Journal of Applied Sciences

ISSN 1812-5654

science alert

ANSInet
an open access publisher
http://ansinet.com

OPEN ACCESS Journal of Applied Sciences

ISSN 1812-5654
DOI: 10.3923/jas.2019.247.251

Research Article
Mechanism of Bondability in Uf-bonded Rice Husk Particle Boards by Isocyanate

Javad Torkaman

Faculty of Natural Resources, The University of Guilan, P.O. Box 1144, Sowmehsara, Rasht, Iran

Abstract

Background and Objective: Agricultural residuals, such as rice husk are the renewable resources that can be used as raw materials for making particle board. The objective of this research was to improve the mechanism of bondability by Polyisocyanate (ISO) resin in the manufacture of rice husk particle board with Urea formaldehyde (UF). **Materials and Methods:** In this experiment, Polyisocyanate (ISO) was used to replace 1 and 2% of Uf adhesive. The properties of the resulting mixed adhesive products were evaluated and compared with control boards. The evaluation properties were the Modulus of Rupture (MOR), Internal Bond (IB), Thickness Swelling (TS) and Water Absorption (WA). **Results:** The results showed using Polyisocyanate (ISO) in the adhesive formulation has positive and significant effects on the board strength and physical properties. The best achievement is to improve about 50 and 100% of the rice husk board physical and mechanical properties, respectively. **Conclusion:** In this paper, the best results obtained an adhesive formulation content 2% ISO and 8% Uf which had higher Mechanical (MOR and IB) and lower Physical (TS and WA) properties.

Key words: Rice husk, polyisocyanate, uf adhesive, particle board, dimensional stability

Citation: Javad Torkaman, 2019. Mechanism of bondability in uf-bonded rice husk particle boards by isocyanate. J. Applied Sci., 19: 247-251.

Corresponding Author: Javad Torkaman, Department of Forestry, Faculty of Natural Resources, The University of Guilan, P.O. Box 1144, Sowmehsara, Rasht, Iran Tel:+981333362765

Copyright: © 2019 Javad Torkaman. This is an open access article distributed under the terms of the creative commons attribution License, which permits unrestricted use, distribution and reproduction in any medium, provided the original author and source are credited.

Competing Interest: The author has declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Supply of industrial wood in the country is considerably lower than the demand. Developing countries have poor wood resources for particle board production. As a result, non-wood fibers will play a major role in providing a balance between supply and demand. On the other hand, large quantities of lignocellulosic wastes including agro-wastes are available which are not properly utilized. These raw materials could be converted into useful panel products like particle boards, fiberboard, MDF boards etc, which can substitute solid wood to a great extent for various purposes, some lignocellulosic agro-wastes have limited alternative uses. Many countries are successfully utilizing such raw materials for manufactures of particle board and fiberboard by utilizing lignocellulosic wastes for building boards large quantities of wood can be saved which will ultimately help in the conservation of forest resources. Research has been carried out on a wide variety of agricultural residues from many different regions of the world: Wheat-cereal straws, rice husks[1,2], ground nut shells, bamboo[3] tea leaf waste[4], bagasse, Sunflower stalks[5] and Maize-cob board[6]. When rice hulls are used for the manufacture of composite boards. It has been discovered that some of their special characteristics have to be taken in to account. It has been found that the surface of rice hulls contains materials that are only loosely bound to the fiber structure underneath. Among all the agricultural residues the most abundantly available is rice husk. It is the by-product of the most important agro-based industry in the country, namely paddy milling. Rice husk is available in Iran country to the extent of over 0.6 million t per annum. Every year approximately 80 millions t of rice husk are reported to be produced by the rice mills of the world. The major chemical constituents of rice husk are Cellulose-a polymer of glucose, about 28% by weight; pentosan-a polymer of hexoses and pentoses about 26% by weight and silica about 15-22 by weight[7]. The silica covers almost the entire outer layer of the rice hull surface which also contains the water repellent cuticle[8]. This silica layer and the partially hydrophobic surface of rice hull are incompatible with aqueous urea formaldehyde (UF) resin and prevent the formation of a good bond between rice hull surfaces. thus a new and improved resin adhesive system is needed to produce high-quality rice hull particle board. Urea formaldehyde resins are often fortified with melamine to increase the bond strength and water resistance of particle board. More recently highly reactive polyisocyanate (ISO) has been used to modify Uf resins[9-12] and Pf resins[13,14] for board products Iso modified adhesives improve the bond strength and performance of wood particle boards so they might have similar beneficial effects on the bonding of rice hulls. Therefore the objective of this study was to investigate the feasibility of developing multi-polymer adhesive systems that could take advantage of the durability of urea formaldehyde and the reactivity of polyisocyanate for manufacturing rice hull particle boards.

MATERIALS AND METHODS

Rice husk was obtained from a rice mill in Sowmehsara city of Guilan province, Iran at the date of 23 July, 2016. The moisture content of the husk was around 8%. The particles were then screened according to Bison Quality Control 44011 standard.

Board manufacturing: The UF resin was sprayed on the particles in a blender at 10% resin content on the oven-dried weight of particles. Two percent of ISO resin (1 and 2%) was replaced in a state of UF resin. Two percent of NH4CL based on the weight of the resin solid was added as the curing catalyst. The hand-formed mats were pressed into 15 mm thick boards using 30 Kp cm^{-3} bars at two press temperature (170 and 180°C) and two press time (6 and 8 min) the board size was 500×500×15 mm with densities 0.7 g cm^{-3}. According to Experimental design of the study (Table 1). Three boards were made in the same condition. All together 36 boards were manufactured.

Board testing: Specimens were cut from the boards after conditioning and tested according to DIN-6871 Standard. The Specimen size for the bending test was 250×50×15 mm. The sample size for Internal Bond (IB) and Thickness Swelling (TS) were 50×50 and 25×25 mm, respectively. Thickness swelling was determined by measuring the changes of board thickness after immersing in 20°C water for 2 and 24 h.

Statistical analysis: Data for each test were statistically analyzed. 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

Table 1: Experimental design of the study

Board type	Replacement (%)	Press time (min)	Press temperature (°C)
1	0	6	170
2	0	6	180
3	0	8	170
4	0	8	180
5	1	6	170
6	1	6	180
7	1	8	170
8	1	8	180
9	2	6	170
10	2	6	180
11	2	8	170
12	2	8	180

factors and levels. Multiple comparison of the means was performed employing a Duncan test to identify which groups were significantly different.

RESULTS AND DISCUSSION

Raw materials characterization: Table 2 showed the measurement and determination of rice husk particle sizes and shapes. Screen analysis is a common tool to research geometry. Determination of Slenderness Ratio, Flatness Ratio and Aspect Ratio is an indication of rice husk particle size and shape. Specifications of the urea formaldehyde (UF) and Polyisocyanate (ISO) are summarized in Table 3. If resin was used at a level of 10% based on the dry weight of solid materials of rice husk. The Polyisocyanate resin was used at two levels of 1 and 2% as Uf replacement.

Physical properties: The average thickness swelling and water absorption values are shown in Table 4. Based on Iranian standards[15]. The maximum swelling (24 h) and the maximum water absorption (24 h) requirement for general purpose board are 15 and 65%, respectively. According to Table 4, the increasing of all factors effect on the physical properties. Figure 3 and 4 showed the effects of Iso on the properties of rice husk board. Both properties of thickness swelling and water absorption were improved with increasing of Iso as replacement of Uf resin. According to Duncan test, there is significantly different in all properties of the board. Increasing of Iso as replacement of Uf resin decrease thickness swelling and water absorption of rice husk particle board. The best thickness swelling (2 and 24 h) and water absorption (2 and 24 h) were obtained in board types 8, 9 and 12. Generally, the results show a 50% reduction in thickness swelling and water absorption values by using 2% Iso as replacement of Uf resin.

Mechanical properties: The average static bending and Internal bond values are shown in Table 4. Based on Iranian standards[15], the static bending and internal bond requirement for general purpose board are 18 and 0.4 Mpa, respectively. According to Table 4, results static bending data ranged 4.77-14.28 Mpa. The increasing of all factors effect on static bending. The results indicated that the board properties are not satisfactory using only of resin as control board consequently it must be improved. Figure 1 and 2 showed the effects of Iso on the properties of rice husk board. Both mechanical properties of the board were improved with increasing of Iso as replacement of Uf resin. According to Duncan test there is significantly different between the mechanical properties of the board. The best bending 14.28 Mpa was obtained at conditions of 2% replacement, 170°C press temperature and 6 min press time. Internal bond data ranged from 0.23-0.47 Mpa. Also, the best internal bond like to static bending was obtained in board types 6, 9 and 12. A research was shown the bondability of rice huck which bonded with a sodium silicate and Isocyanate resin to improve mechanical and physical properties of particle board. Economically, the best condition obtained to use 15% sodium silicate solution and 2% Isocyanate[16]. Another research was shown the bondability of reed and wheat straw particle boards which bonded with a UF resin were improved using silane coupling agents[17,18]. The outer surface of these two straws is covered with much silica and wax[19]. However, the

Table 2: Screen analysis results of rice husk particles

Particle size (mm)	S = L/T	J = W/T	A = L/W
L = 9.7 W = 1.6 T = 0.16	60.6	10	6

S: Slenderness ratio, J: Flatness ratio, A: Aspect ratio, L: Length, W: Width, T: Thickness

Table 3: Specifications of the urea formaldehyde (UF) and polyisocyanate (ISO)

Adhesive	Density (g cm^{-3})	Solids (%)	pH	Viscosity (cP)
UF	1.2	56	6.8	170
ISO	1.27	100	-	300

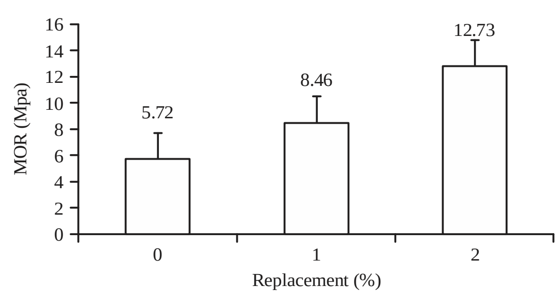

Fig. 1: Average values of MOR against ISO replacement

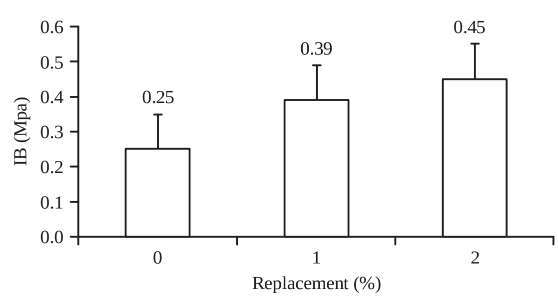

Fig. 2: Average values of IB against ISO replacement

Table 4: Mean values of mechanical and physical properties of rice husk boards

			TS (%)		WA (%)	
Treatments	MOR (Mpa)	IB (Mpa)	2 h	24 h	2 h	24 h
****ISO**						
0%	5.7±0.64[a]	0.25±0.021[a]	2.23±0.29[a]	7.8±0.25[a]	16.4±3.61[a]	37.6±4.5[a]
1%	8.4±0.65[b]	0.39±0.54[b,c]	1.53±0.47[b]	5.1±0.57[b]	6.5±0.68[b,c]	21.3±2.4[b,c]
2%	12.7±1.12[c]	0.45±0.034[b,c]	0.78±0.16[c]	3.87±0.81[c]	6.5±1.06[b,c]	18.3±2.0[b,c]
PT[ns]						
6 min	9±1.34	0.37±0.04	1.62±0.34	5.45±0.79	12.05±3.27	29.14±5.20
8 min	8.9±1.32	0.36±0.03	1.41±0.23	5.69±0.72	7.59±1.33	22.36±3.03
TE[ns]						
170°C	9.37±1.41	0.35±0.036	1.51±0.29	5.68±0.72	10.51±3.44	26.20±5.32
180°C	8.57±1.21	0.37±0.043	1.52±0.30	5.46±0.80	9.14±1.58	25.29±3.53

Results represent mean±standard deviation of the physical and mechanical properties, Mean in the same column having different letters of alphabet are statistically significant (**p<0.01), non-significant (ns: p>0.05), ISO: Polyisocyanate, PT: Press time, TE: Temperature

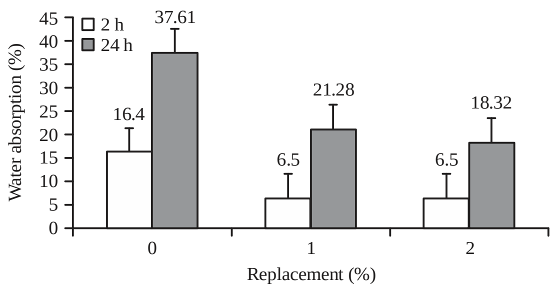

Fig. 3: Average values of WA against ISO replacement

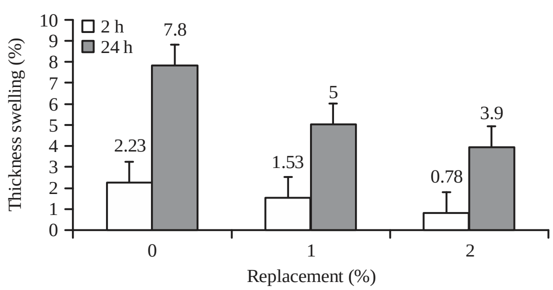

Fig. 4: Average values of TS against ISO replacement

natural characteristics of these materials make them difficult to bond with urea-formaldehyde resin[20,21]. In the current research, this problem was solved using 2% Polyisocyanate (ISO) as replacement of Uf. Generally, the mechanical test results showed by this resin formulation can improve about 100% of the mechanical properties of the rice husk boards.

CONCLUSION

The rice husk board properties are not satisfactory using UF resin completely. The modified UF resin system with a polyisocyanate (ISO) as a minor component significantly improved the strength properties and dimensional stability of rice husk particle boards. The best results obtained an adhesive formulation content 2% ISO and 8% Uf which had higher mechanical (MOR and IB) and lower physical (TS and WA) properties. Totally, the best achievement is to improve about 50 and 100% of the rice husk board physical and mechanical properties, respectively.

SIGNIFICANCE STATEMENT

This study discovered the modification of Uf resin that can be beneficial for making rice husk particle board and this study will help the researchers to uncover the critical areas of adhesive formulation that many researchers were not able to explore. Thus a new theory on these issues may be arrived at.

REFERENCES

1. Chen, T.Y., 1979. Studies on the manufacture of particleboard from rice hulls. Nat. Sci. Council Monthly, 8: 456-462, (In Chinese).
2. Vasisth, R.C. and P. Chandramouli, 1975. New panel boards from rice husks. FAO Background Paper, FO/WCWBP/75.
3. Rowel, R.M. and M. Norimoto, 1998. Dimensional stability of bamboo particleboards made from acetylated particles. Mokuzai Gakkaishi, 34: 627-629.
4. Nemi, G. and H. Kalaycioglu, 1997. An alternative material particleboard industry residues of the tea factory. Proceedings of the 11th World Forestry Congress, Volume 4, October 13-22, 1997, Antalya, Turkey, pp: 49.
5. Khristova, P., N. Yossifov, S. Gabir, I. Glavche and Z. Osman, 1998. Particle boards from sunflower stalks and tannin-modified UF resin. Cellulose Chem. Technol., 32: 327-337.
6. Sampathrajan, A., N.C. Vijayaraghavan and K.R. Swaminathan, 1992. Mechanical and thermal properties of particle boards made from farm residues. Bioresour. Technol., 40: 249-251.
7. Ismail, M.S. and A.M. Waliuddin, 1996. Effect of rice husk ash on high strength concrete. Construct. Build. Mater., 10: 521-526.

8. Juliano, B.O., 1985. Criteria and Tests for Rice Grain Qualities. In: Rice: Chemistry and Technology, Juliano, B.O. (Ed.). 2nd Edn., American Association of Cereal Chemists, St. Paul, MN., USA., ISBN-13: 9780913250419, pp: 443-524.
9. Deppe, H.J. and K. Ernst, 1971. Isocyanate als Spanplattenbindemittel. Holz als Roh-und Werkstoff, 29: 45-50.
10. Deppe, H.J., 1971. Technical Progress in using Isocyanate as an Adhesive in Particleboard Manufacture. In: Proceedings of the 11th Particle Board Symposium, Maeney, T.M. (Ed.)., Washington State University, Pullman, WA., USA., pp: 13-31.
11. Pizzi, A., 1981. A universal formulation for tannin adhesives for exterior particleboard. J. Macromol. Sci. Chem., 16: 1243-1250.
12. Liu, Z. and H. Bingley, 1992. A technology of rice straw particleboard bonded by Urea-Formaldehyde resin modified by Isocyanate. Forest Research Institute, New Zealand Forest service, FRI Bulletin, No. 177, pp: 295-302.
13. Hse, C.Y., 1978. Development of a resin system for gluing Southern hardwood flakeboards. Proceedings of the Structural Flakeboard for Forest Residues Symposium, June 6-8, 1978, Kansas City, MO., USA., pp: 81-92.
14. Hse, C.Y., 1980. Methods for bonding particleboard and the like using polyisocyanate/phenolic adhesives. US Patent No. 4,209,433.
15. ISIRI., 1985. Specification for Medium Density Wood Particleboards. 2nd Edn., Institute of Standards and Industrial Research of Iran, Karaj, Iran.
16. Torkaman, J., 2007. Improvement mechanism of bondability in rice husk particle board was made with sodium silicate by isocyanate resin. Proceeding of the International Panel products Symposium, October 17-19, 2007, Cardiff, Wales, UK., pp: 291-296.
17. Han, G., C. Zhang, D. Zhang, K. Umemura and S. Kawai, 1998. Upgrading of urea formaldehyde-bonded reed and wheat straw particleboards using silane coupling agents. J. Wood Sci., 44: 282-286.
18. Han, G., K. Umemura, S. Kawai and H. Kajita, 1999. Improvement mechanism of bondability in UF-bonded reed and wheat straw boards by silane coupling agent and extraction treatments. J. Wood Sci., 45: 299-305.
19. Han, G.P. and ZG. Lui, 1995. Characteristics of reed material and manufacture technology of reed particleboard. For. Prod. Ind., 14: 37-38, (In Chinese).
20. Sauter, S., 1996. Development composites from wheat straw. Proceeding of the 30th International Particleboard/Composite Material Symposium, March 1996, WSU., pp: 197-214.
21. Dalen, H. and D.T. Shoram, 1996. The manufacture of particleboard from wheat straw. Proceedings of the 30th International Symposium of Washington State University on Particleboard/Composite Materials, April 16-18, 1996, Pullman, pp: 191-196.