

## A study of the Use of Physic Nut Stem of Waste in the manufacture of particleboard การศึกษาการทำแผ่นปาร์ติเกิลบอร์ดจากวัสดุเหลือใช้ทางการเกษตรของต้นสบู่ดำ

Phanudej Kudngaongarm<sup>1</sup> Sombat Chinawong<sup>2</sup> Vicha Monthamkan<sup>3</sup> and Worahtam Oonjittichai<sup>4</sup>  
ภาณุเดช ชัดงาม<sup>1</sup> สมบัติ ชนะนวงค์<sup>2</sup> วิชา หมั่นทำการ<sup>3</sup> และ วรธรรม อุ่นจิตติชัย<sup>4</sup>

<sup>1</sup>Ph.D. candidate in Agriculture Research and Development และ Faculty of Agriculture,  
Kasetsart University, Kamphaeng Saen Campus, Thailand

<sup>2</sup>Assoc.Prof. Vice President for Kamphaeng Saen Campus Kasetsart University, Thailand

<sup>3</sup>Department of Agricultural Engineering, Faculty of Engineering,  
Kasetsart University, Kamphaengsan Campus, Thailand

<sup>4</sup>Specialist in Forest Products, Department of Forest, Thailand

Panudej.9838@gmail.com, sgril.kps.ku.ac.th, fengvcm@ku.ac.th, and woratham@yahoo.com

### Abstract

The purpose of this research was to develop a particleboard made from the top of physic nut stem which waste from agriculture process. The physic nut stems particleboard benefits in economy, sustainability and environmentally friendly particleboard process, capability of full-scale manufacturing and production of quality Particleboard. Physic nut stem is a species of flowering plant in the spurge family called Euphorbiaceae that is native to the American tropics, most likely Mexico and Central America. It is cultivated in tropical and subtropical regions around the world, becoming naturalized in some areas. This study was to develop waste material such as top of physic nut stem to produce a particleboard and was tested under Thailand industrial standard (876-2547). The results show that sizes of plate should not bigger than 2 cm<sup>2</sup>. The suitable proportions are 95% physic nut stems and 5% isocyanates glue. The suitable compression temperature is 120 °C. The suitable density for interior partition is 0.80 g/cm<sup>3</sup>. The average of materials' moisture before compressed is good at 8.96%. The best compression force is 150 lb/in<sup>2</sup>. It shows that ceiling plate could be pass test by Thailand Industrial Standard (876-2547) such as density, modulus of rupture, swelling, elastic modulus, and internal bond. Physic nut stem can be made for production of particleboard.

**Keywords :** agriculture particleboard; physic nut stem; waste reduction; Euphorbiaceae; isocyanates glue

### บทคัดย่อ

ในการวิจัยครั้งนี้ มีวัตถุประสงค์เพื่อการผลิตแผ่นเฟอร์นิเจอร์ที่ทำจากส่วนยอดของต้นสบู่ดำ ที่เป็นวัสดุเหลือใช้จากกระบวนการทางการเกษตร แผ่นเฟอร์นิเจอร์ที่ทำจากส่วนยอดของต้นสบู่ดำจะส่งผลดีต่อเศรษฐกิจ ความยั่งยืน และกระบวนการผลิตแผ่นเฟอร์นิเจอร์ที่เป็นมิตรต่อสิ่งแวดล้อม ความสามารถในการผลิตอย่างเต็มกำลัง และการผลิตแผ่นเฟอร์นิเจอร์ที่มีคุณภาพ ต้นสบู่ดำเป็นสายพันธุ์ของไม้ดอกในตระกูลพืชสกุลสเปิร์มที่เรียกว่ายูพอร์เบียซี ที่ซึ่งมีต้นกำเนิดมาจากเขตร้อนของอเมริกาหรือแควเม็กซิโกและอเมริกากลาง มันถูกเพาะปลูกในเขตร้อนและกึ่งเขตร้อนทั่วโลก และขึ้นตามธรรมชาติในบางพื้นที่ ในการศึกษานี้เป็นการนำเอาวัสดุเหลือใช้ อย่างเช่นส่วนยอดของต้นสบู่ดำไปผลิตแผ่นเฟอร์นิเจอร์แล้วทดสอบตามขั้นตอนของ มอก. 876-2547 ผลการทดลองพบว่า ขนาดวัสดุที่เหมาะสมควรตัดสบู่ดำเป็นขนาดไม่เกิน 2 ซม. สัดส่วนที่เหมาะสม ได้แก่ ต้นสบู่ดำ 95% กาวไอโซไซยาเนต 5% อุณหภูมิที่ใช้ในการอัด 120 °C ความหนาแน่นที่เหมาะสมในการอัดแผ่นผนังเท่ากับ 0.80 กรัม/ลบ.ซม. ปริมาณความชื้นของวัสดุก่อนอัดเฉลี่ยอยู่ที่ 8.96% แรงอัดที่เหมาะสมอยู่ที่ 150 ปอนด์ต่อตารางนิ้ว จากการทดสอบตามมาตรฐานอุตสาหกรรม พบว่า แผ่นฝ้าเพดานสามารถทดสอบผ่านเกณฑ์มาตรฐานใน

ด้านความชื้น ความหนาแน่น ความต้านทานแรงดัด และไม่ผ่านในด้านการพองตัวเมื่อแช่น้ำที่ 2 ซม. แรงยึดเหนี่ยวภายใน และมอดูลัสยืดหยุ่น ในภาพรวม ต้นสับุดำสามารถนำไปผลิตเป็นแผ่นเฟอร์นิเจอร์ได้

**คำสำคัญ:** แผ่นเฟอร์นิเจอร์จากการเกษตร ส่วนยอดของต้นสับุดำ การลดวัสดุเหลือใช้ ต้นยูฟอร์เบียซี กาวไอโซไซยาเนต

## INTRODUCTION

Now the material using in construction business has been develop for human needs but the development also destroy our environment even more. So many productions try to use agriculture waste such as weeds or plant fiber material to make it into small particles, and then felted to make furniture or using as components in the building structure. In 2003, Thailand imported wood more than 5000 million baht [1]. There are many researchers conducted research based on using agricultural waste for material productions [2]. However, many researchers predicted that the demand for particleboard in the year 2017 there will be 1.93 million cubic meters. We see that also has a high rate of demand at present. It is very important to find new sources of raw materials to meet future needs, also reduce import wood from other countries. The global occurrence of wood-based lignocellulosic fibre is still adequate and there is today no general fiber shortage or crises. Yet at the same time, we have some regional deficiency of wood-based fibers. Industrial demand of proper wood based raw materials is critical in several Asian countries. The strong economic growth in Asia has contributed to increased demand of wood-based raw materials. Wood-based biomass is becoming more restricted and expensive for producers of pulp & paper, bio-energy, lumber, and wood-based composite fiber boards. Moreover, the increasing environmental awareness and concerns of the health of forests, wildlife diversity, biomass productivity, climate, and the biological sink directs research to alternative fiber recourses. Annual plant materials are promising candidates for alternative lignocellulosic fiber composites. Several annual plant fibers such as

flax, hemp, jute, kenaf, bagasse, corn, and bamboo have been the subject of extensive research for the manufacture of non-wood particle and fiber board [3]; [4]; [5]; [6]; [7]). Agricultural crop residues such as top of physic nut stem and other wasted of agriculture process and produced in billions of tones around the world. The agro-physic nut stem materials are abundant, inexpensive, and readily available sources of lignocellulosic fibers. The basic challenge for board producers is to convert the agricultural materials into particle boards (PB), medium density fiber board (MDF), or high density particleboard (HDF) in a sound technical and economical process [8]; [9]; [10]; [11]; [12]; [13]; [14].

The researchers found that physic nut stem has wasted in oil business every year. Agriculturists spend a lot of budget to collect and waste them. Physic nut stem are high fiber and very strong. We consider them as good material to make ceiling plates using hot extrusion process with a hydraulic machine just like we do with husk and sawdust.

## DEFINITION OF PARTICLEBOARD

The methods of manufacture of wood-based particleboard are generally divided into wet and dry methods. The definitions of particleboard are formulated in the European Standard (EN 622-5, 2006). Originally, particleboard is classified by their production process as follows:

- Wet process particleboard (fiber distribution in water)
  - Dry process particleboard (fiber distribution in air)
- Wet process boards are particleboard having fiber moisture content (MC) of more than 20% at the stage of forming. Additionally, wet process boards are classified according to density, as follows:

- Hardboards (HB): Boards with a density  $\geq 900$  kg/m<sup>3</sup>
- Medium boards (MD): Boards with a density  $\geq 400$  kg/m<sup>3</sup> to  $< 900$  kg/m<sup>3</sup>

Wet process hardboards use water as the distribution medium for the fibers to be formed into a mat. This method is an extension of paper manufacturing. Dry process particleboard (MDF) having a fiber moisture content of less than 20% at the stage of forming, and having a density  $\geq 450$  kg/m<sup>3</sup>. These boards are essentially produced under heat and pressure with the addition of a synthetic adhesive. For marketing purposes, MDF of specific density range can be given different denominations. For example, the following density-related marketing terms for MDF have become established:

- HDF: MDF with a density  $\geq 800$  kg/m<sup>3</sup>
- Light MDF: MDF with a density  $\leq 650$  kg/m<sup>3</sup>
- Ultra-light MDF: MDF with a density  $\leq 550$  kg/m<sup>3</sup>
- The top of physic nut stem: the part which is far from the top for 15 centimeter.
- Particleboard: the process of hydraulic hot compressed by used the top of physic nut stem with glue mixer.

In this work the more modern dry particleboard method is applied and described for physic nut stem based particleboard. The density range of produced physic nut stem particleboard is in the range of  $\leq 550$  kg/m<sup>3</sup> and according to the above definitions of MDF types as seen in Figures 1.

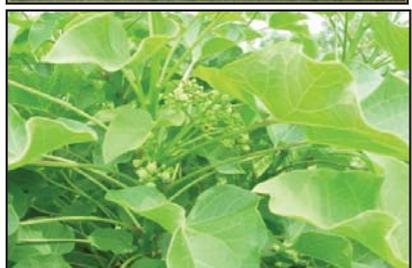
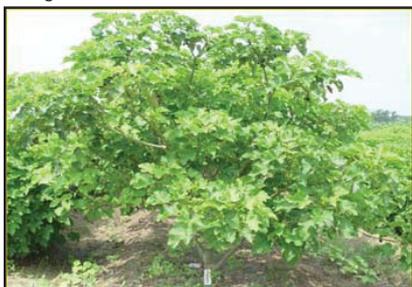


Figures 1 Particleboard

## PHYSIC NUT STEM

The physic nut stem is a drought-resistant species which is widely cultivated in the tropics as a living fence. Many parts of the plants are used in traditional medicine. The seeds, however, are toxic to humans and many animals. Considerable amounts of physic nut stem seeds were produced on Cape Verde during the first half of this century, and this constituted an important contribution to the country's economy. Seeds were exported to Lisbon and Marseille for oil extraction and soap production. Today's global production is, however, negligible. The physic nut, by definition, is a small tree or large shrub which can reach a height of up to 5 m. The plant shows articulated growth, with a morphological discontinuity at each increment. Dormancy is induced by fluctuations in rainfall and temperature/light. The branches contain latex. Normally, five roots are formed from seedlings, one central and four peripheral. A tap root is not usually formed by vegetative propagated plants [15]. The physic nut stem has 5 to 7 shallow lobed leaves with a length and width of 6 to 15 cm, which are arranged alternately. Inflorescences are formed terminally on branches and are complex main possessing and co-florescence with paracladia. Botanically, it can be described as cymes. The plant is monoecious and flowers are unisexual; occasionally hermaphrodite flowers occur [16]. Ten stamens are arranged in two distinct whorls of five each in a single column in the androecium, and in close proximity to each other. In the gynoecium, the three slender styles are connate to about two-thirds of their length, dilating to massive bifurcate stigmata [16]. Pollination of the physic nut stem is by insects. Dehgan and Webster [16] believe that it is pollinated by moths because of "its sweet, heavy perfume at night, greenish white flowers, versatile anthers and protruding sexual organs, copious nectar, and absence of visible nectar guides". When insects are excluded from the greenhouse, seed set does not occur without hand-pollination.

The rare hermaphrodite flowers can be self-pollinating. During field trials, Heller [17] observed a number of different insects that visited flowers and could pollinate. In Senegal, he observed that staminate flowers open later than pistillate flowers in the same inflorescence. To a certain extent, this mechanism promotes cross-pollination. Münch [18] did not observe this chronological order in Cape Verde. It seems that the mechanism is influenced by the environment. After pollination, a trilobular ellipsoidal fruit is formed. The exocarp remains fleshy until the seeds are mature. The seeds are black, 2 cm long and 1 cm thick. The caruncle is rather small. Wiehr [19] and Droit [20] described the microscopically anatomy of the seeds in detail, while Singh (1970) described that of fruits. Gupta [21] investigated the anatomy of other plant parts. The physic nut stem is a diploid species with  $2n = 22$  chromosomes as seen in Figures 2.



Figures 2 The physic nut stem

## THE RESEARCH METHODS

This section briefly describes the materials and methods used in this research. In this section the raw materials, experimental methods, and measurements of physic nut stem material are presented. The methods and measurements of physic nut stem properties are presented in section (industry standards (ISO 876-2547)).

1. Use the top of physic nut stem to produce ceiling path. The ratio between physic nut stem and Isocyanates glue are 90:10, 92:8, 95:5, and 97:3.

2. The glue used in this study was phenol cyanates. However, the result was different in various ratios. The best of ratio after experimental in lab, researcher discover that the best ratio between physic nut stem Isocyanates glue is 95:5.

3. Three sheets made to test using industry standards (ISO 876-2547)

- The density 0.40 – 0.90 g / cm<sup>3</sup>
- Water Content 5 – 13 percent.
- Water Assumption 0.1 percent.
- Thickness swelling not more than 12 percents.
- Bending Strength 18 N / mm<sup>2</sup>
- Modular flexibility not be less than 1800 N / mm<sup>2</sup>
- Tensile strength perpendicular to surface not less than 0.40 N / mm<sup>2</sup>
- The surface density not be less than 0.6 N / mm<sup>2</sup>

Researchers make physic nut stem plates in the same size 350x350 mm. then cut them into

50x50x10 mm. separately each group. They pick 3 of each group up randomly to test according to industry standards (ISO 876-2547) as above.

#### THE SPECIFICATION

- 1) Optimal size is not larger than 2 cm
- 2) The right ingredients are the blend of 95 % physic nut stem and 5% isometric cyanates glue (glue MDI).
- 3) Temperatures during compression are at 120 degrees Celsius.
- 4) Appropriate density of compression plate is 0.80 grams per cubic centimeter.
- 5) The moisture content of the material is at average of 8.96 % (defined TIS in the range 5-13%)
- 6) The force required to compress the plate is at 150 pounds per square inch.

#### DATA ANALYSIS

Testing plates were analyzed using statistical process to determine the average and percentage, then selected one that met the Thai Industrial Standard (TIS).

#### RESULT

Water Content and Density test showed that they meet the standard. Probably because of the compression process, the researcher calculated ratio carefully whereby the density of 0.80 g / cubic cm and the compression is at 150 psi which is reasonable.

Testing for the swelling (Thickness Swelling) and water absorption showed those ceiling plates don't meet the standards probably because dust which make the glue cannot grip the materials.

For Internal bond testing or the tensile strength perpendicular to the surface test, the experiment showed that the plate did not meet Thai industrial standards. It is because of the gluing process between steel and material during tensile test. The glue may not cover or glue may not be melt enough.

For testing of Bending Strength and modular flexibility, at this stage the material was not meet standard. The reason was the quality of glue. Isocyanides deteriorated in heat or humidity (Optimum temperature for storage is approximately 30 – 35 degrees Celsius). Also, dust and debris, weeds might be mixed into the material making it not as strong as it should be.

#### SUGGESTION AND FUTURE RESEARCH

Every year the physic nut stem may need pruning or cutting then we can use the top of physic nut stem to produce ceiling tiles. In another way, the ingredients and the process of compression, such as temperature, pressure, the density and more which are found in this provided some idea for other researchers and future study. The researchers will test other features related to producing ceiling tiles such as thermal conductivity properties, sound absorbing properties and installing techniques.

#### CONCLUSION

Natural resources are gift from God for mankind. However, with time these renewable resources and natural fiber will soon deplete. So, there is a great need to sustain and procure them for the future. They should be used economically and wisely. We should seek more fruitful means to explore the maximum potential and utilize the natural fiber for the development of science and technology. The results indicated that the thermal insulation from physic nut stem fibers with a density of 0.80 g / cubic cm and a thickness 10 mm. which bonded by particleboard during hot pressing process have a good physical, mechanical and thermal properties according to TIS. It can be seen that the particleboard of physic nut stem fibers has the thermal conductivity with the compression of 150 psi. This shows the physic nut stem particleboard is a candidate raw material for an insulator of wall, ceiling and building materials for energy saving.

**Table 1** Test according to industry standards (ISO 876-2547)

Plate Group	Thickness Swelling (%)		Water Assumption (%)		Bending Strength (MOR) (Mpa)	Modular flexibility	Tensile Strength (Mpa)	Density (gm/cm <sup>3</sup> )	Water Content (%)
	2 hours soak	24 hours soak	2 hours soak	24 hours soak					
1	35.56	95.34	16.68	46.01	14.91	1359	0.33	841.61	9.09
2	54.67	73.37	15.07	42.06	16.10	1604	0.52	793.14	9.24
3	24.76	73.15	14.97	42.23	16.03	1476	0.68	792.45	8.81
Average ( $\bar{X}$ )	38.33	80.62	15.57	43.61	15.68	1480	0.51	809.07	9.05
standard	<=12		-		-	1800	0.30	0.90-0.40	13-5

#### ACKNOWLEDGMENT

This work has been done exceptional thanks to committee of Kasetsart University, Bangkok Thailand and Kasetsart Kamphaeng Saen University, Thailand. Without their guidance and support, this study would not have taken its current form, nor would it have come to completion. Foremost, I would also like to thank the people in Faculty of Agriculture and Department of Agriculture Engineering Faculty of Engineering for their support. Also I would like to thanks to Assoc. Prof. Dr. Sombat Chinawong, Assoc. Prof. Wicha Montumkan and Mr.Vorrathum Oonjittichai for making some useful comments on both the concept of the evolutionary approach and a draft of the paper.

#### REFERENCES

- [1] Forest industrial organization of Thailand. 2003. **Thailand imported wood more than 5000 million baht**. Retrieved February 15, 2014 from <http://www.fio.co.th/>
- [2] Thanate P., Sakchai S. and Songkod J. 2013. Development of material for products design using grass with agricultural waste. **Journal of Industrial Education, Faculty of Industrial Education, King Mongkut's Institute of Technology Ladkrabang, Thailand**. 12(2). (May-August 2013). P. 69-76.
- [3] Rowell, R.M. 1996. **Composites from agri-based resources**. In: Falk, R.H. (Ed.). Use of Recycled Wood and Paper in Building Applications Conference, Madison, Wi, p. 217-222.
- [4] Youngqvist, J.A., Krzysik, A.M., English, B.W., Spelter, H.N., Chow, P. 1996. **Agricultural fibres for use in building components**. p. 123-134.
- [5] Rowell, R.M., Rowell, J. (Eds.). 1997. **Paper and Composites from Agro-Based Resources**. CRC Press, Inc., Madison, WI.
- [6] Hague, J., McLauchlin, A., Quinney, R. 1998. Agri-materials for panel products: A technical assessment of their viability. **32nd International Particleboard/Composite Materials, Symposium Proceedings**. p. 151-159.
- [7] Rowell, R.M. 2001. Performance driven composites from lignocellulosic resources. **COMAT 2001 Mar Del Plata Argentina 10 -12 December, International Conference on Science and Technology of Composite Materials**. p. 29-32.

- [8] Sauter, S.L. 1996. Developing composites from wheat straw. In: Wolcott, M.P. (Ed.). **30th Washington-State-University International Particleboard/Composite Materials Symposium, Pullman, Wa.** p. 197-214.
- [9] Eroglu, H., Istek, A. 2000. Medium Density Fibreboard (MDF) manufacturing from wheat straw (*Triticum Aestivum* L.). **In paper International (Apr-Jun).** p. 11 -14.
- [10] Han, G.P., Umemura, K., Zhang, M., Honda, T., Kawai, S. 2001b. Development of high-performance UF-bonded reed and wheat straw medium-density fiberboard. **Journal of Wood Science.** 47. p. 350-355.
- [11] Xing, C., Zhang, S.Y., Deng, J., Riedl, B., Cloutier, A. 2006. Medium-density fiberboard performance as affected by wood fiber acidity, bulk density, and size distribution. **Wood Sci. Technol.** 40. p. 637-646.
- [12] Halvarsson, S., Edlund, H., Norgren, M. 2009. Manufacture of non-resin wheat straw fibreboards. **Industrial Crops and Products.** 29. P. 437-445.
- [13] Halvarsson, S., Edlund, H., Norgren, M. 2010a. Manufacture of High-Performance Rice-Straw Fiberboards. **Industrial & Engineering Chemistry Research.** 49. p. 1428- 1435.
- [14] Halvarsson, S., Edlund, H., Norgren, M. 2010b. Wheat-straw as a raw material for manufacture of straw MDF. **Bioresources.** 5. p. 1215-1231.
- [15] Kobilke, H. 1989. **Untersuchungen zur Bestandesbegründung von Purgiernuß (*Jatropha curcas* L.).** Diploma thesis. University Hohenheim, Stuttgart.
- [17] Heller, J. 1992. Untersuchungen über genotypische Eigenschaften und Vermehrungs- und Anbauverfahren bei der Purgiernuß (*Jatropha curcas* L.). **[Studies on genotypic characteristics and propagation and cultivation methods for physic nuts (*Jatropha curcas* L.).]** Dr. Kovac, Hamburg.
- [18] Münch, E. 1986. **Die Purgiernuß (*Jatropha curcas* L.) - Botanik, Ökologie, Anbau.** Diploma thesis. University Hohenheim, Stuttgart.
- [19] Wiehr, E. 1930. **Beiträge zur Kenntnis der Anatomie der wichtigsten Euphorbiaceensamen unter besonderer Berücksichtigung ihrer Erkennungsmerkmale in Futtermitteln.** Ph.D. Dissertation. Mathematical-Natural Scientific Faculty, University Hamburg.
- [20] Droit, S. 1932. **Recherches sur la graine et l'huile de Purgiernuß (*Jatropha curcas* L.).** Dissertation. Université de Paris, Faculté de Pharmacie, Paris.
- [21] Gupta, R.C. 1985. Pharmacognostic studies on 'Dravanti'. **Part I *Jatropha curcas* Linn. Proc. Indian Acad. Sci. (Plant Sci.)** 94(1). p. 65-82.