Turk J Agric For
27 (2003) 99-104
© TÜBİTAK

Effects of Some Manufacturing Factors on the Properties of Particleboard Manufactured from Alder (*Alnus glutinosa* subsp. *Barbata*)

Gökay NEMLİ
Karadeniz Technical University, Faculty of Forestry, Trabzon - TURKEY

Received: 30.06.2002

Abstract: In this study, Alder (*Alnus glutinosa subsp.Barbata*) wood was used for particleboard manufacturing. The purpose of this study was to determine the effects of particle moisture content, shelling ratio and the addition of wood dust on the mechanical properties (static bending, modulus of elasticity and internal bond) and physical property (thickness swelling) of particleboard. The addition of 10% wood dust to particles decreased the thickness swelling, modulus of elasticity and bending strength, while increasing the internal bond. Particleboards manufactured from particles with 1% moisture content had lower internal bond, modulus of elasticity and bending strength and higher thickness swelling values than those produced from particles with 4% moisture content. Increasing face:core ratio from 30:70% to 45:55% improved the physical and mechanical properties of particleboards. Overall results showed that particleboards made from Alder exceed the EN standards for internal bond, modulus of elasticity and static bending. However, thickness swelling values were higher (poor) than requirements. For this reason, additional work needs to be done on improving the physical properties of particleboard produced from Alder.

Key Words: Particleboard, Alder (*Alnus glutinosa* subsp. *Barbata*), Static Bending, Modulus of Elasticity, Internal Bond, Thickness Swelling, Manufacturing Factors

Bazı Üretim Faktörlerinin Kızılağaç (*Alnus glutinosa* subsp. *Barbata*)'tan Üretilen Yongalevha Özellikleri Üzerine Etkileri

Özet: Bu çalışmada, Kızılağaç (*Alnus glutinosa* subsp. *Barbata*) odunu yongalevha üretiminde kullanılmıştır. Bu çalışmanın amacı; kurutulmuş yonga rutubeti, dış:orta tabaka yonga oranı ve odun tozunun yongalara katılmasının yonga levhanın kalınlığına şişme oranı, eğilme ve yapışma dirençleri ile elastiklik modülü üzerindeki etkilerinin belirlenmesidir. Odun tozunun yongalara % 10 oranında katılması yapışma direncini arttırırken, kalınlığına şişme oranı, eğilme direnci ve elastiklik modülünü azaltmıştır. % 1 rutubete kadar kurutulmuş yongalardan üretilen yongalevhaların eğilme ve yapışma dirençleri ile elastiklik modülleri % 4 rutubete kadar kurutulmuş yongalardan üretilen levhalara oranla daha düşük, kalınlığına şişme oranları ise daha yüksek çıkmıştır. Dış:orta tabaka oranının % 30:70'den % 45:55'e çıkarılması sonucu fiziksel ve mekanik özellikler iyileşmiştir. Test sonuçlarına göre Kızılağaç (Alnus glutinosa subsp. Barbata)'dan üretilen yongalevhaların eğilme ve yapışma direnci ile elastiklik modülü değerleri standartlarda öngörülen değerlerden yüksek bulunmuştur. Bununla birlikte, kalınlığına şişme oranları standartlarda öngörülen değerlerden yüksek çıkmıştır. Bu nedenle Kızılağaç (*Alnus glutinosa* subsp. *Barbata*)'dan üretilen yonga levhaların fiziksel özelliklerini iyileştirici ek bir çalışmaya ihtiyaç duyulmaktadır.

Anahtar Sözcükler: Yongalevha, Kızılağaç (*Alnus glutinosa* subsp. *Barbata*), Eğilme Direnci, Elastiklik Modülü, Yapışma Direnci, Kalınlığına Şişme Oranı, Üretim Faktörleri

Introduction

The manufacture of wood-based panels has been brought about by the ever increasing cost of logs and lumber, which in turn has caused managers of the world's forest resources to investigate ways and means of using trees more efficiently. Wood composites can utilise low-grade logs such as thinnings and bowed and twisted logs. They can also use wood waste material. All sawmills produce a lot of residue in the form of chips, sawdust and slabs. These residues can be utilised to manufacture many composites such as particleboard.

The demand for foresty and agricultural land is increasing. As a result of population expansion, a permanent decline in forest areas has been noted (Ntalos and Grigoriou, 2002). Environmental pressures have managed to prohibit forest harvesting resulting in wood shortages, the closing down of wood industries, unemployment, etc. in some countries (MacCleery,

---

Correspondence to: nemli@ktu.edu.tr

1995). Growing social demands for wood-based panels results in the continuous need to find new wood resources as an alternative to forest wood.

Developing countries have poor wood resources for particleboard production. As a result, non-wood fibres will play a major role in providing the balance between supply and demand. Agricultural residues are renewable resources that can be utilised as raw materials for particleboard manufacturing (Wang and Sun, 2002). Research has been carried out on a wide variety of agricultural residues from many different regions of the world: wheat-cereal straws (Mosesson, 1980), rice husks (Vasisth and Chandramouli, 1975), groundnut shells (Jain et al., 1967), bamboo (Rowell and Norimoto, 1988), tea leaf waste (Yalınkılıç et al., 1998; Nemli and Kalaycıoğlu, 1997), bagasse (Mitlin, 1968), sunflower stalks (Khristova et al., 1998), and maize husk and cob (Sampathrajen et al., 1992).

As for the poor resources of wood for particleboard production in developing countries such as Turkey, fast-growing wood species can play a major role in providing the balance between supply and demand. For this reason, researche in Turkey has been carried out on a wide variety of fast-growing raw materials: i.e., *Pinus pinaster* (Kalaycıoğlu, 1991), and *Eucalyptus camaldulensis Dehn.* (Nacar, 1997) Over the last few decades, fast-growing plantations have steadily spread worldwide and their number, for both softwood and hardwood, will continue to increase until they become predominant. Kamdem (1994) and Mallari et al. (1989) reported that *Robinia pseudoacacia*, *Cryptomeria japonica* and *Populus tremuloides* woods could be used as a raw material for particleboard manufacturing.

Research was carried out on the effects of some manufacturing factors on the properties of particleboard. Motted (1967) reported that small particles decreased the static bending and modulus of the elasticity of particleboard. Low particle moisture content decreased the mechanical properties of particleboard (Lynam, 1969; Kolman, 1975). Huş (1979) stated that dust and thin particles filled the holes and increased the connection between the particles. Akbulut (1995) reported that increasing the shelling ratio improved the physical and mechanical properties of particleboard.

In this study, Alder (*Alnus glutinosa subsp. Barbata*) wood, which is a fast-growing wood species, was used for particleboard manufacturing. The purpose of this study was to determine if dried particle moisture content, shelling ratio and addition of wood dust to particles adversely affected the thickness swelling, static bending, modulus of elasticity, and internal bond properties of particleboards.

Materials and Methods

The wood used in this study was obtained from 20-year-old Alder (*Alnus glutinosa subsp. Barbata*) grown in the Black Sea region near Trabzon in Turkey.

A hacker was used to initially break the raw material down, then a knife ring flaker was used to reduce the hacker chips to particles. After these processes, the particles were dried with a laboratory-made hot air dryer to 1% and 4% moisture contents. Before blending, wood particles were screened by a screening machine through meshes with 3 mm, 1.5 mm and 0.8 mm apertures to remove oversize and undersize (wood dust) particles and separate the core and surface layer particles. For the blending, urea formaldehyde (UF) adhesive of grade E_3 (solid content: 60%, density: 1.285 g cm^{-3}, viscosity: 545 cps. pH: 7.5, free formaldehyde: 0.70 % max., gelation time 25-35 s), predominately used in the Turkish particleboard industry, which was 8% and 10% of the oven dry weight of the core and surface layers particles, respectively, and as a hardener ammonium chloride (solid content: 33%), which was 1% of the oven dry weight of the particles, were used in the production of particleboards. The mat configuration was three-layer and formed by hand distribution after adhesive application in a blender. The shelling ratios (face:core) were 30:70% and 45:55%. The boards were pressed by a single daylight press under 26 kg cm^{-2} pressure, at 150 °C press temperature for 7 min. The dimensions of the particleboards were 56.5 x 56.5 x 2 cm. After pressing, the particleboards were conditioned at a temperature of 20 ± 2°C and 65 ± 5% relative humidity, and the edges trimmed to 55 x 55 cm. Three panels were made for each group. The target density was 0.70 g cm^{-3}.

Thickness swelling (in 24 h immersion), static bending, modulus of elasticity and internal bond were determined according to EN 317 (1993), EN 310 (1993), and EN 319 (1993), respectively. All samples were conditioned to an equilibrium at a temperature of 20 ± 2 ºC and 65 ± 5% relative humidity. Thirty samples were used for each test. Table 1 shows the experimental design of the study.

Table 1. Experimental design.

Board Type	Dryed Particle Moisture Content (%)	Shelling Ratio (%)	Wood Dust Addition (%)
1	1	30:70	-
2	4	30:70	-
3	1	45:55	-
4	4	45:55	-
5	1	30:70	10
6	4	30:70	10
7	1	45:55	10
8	4	45:55	10

Data for each test were statistically analysed. Multifactor analysis of variance was used ($\alpha = 0.05$) to test for significance between factors and levels. When the variance analysis indicated a significant difference among factors and levels, a multiple comparison of the means was performed employing a Tukey test to identify which groups were significantly different.

Results and Discussion

Static bending data ranged from 9.49 to 14.83 N mm^{-2}. The static bending requirement for general purpose boards by EN 312-2 (1996) is 11.5 N mm^{-2}. Except for board types 5-7, all of the other boards had higher static bending than the general purpose requirements. The average static bending, modulus of elasticity, internal bond, and thickness swelling values are shown in Table 2.

The range of data in the modulus of elasticity was from 1308.57 N mm^{-2} to 2167.41 N mm^{-2}. The modulus of elasticity requirement is 2000 N mm^{-2} for general purpose boards. Board types 2-4 had the required level of modulus of elasticity.

Internal bond data ranged from 0.321 N mm^{-2} to 0.411 N mm^{-2}. The minimal requirement of internal bond for general purpose boards by EN 312-2 (1996) is 0.24 N mm^{-2}. All of the particleboards produced from Alder (*Alnus glutinosa subsp. Barbata*) were higher than the requirement for general purpose.

The maximum thickness swelling (24 h) requirement EN 312-4 (1996) is 15%. The thickness swelling values of particleboards produced from *Alnus glutinosa subsp. Barbata* were very poor (i.e. high). This may be due to not using a hydrophobic substance in the production of boards. As a consequence, the boards require additional treatments such as the coating of particleboard surfaces with melamine-impregnated papers or laminates (Nemli, 2000) or high press temperature usage (Nemli, 2002) to become a more stable product.

Multifactor analysis of variance on the effects of dried particle moisture content, shelling ratio and wood dust addition on the static bending, modulus of elasticity, internal bond and thickness swelling of the particleboards are given in Table 3.

Tests showed that particleboard made from particles dried to 4% had better static bending, modulus of elasticity, and internal bond properties and lower thickness swelling values than those of particleboard made from particles dried to 1%. This can be explained by the fact that as the particle moisture content is very

Table 2. The average values of static bending, modulusof elasticity, internal bond, and thickness swelling. For board type see Table 1.

Board Type	Static Bending (N mm^{-2})	Modulus of Elasticity (N mm^{-2})	Internal Bond (N mm^{-2})	Thickness Swelling (%)
1	12.65 (0.12)	1848.36 (15.31)	0.321 (0.010)	23.86 (0.46)
2	14.01 (0.24)	2073.02 (23.48)	0.375 (0.013)	20.11 (0.52)
3	13.52 (0.36)	1956.13 (14.12)	0.337 (0.008)	23.03 (0.15)
4	14.83 (0.20)	2167.41 (17.12)	0.389 (0.011)	21.17 (0.23)
5	9.49 (0.17)	1308.57 (21.46)	0.348 (0.005)	20.28 (0.18)
6	11.43 (0.13)	1556.28 (45.01)	0.397 (0.009)	18.06 (0.21)
7	10.38 (0.34)	1424.69 (36.14)	0.361 (0.012)	19.16 (0.11)
8	12.14 (0.21)	1678.45 (21.21)	0.411 (0.006)	16.83 (0.13)

Note: The values in parantheses are standard deviations.

Table 3. Multifactor analysis of variance own to effects of dryed particle moisture content, shelling ratio and wood dust addition on the physical and mechanical properties.

Tests	Source of variation	F-Ratio	Significant Level
Static Bending	Moisture Content	12.17	**
	Shelling Ratio	116.31	***
	Wood Dust Addition	85.68	**
Modulus of Elasticity	Moisture Content	45.13	**
	Shelling Ratio	124.36	***
	Wood Dust Addition	15.46	**
Internal Bond	Moisture Content	145.26	***
	Shelling Ratio	92.38	***
	Wood Dust Addition	23.03	**
Thickness Swelling	Moisture Content	17.25	**
	Shelling Ratio	168.69	***
	Wood Dust Addition	98.24	***

Note: *** = $p \leq 0.001$, ** = $p \leq 0.01$

low, the particles absorb more adhesive. There is not enough adhesive on the particle surfaces. Excessive drying may cause surface deactivation, which may result in poor adhesion (Kolman, 1975). In addition, heat transfer can be accelerated by increasing particle moisture content. Similar results were reported by Lynam (1969) and Kolman et al. (1975). Table 4 displays the results of statistical analysis for different variables.

Increasing the shelling ratio statistically improved static bending, modulus of elasticity, thickness swelling, and internal bond. This may be explained by the fact that higher amounts of particle usage on the surface layers cause an even tighter structure on the particleboard. The positive influence of increasing the shelling ratio on the physical and mechanical properties of particleboard was mentioned in a similar work (Akbulut, 1995).

Wood dust addition by about 10% to particles improved thickness swelling and internal bond, and decreased static bending and modulus of elasticity. The dust and thin particles filled the holes and increased the connection between the particles (Huş, 1979). For this reason, wood dust usage decreased thickness swelling and improved internal bond properties. The decreasing static bending and modulus of elasticity may be due to the small dimensions of the wood dust (Kolman, 1975; Motted, 1967).

Table 4. The statistical analysis of the properties for different variables.

Variables	Static Bending ($N\ mm^{-2}$)	Modulus of Elasticity ($N\ mm^{-2}$)	Internal Bond ($N\ mm^{-2}$)	Thickness Swelling (%)
Moisture Content: 1%	11.51a	1634.43 a	0.341 a	21.58 a
Moisture Content: 4%	13.10 b	1868.79 b	0.393 b	19.04 b
Shelling Ratio: 30:70%	11.89 c	1696.55 c	0.360 c	20.57 c
Shelling Ratio: 45:55%	12.71 d	1806.67 d	0.384 d	19.04 d
Wood Dust Addition: 0%	13.75 e	2011.23 e	0.355 e	22.04 e
Wood Dust Addition: 10%	10.86 f	1491.99 f	0.379 f	18.58 f

Note: Different letters represent statistical significance.

Conclusion

The increased demand for forestry and agricultural land as a result of population expansion leads to a permanent decline in forest areas. Growing social demands for various wood products and especially wood-based panels have led to fresh effort to find new wood resources.

The potential for using fast-growing wood species to replace other woods as raw materials for panel products has received considerable attention in recent years. One fast-growing wood species is Alder (*Alnus glutinosa subsp. Barbata*).

Wood dust, which many particleboard manufacturers buy and use, is inexpensive. When used as a surface layer furnish it helps to produce a hard, smooth dense surface which many furniture manufacturers prefer. Internal bond strength, often called tensile strength, perpendicular to the plane of the board, is improved. This is due to increased interparticle contact. Thickness swelling is also lowered by wood dust addition.

Once the particles have been produced, their moisture content must be reduced to between 1 and 5% depending on the adhesive system used. Low moisture content is required because residual moisture is converted to steam in the press; if too much steam is generated then when the press opens the board is likely to be delaminated by the sudden release of steam pressure. However, this study showed that particles with 4% MC had higher mechanical properties and lower thickness swelling values than those produced from particles with 1% moisture content. This may be due to accelerating of the heat transfer to the core layer by increasing of particle moisture content, and the extra adhesive absorbing the particles at the lower moisture content.

This study showed that particleboards produced from Alder (*Alnus glutinosa subsp. Barbata*) had the required levels of static bending, modulus of elasticity and internal bond strength. Strong particleboard can be produced from this fast-growing raw material. As wood dust was used in particleboard manufacturing, shelling ratio and particle moisture content should be 45:55 and 4%, respectively. However, the thickness swelling of the board was very poor (i.e. high). For this reason, additional work needs to be done on improving the thickness swelling of particleboard produced from Alder.

References

Akbulut, T. 1995. Çeşitli faktörlerin yatay preslenmiş yonga levhaların özellikleri üzerine etkisi. Doktora Tezi. İÜ Fen Bilimleri Enstitüsü. p.149

EN 310. 1993. Wood based panels, determination of modulus of elasticity in bending and bending strength. European Standardization Committee. Brussells.

EN 317. 1993. Particleboards and fibreboards, determination of swelling in thickness after immersion. European Standardization Committee. Brussells.

EN 319. 1993. Particleboards and fibreboards, determination of tensile strength perpendicular to plane of the board. European Standardization Committee. Brussells.

EN 312-2. 1996. Particleboards-specifications-Part 2: requirements for general purpose boards for use in dry conditions. European Standardization Committee. Brussells.

EN 312-4. 1996. Particleboards-specifications-Part 4: requirements for load-bearing boards for use in dry conditions. European Standardization Committee. Brussell.

Huş, S. 1979. Teknolojik faktörlerin yongalevhanın özellikleri üzerine etkisi. İ. Ü. Orman Fakültesi Dergisi. Seri B. 29: 2.

Jain, N.C., R.C. Gupta and D.K. Jain. 1967. Particleboard from groundnut shells. In: Proceedings 11th Silviculture Conference. India. pp. 141-147.

Kalaycıoğlu, H. 1991. Sahil çamı odunlarının yongalevha endüstrisinde kullanılması imkanları. Doktora Tezi. KTÜ Fen Bilimleri Enstitüsü. p.134

Kamdem, D.P. 1994. The durability of phenolic bonded particleboards made of decay resistant, black locust and nondurable aspen. Forest Products Journal. 44 (2): 65-68.

Khristova P., N. Yussifou, S. Gabir, I. Glavche, and Z. Osman. 1998. Particleboards from sunflower stalks and tannin modified UF resin. Cellul. Chem. Technol. 32: 327-337.

Kolman, F., E.W. Kuenzi, and A.S. Stam. 1975. Principles of wood science and technology. Springer Verlag, Berlin, Heidelberg, New York.

Lynam, F.C. (1969). Factors influencing the properties of wood chipboard. In: L. Mitlin: Particleboard Manufacture and Applications. Pressmedia Books Ltd. UK. pp. 145-149

MacCleery, R. 1995. Resiliency the trade mark of American forests. Forest Prod. J. 45: 19-28.

Mallari, V.C., S. Kawai, S. Hara, T. Sakuno, I. Furukowa, and J. Kishimota. 1989. The manfacturing of particleboard. II-Board Qualities of Sugi and Niseakashia. Makuzai Gakkaishi. 35 (1): 1-7.

Mitlin. L, 1968. Particleboard manufacture and application. Novello & Co. Ltd., Kent.

Mosesson, J.G. 1980. The processing and use of waste straw as a constructional material. Conservation and Recycling. 3:389-412

Mottet, A.L. 1967. The particle geometry factor. In: T. Maloney: Proceedings of the WSU Particleboard Symposium. No.1., Pullmann, Wash. pp. 189-195.

Nacar, M. 1997. Okaliptus odunun yonga levha üretiminde kullanılması imkanları. Yüksek Lisans Tezi. KTÜ Fen Bilimleri Enstitüsü. p.108

Nemli, G., and H. Kalaycıoğlu. 1997. An alternative material in particleboard industry: residues of tea factory. In: Proceedings of the XI World Forestry Congress. Volume 4. Antalya-Turkey. p. 49.

Nemli, G. 2000. Yüzey kaplama malzemeleri ve uygulama parametrelerinin yonga yevha teknik özellikleri üzerine etkileri. Doktora Tezi. KTÜ Fen Bilimleri Enstitüsü. p.181.

Nemli, G. 2002. Factors affecting the production of E_1 type particleboard, Turk J Agric For, 26 (1): 31-36.

Ntalos, G.A., and A.H. Grigoriou. 2002. Characterisation and utilisation of vine prunings as a wood substitute for particleboard production. Industrial Crops and Products. 16 (1): 59-68.

Rowell, R.M., and M. Norimoto. 1988. Dimensional stability of bamboo particleboards made from acetylated particles. Mokuzai Gakkaishi 34 (7): 627-629

Sampathrajan, A., N.C. Vijayaraghavan, and K.R. Swaminathan. 1992. Mechanical and thermal properties of particleboards made from farm residues. Bioresource Technology. 40: 249-251.

Vasisth, R.C., and P. Chandramouli. 1975. New panel boards from rice husks. FAO Background Paper. Forest Products Laboratory. N. 75. Washington.

Wang, D., and X.S. Sun. 2002. Low density particleboard from wheat straw and corn pith. Industrial Crops and Products. 15: 47-50.

Yalınkılıç, M.K., Y. Imamura, M. Takahashi, H. Kalaycıoğlu, G. Nemli, Z. Demirci, and T. Özdemir. 1998. Biological, physical and mechanical properties of particleboard manufactured from waste tea leaves. International Biodeterioration and Biodegration. 41 (1): 75-84.