based on EN 312 standard, the minimal condition of internal bond strength for general uses is 0.28 N/mm^2 while it is 0.40 N/mm^2 for interior fitments. While the particleboard type had essential IB level for general uses, all of the other panel types expect panel type G satisfied the required level of IB for furniture manufacturing. The produced particleboards were not required to have level of thickness swelling based on EN 312 standard since any water-repellent agents was not used. The formaldehyde content for indoor applications is maximum 8 mg CH_2O/100 g dry sample (EN 120-1, 1993). All panel types had the desired level of FE.

10% dust usage improved surface roughness, thickness swelling, and mechanical properties of particleboard panels. 20 % dust usage was not to be found effective on the mechanical strength properties, surface roughness and formaldehyde emission. However, thickness swelling of the panels was improved by using 20% dust. Dust fills the pores between the particles. Filling of pores causes surface smoothness and more compact structure. Compact structure increases the mechanical strengths. The water diffusion into the particleboard is difficult since its structure is more compact. The thinner particles absorb less amount water. Dust usage did not statistically affect the formaldehyde emission. Dust is not a formaldehyde scavenger. Increasing dust usage to 30% negatively affected the mechanical strength properties and surface smoothness. Increasing dust usage causes new layer in the surface layers. This layer was easily removed by sanding operationg. The pits are formed in the surface layers. Thinner particles are easily broken (Shuler and Kelly, 1976; Henderto, et al., 2006; Erakhruman, et al., 2008).

It is found that 10% rude particle usage was not influential on all of the quality properties of particleboard. Increasing rude particle usage from 10% to 20 % and 30% statistically decreased the mechanical strength properties and negatively affected the thickness swelling of the test panels. Rude particles are not formaldehyde scavenger. They used only in the core layer of the test panels. For these reasons, rude particles usage did not statistically affected the surface roughness and formaldehyde emission. The amount of pores between the particles is increased by using thick particles. The pores increase the water diffusion into panel and decrease the strength properties. The water can easily penetrate to particleboard. The thick particles soak in more amount of water than thin particles. Thick particles soak in more amount of adhesive. For this reason, there is not sufficient amount of adhesive on the particle surfaces. Low adhesive amount on the particle surfaces decreases the mechanical strengths (Liu and Mcnatt, 1991; Akbulut, 1995; Bardak, et al., 2010).

4. Conclusions

The following statements can be safely expressed as conclusions:

1. Fast grown *Ailanthus Altissima* (Mill.) Swingle wood can be used in particleboard manufacturing.

2. 10% dust usage decreased the surface roughness, thickness swelling, and raised the mechanical properties of particleboard. 20 % dust usage did not affect the mechanical strength properties, surface roughness and formaldehyde emission. Thickness swelling of the panels was improved by 20% dust usage enhanced the thickness swelling. Increasing dust usage to 30% caused poorer mechanical strength properties and surface smoothness.

3. 10% rude particle usage did not affect all of the quality properties of particleboard. Increasing rude particle usage from 10% to 20 % and 30% negatively affected the mechanical strength properties and thickness swelling of the particleboards.

4. The dust can be used in the core and surface layers of particleboards by about 20 %. Dust usage in particleboard manufacturing should not exceed 20%.

5. The rude particles can be used in the core layer of test panels by about 10%. Rude particle usage in particleboard manufacturing should not exceed 10 %.

6. Considering all the standards related to mechanical properties, all panels except the panel type which uses 30% rude particle in the core layer are useful for furniture and general use.

References

1. **Akbulut T (1995).** Effects of Various Factors on Properties of Horizontalppressed Particleboard. PHd Dissertion Thesis, İstanbul University, Institute of Natural Sciences. İstanbul (in Turkish).
2. **Bardak S, Nemli G, Sari B, Baharoğlu M Zekoviç E (2010).** Manufacture and Properties Composite from Waste Sanding Dusts. High Temperature Materials and Process, 29: 159-168.
3. **Bekhta P, Lyutyy P, Hiziroglu S, Ortynska G (2016).** Properties of Composite Panels Made from Tetra-Pak and Polyethylene Waste Material. Journal of Polymers and the Environment, 24: 159-165.
4. **Carvalho AG, De Andrade BG, Cabral CPT, Vital BR (2015).** Effect of Adding Yerba Mate Pruning Residues in Particleboard Panels. Revistra Arvore, 39: 209-214.
5. **Cravo JCM, Sartori DD, Fiorelli J, Balireio JCD, Savastano H (2015).** Particleboards of Agroindustrial Wastes. Ciencia Florestal, 25: 721-730.
6. **EN 310 (1993).** Wood based panels, Determination of Modulus of elasticity in bending and bending strength, EN, Brussels.
7. **EN 317 (1993).** Particleboard and fiberboards, determination of tensile strength perpendicular to the plane of the board, EN, Brussels.
8. **EN 319 (1993).** Particleboards and fiberboards, determination of tensile strength perpendicular to the plane of the board, EN, Brussels.
9. **EN 120-1 (1993).** Wood based panels, determination of formaldehyde content-extraction method called perforator method, EN, Brussels.
10. **EN 312 (2005).** Particleboards-specifications, EN, Brussels-Belgium.
11. **Erakhruman AA, Areghan SE, Ogunleye MB (2008).** Selected Physic-Mechanical Properties of Cement Bonded Particleboard Made from Pine Sawdust-Coir Mixture. Scientific Research and Essays, 3: 197-203.
12. **Gamage N, Setunda S (2015).** Modelling of Vertical Density Profile of Particleboard, Manufactured from Hardwood Sawmill Residue. Wood Material Science & Engineering, 10: 57-67.
13. **He X, Wang DF, Zhang YL, Tang Y (2016).** Manufacturing Technology and Parameter Optimization for Composite Board from Corn Stalk Rinds. Bioresources, 11: 4564-4578.
14. **Hendarto B, Shayan E, Ozarska B, Carr R (2006).** Analysis of Roughness of A Sanded Wood Surface. International Journal of Advanced Manufacturing Technology, 28: 775-780.
15. **ISO 4287 (1997).** Geometrical product specifications (GPS)-surface texture; profile method terms, definations and surface texture parameters, ISO Geneva.
16. **Keskin H, Kucuktuvek MC, Guru M (2015).** The Potential of Poppy (Papaver Somniferum Linnaeus) Husk for Manufacturing Wood-Based Particleboards. Construction and Building Materials, 95: 224-31.
17. **Khazaeian A, Ashori A, Dizaj MY (2015).** Suitability of Sorghum Stalks Fibers for Production of Particleboard. Carbohydrate Polymers, 120: 15-21.
18. **Klimak P, Meinlschmidt P, Wimmer R, Plinke B, Schirp 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.
19. **Kord B, Zare H, Hosseinzadeh A (2016).** Evaluation of The Mechanical and Physical Properties of Particleboard Manufactured from Canola Straws. Maderas-Ciencia Y Tecnologia, 18: 9-18.
20. **Kurokochi Y, Sato M (2015).** Effect of Surface Structure, Wax and Silica on The Properties of Binderless Board Made from Rice Straw. Industrial Crops and Products, 77: 949-953.
21. **Liu JY, Mcnatt JD (1991).** Thickness Swelling and Density Variation in Aspen Flakeboard. Wood Science and Technology, 82: 52-33.
22. **Nasser RA, Salem MZM, Al-Mefarrej HA, Aref IM (2016).** Use of Tree Pruning Wastes For Manufacturing of Wood Reinforced Cement Composites. Cement & Concrete Composites, 72: 246-256.
23. **Nazerian M, Beyki Z, Gargarii RM, Kool F (2016).** The Effect of Some Technological Production Variables on Mechanical and Physical Properties of Particleboard Manufactured from Cotton Stalks. Maderas-Ciencia Y Tecnologia, 18: 67-78.
24. **Oliveira SL, Mendes RF, Mendes LM, Freire TP (2016).** Particleboard Panels Made from Sugarcane Bagasse: Characterization For Use In The Furniture Industry. Materials Research-Ibero-American Journal of Materials, 19: 914-22.
25. **Rios PD, Vieria HC, Stupp AM, Kniess DD, Borba MH, Da Cunha AB (2015).** Physical and Mechanical Review of Particleboard Composed of Dry Particles of Branches of Araucaria Angustifolia (Bertol.) Kuntze and Wood of Eucalyptus Grandis Hill Ex Maiden. Scientia Forestalis, 43: 283-89.

26. **Rokiah H, Wan NWNA, Othman S (1987).** Evaluations Of Some Properties Of Exterior Particleboard Made From Oil Palm Biomass. J. Compos. Mater, 45: 1659-1665.
27. **Sam-Brew S, Smith GD (2015).** Flax and Hemp Fiber-Reinforced Particleboard. Industrial Crops and Products, 77: 940-48.
28. **Scatoloni MV, Protasio TD, Mendes RF, Mendes LM (2015).** Thermal Stability of Pinus Oocarpa and Maize Cob Particleboards. Ciencia E Agrotecnologia, 39: 348-354.
29. **Shuler CE, Kelly RA (1976).** Effect of Flake Geometry on Mechanical Properties of Eastern Spruce Flake-Type Particleboard. Forest Prod. J, 26: 24-28.
30. **Sogutlu C, Dongel, N, (2007).** Tensile Shear Strengths of Some Local Woods Bonded with Polyvinyl Acetate and Polyurethane Adhesives. Journal of Polytechnic, 10(3): 287-293
31. **Wang D, Sun XS (2002).** Low Density Particleboard from Wheat Straw and Corn Pith. Ind. Crops Products, 15: 47-50.
32. **Wang JG, Hu YC (2016).** Novel Particleboard Composites Made From Coir Fiber and Waste Banana Stem Fiber. Waste Biomass Valorization, 7:1447-1458.
33. **Wang SY, Yang TH, Lin LT, Lin CJ, Tsai MJ (2008).** Fire Retardant Treated Low Formaldehyde Emission Particleboard Made from Recycled Wood Waste. Bioresource Technology, 99: 2072-2077.
34. **Yang TH, Cheng JL, Song YW, Ming JT (2007).** Characteristics of Particleboard Made from Recycled Wood Waste Chips Impregnated With Phenol Formaldehyde Resin. Building and Environment, 42: 189-195.
35. **Yeniocak M, Goktas O, Ozen E, Gecgel A (2016).** Improving Mechanical and Physical Properties of Particleboard Made from Vine Prunings By Addition Reinforcement Materials. Wood Research, 61: 265-74.
36. **Zor M, Sozen E, Bardak T. (2016).** Mechanical Performances of Laminated wood and Determination of Deformation in The Bending Test with The Aid of Image Analysis Method. Journal of Bartin Faculty of Forestry, 18(2), 126-136.