Available online at www.sciencedirect.com
SCIENCE DIRECT®
Materials and Design 27 (2006) 1148–1151
Materials & Design
www.elsevier.com/locate/matdes

Short communication

Manufacturing of urea–formaldehyde-based composite particleboard from almond shell

M. Gürü [a,*], S. Tekeli [b], İ. Bilici [c]

[a] Gazi University, Faculty of Architecture, Chemical Engineering Department, Maltepe, 06570 Ankara, Turkey
[b] Gazi University, Metallurgy Education Department, Besevler, 06500 Ankara, Turkey
[c] Gazi University, Chemical Engineering Department, 19030 Çorum, Turkey

Received 11 November 2004; accepted 4 March 2005
Available online 12 April 2005

Abstract

The purpose of present study was to investigate a cheap method to manufacture particleboard. The experiments were carried out using almond shell that had no economical value other than being used merely as low grade fuel and fodder. The parameters affecting composite particleboard production from almond shell and urea–formaldehyde were determined to be urea–formaldehyde ratio, reaction temperature, reaction time and almond shell particle size and the effect of these parameters on hardness and bending strength were investigated. The experimental results showed that maximum hardness and bending strength were 97.5 Shore A and 84.52 N/cm^2, respectively, at a urea–formaldehyde ratio of 0.97, reaction temperature of 70 °C, reaction time of 25 min and mean particle size of 0.3 mm.

Keywords: Urea–formaldehyde; Particleboard; Almond shell; Hardness and bending strength

1. Introduction

High demand for wooden materials and rises in agricultural areas and forest fires increased the importance of composite particleboard instead of using solid woods. Particleboards are among the most popular materials used in interior and exterior applications in floor, wall, ceiling panels, office dividers, bulletin boards, cabinets, furniture, counter and desk tops [1]. The extensive use of particleboards can be related to the economical advantage of low cost wood raw material, inexpensive agents and simple processing. Agricultural residues are used widespreadly for manufacturing of particleboards. Among the raw materials are pomace [2,3], kiwi prunings [4], wheat straws [5], bamboo [6], cotton seed hulls [7], flax shiv [8], rice straw-wood [9], vine prunings [10], coir pith [11], and wood flour [12]. Urea–formaldehyde, phenol–formaldehyde, polyethylene and polyvinylidene are extensively used as a binder. Among these binders, urea–formaldehyde is the most economic and useful glue because of its low cost and easy production.

The aim of the present study was to determine the effects of urea/formaldehyde ratio, reaction temperature, reaction time and almond shell particle size on hardness and bending strength of composite particleboard produced from almond shell.

2. Material and methods

The experimental set-up for the urea–formaldehyde reaction consisted of a spherical flask reactor, a reflux condenser, a thermometer and a heating mantle with a magnetic stirrer. A 1000-ml three necked volumetric

* Corresponding author. Tel.: +90 312 2317400/2555; fax: +90 312 2308434.
E-mail address: mguru@gazi.edu.tr (M. Gürü).

0261-3069/$ - see front matter
doi:10.1016/j.matdes.2005.03.003

pyrex flask was used as a reactor. The purity of chemicals reacted for the production of urea–formaldehyde binder were 37% formaldehyde solution and 99.99% urea. Concentrated NaOH solution was used as a catalyst in the reaction. Almond shells were employed throughout the study as a filler material. Almond shells were first ground, sieved and dried in oven at 105 °C for about 1 h.

Depending on the parameters of each trial, 6 ml concentrated NaOH catalyst solution and urea were added to 30 g heated formaldehyde solution. Reaction temperature was controlled within ±2 °C by thermostat. After the polymerization reaction had been completed at specified temperature and time, filler material was added into the polymer until it was saturated and the mixture was then cast into a mould and dried for 24 h at atmospheric conditions. The cast material was removed from the mould, turned of opposite side and dried again for 24 h. Finally, it was dried at 70 °C in an oven until constant weight was reached. In order to see how the conditions in the reactor affected the mechanical properties, urea/formaldehyde ratio, reaction temperature and time and filler material particle size were chosen as parameters.

Mechanical properties were determined by means of hardness and bending tests. Shore A hardness tests were carried out using a Durotech M202 hardness tester. Shimadzu AG-I was used for three points bending tests. For three point bending test, the span length was 27 mm and the cross head speed was 10 mm/min. The dimension of the rectangular specimen was 15-mm high, 23-mm wide and 50-m long. Before testing the edges of the surface of specimens undergoing tensile stresses were beveled at 45° to avoid the fracture from the specimen edges. A minimum of five specimens for bending tests and ten different points on each specimen for hardness tests were carried out in order to establish average values. Scanning electron microscopy (SEM, JEOL 6360) was used to characterize the microstructure of specimens.

3. Results and discussion

The effect of processing parameters, namely urea/formaldehyde ratio, reaction temperature, reaction time and shell particle size were investigated and optimum values were determined. To determine the optimal urea/formaldehyde ratio, a resin containing various ratio of urea/formaldehyde was prepared. The effect of urea/formaldehyde ratio on hardness of composite particleboard was investigated at reaction temperature of 65 °C, reaction time of 20 min and mean particle size of 0.6 mm. The relationship between hardness and urea/formaldehyde ratio is shown in Fig. 1. The hardness values increased linearly with increasing urea/formaldehyde ratio up to 0.97 and further increase in urea/formaldehyde ratio caused slight hardness decrease. The increase in the hardness with an increase in urea/formaldehyde ratio was as a result of developing urea formaldehyde reaction, whereas slight decrease in hardness after 0.97 was due to the insufficient formaldehyde. Trial-and-error experiments to find out the optimum urea/formaldehyde ratio showed that urea/formaldehyde ratio of 0.97 corresponding to highest hardness value was a reasonable choice and it was recorded as a constant parameter in the further experiments.

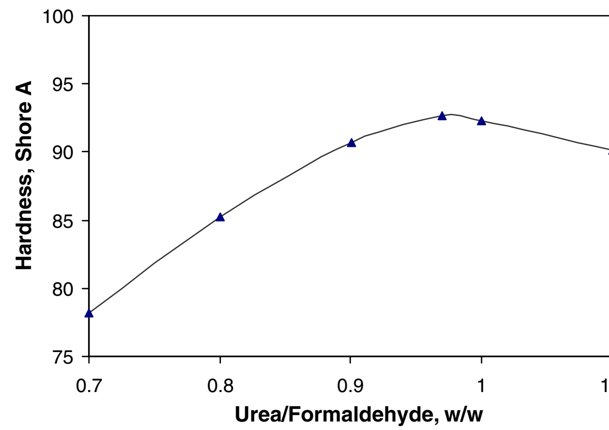

Fig. 1. Effect of urea/formaldehyde ratio on the hardness of composite particleboard.

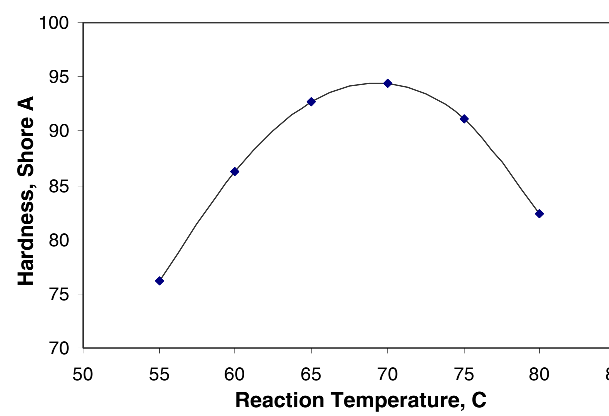

Fig. 2. Effect of reaction temperature on the hardness of composite particleboard.

For the determination of optimal reaction temperature (varying from 55 to 80 °C), a fixed urea/formaldehyde ratio of 0.97 and reaction time of 20 min were used and the optimum hardness was defined by changing the reaction temperatures. Fig. 2 shows the relationship between hardness and reaction temperature. It is evident from Fig. 2 that the hardness values increased with increasing reaction temperature up to 70 °C and then decreased with further reaction temperature increase. It can be deduced from the experimental results that the reaction temperature up to 70 °C affected the

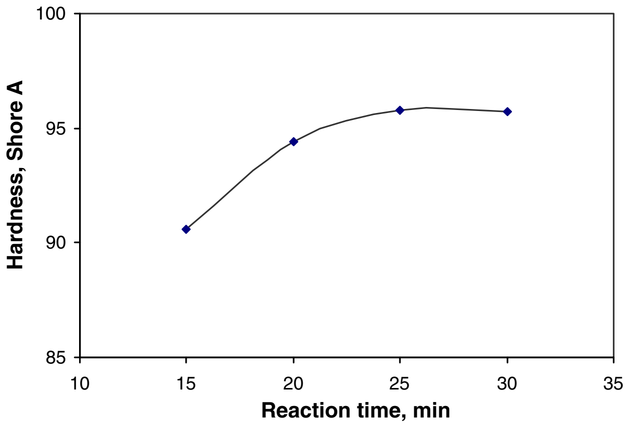

Fig. 3. Effect of reaction period on the hardness of composite particleboard.

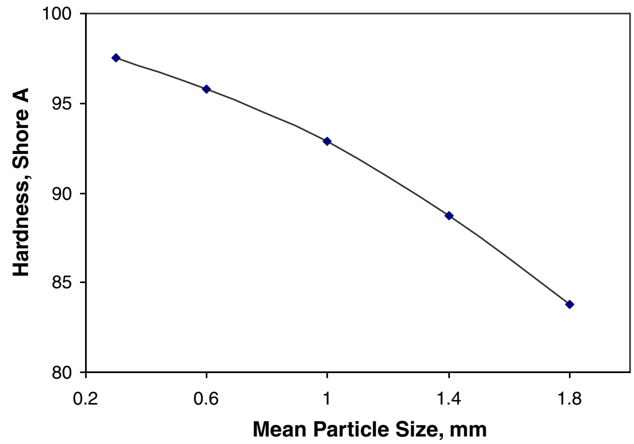

Fig. 4. Effect of mean particle size on the hardness of composite particleboard.

reaction rate and time. The increase of temperature up to 70 °C was effective to meet the activation energy of molecules and to increase the product efficiency. Also, it was seen that at the end of the time held constant, the transition from transparent stage to turbidity (white opac color) which is the indication of the completion of reaction was not formed sufficiently at lower temperatures. The decrease in hardness at higher temperatures was due to the decomposition of reactants to CO_2, H_2O and probably formation of NH_4OH.

To investigate the effect of reaction time on the hardness, a resin with optimal values of urea/formaldehyde ratio of 0.97 and reaction temperature of 70 °C were

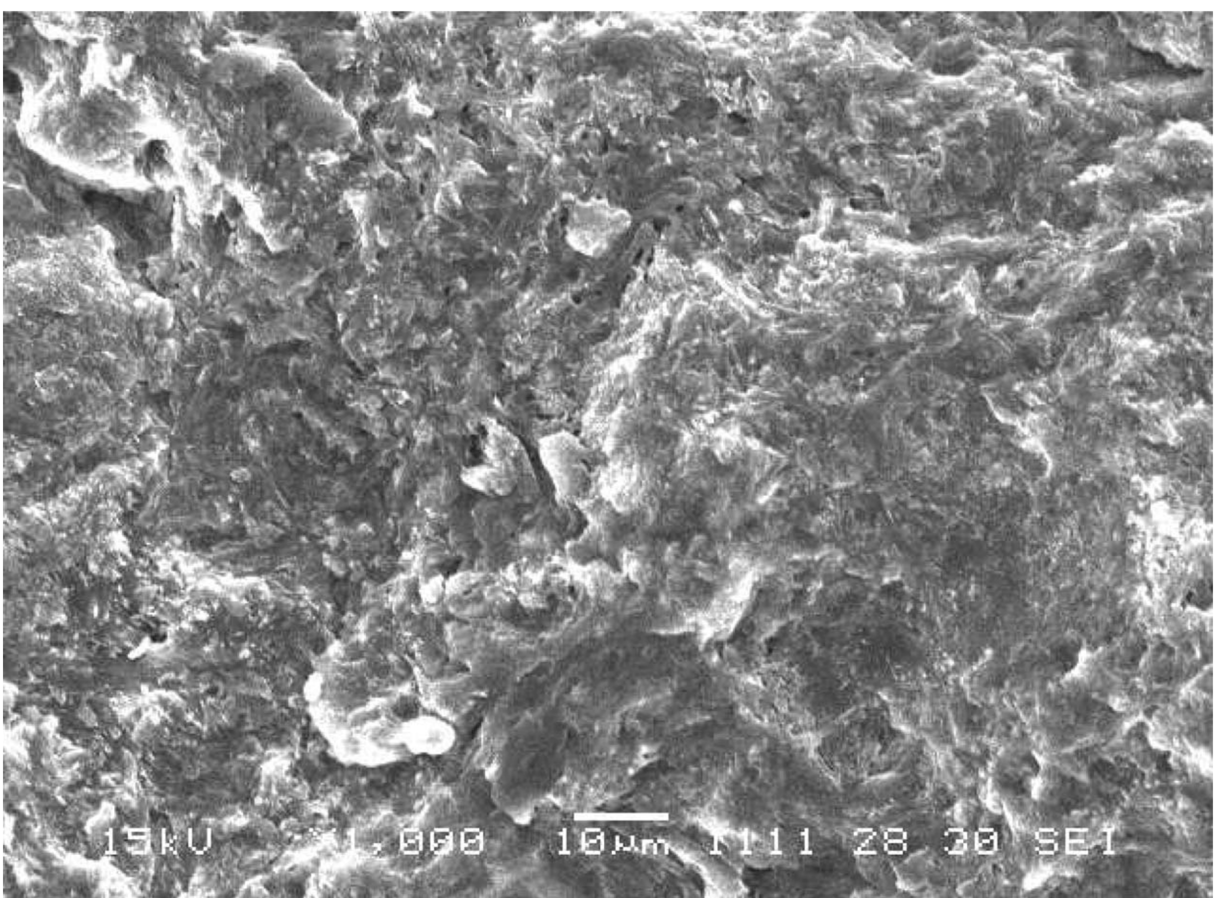

Fig. 5. SEM micrograph of composite particleboard.

prepared. As can be seen in Fig. 3, the hardness of composite particleboard increased with increasing reaction time up to 25 min and the hardness did not vary with further increase in the reaction time. The increased hardness with an increase in reaction period could be due to the completion of reaction period between 15 and 25 min.

In order to determine the effect of particle size on the hardness, experiments were carried out with four mean particle sizes ranging between 0.3 and 1.8 mm and optimal values of urea/formaldehyde ratio of 0.97, reaction temperature of 70 °C and reaction time of 25 min were used. As can be evident from Fig. 4, the hardness values continuously decreased with increasing particle size due to the decrease in particle surface area. Therefore, the properties of composite particleboard with fine particles were better than those made from coarse particles. This opinion was also supported by Han et al. [5].

It was recorded that the bending strength of the composite particleboard was 84.52 N/cm^2 at above optimum test conditions. Micrograph of the composite particleboard obtained at above the optimum conditions is given in Fig. 5. Uniformity of composite construction can be seen clearly from the micrograph.

4. Conclusion

It is concluded that the composite particleboard material can be manufactured from almond shell which has no economical value other than being used as very low grade fuel. Waste raw material and low operating cost make this study a promising one for technological application. Optimum conditions recorded in this work may be applied to industrial scale economically and are environment friendly.

Acknowledgment

This study was supported by State Planning Orginizing of Turkey under Project No. 2001 K 120590.

References

[1] Wang D, Sun XS. Low density particleboard from wheat straw and corn pith. Ind Crop Prod 2002;15:47–50.
[2] Gürü M. Uçucu kül ve pirinadan kompozit malzeme üretimi. Politeknik Dergisi 2001;4:35–8.
[3] Gürü M. Uçucu kül ve pirinadan yapı malzemeleri üretimi. Certificate No: TR 2000 01751 Y., Turkish Patent Institute; 2001.
[4] Nemli G et al. Suitability of kiwi prunings for particleboard manufacturing. Ind Crop Prod 2003;17:39–46.
[5] Han et al. Upgrading of urea formaldehyde bonded reed and wheat straw particleboard using slane coupling agents. J Wood Sci 1998;44:282–6.
[6] Rowel RM, Norimoto M. Dimensional stability of bamboo particleboards made from acetylated particles. Mokuzai Gakkaishi 1998;34:627–9.
[7] Gurjar RM. Effect of different binders on properties of particle board from cotton seed hulls with emphasis on water repellency. Bioresource Technol 1993;43:177–8.
[8] Papadopoulos AN, Hague JRB. The potential for using flax shiv as a lignocellulosic raw material for particleboard. Ind Crop Prod 2003;17:143–7.
[9] Yang HS, Dae-Jun Kim, Hun-Joong Kim. Rice straw-wood particle composite for sound absorbing wooden construction materials. Bioresource Technol 2003;31:736–41.
[10] Ntalos GA, Grigoriou AH. Characterization and utilization of vine prunings as a wood substitute for particleboard production. Ind Crop Prod 2002;16:59–68.
[11] Viswanathan R, Gothandapani L. Optimum process variables for the production of coir pith particle board. J Agri Eng Res 1999;74:331–7.
[12] Kamdem DP et al.. Properties of wood plastic composites made of recycled HDPE and wood flour from CCA-treated wood removed from service. Composites A 2004;35:347–55.