Materials and Design 32 (2011) 2520–2525

Contents lists available at ScienceDirect

Materials and Design

journal homepage: www.elsevier.com/locate/matdes

Influence of press temperature on the properties of binderless particleboard made from oil palm trunk

Rokiah Hashim [a,*], Norafizah Said [a,1], Junidah Lamaming [a,1], Mohana Baskaran [a,1], Othman Sulaiman [a,2], Masatoshi Sato [b,3], Salim Hiziroglu [c,4], Tomoko Sugimoto [d,5]

[a] Division of Bio-resource, Paper and Coatings Technology, School of Industrial Technology, Universiti Sains Malaysia, 11800 Minden, Penang, Malaysia
[b] Graduate School of Agricultural and Life Sciences, The University of Tokyo, 1-1-1, Yayoi, Bunkyo-ku, Tokyo 113-8657, Japan
[c] Department of Natural Resource Ecology and Management, Oklahoma State University, Stillwater, OK 74078-6013, USA
[d] Japan International Research Center for Agricultural Sciences, 1-1, Owashi, Tsukuba, Ibaraki 305-8686, Japan

ARTICLE INFO

Article history:
Received 19 October 2010
Accepted 28 January 2011
Available online 2 February 2011

Keywords:
A. Composites
B. Particulates and powders
E. Physical

ABSTRACT

The objective of this investigation was to evaluate the properties of binderless particleboard manufactured from oil palm trunk as a function of press temperature. Particleboard samples were manufactured with a target density of 0.80 g/cm^3 using press temperatures of 160 °C, 180 °C and 200 °C. The modulus of rupture, internal bond strength, water absorption and thickness swelling of the boards were determined based on Japanese Industrial Standards (JIS). Thermal gravimetric analysis, Fourier transform infrared spectroscopy and field-emission scanning electron microscopy coupled with energy dispersive X-ray analysis were employed to characterize the properties of the raw materials and the manufactured panels. The moduli of rupture of the samples were observed to increase with increasing press temperature, but they did not meet the standard values. However, the internal bond strength of the samples attained satisfactory values according to the JIS standard for all three temperature levels. Water absorption and thickness swelling of the boards decreased with increasing pressing temperature. Based on the findings in this study, increasing the pressing temperature may be considered a potential way of improving the properties of binderless particleboard.

1. Introduction

It is well known that the worldwide demand for particleboard has been growing over the last 20 years [1]. Currently, most of the commercially produced particleboard is bonded with formaldehyde-based adhesives, which may result in environmental and health concerns due to formaldehyde emission. The global trend indicates that the marketplace is moving towards using particleboard with little or no formaldehyde [2]. The decreasing supply of raw materials and the need for formaldehyde-free particleboard have led to studies on the manufacture of particleboard without using synthetic adhesives and towards using raw materials other than wood [3].

One of the most important manufacturing parameters influencing board properties is the pressing temperature. Binding in binderless particleboard without synthetic resin is mainly accomplished using naturally occurring materials. A previous study carried out by Okuda et al. [4] has shown that hemicelluloses and lignin were decomposed during the pressing process. The condensation reactions of lignin contributed to a self-bonding mechanism, and the sugar content of the boards decreased with increasing pressing temperature. According to Bouajila et al. [5], the bonding strength of binderless boards may be due to lignin-lignin and lignin-polysaccharide cross-linking reactions that occur at high temperature and deformation of the system under pressure. Other studies have also shown that binderless boards developed from sugar-containing lignocellulosic materials such as sorghum need to be pressed at a temperature of 180 °C or higher to achieve satisfactory bonding [6]. Salvadò et al. [7] tried to maximize the properties of binderless boards using steam-exploded *Miscanthus sinensis* by pressing them at temperatures ranging from 195 to 245 °C and have obtained satisfactory results. The generation of simple sugars from the degradation of hemicelluloses at 170 °C and the partial degradation of cellulose around 220 °C to produce simple sugars have been reported to contribute to bonding in binderless boards made from steam-exploded materials [8].

* Corresponding author. Tel.: +60 4 653 5217; fax: +60 4 657 3678.
E-mail addresses: hrokiah@usm.my (R. Hashim), norafizahsaid@gmail.com (N. Said), junejunidah@gmail.com (J. Lamaming), mohna23@gmail.com (M. Baskaran), othman@usm.my (O. Sulaiman), amsato@mail.ecc.u-tokyo.ac.jp (M. Sato), salim.hiziroglu@okstate.edu (S. Hiziroglu), tomosg@affrc.go.jp (T. Sugimoto).
[1] Tel.: +60 4653 5217; fax: +60 4657 3678
[2] Tel.: +60 4653 2241; fax: +60 4657 3678
[3] Tel./fax: +81 3 5841 7507.
[4] Tel.: +1 405 744 5445; fax: +1 405 744 3530.
[5] Tel.: +81 29 838 6363; fax: +81 29 838 6654.

0261-3069/$ - see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.matdes.2011.01.053

Oil palm is a lignocellulosic material rich in carbohydrates in the form of starch and sugar and contains cellulose, hemicelluloses and lignin [9]. It is an abundant waste material found in replantation and harvesting sites in Malaysia and in many parts of South East Asia [10]. Large quantities of this waste persist as underutilized resources. Oil palm is considered an ideal raw material for the production of value-added, environmentally friendly, binderless composite panels due its abundance, sustainability and carbohydrate richness. Therefore, the objective of our study was to evaluate the properties of binderless particleboard made from oil palm trunk pressed at different temperature levels. The physical and mechanical properties of the panels, including modulus of rupture (MOR), internal bond (IB) strength, thickness swelling (TS), water absorption (WA) and surface roughness were evaluated. Fourier transform infrared (FT-IR) spectroscopy, thermal gravimetric analysis and field-emission scanning electron microscopy (FESEM) coupled with energy dispersive X-ray analysis (SEM–EDXA) were used to characterize the differences between raw materials and samples from manufactured panels.

2. Materials and methods

2.1. Preparation of samples

Oil palm trunks were harvested from a plantation in Kedah, Malaysia. The trunks were sawn into round sections 10 cm in thickness before they were chipped into small pieces with approximate dimensions of 5 cm × 2 cm × 1 cm employing a laboratory-type hammer mill. An oven was used to reduce the moisture content of the chips to 7–8% of their original weights. All coarse particles were ground into fine particles using a Willey Mill to a size of less than 1 mm. The particles used to manufacture the experimental panels were less than 1.0 mm in size.

A total of 24 experimental single-layer panels (eight for each press temperature) with dimensions of 20.05 cm × 20.05 cm × 0.48 cm were manufactured. Manually formed mats were compressed in a computer-controlled hot pressed at 160 °C, 180 °C and 200 °C with a pressure of 5 MPa for 20 min. All panels had a target density of 0.80 g/cm^3. Pressed panels were cut into test samples based on JIS A-5908 and were later conditioned in a climate chamber at a temperature of 20 °C and relative humidity of 65% [11].

2.2. Testing of the mechanical and physical properties of the samples

Nine MOR and three IB samples were cut from each panel for the evaluation of the mechanical properties of the panels. Both tests were carried out on an Instron Testing System Model UTM-5582 equipped with a load cell capacity of 1000 kg. Six samples measuring 5 cm × 5 cm were used to determine thickness swelling (TS) and water absorption (WA) of the panels. The thickness of each sample was measured at the midpoint of each side, 1 cm from the edge of the specimens. The samples were submerged in distilled water for 24 h before thickness measurements were taken from the same location to calculate thickness swelling values. Each sample was also weighed at an accuracy of 0.01 g to determine water absorption values.

In addition to the TS and WA properties of the samples, the surface roughness of the samples was also evaluated. Three samples from each panel type measuring 5 cm × 5 cm were used for roughness measurements. Three measurements with a tracing span of 15 mm were taken from each side of the samples by employing a portable stylus-type T-500 Hommel tester. The profilometer consisted of a main unit and a pick-up with a skid-type diamond stylus with a 5 μm tip radius and 90° tip angle. Various roughness parameters such as average roughness (R_a), mean peak-to-valley height (R_z) and maximum roughness (R_{max}) can be calculated from the acquired digital data [12].

2.3. Thermogravimetric analysis

The thermogravimetric analyses (TGA) of the raw materials and manufactured panels at different temperatures were conducted using a Perkin Elmer TGA 7 thermogravimetric analyzer. Scans were recorded from 30 to 800 °C with a heating rate of 20 °C min^{-1} under a nitrogen atmosphere.

2.4. Spectroscopic analysis

Fourier transform infrared (FT-IR) spectroscopy was used to characterize the type of functional groups existing in the raw materials and in samples from pressed panels at different temperatures. Pellets were prepared by mixing approximately 5 mg of powder of each sample type with 95 mg of finely ground potassium bromide (KBr) and pressing the mixture into pellets approximately 1 mm in thickness. The FT-IR spectrum of each sample was then analyzed using a Nicolet infrared spectrophotometer (Avatar 360 FT-IR E.S.P) between 4000 cm^{-1} and 470 cm^{-1} with a resolution of 4 cm^{-1} to detect the functional groups of the compounds of each material.

2.5. Microstructure analysis

Field-emission scanning electron microscopy (FESEM) was used to determine the surface characteristics and structure of parenchyma cells related to the bonding quality between the materials

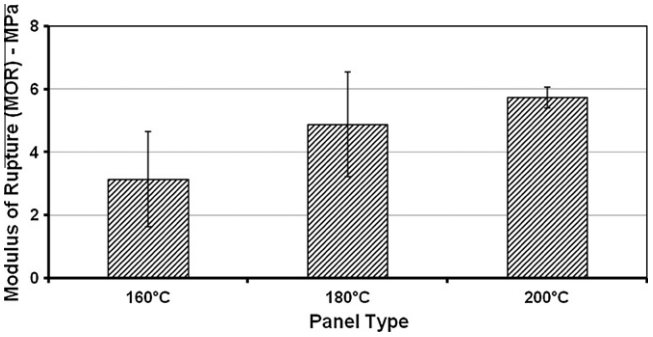

Fig. 1. Modulus of rupture of the samples.

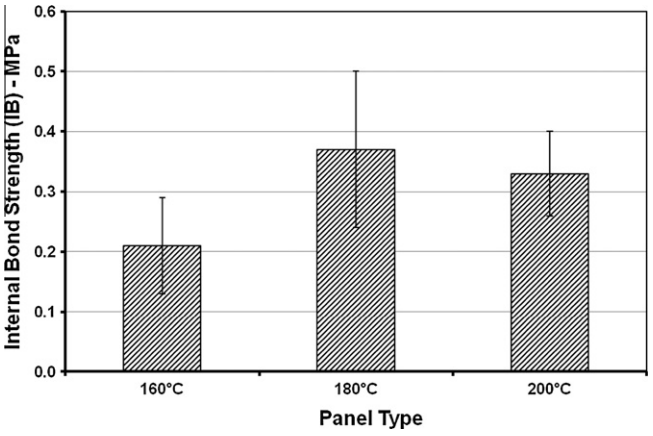

Fig. 2. Internal bond strength of the samples.