BIOMASS UTILIZATION OF WASTE OIL PALM

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Othman Sulaiman holds a Doctorate degree in Timber Technology from Imperial College London (in England) and is a professor of Universiti Sains Malaysia, Malaysia. His expertise is in the area of wood science and technology on the basic properties of plant biomass. Currently, he is dean of the Institute of Postgraduate Studies, Universiti Sains Malaysia.

ABSTRACT

This presentation describes some of the collaborative research works and their findings on biomass utilization of waste oil palm between School of Industrial Technology, Universiti Sains Malaysia (USM) and Japan International Research Center for Agricultural Sciences (JIRCAS). Basically two kinds of collaborations exist between the two organizations.

The first collaboration was a continuation of work based on Memorandum of Understanding (MoU) signed in 1995 between USM and JIRCAS. This collaboration focused on the utilization of plantation timber in Malaysia. It was then continued on the chemical composition of tropical timber. The collaboration is still continuing and currently working on biomass of waste oil palm.

The research on biomass of waste oil palm focused on the manufacturing of binderless particleboard from oil palm trunk, compressed panel from oil palm trunk, and the production of particleboard of oil palm trunk with the addition of polyhydroxyalkanoates was also tried (Hashim, et al., 2012; Baskaran, et al., 2012; Hashim, et al., 2011a; Lamaming, et al., 2013).

Several preliminary trials were done using bark, leaves, fronds, mid-parts and core-parts of the trunks to manufacture experimental binderless particleboard panels. Binderless particleboard panels were made with a target density of 0.80 g/cm^3 and pressed at a temperature of 180ºC and a pressure of 12 MPa. Samples made from the core-parts and fronds had sufficient modulus of rupture and internal bond strength to meet the Japanese Industrial Standards. The internal bond strength of the mid-part panels also met the standard (Hashim, et al., 2011a). However, binderless board prepared from bark and leaves showed poor modulus of rupture and internal bond strength. Samples from the core-parts had the lowest thickness swell and water absorption but did not meet the above standard. Waste oil palm trunk has the potential to be used to manufacture binderless panel products, and further study is carried out to improve the dimensional stability of the board (Hashim, et al., 2011b). Our findings showed that the mechanical and physical properties of such experimental panels were influenced by particle geometry, temperature and chemical composition (Lamaming, et al., 2013; Hashim, et al., 2012).

Experimental compressed lumber from oil palm trunks were made using several parameters including steaming time, pressure, pressure time and temperature ranging from 2 to 4 hrs, from 5 to 12 MPa, from 20 to 60 mins and from 100 to 200ºC, respectively. Compression and recovery ratios of the specimens were determined. Based on the results, the specimens were steamed for 2 hrs before they were compressed using a pressure of 11 MPa at a temperature of 200ºC for 60 mins; they resulted in optimum conditions (Salim, et al., 2012).

The other collaboration was created by being a research counterpart in a grant from the New Energy and Industrial Technology Development Organization (NEDO) working on basic characterization of pressed sap, especially on the sugar content from old oil palm trunk during storage. Upon completion of the NEDO grant, the research work is still continuing with the fund from JIRCAS on the basic characterization of separated oil palm trunk fibers and the elucidation of sugar accumulation mechanism during storage.

The results showed that the felled oil palm trunk contains a large quantity of sap that accounts for approximately 70% of the whole trunk weight. The sugars existing in the sap increased remarkably after 30 days of storage, followed by a gradual decrease. The total sugar concentration in the sap increased from 83 to 153 mg ml^{-1}, that is comparable to that of sugar cane juice. The sugars contained in the sap were glucose, sucrose, fructose and galactose. The results indicate that old oil palm trunk could be a promising source of sugars by proper aging, and its sap can be a good feedstock for production of bioethanol (Yamada, et al., 2010).

We have also characterized the separated parenchyma and vascular bundle of oil palm trunk as functions

of storage time. The outer parts of the trunks had a larger amount of vascular bundles than the inner and middle parts. Moisture content of the samples from the inner part of the trunks was significantly higher than other parts (Mhd Ramle, et al, 2012).

Oil palm waste biomass was found to be highly potential to be utilized as a raw material in related industries. The biomass such as the trunk and the frond could be used for producing wood products. The sap from the trunk could be used as feedstock for the production of ethanol and biogas. Oil palm biomass waste is sustainable and continuously available throughout the year. Utilizing oil palm biomass will reduce the pressure on the utilization of trees from forests.

KEYWORDS

Oil palm, biomass waste, binderless particleboard, compressed oil palm panel, oil palm sap

REFERENCES

Baskaran, M., R. Hashim, N. Said, S.M. Raffi, K. Balakrishnan, K. Sudesh, O. Sulaiman, T. Arai, A. Kosugi, Y. Mori, T. Sugimoto, M. Sato, 2012. Properties of binderless particleboard from oil palm trunk with addition of polyhydroxyalkanoates. Composites Part B: Engineering 43(3):1109-1116.

Hashim, R., W.N.A.W. Nadhari, O. Sulaiman, F. Kawamura, S. Hiziroglu, M. Sato, T. Sugimoto, T.G. Seng, R. Tanaka, 2011a. Characterization of raw materials and manufactured binderless particleboard from oil palm biomass. Materials and Design 32(1):246-254.

Hashim, R., W.N.A.W. Nadhari, O. Sulaiman, M. Sato, S. Hiziroglu, F. Kawamura, T. Sugimoto, G.S. Tay, R. Tanaka, 2012. Properties of binderless particleboard panels manufactured from oil palm biomass. BioResources 7(1):1352-1365.

Hashim, R., N. Said, J. Lamaming, M. Baskaran, O. Sulaiman, M. Sato, S. Hiziroglu, T. Sugimoto, 2011b. Influence of press temperature on the properties of binderless particleboard made from oil palm trunk. Materials and Design 32(5):2520-2525.

Lamaming, J., O. Sulaiman, T. Sugimoto, R. Hashim, N. Said, M. Sato, 2013. Influence of chemical components of oil Palm On Properties Of Binderless Particleboard. Bioresources 8 (3).

Mhd Ramle, SF., O. Sulaiman, R. Hashim, T. Arai, A. Kosugi, H. Abe, Y. Murata, Y. Mori, 2012. Characterization of parenchyma and vascular bundle of oil palm trunk as function of storage. Lignocellulose1(1):33-44.

Salim, N., R. Hashim, O. Sulaiman, M. Ibrahim, M. Sato, S. Hiziroglu, 2012. Optimum manufacturing parameters for compressed lumber from oil palm (*Elaeis guineensis*) trunks: Respond surface approach. Composites Part B: Engineering 43 (3), 988-996.

Yamada, H., R. Tanaka, O. Sulaiman, R. Hashim, M.K.A. Yahya, Z.A.A. Hamid, A. Kosugi, T. Arai, Y. Murata, J. Nakajima, K. Yamamoto, S. Ohara, M.N. Mohd Yusof, W.A. Ibrahim, Y. Mori, 2010. Old oil palm trunk: A promising source of sugars for bioethanol production. Biomass and Bioenergy. 34:1608-1613.


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JIRCAS International Symposium 2013
New Direction of Sustainable Technology
Development in Asia: Changing Rural Livelihood and Japanese Advantage
www.usm.my
Venue: U Thant Hall, United Nations University, Tokyo, Japan
NOV 21 2013

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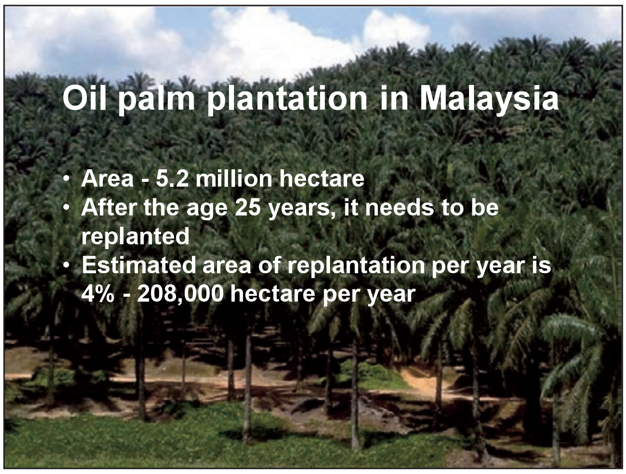
Oil palm plantation in Malaysia
• Area - 5.2 million hectare
• After the age 25 years, it needs to be replanted
• Estimated area of replantation per year is 4% - 208,000 hectare per year

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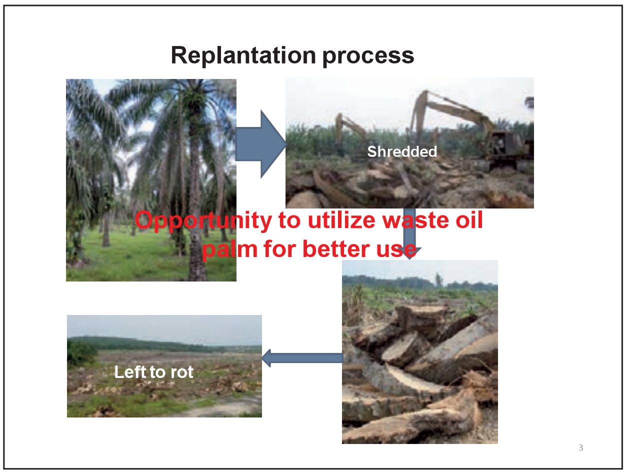
Replantation process
Shredded
Opportunity to utilize waste oil palm for better use
Left to rot

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UNIVERSITI SAINS MALAYSIA
Outline
The presentation describes some of the collaborative research works and their findings on biomass utilization of waste oil palm between School of Industrial Technology, Universiti Sains Malaysia (USM) and Japan International Research Center for Agricultural Sciences (JIRCAS)

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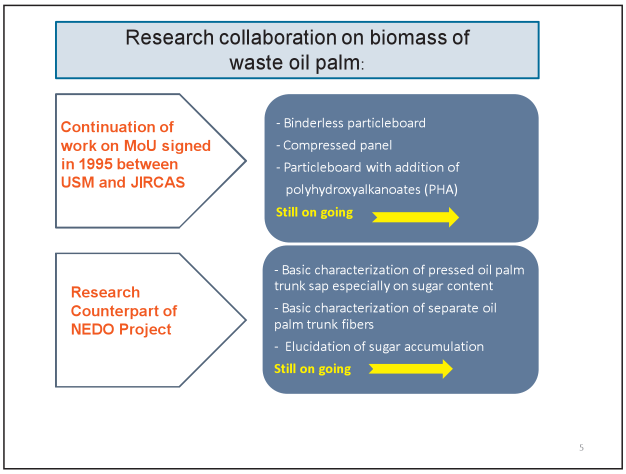
Research collaboration on biomass of waste oil palm:
Continuation of work on MoU signed in 1995 between USM and JIRCAS
- Binderless particleboard
- Compressed panel
- Particleboard with addition of polyhydroxyalkanoates (PHA)
Still on going
Research Counterpart of NEDO Project
- Basic characterization of pressed oil palm trunk sap especially on sugar content
- Basic characterization of separate oil palm trunk fibers
- Elucidation of sugar accumulation
Still on going

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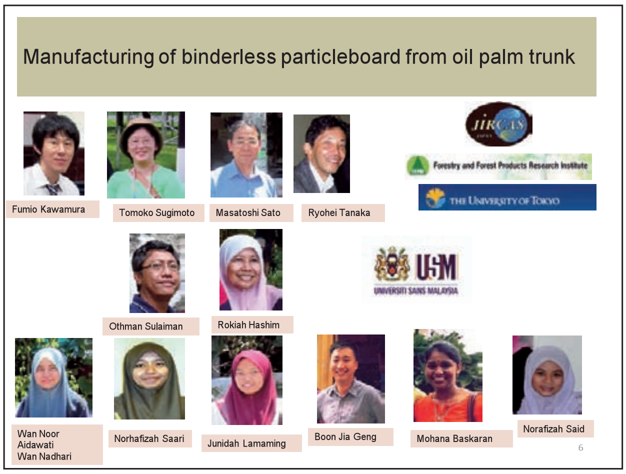
Manufacturing of binderless particleboard from oil palm trunk
Fumio Kawamura
Tomoko Sugimoto
Masatoshi Sato
Ryohei Tanaka
Forestry and Forest Products Research Institute
THE UNIVERSITY OF TOKYO
Othman Sulaiman
Rokiah Hashim
UNIVERSITI SAINS MALAYSIA
Wan Noor Aidawati Wan Nadhari
Norhafizah Saari
Junidah Lamaming
Boon Jia Geng
Mohana Baskaran
Norafizah Said

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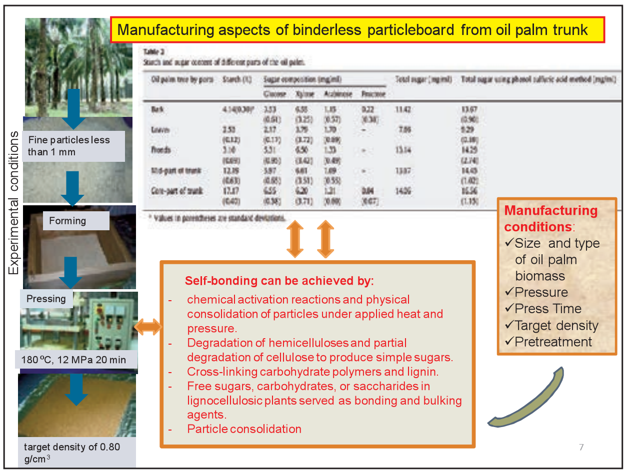
Manufacturing aspects of binderless particleboard from oil palm trunk
Experimental conditions
Fine particles less than 1 mm
Forming
Pressing
180 °C, 12 MPa 20 min
target density of 0.80 g/cm³
Manufacturing conditions:
✓Size and type of oil palm biomass
✓Pressure
✓Press Time
✓Target density
✓Pretreatment
Self-bonding can be achieved by:
- chemical activation reactions and physical consolidation of particles under applied heat and pressure.
- Degradation of hemicelluloses and partial degradation of cellulose to produce simple sugars.
- Cross-linking carbohydrate polymers and lignin.
- Free sugars, carbohydrates, or saccharides in lignocellulosic plants served as bonding and bulking agents.
- Particle consolidation

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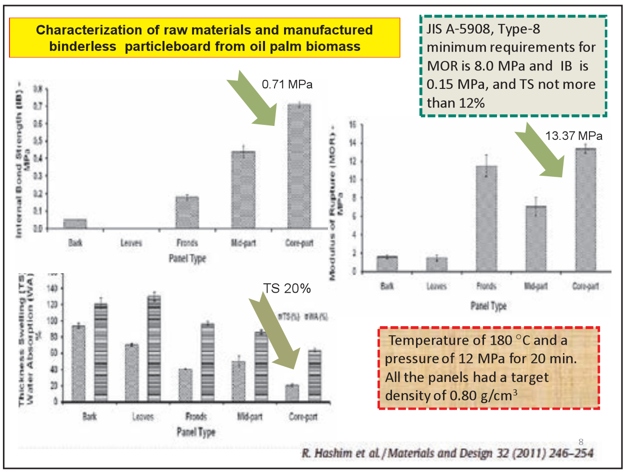
Characterization of raw materials and manufactured binderless particleboard from oil palm biomass
JIS A-5908, Type-8 minimum requirements for MOR is 8.0 MPa and IB is 0.15 MPa, and TS not more than 12%
0.71 MPa
13.37 MPa
TS 20%
Temperature of 180 °C and a pressure of 12 MPa for 20 min. All the panels had a target density of 0.80 g/cm³
R. Hashim et al. / Materials and Design 32 (2011) 246–254

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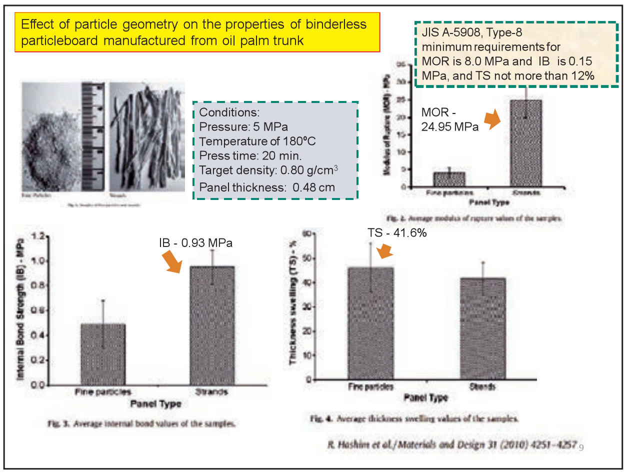
Effect of particle geometry on the properties of binderless particleboard manufactured from oil palm trunk
JIS A-5908, Type-8 minimum requirements for MOR is 8.0 MPa and IB is 0.15 MPa, and TS not more than 12%
Conditions:
Pressure: 5 MPa
Temperature of 180°C
Press time: 20 min.
Target density: 0.80 g/cm³
Panel thickness: 0.48 cm
MOR - 24.95 MPa
IB - 0.93 MPa
TS - 41.6%
R. Hashim et al. / Materials and Design 31 (2010) 4251–4257

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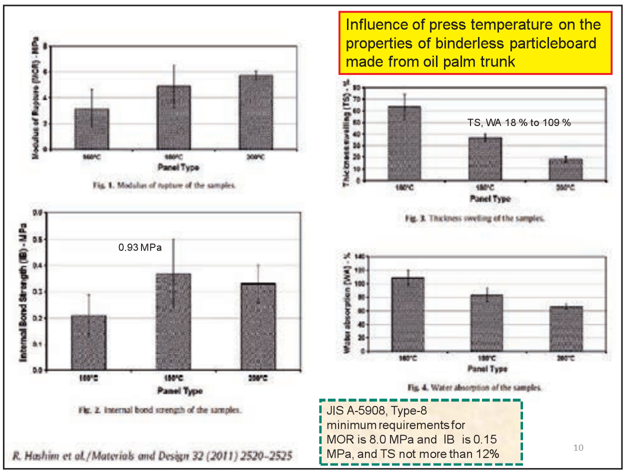
Influence of press temperature on the properties of binderless particleboard made from oil palm trunk
TS, WA 18 % to 109 %
0.93 MPa
JIS A-5908, Type-8 minimum requirements for MOR is 8.0 MPa and IB is 0.15 MPa, and TS not more than 12%
R. Hashim et al. / Materials and Design 32 (2011) 2520–2525

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Compressed lumber from oil palm trunk
Tomoko Sugimoto
Masatoshi Sato
Forestry and Forest Products Research Institute
The University of Tokyo
USM
Othman Sulaiman
Rokiah Hashim
Nurjannah Salim
Noor Afeefah Nordin

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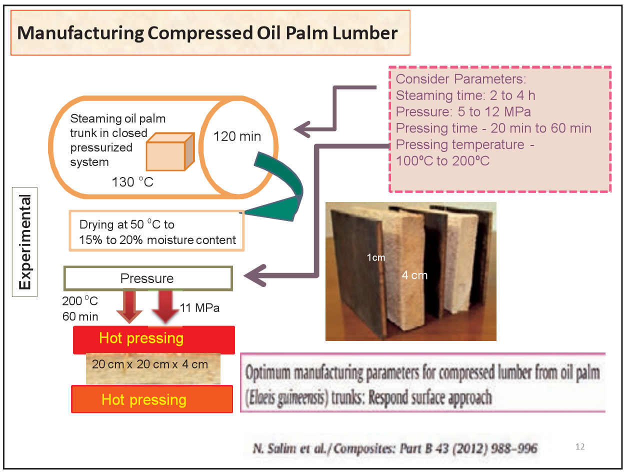
Manufacturing Compressed Oil Palm Lumber
Consider Parameters:
Steaming time: 2 to 4 h
Pressure: 5 to 12 MPa
Pressing time - 20 min to 60 min
Pressing temperature - 100°C to 200°C
Steaming oil palm trunk in closed pressurized system
120 min
130 °C
Experimental
Drying at 50 °C to 15% to 20% moisture content
Pressure
200 °C
60 min
11 MPa
Hot pressing
20 cm x 20 cm x 4 cm
Hot pressing
1cm
4 cm
Optimum manufacturing parameters for compressed lumber from oil palm (Elaeis guineensis) trunks: Respond surface approach
N. Salim et al. / Composites: Part B 43 (2012) 988–996

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Table 1. Moisture Content and Density of Compressed Oil Palm Trunk

	Moisture Content (%)	Density (g/cm³)	Compression Ratio (%)	Recovery Ratio (%)
Steamed Compressed OPT	4.31 (0.32)[a]	0.76 (0.04)	77.16 (0.87)	1.75 (0.22)
Compressed OPT	5.19 (0.09)	0.69 (0.01)	76.98 (0.56)	2.41 (0.42)
Solid OPT*	9.74	0.43	-	-
Solid Rubberwood*	9.71	0.62	-	-

[a] Value in parentheses are standard deviation   *Sulaiman *et al.* 2009

Fig. 6. Image of samples after the dynamic bending test: a) Steamed compressed OPT; b) Compressed OPT

Salim *et al.* (2013). ***BioResources*** 8(2), 2310-2324.

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Effect of Steaming on Some Properties of Compressed Oil Palm Trunk Lumber

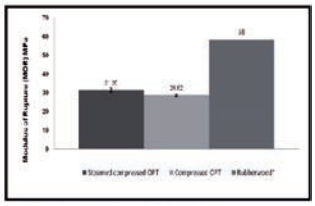

Fig. 3. Modulus of rupture of the samples (*Killmann and Lim 1985)

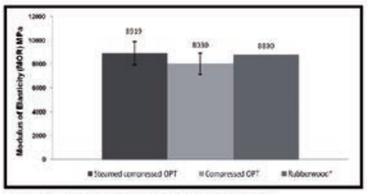

Fig. 4. Modulus of elasticity of the samples (*Killmann and Lim 1985)

Salim *et al.* (2013). ***BioResources*** 8(2), 2310-2324.

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The other collaboration was created by being a research counterpart in a grant from New Energy and Industrial Technology Development Organization (NEDO) working on basic characterization of pressed sap especially on the sugar content from old oil palm trunk during storage

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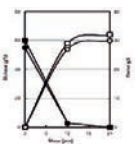
Sugar content from old oil palm trunk during storage

- The results showed that the felled oil palm trunk contains large quantity of sap, that accounts for approximately 70% of the whole trunk weight.
- The sugars existing in the sap increased remarkably after 40 days of storage, followed by the gradual decrease.
- Total sugar concentration in the sap increased from 83 mg ml-1 to 153 mg ml-1, that is comparable to that of sugar cane juice. The sugars contained in the sap were glucose, sucrose, fructose and galactose.
- The results indicate that old oil palm trunk could be a promising source of sugars by proper aging and its sap can be a good feedstock for production bioethanol (Yamada, et al., 2010).



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Basic characterization of separated oil palm trunk fibers and the elucidation of the sugar accumulation mechanism during storage

Fig. 2. Oil palm trunks samples used for experiments
a – Mixed material in different zone A (inner), B (middle) and C (outer)
b – Parenchyma, c – Vascular bundles

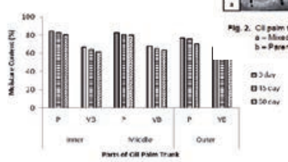

Fig. 4. Moisture content of parenchyma (P) and vascular bundle (VB) of oil palm trunk in different parts based on storage time

We have also characterized separated parenchyma and vascular bundle of oil palm trunk as function of storage time.

The outer parts of the trunks had a larger amount of vascular bundles than the inner and middle parts.

Moisture content of the samples from the inner part of the trunks was significantly higher than other parts (Mhd Ramle, et al., 2012).

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Conclusion

- Oil Palm waste biomass was found to be highly potential to be utilized as raw materials in related industry.
- The biomass such as the trunk and the frond could be used for producing wood products.
- The sap from the trunk could be used as feed stock for production of ethanol.

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Shared publications USM-JIRCAS

Binderless boards

- Saari, N., Hashim, R., Sulaiman, O., Hiziroglu, S., Sato, M., Sugimoto, T. 2014. Properties of steam treated binderless particleboard made from oil palm trunks. Composites Part B: Engineering 56():344-349.
- Boon, J.G., Hashim, R., Sulaiman, O., Hiziroglu, S., Sugimoto, T., Sato, M. 2013. Influence of processing parameters on some properties of oil palm trunk binderless particleboard. European Journal of Wood and Wood Products 71(5):583-589.
- Lamaming, J., Hashim, R., Sulaiman, O., Sugimoto, T., Sato,M., Hiziroglu, S. 2013. Measurement of some properties of binderless particleboards made from young and old oil palm trunks. Measurement. In press
- Lamaming, J., Sulaiman, O., Sugimoto, T., Hashim, R., Said, N., Sato, M. 2013. Influence of chemical components of oil palm on properties of binderless particleboard. BioResources 8(3):3358-3371.
- Nadhari, W.N.A.W., Hashim, R., Sulaiman, O., Sato, M., Sugimoto, T., Selamat, M.E. 2013. Utilization of oil palm trunk waste for manufacturing of binderless particleboard: Optimization study. BioResources 8(2):1675-1696.
- Hashim, R., Nadhari, W.N.A.W., Sulaiman, O., Sato, M., Hiziroglu, S., Kawamura, F., Sugimoto, T., Seng, T.G., Tanaka, R. 2012. Properties of binderless particleboard panels manufactured from oil palm biomass. BioResources 7(1):1352-1365.
- Hashim, R., Wan Nadhari, W.N.A., Sulaiman, O., Hiziroglu, S., Sato, M., Kawamura, F., Seng, T.G., Sugimoto, T., Tanaka, R. 2011. Evaluations of some properties of exterior particleboard made from oil palm biomass. Journal of Composite Materials 45(16):1659-1665.
- Hashim, R., Said, N., Lamaming, J., Baskaran, M., Sulaiman, O., Sato, M., Hiziroglu, S., Sugimoto, T. 2011. Influence of press temperature on the properties of binderless particleboard made from oil palm trunk. Materials and Design 32(5):2520-2525.
- Hashim, R., Nadhari, W.N.A.W., Sulaiman, O., Kawamura, F., Hiziroglu, S., Sato, M., Sugimoto, T., Seng, T.G., Tanaka, R. 2011. Characterization of raw materials and manufactured binderless particleboard from oil palm biomass. Materials and Design 32(1):246-254.
- Hashim, R., Saari, N., Sulaiman, O., Sugimoto, T., Hiziroglu, S., Sato, M., Tanaka, R. 2010. Effect of particle geometry on the properties of binderless particleboard manufactured from oil palm trunk. Materials and Design 31(9):4251-4257.

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Shared publications USM-JIRCAS

Oil palm Sap and related

- Lokesh, B.E., Hamid, Z.A.A., Arai, T., Kosugi, A., Murata, Y., Hashim, R., Sulaiman, O., Mori, Y., Sudesh, K. 2012. Potential of Oil Palm Trunk Sap as a Novel Inexpensive Renewable Carbon Feedstock for Polyhydroxyalkanoate Biosynthesis and as a Bacterial Growth Medium. Clean - Soil, Air, Water 40(3):310-317.
- Kosugi, A., Tanaka, R., Magara, K., Murata, Y., Arai, T., Sulaiman, O., Hashim, R., Hamid, Z.A.A., Yahya, M.K.A., Yusof, M.N.M., Ibrahim, W.A., Mori, Y. 2010. Ethanol and lactic acid production using sap squeezed from old oil palm trunks felled for replanting. Journal of Bioscience and Bioengineering 110(3):322-325.
- Yamada, H., Tanaka, R., Sulaiman, O., Hashim, R., Hamid, Z.A.A., Yahya, M.K.A., Kosugi, A., Arai, T., Murata, Y., Nirasawa, S., Yamamoto, K., Ohara, S., Mohd Yusof, M.N., Ibrahim, W.A., Mori, Y. 2010. Old oil palm trunk: A promising source of sugars for bioethanol production. Biomass and Bioenergy 34(11):1608-1613.
- Murata, Y., Tanaka, R., Fujimoto, K., Kosugi, A., Arai, T., Togawa, E., Takano, T., Ibrahim, W.A., Elham, P., Sulaiman, O., Hashim, R., Mori, Y. 2013. Development of sap compressing systems from oil palm trunk. Biomass and Bioenergy 51():8-16.
- Murata, Y., Tanaka, R., Fujimoto, K., Kosugi, A., Arai, T., Togawa, E., Takano, T., Ibrahim, W.A., Elham, P., Sulaiman, O., Hashim, R., Mori, Y. 2013. Development of sap compressing systems from oil palm trunk. Biomass and Bioenergy ():-.
- Rathi, D.-N., Amir, H.G., Abed, R.M.M., Kosugi, A., Arai, T., Sulaiman, O., Hashim, R., Sudesh, K. 2013. Polyhydroxyalkanoate biosynthesis and simplified polymer recovery by a novel moderately halophilic bacterium isolated from hypersaline microbial mats. Journal of Applied Microbiology 114(2):384-395.

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Shared publications USM-JIRCAS

Separated Vascular bundle and Parenchyma of OPT

- Prawitwong, P., Kosugi, A., Arai, T., Deng, L., Lee, K.C., Ibrahim, D., Murata, Y., Sulaiman, O., Hashim, R., Sudesh, K., Ibrahim, W.A.B., Saito, M., Mori, Y. 2012. Efficient ethanol production from separated parenchyma and vascular bundle of oil palm trunk. Bioresource Technology 125():37-42.
- Abe, H., Murata, Y., Kubo, S., Watanabe, K., Tanaka, R., Sulaiman, O., Hashim, R., Ramle, S.F.M., Zhang, C., Noshiro, S., Mori, Y. 2013. Estimation of the ratio of vascular bundles to parenchyma tissue in oil palm trunks using NIR spectroscopy. BioResources 8(2):1573-1581.
- Sitti Fatimah, M.R., Sulaiman, O., Hashim, R., Arai, T., Kosugi, A., Abe, H., Murata, Y., Yutaka, M. 2012. Characterization of parenchyma and vascular. Lignocellulose Journal 1(1):33-44.

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Shared publications USM-JIRCAS

Particleboard with addition of PHA

- Baskaran, M., Hashim, R., Sudesh, K., Sulaiman, O., Hiziroglu, S., Arai, T., and Kosugi, A. 2013. Influence of steam treatment on the properties of particleboard made from oil palm trunk with addition of polyhydroxyalkanoates. Industrial Crops and Products 51:334-341.
- Baskaran, M., Hashim, R., Said, N., Raffi, S.M., Balakrishnan, K., Sudesh, K., Sulaiman, O., Arai, T., Kosugi, A., Mori, Y., Sugimoto, T., Sato, M. 2012. Properties of binderless particleboard from oil palm trunk with addition of polyhydroxyalkanoates. Composites Part B: Engineering 43(3):1109-1116.

Compressed oil palm trunk lumber

Salim, N., Hashim, R., Sulaiman, O., Nordin, N.A., Ibrahim, M., Akil, H.M., Sato, M., Sugimoto, T., Hiziroglu, S. 2013. Effect of steaming on some properties of compressed oil palm trunk lumber. BioResources 8(2):2310-2324.

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Workshop
on
Technology Transfer:
Universiti Sains Malaysia(USM)-Japan International Research Center for Agricultural Sciences(JIRCAS)-The University of Tokyo(UT)
International Research Collaboration
- Binderless board and compressed lumber -

In collaboration with Malaysia Timber Industry Board(MTIB)
Jointly organized by USM and JIRCAS
Supported by FFPRI.

(27th August 2013)

Venue:
Fibre and Biocomposite Development Centre (FIDEC)
(Malaysia Timber Industry Board)
Lot 152, Jalan 4, Kompleks Perabot Olak Lempit,
42700, Banting, Selangor, Malaysia

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ACKNOWLEDGEMENT

- Japan International Research Center for Agricultural Sciences
- United Nations University

Terima kasih
Arigato

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Chair Saito: Now we invite Prof. Othman Sulaiman. He is a professor of Universiti Sains Malaysia. His expertise is in the area of wood science and technology on the basic properties of plant biomass. Currently he is the dean of the Institute of Post Graduate Studies, Universiti Sains Malaysia. His presentation today is "Biomass Utilization of Waste Oil Palm." Prof. Othman, please.

Dr. Othman Sulaiman: Thank you. Thank you very much. Before I start I would like to thank JIRCAS for inviting me to this symposium. And also I would like to thank Dr. Iwanaga and also Dr. Saito, Dr. Noda, Dr. Sugimoto, and also Dr. Yamamoto.

So today, I would like to talk on my presentation titled "Biomass Utilization of Waste Oil Palm in Malaysia." And you know oil palm plantation in Malaysia is one of the biggest plantations in Malaysia, with an area of 5.2 million hectares. And it was the largest in the world before, but now Indonesia is larger than Malaysia, I think about 8 million hectares now. So we are No. 2 in terms of plantation area.

And in terms of oil palm plantation, after the age of 25 years, it needs to be replanted, and it is estimated, the area of replantation per year is around 4 percent of the total area of oil palm plantation. So these account for around 200,000 hectares of oil palm replantation available per year.

I show you a little bit on the replantation process. The replantation process is very simple. We have old oil palm plantation here, and individual oil palm trunk will be pushed by a bulldozer and it will then fall. It doesn't need to be cut, just push, and it will fall. And normally it will be shredded in the field and the shredding was done by the bulldozer itself with the special front, and then it will be shredded here, and it will be left in the field to rot. I think it's an opportunity to utilize this waste oil palm for better use and to increase income, especially for rural people.

So my talk will be based on this perspective and also based on our research collaboration with JIRCAS and findings on biomass utilization of waste oil palm between our university, especially our school, the School of Industrial Technology, and JIRCAS.

And the research collaboration on the biomass of waste oil palm is actually a continuation of our work which was signed based on an MOU between USM and JIRCAS in 1995, and Dr. Yamamoto came to USM as our research fellow. As continuation of this research, we work on binderless particleboard and also compressed panel and also particleboard with the addition of PHA and I'll just talk about the first two, binderless board and compressed panel. And also through this USM-JIRCAS collaboration, in 2006 we became the counterpart of JIRCAS proposed NEDO project that researches on the sap of oil palm. So in our case we did on the basic characterization of pressed oil palm trunk sap, characterization of the sap, especially on the sugar content. And also basic characterization of separated oil palm trunk fiber. And the research is still ongoing in terms of elucidation of sugar accumulation based on storage, and also now we are also elucidating sugar and starch based on living oil palm tree.

So I will talk on the manufacturing of binderless particleboard that we did together with Dr. Sugimoto, Dr. Kawamura earlier, and also Prof. Sato from the University of Tokyo, and also with Dr. Tanaka. And these are all the students who are involved in our projects. So this is really a consortium of work with JIRCAS and the University of Tokyo and also with JIRCAS.

In terms of the properties of oil palm trunk, through our initial work, and after discussion and with Prof. Sato we thought it is a good opportunity and it is a good material to explore for binderless particleboard.

Binderless particleboard is a board made without any glue, so based on the basic properties, it is possible to produce board without any additional glue. So the process is very simple, but the background data is very important. So the process involves the oil palm and the raw material, we need to shred it and put it in a smaller size, placed it in mould form and press at a certain pressure and temperature and time. It produces binderless board without any glue. This is going to a be very good process because it doesn’t use any glue. Manufacture of particleboard normally use formaldehyde-based glue.

In self-bonding or binderless board the question is how the board is bonded together? One of the reasons why it is bonded together is probably because of the chemical activation reaction existing within the oil palm trunk. That’s what is unique about oil palm trunk. They have this within the oil palm trunk. If you look here, in terms of chemical content, it has a high amount of sugar and also a high amount of starch. That probably activates the bonding.

Degradation of hemicellulose and also partial degradation of cellulose probably contribute to the bonding of binderless board.

We need to consider some manufacturing conditions that are important in this manufacturing of binderless paticleboard. We need to consider pressure, press particle time, and also the target density of board, and also the size of the particle that we use.

In terms of which part of oil palm trunk, it seems that the core part is the best. The reason to this probably, oil palm trunk contains more starch and sugar in the core part.

And in terms of internal bond strength and MOR it is good, so much so that it meets JIS standard of Type-8, which is good. However, thickness swelling is not so good but the board, the strength is there.

And we also studied in terms of different particle geometry, with different sizes, one with only fiber or vascular bundle or only parenchyma. Sample using only fiber showed a higher strength, this might be attributed to higher density of the fiber compare to others. The press temperature is also important in this binderless board. The optimum temperature we found at 180˚C. Binderless board produced at 180˚C seems to be optimum however the board becomes dark because of the heat.

We also did on compressed lumber from oil palm trunk. The compressed lumber is another product produced without any glue. If you look at this, this is the original raw material. When we compress it, it will become 1 cm from the original of 4 cm. We need to consider a lot of things in terms of compressing to produce compress lumber from oil palm trunk.

In our case we did steaming in a close chamber and under pressure. We used an autoclave with a pressure of around 5 to 12 MPa, and the temperature will go to around 130˚C and after steaming the boards were dried. These are some examples, and we did apply pressure for a certain amount of time, and then we produce this board. The boards produced seem to be very good. And we characterize the sample by comparing the compressed oil palm lumber with solid oil palm trunk and also with solid rubber wood. And the properties seem to be improved. If you steam it, the strength become higher compared to non-steaming. And the properties of compressed board were found to be not much different from rubberwood. So it is possible to produce compressed lumber by pressing it.

So in another work which is supposed to be a big project that I would like to just mention here is the work that we did together with JIRCAS in the NEDO project that focuses on oil palm trunk sap. The problem in the oil palm wood industry, they tried to use oil palm as a raw material but the moisture content of the oil palm is very high that create main problem in utilizing the oil palm trunk, so we did investigate the sap in term of sugar content in the oil palm trunk.

So the results show that the felled oil palm trunk contains large quantity of sap. That accounts for about 70 percent of the whole trunk weight, meaning that more water or more sap than the wood itself. And the sugar existing in the sap can be increased if you store the trunk for a certain amount of time, around 40 days, sometimes 45 days, the sugar will increase. So the sugar content can be increased probably from 85 mg/ml to 153 mg/ml. It means at 153 mg/ml is almost the same if not higher than sugarcane.

And this can be a very big potential raw material to produce bioethanol because if you can have high sugar, definitely you can produce higher bioethanol.

The results indicate that oil palm trunk could be a promising source of sugars, by proper aging, and its sap can be a good feedstock for production of bioethanol.

And at the same time, when you get the sap, the residual leftover would be the fiber and also the parenchyma. We did characterize the separated oil palm fiber and also the parenchyma, and also elucidation of sugar accumulation, how sugar accumulates during storage. These are some of the results that we obtained.

So in conclusion, oil palm waste or biomass was found to be high potential for use as raw material in related industry, mostly in the wood industry, especially binderless board and also the compressed lumber. It can be used, and probably not for very high strength but for certain utilization it is possible, probably like packaging or siding or whatever. But for strength purposes probably we have to do more research on that.

The biomass such as the trunk and the frond could be used for producing wood products, and the sap. The problem in the wood industry in utilizing oil palm is the sap. However, the sap can actually be used as a feed stock for the production of bioethanol. At the moment, most of the bioethanol produced from sugarcane and there are a lot of issues about food security when you use food for ethanol. In this case it’s already available as a waste and you produce from the waste to produce ethanol. So the issue of food safety will be a non-issue because the amount that is available is quite substantial of about 200,000 hectares per year, and it can easily be exploited.

If you need further information of our work, we have shared publications with JIRCAS. It’s quite recent, in 2013 here, in a print journal and so on. This is all the binderless board work and these are all the oil palm sap-related projects. And these are separated bundles, and also parenchyma OPT.

We also did a workshop last February to wrap up the work with the wood product section, and also we did a workshop with industry, inviting all the industry for the workshop for the technology transfer.

The work with JIRCAS is still ongoing, especially on the elucidation of sap in the living oil palm trunk and also during storage. Study on binderless and compressed lumber is also ongoing looking at various properties characterization problems. Even though the project officially has already ended we still carry on with the research.

So I would like to thank all these persons, Dr. Iwanaga, Dr. Saito, Dr. Noda, Dr. Gotoh, Dr. Tadao Gotoh, Dr. Kosugi, Dr. Arai and all the rest of JIRCAS members who were involved in this project. Especially so to JIRCAS as a whole and also the United Nations University for a very nice place here. And thank you, *arigato-gozaimasu*.

Chair Saito: Thank you very much, Prof. Othman, for introducing our long-term partnership and important outputs.