UNIVERSITI PUTRA MALAYSIA

PHYSICAL AND MECHANICAL PROPERTIES OF COMPOSITE BOARDS BASED ON WOOD FIBER/OIL PALM KERNEL SHELL WITH DIFFERENT POLYURETHANE COMPOSITION

FAIZATUL AZWA ZAMRI

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By

FAIZATUL AZWA BINTI ZAMRI

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fullfilment of the Requirement for the Degree of Masters of Science

November 2016

DEDICATION

I dedicate this thesis to my family especially my husband, children, my parent and parent in-law

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

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Chairman: Walter Charles Primus, PhD
Faculty: Agriculture and Food Science

In Malaysia, the oil palm industry has brought significant impacts to the economy, social, geographical as well as the environment but the waste produced from palm oil production has become concerned. Palm kernel shell is an abundant residue produced from the oil palm processing. The possibility of utilizing palm kernel shell in the fiberboard could help to overcome the shortage of wood resources facing in the wood based industry. Therefore, a series of fiberboard samples have been fabricated using wood fiber/palm kernel shell at ratio of 100/0, 85/15, 75/25, and 65/35. The polyurethane adhesive was added at different percentage (20, 30, 40, 50, 60, and 70%). The effect of polyurethane and palm kernel shell composition addition into the composite has been studied in terms of physical and mechanical properties.

The results showed that the bulk density of the sample obtained was within the range of medium density fiberboard types. Generally, the hardness, tensile modulus, tensile strength, flexural modulus and flexural strength were increased with the increase of polyurethane adhesive percentage. The porosity, moisture content and water absorption also were improved with the increment of polyurethane percentage. The effects were also explained in terms of surface morphology. Besides that, 15% to 25% of palm kernel addition in the medium density fiberboard was increased its mechanical properties. However, low properties observed with further palm kernel shell addition.

According to the Japanese Industrial standard, the sample met the JIS A 5905 for board type 5 except 85/15 and 75/25 of wood fiber/palm kernel shell composites using 20% of polyurethane addition. In addition, the percentage of moisture content meet minimum requirement of medium density fiberboard for decorative purpose.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Sarjana Sains

SIFAT FIZIKAL DAN MEKANIKAL BAGI PAPAN KOMPOSIT BERDASARKAN SERAT KAYU/TEMPURUNG BIJI SAWIT DENGAN PELBAGAI KANDUNGAN POLIURETANA

Oleh

FAIZATUL AZWA BINTI ZAMRI

November 2016

Pengerusi: Walter Charles Primus, PhD
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Industri kelapa sawit telah memberi impak yang besar terhadap ekonomi, sosial, geografikal dan juga persekitaran tetapi sisa daripada pemprosesan minyak kelapa sawit telah menjadi kebimbangan.Tempurung biji sawit ialah sisa terbiar yang terhasil daripada pemprosesan minyak kelapa sawit.Kemungkinan menggunakan tempurung kelapa sawit dalam papan gentian dapat membantu kekurangan sumber kayu yang sedang dialami oleh industriberasaskan kayu.Oleh itu, satu siri sampel papan gentian telah di buat menggunakan serat kayu/tempurung kelapa sawitpada nisbah 100/0, 85/15, 75/25, dan 65/35.Pengikat poliuretana di tambah pada peratusan yang berbeza (20, 30, 40, 50, 60, dan 70%).Kesan penambahan komposisi poliuretana dan tempurung biji sawit dikaji dari segi sifat fizikal dan mekanikal.

Keputusan menunjukkan bahawa ketumpatan sampel yang diperolehi adalah jenis papan gentian berketumpatan sederhana.Secara keseluruhan, kekerasan, modulus tegangan, kekuatan tegangan, modulus lenturan, dan kekuatan lenturan semakin meningkan dengan peningkatan peratusan poliuretana.Keliangan, kandungan lembapan, dan serapan air juga bertambah baik dengan peningkatan peratusan poliuretana.Kesannya juga diterangkan dalam morfologi permukaan.Selain itu, penambahan 15% hingga 25%tempurung biji sawit ke dalam papan gentian berketumpatan sederhana telah meningkatkn sifat mekanikalnya. Walaubagaimanapun, diperhatikan sifatnya menurun dengan peningkatan tempurung biji sawit.

Berdasarkan kepada piawaian perindustrian Jepun, papan tersebut mematuhi piawaian JIS A 5905 bagi papan jenis 5 kecuali serat kayu/tempurung biji sawit yang berkomposisi 85/15 dan 75/25 dengan menggunakan penambahan 20% poliuretana. Tambahan lagi, peratusan kandungan kelembapan memenuhi keperluan minimum bagi MDF untuk tujuan perhiasan.

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Lastly, thank you to my friends, Mrs. Aaliyawani Ezzerin,and Mrs. Siti Hashimah for accompanied me during doing the research.

I certify that a Thesis Examination Committee has met on 10th November 2016 to conduct the final examination of Faizatul Azwa Binti Zamri on her thesis entitled "Physical and Mechanical Properties of Composite Boards Based on Wood Fiber/Oil Palm Kernel Shell With Different Polyurethane Composition" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the Degree of Masters of Science. The members of the Supervisory Committee were as follows:

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LIST OF ABBREVIATIONS

BD	Bulk density
FM	Flexural modulus
FS	Flexural strength
JIS	Japanese Industrial standard
MC	Moisture content
MDF	Medium density fiberboard
PD	Particle density
PKS	Palm kernel shell
PU	Polyurethane
R	Gas constant
SEM	Scanning electron microscope
TM	Tensile modulus
TS	Tensile strength
WA	Water absorption
WF	Wood fiber
php	Part per hundreds of total polymer

CHAPTER ONE

INTRODUCTION

1.1 Research Background

In Malaysia, forest area has been decreasing over the years while area of oil palm plantation keeps increasing. In 1990's, the total forest area was 22 376 thousand hectares, then 3.6% from the forest areas converted to other land in the year 2000. Meanwhile in 2005, addition 3.2% from the forest area was deforested. According to the latest Global Forest Resources Assessment (GRFA) report, the statistics in the year 2010 show that total forest area remaining was 20 456 thousand hectares which 2.03% decreased from year 2005. The growth of the oil palm plantation is because of high global demand for oil and fats produced from the oil palm tree. Since 1990, the oil palm planted area was 2029 thousand hectares. However, the planted area has increased by 66.4% in the year 2000, and it is increased to 4854 thousand hectares area in 2010's. The latest year, 2012 reported that the oil palm areas become larger with 5077 thousand hectares area in Malaysia. (www.fao.org – GRFA, 2015). Since then, the palm oil industry was generated more revenue to the Malaysian economy. In addition, the development in the palm oil plantation has uplifting living standard and economic well-being of the rural people since it offered more job opportunities. However, the major problem arise from the palm oil plantation is to manage the wastes produced from the processing such as palm kernel shell (PKS).

The oil palm fruit consist of hard seed (kernel) enclosed in a shell (endocarp) which is surrounded by fleshy husk (mesocarp). Palm oil is extracted from the mesocarp meanwhile kernel shell oil is derived from the kernel after being separated from the mesocarp with mostly the shell (endocarp) left as waste. The shell or palm kernel shell (PKS) is lignocellulosic fiber which is most widely used as biodegradable filler. The advantages of lignocellulosic fibers are biodegradable and renewable, with acceptable specific properties compared to glass fibers. Intrinsically, these fibers have a number of interesting mechanical and physical properties (Jain et al., 2013). Besides that, other sources of lignocellulosic are including wood, agriculture residues, water plants, grasses and other plant substances (Rowell, 1992).

Nowadays, the wood based composite products are commonly instead of solid wood in today's building structures due to the excellent of mechanical properties of wood composites materials (Abd. Aziz et al., 2015). The common product of wood based composite is plywood, oriented strandboard, particleboard, and fiberboard (Stark et al., 2010).Fiberboard can be categories by its density which is hard, medium and low density fiberboard. Medium Density Fiberboard (MDF) is made from lignocellosic fiber combined with a synthetic resin or other suitable bonding system that are combined together under heat and pressure. MDF is denser than plywood or particle board, hence widen its application (Mahzan, et al., 2011). The production of MDF has increase consistently due to its numerous advantages over solid wood and other composite materials. Fiberboards with uniform fiber distribution in their structure meet most end-use requirements. With fiberboards, smooth and solid edges can easily be machined and finished for various purposes, especially furniture production. Smooth and uniform surface also provide an excellent substrate for paint and decorative overlays. The surface smoothness of MDF makes it the best matched for cabinet manufacturing (Akgul et al., 2010).

In the manufacturing of fiberboards, dry and wet processes are used. The significant difference between these two processes is that in wet process, water is used as the fiber distribution medium for mat formation. Besides that, some wet process is made without addition binders. This is because the lignocellulosic fiber is containing lignin which can serve as the binder. However, the lignocellulosic must contain sufficient lignin and retained during refining operation. Therefore, the lignin will flow and act as thermosetting adhesive under heat and pressure, enhancing the naturally occurring hydrogen bond (Stark et al., 2010). Generally, MDF made by waste from sawmill residues and wood chips (in a fiber form) as raw material and thermosetting adhesive such as phenol-formaldehyde, urea-formaldehyde, melamine-formaldehyde, and isocyanate (Stark et al., 2010).

1.2 Problem Statement

The supplies of the wood resources are become limited but the demand on the wood product is increasing with the increase of population. The lack of raw materials in the wood based composite was enforce wood industry to find alternative for existing wood fiber with other lignocellulose materials or blend in order to produce composite product with the comparable properties with existing commercial composite. In previous research, the study on physical and mechanical properties of wood composite from several species of natural waste including Batai (Tomimura et al, 1988), wheat straw (Halvarsson et al., 2008), Canola straw (Yousefi, 2009), Empty Fruit Brunch (Norul Izani et al., 2013), Munro Bamboo (Marinho et al., 2013) and banana steam and midrib (Rashid et al., 2014) has been conducted. Besides that, the study of mixture of more than two species ofnatural waste or natural waste with existing wood fiber also had been done including wheat straw/WF (Eroglu et al., 2001), wheat/soybean straw (Yee et al., 2007), Rhododendrom/industrial WF (akgul and Camlibel, 2008), Corn stalk/oak wood fiber (Akgul et al., 2010) hazelnut shell/WF (Copur et al., 2008) and sycamore leaves flour/industrial WF (Agakhani et al., 2013).

Sarawak has the largest area of oil palm plantation. Currently, the PKS waste was used in biomass industry but the potential of PKS as reinforcement in the polymer composite become interest to many researcher such as PKS/LDPE with compatibilizer (Salmah et al., 2011), PKS/RLDPE (Olumuyiwa et al., 2012) PKS/PP (Jain et al., 2013), PKS /PE (Shehu et al., 2014, Nabinejad et al., 2015), and PKS in natural rubber polymer (Daud et al., 2016). However, very limited resources of research using PKS mixed with WF to produce composite product. Therefore, it could be advantages if the PKS could be potentially used in composite product in order to overcome the shortage of wood resources.

The health hazard produce from the existing MDF using formaldehyde resin become a concerned to the human health. Recently, the reinforcement of polymer into MDF was a solution to overcome the formaldehyde issue. However, the compatibility between constituent materials is a concerned in order to produced good physical and mechanical properties of composite.

1.3 Research Objectives

In this research, wood fiber (WF) and oil palm kernel shell (PKS) was used in a composite board with ratio of 100/0%, 85/15%, 75/25% and 65/35% (WF/PKS). The target density for fabrication sample is 0.5-0.8 g/cm^3. Others, the loading of

Polyurethane (PU) adhesive were varied at 20, 30, 40, 50, 60 and 70 by weight percentage from the total mass of the WF and PKS. Thus, the objectives of this research are:

1. to prepare WF-PKS composite board and PU adhesive as a binder,
2. to determine physical and mechanical properties of WF/PKS at various PU loading according to Japanese International standard (JIS A5905) for fiberboard through its mechanical and physical properties, and
3. to determine physical and mechanical properties of WF/PU at various PKS loading for fiberboard through its mechanical and physical properties.

1.4 Scope of Studies

This research has been done in faculty of agriculture and food sciences in UPM Bintulu Campus, Sarawak. The fiberboard samples preparation and the characterization are performed using available equipment in the faculty. For scanning electron microscope and pcynometry test was done in University of Malaysia Sabah (UMS) and University of Science Malaysia (USM) respectively. Prior fiberboard samples preparation, the preliminary work has been done to determine the suitable process flow using equipment available. Therefore, the sample fabrication in this research is slightly different with the existing method. The physical and mechanical properties including density, porosity, moisture content, water absorption, hardness, tensile properties and flexural properties were carried out. Some ofothers important measurement in the fiberboard could not be done due to financial and equipment limitation. Since the raw material used in this research was contributed from the local company such as wood fiber and palm kernel shell waste, therefore Japanese Industrial Standard was used as guidelines in this research adaptation from the company practices. It is known that latest version of the standard is 2014 but this research using 2003 version due to limited of access.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

A wood composite is defined as a combination of one or more wood material and bonded together with adhesives. The mechanical properties of wood composites depend upon a variety of factors, including wood species, forest management regimes (naturally regenerated, intensively managed), the type of adhesive used to bind the wood elements together, geometry of wood elements (fibers, flakes, strands, particles, veneer, lumber) and density of the final product (Cai et al., 2006).

2.1 Medium Density Fiberboard Properties and Its Type

In the Medium density fiberboard (MDF), the lignocellulose fibers combined with a synthetic resin or other suitable bonding system under heat and pressure (Mahzan et al., 2011). The lignocellulosic fibers are natural fibers which classified by based on its origin or botanical types (Pickering, 2008). The chemical composition of wood materials is generally preferred and required in many processes and application in wood industry (Akgul and Camlibel, 2008). Table 2.1 shows the chemical composition of natural fibers had been widely used in the MDF manufacturing.

Table 2.1 Properties of natural fibers (Lilhot and Lawther, 2000, Rowell et al., 2000,Stokke et al., 2000 and Vaisanen et al., 2016).

Fiber type	Softwood	Hardwood
Density (g/cm^3)	1.4	1.4
Cellulose	40-45	40-50
Hemicellulose	30	23-39
Lignin	26-34	20-30
Extractives (wt%)	2-5	2-4
Ash (wt%)	0.2-0.8	0.2-0.4
Pectins (wt%)	0-1	0-1
Waxes (wt%)	0.4-0.5	0.4-0.5

Recently, agriculture waste was used as alternative lignocellulose materials in order to replace existing wood fiber due to its limited forest resources in the MDF manufacturing. The agriculture wastes include wheat husk, rice husk, and their straw, hemp fiber and shell of various dry fruits (Olumuyiwa et al., 2012). In addition, the compatibility between new type of fiber with selected adhesive also studied. The physical and mechanical properties obtained were indicating the performance of the MDF produced. Besides that, the resination techniques also effect the mechanical properties of the MDF produced. The commercial size of MDF boards with density varied from 680 to 708 kg/m^3. The chemicals were added based on oven-dry fiber including 1% of paraffin, 1% of NH_4Cl as hardener, and 11% of urea formaldehyde resin. Total four type of MDF produced using two type of resin application including the blowline resin injection and short retention blender method with resin ratio 11/0, 10.5/0.5, 10/1, and 9.5/1.5 respectively. The MDF produced using pressure 3.5 MPa at temperature 220 °C for 4 minutes. The mechanical properties such as MOR, MOE, IB strength, and screw withdrawal resistance were determined according to EN 310, EN

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