Composites: Part B 56 (2014) 344–349

Contents lists available at ScienceDirect

Composites: Part B

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

Properties of steam treated binderless particleboard made from oil palm trunks

Norhafizah Saari [a], Rokiah Hashim [a,*], Othman Sulaiman [a], Salim Hiziroglu [b], Masatoshi Sato [c], Tomoko Sugimoto [d]

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

ARTICLE INFO

Article history:
Received 21 June 2013
Accepted 12 August 2013
Available online 21 August 2013

Keywords:
A. Strand
B. Mechanical properties
D. Electron microscopy

ABSTRACT

The objective of this study was to evaluate both physical and mechanical properties of particleboard panels manufactured from steamed material of oil palm trunks without using any adhesives. Experimental panels from fine particles and vascular strands of oil palm were manufactured. Modulus of rupture (MOR), internal bond strength (IB), thickness swelling (TS) and water absorption (WA) of the samples were tested based on Japanese Industrial Standards. Bonding quality of such binderless samples was also evaluated by using scanning electron microscope (SEM). Based on the findings on this work steaming of the raw material enhanced overall mechanical and physical characteristic of the samples. The highest MOR values of 8.12 MPa and 25.84 MPa were found for the samples made from fine particles and strands steamed at a temperature of 130 °C for 30 min, respectively. It appears that mechanical properties of the panels reduced when they exposed to beyond 30 min steaming time.

1. Introduction

Oil palm (*Elaeis guineensis*) is one of the most important agricultural crops in Malaysia which is the largest producer of palm oil in the world. Having very large oil palm plantation in the country creates substantial amount of waste including trunks which are not used very efficiently. Open burning and land filling are common practices to eliminate this lignocellulosic biomass which puts adverse impact to our ecosystem [1].

Composite panel manufacturing consumes wood as most commonly used raw material, particularly softwoods, hardwoods and their mixtures of different kind of species [2]. However due to forestry regulations, wood shortage, and sustainable use of forest resources have urged researchers all over the world to discover alternative ways to use different kinds of lignocellulosic biomass for composite panel production. Oil palm being a lignocellulosic material suitable raw material for different composite panels manufacture.

For several decades, wood composite panel manufacturers used formaldehyde base binders such as urea formaldehyde (UF), urea-melamine-formaldehyde (UMF) and phenol-formaldehyde to produce panels with accepted physical and mechanical properties [2]. Even though urea formaldehyde is the least expensive binder compared to other adhesives, it makes up about 60% of overall cost of composites panel production [3]. The other disadvantage of formaldehyde based resins is the emission of formaldehyde from the panels into environment which can cause health and pollution problem [3,4]. Therefore the main idea behind of binderless particleboard manufacture is a potential way to reduce cost of production, eliminate health and pollution concerns [1].

Binderless or self bonding board is a term to describe composite panel that is manufactured without using of any synthetic binders. The bonding of the particles is created by the existence of free sugar, carbohydrates, or saccharides pressed at temperature 180 °C in a typical binderless panel technology [5]. Shen investigated properties of panels manufactured from sugar cane and sorghum stalks to produce binderless boards [5]. There are also other studies attempted on binderless board manufacture using different kinds of lignocellulosic materials such as kenaf, wheat straw, coconut husk, banana bunch and oil palm frond [2,6–10]. Previously, different panel products using oil palm as raw material have been studied in past works [9,11–13]. However, there is very limited available information on properties of binderless panels made from oil palm trunk.

Steam explosion had been reported to give positive effects on properties of binderless board [10,11,14–16]. Many recent works have been carried out on binderless board using steam explosion

* Corresponding author. Tel.: +60 4 653 5217; fax: +60 4 657 3678.
E-mail address: hrokiah@usm.my (R. Hashim).

1359-8368/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.compositesb.2013.08.062

to enhance and improve the quality of the final product [14,16,17]. Steam explosion could result in generating fibers with more flexibility and activate lignin. Self bonding of such fibers and softening lignin contributes to the formation of high performance of binderless board during hot pressing process [18]. Moreover during the hot pressing, binding between and within the fibers is developed by activation of reactive components which are part of lignocellulosic materials [19,20]. In a previous study, steam explosion produced board with greater dimensional stability affected by the existence of bonding strength together with the decrease in internal force that is generated by water [11]. Moreover, severe steam explosion will cause the fiber lose its elasticity. This happens through the destruction of the aromatic nuclei during the steam explosion [14]. This technique carries out to hydrolyze most of the hemicelluloses. It is a well known fact that wide variety of composite panels can be manufactured by modifying the raw material, the pretreatment operation parameters including temperature and time or using preservatives and catalysts.

Therefore, the objective of this study was to manufacture experimental panels from fine particles and strands of oil palm trunks and evaluate their properties as compared to those of commercially manufactured and also to explore the suitability of steam treated particles from oil palm trunk in manufacture of binderless particleboard.

2. Materials and methods

2.1. Panel manufacture and sample preparation

Oil palm trunks were harvested in a local plantation in Northern Malaysia. The trunks were initially cut into disks using chainsaw before they were debarked. The disks were reduced into chip by using a laboratory type hammer mill. An autoclave was employed to steam chips using three temperature levels of 100 °C, 115 °C and 130 °C for 10, 30 and 50 min steaming time spans before they were dried to 6–8% moisture content in a laboratory oven. After chips were dried they were furthered reduced into fine particles using Willey mills. Strands as vascular bundles were also manually separated from the materials. Vascular bundles were laid out across to each other in the form of eight layers. In the next step fine particles were manually distributed on the vascular bundles as homogenous as possible.

Formed mats were compressed in a computer controlled press using a pressure of 5 MPa at a temperature of 180 °C for 20 min to have a target density of 0.80 g/cm^3. The panel thickness was 0.5 cm. After the samples were conditioned in a climate room having a temperature of 20 °C and a relative humidity of 65% they were cut into test specimens based on Japanese Industrial Standards [21].

2.2. Mechanical and physical properties

Internal bond strength and modulus of rupture tests were carried out on an Instron Testing System Model UTM-5582 equipped with a load cell having a capacity of 1000 kg. Two samples from each panel were used to evaluate dimensional stability in term of thickness swelling (TS) and water absorption (WA). The samples were soaked in water for 24 h. Weight and thickness were measured before and after the samples were soaked.

2.3. Scanning electron microscopy (SEM)

Scanning electron microscopy (SEM) was used to characterize the morphology of oil palm trunk as parenchyma cells in the panel in order to have better understanding of the bonding between the particles. The samples with cross section of 0.5 cm × 0.5 cm from each panel were coated with gold by an ion sputter coater (Polararon SC515, Fisons Instruments, UK) before the micrographs from their surface were taken.

2.4. Fourier transforms infrared spectroscopy (FTIR)

Fourier transform infrared spectroscopy (FTIR) was employed to identify chemicals elements in the samples of binderless board. The sample from strand and fine particles which were steam pretreated were added with potassium bromide (KBr) to make small pellets. Later these pellets were tested using FTIR instrument.

2.5. Thermogravimetric analysis (TGA)

Thermogravimetric analysis (TGA) was performed on steam pretreated at condition 130 °C, 30 min binderless board for both fine particles and strands to determine the degradation temperature which a changes in weight in relation to change in temperature. This analysis depends on high degree of precision in three measurements; weight, temperature, and temperature change. This test was carried out by loaded the sample in the pan. The analyzer then raised the temperature of the sample gradually and weight percentage against temperature was plotted.

2.6. Starch analysis

Starch analysis was carried out using Humphreys method [32]. The samples was prepared by putting oil palm trunk with size passing through 200 mesh sieve in a desiccator over concentrated sulphuric acid for 3 days. The samples then was weighed approximately 0.40 g. after that, the samples was added with 7.2 M perchloric acid and followed by distilled water, phenolptalein, natrium hydroxide, acetic acid, potassium iodide and potassium iodate. The absorbance characteristics of the specimens were measured.

3. Results and discussions

3.1. Mechanical properties of the samples

Results of mechanical and physical properties of the samples are presented in Tables 1 and 2. Both bending and internal bond strength characteristics of the panels made from strands resulted in higher values than those made from fine particles. The highest MOR value of 25.84 MPa was determined for strands type panels made from particles steam treated for 30 min. This value was 69% times higher than value of panels made from fine particles at the same conditions. It is a well known fact that the slenderness ratio plays an important role on development of glue line between the particles [22]. Higher bonding strength properties of the panels made from strands can be related to better glueline development due to their geometry. Steaming of both types of raw material enhanced both MOR and IB values of the panels. However, once steaming time increases from 30 min to 50 min its appears that steaming adversely influenced strength values of the samples as can be observed in Figs. 1 and 2. In the case of strand type of panel's MOR value of the samples reduced 19% with increasing exposure time from 30 min to 50 min. Corresponding value for the samples made from fine particles was 24%. Increase steam exposure time to 50 min seems that some chemical structure of the particle were destroyed resulting in reduction of strength properties. IB characteristics also followed similar trends to the findings for MOR.