CHARACTERIZATIONS OF MALAYSIA PALF PROPERTIES BETWEEN HAND SCRAPPING AND PALF M1

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A thesis submitted in
fulfilment of the requirement for the award of the
Degree of Master of Mechanical Engineering

Faculty of Mechanical and Manufacturing Engineering
Universiti Tun Hussein Onn Malaysia

APRIL 2016

This thesis is special dedicated to my beloved parents (Mr.Yahya&Mrs.Norizan),
siblings (Angah,Atie,Anis&Dekya), and my lovely husband (Mr.Faiz)
for their love, endless support, and encouragement.
My honourable supervisor; Prof. Dr. Yusri Yusof for
the valuable knowledge and guidance. All dearest lecturers,
colleagues, and technician for theirs assistance.
May Allah bless us all for all the kindness we have done.

ACKNOWLEDGEMENTS

Bismillahirrahmannirahim. First of all I would like to show my gratitude to Allah S.W.T. for giving a chance to me in completing this master's journey. To my supervisor, Prof. Dr. Yusri bin Yusof, it was such an honour for the trust towards my works and I am so thankful for all the motivations, guidance, and the inspirations along this arduous journey.

I would like to thank to all team mate included lecturers, technicians, and my colleagues for the valuable advices, suggestions, and encouragement that always demonstrated along these years of realisation of this works.

Besides that, a big appreciation to each person and organization which have been involved directly or in-directly in contributing ideas, knowledge, as well as financial assistance along this research. Special thanks to Ministry of Higher Education Malaysia (MOHE) and Economic Planning Unit (EPU), Science fund, MIMTECH Technology Sdn. Bhd., Malaysian Pineapple Industry Board (MPIB), and last but not least to my beloved institutions, Universiti Tun Hussein Onn Malaysia (UTHM).

Finally, I would like to express my deepest gratitude to my beloved parents, siblings, family, and my fiancé for theirs love, understanding, supports, and enthusiasm that always encouraged me to complete this precious journey.

ABSTRACT

In agricultural sector, there is an environment and technical issue during disposal process of agro waste after harvesting. Regarding to environmental and sustainability awareness, concerns on the long term effect of burning crop waste have been expressed including pineapple leaves burning. Responding to this emerging issue, there are emphases on transformation of crop waste to wealth in order to create a sustainable agriculture industry. This work presented the new technology invented named Pineapple Leaf Fibre Machine 1 (PALF M1) for pineapple leaf fibres (PALF) productions. Effects of extractions method and surface treatments towards PALF's properties are evaluated. The findings of this study confirmed that PALF M1 increased PALF's productions rate by 8 times and minimize pineapple leaves waste up to 80% compared to traditional method (hand scrapping). From the experimental results, PALF M1 yield fibre with diameter of 75.7μm and tensile strength of 322.70MPa while hand scrapping produced fibre with diameter of 90.7μm and tensile strength of 337.30MPa. Besides that, surface treatments enhanced mechanical properties of PALF extracted by both methods up to 18% from untreated PALF. Despite of reducing the environment pollution and minimizing the waste, the proposed technology involved in sustainable pineapple leaf fibres (PALF) productions also yield better fibre in terms of quality and mechanical properties.

ABSTRAK

Dalam sektor pertanian, terdapat isu alam sekitar dan isu teknikal semasa proses pembuangan sisa pertanian setelah musim menuai. Kebimbangan terhadap kesan jangka panjang pembakaran sisa tanaman termasuk pembakaran daun nanas telah diberi perhatian berikutan kesedaran terhadap kelestarian alam sekitar. Bagi menangani isu ini, penekanan diberikan dalam usaha transformasi sisa tanaman kepada sesuatu yang bernilai bagi mewujudkan industri pertanian yang mampan. Hasil kerja ini membentangkan tentang teknologi baru yang dihasilkan iaitu *Pineapple Leaf Fibre Machine 1* (PALF M1) untuk penghasilan serat daun nanas. Keberkesanan kaedah pengekstrakan dan rawatan permukaan terhadap sifat serat daun nanas telah dinilai. Hasil kajian ini membuktikan bahawa PALF M1 meningkatkan kadar pengeluaran serat daun nanas sehingga 8 kali ganda dan mengurangkan hasil buangan daun nanas sebanyak 80% berbanding kaedah tradisional (rautan tangan). PALF M1 berjaya menghasilkan serat berdiameter 75.7μm dengan kekuatan tarik 322.70MPa sementara rautan tangan menghasilkan serat berdiameter 90.7μm dengan kekuatan tarik setakat 337.30MPa. Selain daripada itu, rawatan permukaan serat daun nanas menunjukkan peningkatan yang ketara terhadap sifat mekanikal serat, iaitu sehingga 18% daripada serat yang tidak dirawat. Di samping mengurangkan pencemaran alam sekitar dan meminimumkan sisa buangan, PALF M1 juga menghasilkan serat yang lebih baik dari segi kualiti dan sifat mekanikal.

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CHAPTER 1

INTRODUCTION

1.1 Background of study

There is stimulation of looking alternatives materials to replace synthetic fibres in most industries including construction, packaging, automotive, and textile with regard to the increasing environmental consciousness as well as the greenhouse effect [1]. One of the alternatives that seem good in replacing synthetic fibres is natural fibres. Apart from being readily available, natural fibres have few advantages that no synthetic fibres can surpass those advantages [2]. Besides it can be extracted from the plants at a very low cost, they are biodegradability, reduced greenhouse effect, offer low energy consumption, low density, and provide acceptable specific strength properties.

The current development of new potential fibres is widening the areas of application. Recently, there are exceptional accomplishments of those fibres in material science field via the natural fibres development due to environmental and sustainability issues. In last decade, natural fibres have been traditionally used in textile industry domain for applications such as clothing, upholstery, and fabrics. Nowadays, due to the advent of high modulus fibres, the application of natural fibres have been extended to highly engineered materials such as automobile and structural applications [2].

In agricultural sector, there is an environment and technical issue during disposal process of agro waste after harvesting. Nowadays, there are some efforts being made worldwide in order to promote agricultural waste in a series of value-added products. Concerned on depletion of resources and global warming have urged most industries for looking naturally abundant resources [3]. There are several types of natural fibres available abundantly from both naturally and agricultural wastes included jute, pineapple leaf, bamboo, coir, rice husk, banana, and bagasse. The establishment of high-performance materials made from natural resources is a good approach towards developing sustainable agriculture sector.

Agro-based industry produced a significant amount of post-processing waste and residue in Malaysia, such as palm oil. Agro-based industry generates several types of waste. However these wastes are mostly composed of organic matter that has high potential to be converted into value added products [4]. The Third National Agricultural Policy (NAP3, 1998-2010) is introduced around 1998, giving agriculture sector a renewed role to meet one of NAP3 objectives which aimed to maximise country's income through optimal utilisation of resources [5].

The introductions of agricultural wastes as new potential fibres not only conserved energy and environment, but it also served as a basis of developing sustainable agriculture industry in Malaysia. Furthermore, it will increase the income of local farmer as well as boost economy growth. These will lead agriculture sector as the country's engine of growth which meet one of the objectives set by Ministry of Agriculture and Agro-based Industry Malaysia [6]. In Malaysia, one of the potential fibres from agricultural waste developed in Malaysia is pineapple leaf fibre (PALF).

An extensive research showed PALF have been successfully performed in textiles industry and reveal PALF immense potential in yarns productions [7, 8]. Regarding to these concerned, there are few research carried out to figure out the possibility adding values to pineapple leaves [9-11]. The discovery of PALF's potential in 'new markets' area not only proposed the solutions to environmental issues, but provided a potential for the mass consumption of these resources with applying some technologies. This work presented the new technology invented for PALF productions.

1.2 Problem statement

Recently, the concerns of sustainable development have encouraged efforts toward increasing the efficiency utilization of raw resources and reduce the waste productions. In this context, utilization of agricultural by-products as an alternatives fibre resource has been highlighted. Reuse of these wastes will lead to significant reduction of generated waste hence decreased environmental impact. Apart from that, reuse of these by-products for value-added products manufacturing will become one of an additional revenue source for farmers and developed the diversification of agricultural industry.

Due to the rapid development in agricultural sectors, there are approximately 1.2 million tonnes of agricultural waste being disposed annually in Malaysia [12]. This kind of waste is usually eliminated by burned or decomposed and lead to the arising of some environmental issues. Apart from wasting some sources of potential fibres, burning led to environmental pollution and decreased soil biological activity [13].

Pineapple is one of the most familiar tropical fruits widely cultivated around the world for its fruits. Pineapple leaves, the major part of the plant which is currently unused needs global attention for its commercial exploitation. After fruit harvesting, the leaves are disposed by burning or decomposed. Regarding to environmental and sustainability awareness, concerns on the long term effect of burning crop waste have been expressed including pineapple leaves burning. Responding to this emerging issue, there are emphases on transformation of crop waste to wealth in order to create a sustainable agriculture industry.

This study chose pineapple leaves because they are abundantly available yet rarely used and is of limited value at present compared to others agricultural wastes such as jute, bagasse, and rice husk. In pineapple cultivation, the pineapple leaves can be further processed to produce value-added products. Pineapple waste is no longer something that is unwanted. Recently, it is regarded as resources for economy development. Turning pineapple leaves into wealth not only makes good environmental sense, but also turns "trash" into "cash".

In Malaysia, several initiatives have been done in order to extract fibre from pineapple leaves and convert into commercial products. However, the process involved in pineapple leaves fibre productions is still lag behind technologies development in this era. The major issue with PALF's extraction is either labour intensive and high cost or lead to environmental pollutions [3].

PALF can be extracted physically, mechanically, and chemically and each of these methods have influences on fibre costs, yield, and final fibre quality [14]. Hand scrapping (physical method) is labour intensive and tedious process. Besides that, it only can extract PALF in small quantity which will lead to abundance of pineapple leaves waste which needs to be decomposed. As a result cause to environmental pollutions.

On the other hand, decortication machines (mechanical method) will induce high damage to PALF through breaking, scotching, and hackling actions [14]. These will produce low quality of PALF. Besides that, the existing decorticating machine mostly produced short PALF [8, 15-17]. In case of our study, we aim to produce long PALF that is more suitable for yarn and textile applications. Comprehensive studied has been done in order to develop better mechanism of PALF's extraction that will overcome all of the major issues included final fibre quality and environmental pollutions.

Regarding to these concerned, in our endeavour to develop pineapple leaf fibre diversifications, we have introduced PALF M1 for sustainable pineapple leaf fibres productions. This work presented the initial phase of larger-scale study on the innovations involved in PALF productions. Besides reducing pineapple leave wastes accumulated, this technology also yield acceptable quality of PALF produced.

1.3 Aim of the study

To study the characterization of long fibre of PALF produced from PALF M1 and hand scrapping and effects of surface treatments towards PALF's tensile properties.

1.4 Objectives

There are few objectives need to be achieved at the end of this study. All the objectives are briefly explained as followed:

a) To analyse PALF's mechanical properties extracted by traditional method and new machine; PALF M1 [18].

b) To compare properties of PALF extracted using new machine and traditional methods.

c) To investigate the effects of surface treatments towards PALF's tensile properties.

1.5 Scope of the study

In order to achieve above objectives, the following scopes for this work have been highlighted and draws as follow:

a) Pineapple leaves from *Josapine* variety is used.

b) PALF is extracted by PALF M1 and hand scrapping.

c) Sodium carbonate (Na_2CO_3) with 3% concentration is employed for alkaline treatment in this study.

d) Morphology characterizations only involved observations of PALF's surface at nano-scale by using JEOL model field emission-scanning electron microscope (FE-SEM).

e) Fibre length and fibre diameter are covered in physical properties testing.

f) Mechanical properties test only covered the fibre's tensile properties included tensile strength, Young's moduli, and strain to failure.

1.6 Significance of the study

This study is a significant endeavour in promoting PALF M1 for sustainable pineapple leaf fibre productions among pineapple's farmers especially. Besides that, this kind of work is beneficial to farmers and community in developing sustainable agriculture when they employ strategic agricultural waste management.

Moreover, this research provided solutions on how it can reduce pineapple waste, lower the cost, and conserve energy as well as environment during PALF productions. Furthermore, this study exposed the new potential fibre in replacing glass fibre and other man-mad fibre for industry applications. It also served as a future reference for researchers in related area.

1.7 Outline of the thesis

This thesis consists of five main chapters. Chapter One establishes the research's background, problem statement, objectives, scope of study, aim of study, and study's significant. Meanwhile for Chapter Two provides comprehensive and relevant review of literature regarding to study's concern. All the procedures, methodology, tools, equipment, and standard used well explained in Chapter 3. Chapter Four, discussed all the analysis of experimental data and results obtained. Finally, conclusions from research findings, present recommendations, and opportunities for future study are covered in last chapter, Chapter Five.

1.8 Summary of chapter

The development of pineapple leaf fibre is still at infancy stage. Nevertheless, due to its superior properties like high specific strength and high specific modulus, pineapple leaf fibre is now starting to gain attentions in the industry demand. Compare to glass fibre, pineapple leaf fibre offered a low cost and abundant since it is categorised as agricultural waste. Despite of developing sustainable agriculture industry, the utilization of pineapple leaf fibre reduced the impact of environmental issues and conserved energy.

This study is a preliminary stage to sustainable pineapple leaf fibre productions where focus on the improvement on scrapping method and how it affected the PALF's properties. In fact, the effect of surface treatment towards PALF is equally important. The application of PALF in replacing glass fibre is possible but requires more study and development in future.

CHAPTER 2

LITERATURE REVIEW

2.1 Introductions

The development of pineapple leaf fibre (PALF) especially in Malaysia is still at infancy stage. This might be due to the lack of disclosure of PALF potential and out-dated technology involved in PALF's productions. A comprehensive background of PALF is discussed in the following topics. All the fundamental background is included the pineapple's background, PALF's productions, PALF's properties, PALF's surface treatment, and potential used of PALF.

2.2 Pineapples background

Pineapples are one of the significant harvests, contributing about 20% of the world production of tropical fruits [19]. It takes about 70% of the pineapples are consumed as fresh fruits all over the world. It has been traced that pineapples are originates from Brazil and Paraguay. In 1493, Europeans have discovered pineapple originated in South America. Brazil and China, are among the main pineapple productions countries based on the statistics show in Table 2.1 [20].

In 2005, 32.2% of world pineapple production is contributed by an ASEAN and monopoly by Thailand and Philippines [21]. Not only in ASEAN, Thailand and Philippines is also the world's leading producer of pineapple as showed in Table 2.1.

Table 2.1 World pineapple productions [20]

Countries	Pineapple productions (Metric Tonne)									
	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Brazil	2 145 130	2 149 850	2 160 020	2 215 950	2 292 470	2 560 630	2 676 420	2 568 550	2 206 490	2 120 030
Thailand	2 078 290	1 738 830	1 899 420	2 100 980	2 183 280	2 705 180	2 815 280	2 278 160	1 894 860	1 924 660
Philippines	1 607 910	1 639 160	1 697 960	1 759 810	1 788 220	1 833 910	2 016 460	2 209 340	2 198 500	2 169 230
China	1 257 740	1 243 587	1 269 675	1 266 753	1 288 774	1 382 289	1 381 901	1 385 693	1 477 329	1 519 072
Costa Rica	950 400	992 000	984 223	1 160 000	1 605 240	1 805 000	1 547 530	1 667 530	1 682 040	1 976 760
India	950 400	1 180 000	1 310 000	1 234 200	1 278 900	1 262 600	1 362 000	1 245 000	1 341 000	1 420 000
Indonesia	494 968	555 588	677 089	709 918	925 082	1 427 780	1 395 570	1 433 130	1 558 200	1 390 380
Nigeria	925 930	889 000	945 843	1 011 880	890 000	895 000	900 000	810 832	898 376	1 052 000
Mexico	625 957	659 817	678 603	669 225	551 672	633 747	671 131	685 805	749 396	701 746
Kenya	612 248	619 860	399 103	600 000	600 000	417 860	429 065	339 850	257 623	272 231
Vietnam	284 500	373 800	383 200	414 900	470 000	572 732	519 300	482 600	460 000	477 200
Colombia	313 573	353 490	390 545	391 488	378 007	396 995	434 574	436 044	427 766	398 010
Venezuela	300 090	347 297	340 221	322 768	349 182	356 879	363 075	358 796	360 000	371 400
Malaysia	288 938	310 000	320 000	330 000	340 000	299 318	316 210	384 673	400 070	416 070
U.S.A.	293 022	290 301	272 156	199 581	192 323	170 551	172 000	180 000	200 000	170 000
Peru	150 570	156 318	164 371	177 055	203 930	234 281	212 059	243 492	274 393	310 556
Bangladesh	152 000	153 000	154 230	212 775	234 865	253 825	238 360	210 283	229 068	234 493
Congo*	192 080	193 120	194 160	195 210	195 210	196 260	197 320	193 390	199 466	200 548
Côte d'Ivoire	248 890	227 501	243 242	215 989	195 204	176 698	159 668	86 147	66 730	65 000
South Africa	167 720	176 490	160 820	164 434	180 618	166 335	160 088	144 791	122 993	92 892
Guatemala	101 287	102 299	51 923	71 785	197 096	194 423	200 404	200 444	201 447	207 800
Australia	119 618	119 328	104 743	110 417	104 022	153 015	164 732	162 000	157 679	153 000
Benin	57 147	86 700	105 910	110 819	121 182	80 055	129 287	134 966	222 223	220 800
Honduras	83 000	102 960	116 945	122 335	144 953	147 000	132 131	134 100	115 059	124 719
Ecuador	47 318	76 616	67 206	75 206	103 478	105 000	110 000	100 000	110 000	113 900
Ghana	63 798	70 105	71 637	67 000	60 000	66 000	68 000	70 000	74 715	73 700
Panama	22 179	24 152	34 424	49 771	45 628	49 805	71 002	75 907	87 849	90 600

Malaysia is one of the world's major producers besides Indonesia, Thailand, Philippines, and South Africa. Pineapple have been introduced to Malaysia by Portuguese [22]. Total area of planted pineapples at Malaysia is about 11 684 ha. with 265 680 tonnes production in 2000 [23]. Until 2012, the total area of planted pineapple is about 15,649 ha. as mentioned by Minister of Agriculture and Agro-based Industry [24].

Johor is the largest state that produced pineapple [25]. Table 2.2 showed the pineapple productions according to each state in Malaysia from year 2008 until year 2011. Besides Johor, Kelantan, Selangor, and Sarawak also are the major producing states of pineapples in Malaysia.

Table 2.2 Pineapple productions at Malaysia [25]

State / Year	Metric Tonne			
	2008	2009	2010	2011
Johor	143 963.00	75 019.00	91 939.00	80 389.22
Melaka	-	531.00	1472.00	223.88
Negeri Sembilan	330.25	7416.00	1453.00	925.51
Selangor	504.05	1284.00	887.50	2367.44
Perak	532.57	2052.00	1933.00	823.14
Pulau Pinang	681.64	3780.00	2315.00	531.16
Kedah	1121.17	9342.00	5232.00	1900.76
Perlis	-	112.00	18.50	22.76
Kelantan	8209.60	7974.00	4233.50	1153.30
Terengganu	-	5108.00	3367.00	1475.86
Pahang	768.64	2340.00	3723.00	1305.12
Sarawak	-	-	10 841.00	5839.05
TOTAL:	**156 110.92**	**114 958.00**	**127 414.50**	**96 957.20**

2.2.1 Taxonomy of pineapple

Pineapple (*Ananas comosus Merr.)* is a member of the Bromeliaceae, a large, diverse family of about 2794 species from approximately 30 cultivars of *A. comosus* [26]. Based on the current classification, there are six botanical varieties of *A. comosus* that have been identified. The six varieties are listed as follow [27]:

a) *A. comosus* var. *ananassoides* (formerly two species: *A. ananassoides* and *A. nanus*)

b) *A. comosus* var. *bracteatus* (formerly two species: *A. bracteatus* and *A. fritzmuelleri*)

c) *A. comosus* var. *comosus* (formerly *A. comosus*)

d) *A. comosus* var. *erectifolius* (formerly *A. lucidus*)

e) *A. comosus* var. *parguazensis* (formerly *A. parguazensis*)

f) *A. macrodontes* (formerly *Psuedananas sagenarius*)

In Malaysia, there are three main cultivars of pineapple mostly planted [28]. They are *Cayenne*, *Spanish*, and *Queen*. Each of these cultivars comprised of varieties as summarized in Figure 2.1.

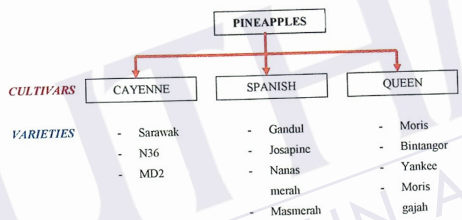

Figure 2.1 Cultivars and varieties of pineapples at Malaysia

2.2.2 Commercial uses of pineapple

Usually, pineapples are cultivated predominantly for its fruit that consumed either fresh or canned. Pineapple fruit is one of the good sources of vitamins A, B1, B6 and C, copper, manganese and dietary fibre [29]. Apart from that, pineapple plant is one of the fibre sources. The fibre sources obtained from the pineapple plant stems and leaves can be processed into variable value added products such as cloth, textile products, and paper products. The commercial uses of pineapple can be summarized as shown in Figure 2.2.

LIST OF PUBLICATIONS

1. Yusri Yusof, Siti Asia Yahya, and Anbia Adam, *Novel Technology for Sustainable Pineapple Leaf Fibers Productions*. Procedia CIRP, 2015. 26: p. 756-760.
2. Yusri Yusof, Siti Asia Yahya, and Anbia Adam, *A New Approach for PALF Productions and Spinning System: The Role of Surface Treatments.* Journal of Advanced Agricultural Technologies, 2014. 1(2): p. 161-164.
3. Siti Asia Yahya and Yusri Yusof, *Utilization of Pineapple Leaf Fibre as Technical Fibres*. in Applied Mechanics and Materials. 2014. Trans Tech Publications.
4. Yusri Yusof and Siti Asia Yahya, *Pineapple Leaf Fibre as a New Potential Natural Fiber in Rope Making*. Advanced Materials Research, 2013. 785: p. 628-633.
5. Siti Asia Yahya and Yusri Yusof, *Comprehensive Review on the Utilization of PALF*. Advanced Materials Research, 2013. 701: p. 430-434.

REFERENCES

1. Silva, Flavio de Andrade, Chawla, Nikhilesh, and Filho, Romildo Dias de Toledo, *Tensile behavior of high performance natural (sisal) fibers.* Composites Science and Technology, 2008. 68(15-16): p. 3438-3443.
2. Feng, Loh Yueh, *The biomaterial for green composites*, in *JEC Composites Magazine*. 2010. p. 29-30.
3. Kengkhetkit, Nanthaya and Amornsakchai, Taweechai, *Utilisation of pineapple leaf waste for plastic reinforcement: 1. A novel extraction method for short pineapple leaf fiber.* Industrial Crops and Products, 2012. 40: p. 55-61.
4. (IPCC), Intergovernmental Panel on Climate Change, *IPCC Guidelines for National Greenhouse Gas Inventories*, in *Agriculture, Forestry and Other Land Use*. 2006, Intergovernmental Panel on Climate Change (IPCC): Switzerland.
5. Malaysia, Education and Research Association for Consumers, *Sustainable Agriculture in Malaysia: An Assessment*, in *Situation of Agriculture In Malaysia - A Cause For Concern*, Chamhuri Siwar and Md Amzad Hossain, Editor., Education and Research Association for Consumers: Malaysia. p. 32.
6. Malaysia, Ministry of Agriculture and Agro-based Industry, *Official Portal of Ministry of Agriculture and Agro-based Industry Malaysia* in *Objectives*. Ministry of Agriculture and Agro-based Industry Malaysia Malaysia.
7. S.K. Dey, K.K. Satapathy, *A Combined Technology Package For Extraction of Pineapple Leaf FibreAn Agrowaste, Utilization of biomass and for application in Textiles.* 2013.
8. Sunil Pardeshi, Mahamed Jafer Mirji, Vijay Goud, *Extraction of Pineapple Leaf Fiber and its Spinning: A Review*, in *Textile Review*. 2012, Saket Projects Limited: Ahmedabad.
9. Leão, A. L. , Cherian, B. M., Narine, S., Souza, S. F., Sain, M., Thomas, S., *The use of pineapple leaf fibers (PALFs) as reinforcements in composites.* 2015: p. 211-235.
10. Yuliati Indrayani, Dina Setyawati, Tsuyoshi Yoshimura, Kenji Umemura, *Mechanical and Physical Properties Ofmedium Density Fiberboard Produce*

from Renewable Biomass of Agricultural Fiber. International Journal on Advanced Science Engineering Information Technology, 2013. 3.

11. Wan Mohd Aznan bin Wan Ahamad, Zainuddin bin Zakaria@Zahari, *Pineapple Leaf Fibre (PALF): From Waste to Wealth*, in *JURUTERA*. 2013, IEM: Petaling Jaya.
12. P. Agamuthu, *Challenges and Opportunities in Agro-waste Management: An Asian Perspective*. 2009: Universiti of Malaya.
13. H.P.S. Abdul Khalil, M. Siti Alwani, A.K. Mohd Omar, *Chemical Composition, Anatomy, Lignin Distribution, and Cell Wall Structure of Malaysian Plant Waste Fibers.* Bioresources, 2006. 1(2): p. 220-232.
14. A.R. Mohamed, S.M. Sapuan , and Khalina, A., *Mechanical and Thermal Properties of Josapine Pineapple Leaf Fiber (PALF) and PALF-reinforced Vinyl Ester Composites.* Fibers and Polymers, 2014. 15(5): p. 1035-1041.
15. Ukrit, W., Sombat, T., Taweechai, A., *Remarkable improvement of failure strain of preferentially aligned short pineapple leaf fiber reinforced nitrile rubber composites with silica hybridization.* Polymer Testing, 2014. 38: p. 91-99.
16. Ukrit, W., Sombat, T., Taweechai, A., *Mechanical properties of highly aligned short pineapple leaf fiber reinforced – Nitrile rubber composite: Effect of fiber content and Bonding Agent.* Polymer Testing, 2014. 35: p. 20-27.
17. Kalapakdee, Asama and Amornsakchai, Taweechai, *Mechanical properties of preferentially aligned short pineapple leaf fiber reinforced thermoplastic elastomer: Effects of fiber content and matrix orientation.* Polymer Testing, 2014. 37: p. 36-44.
18. Yusri Yusof, Md Saidin Wahab, Mohammad Sukri Mustapa, Erween Abd Rahim, and Adam, Anbia, *An Apparatus for Extraction of Leaf Fibre*, Universiti Tun Hussein Onn Malaysia, Editor. 2013, PINTAS: Malaysia.
19. J. De La Cruz Medina, H.S. Garcia, *Pineapple: Post-Harvest Operations.* 2005, Instituto Technologico de Veracruz.
20. FAOSTAT, The Statistical Division of. 2010, Food and Agriculture Organization of the United Nations (FAO).

21. Ahmad, Izham and Chua, PC. *Trends in production and trade of tropical fruits in Asean countries*. in *IV International Symposium on Tropical and Subtropical Fruits 975*. 2008.
22. Nordin, A.O.A. Farimin and E., *Physical Properties of Powdered Roselle Pineapple Juice Effects of Maltodextrin*, in *National Conference on Postgraduate Research (NCON-PGR)*. 2009.
23. Othman, Asna Booty, *Technical Document for Market Access on Pineapple (Ananas comosus)*, Crop Potection and Plant Quarantine Services Division Department of Agriculture, Editor. 2004, Ministry of Agriculture and Agro-based Industry Malaysia: Kuala Lumpur, Malaysia.
24. Bernama. *Industri nanas negara ada potensi.* in *Sinar Harian*. [cited 30 August 2013]; Malaysia.
25. MPIB, *Maklumat Industri Nanas*, in *Pengeluaran Buah Nanas Mengikut Negeri*. 2011, Malaysian Pineapple Industry Board: Malaysia.
26. *The Pineapple; botany, production, and uses* in *The Pineapple; botany, production, and uses* D.P. Bartholomew, Paull, R.E., Rohrbach, K.G., Editor. 2003, CABI Publishing: Wallingford, U.K. p. 1-301.
27. Geo Coppens d'Eeckenburugge, Freddy Leal, *Morphology, Anatomy, and Taxonomy*, in *The Pineapple: Botany, Production, and Uses*, R.E. Paull D.P Bartholomew, K.G. Rohrbach, Editor. 2003, CAB International: UK.
28. *Cultivar*. Malaysian Pineapple Industry Board.
29. Mateljan, George, *Healthy Weight Loss without Dieting*. 2010, Seattle George Mateljan Foundation.
30. Shah, Darshil U., *Natural fibre composites: Comprehensive Ashby-type materials selection charts.* Materials & Design, 2014. 62: p. 21-31.
31. Textiles, Ministry of, *Other Natural Fibers*, Ministry of Textiles, Editor. 2011, Government of India: India. p. 398-464.
32. Joy, P.P., *Benefits and uses of Pineapple*. 2010, Pineapple Research Station, Kerala Agricultural University Kerala, India.
33. Mwaikambo, L. Y., *Review Of The History, Properties And Application Of Plant Fibres.* African Journal of Science and Technology (AJST), 2006. 7(2): p. 120 - 133.

34. Ho, Mei-po, Wang, Hao, Lee, Joong-Hee, Ho, Chun-kit, Lau, Kin-tak, Leng, Jinsong, and Hui, David, *Critical factors on manufacturing processes of natural fibre composites.* Composites Part B: Engineering, 2012. 43(8): p. 3549-3562.

35. A.R. Mohamed, S.M. Sapuan , M. Shahjahan, A. Khalina *Characterization of pineapple leaf fibers from selected Malaysian cultivars.* Journal of Food, Agriculture & Environment, 2009. 7(1): p. 235-240.

36. Satyanarayana, K. G., Guimarães, J. L., and Wypych, F., *Studies on lignocellulosic fibers of Brazil. Part I: Source, production, morphology, properties and applications.* Composites Part A: Applied Science and Manufacturing, 2007. 38(7): p. 1694-1709.

37. Idicula, Maries, Boudenne, Abderrahim, Umadevi, L., Ibos, Laurent, Candau, Yves, and Thomas, Sabu, *Thermophysical properties of natural fibre reinforced polyester composites.* Composites Science and Technology, 2006. 66(15): p. 2719-2725.

38. Arib, R. M. N., Sapuan, S. M., Ahmad, M. M. H. M., Paridah, M. T., and Zaman, H. M. D. Khairul, *Mechanical properties of pineapple leaf fibre reinforced polypropylene composites.* Materials & Design, 2006. 27(5): p. 391-396.

39. Reddy, Narendra and Yang, Yiqi, *Biofibers from agricultural byproducts for industrial applications.* Trends in Biotechnology, 2005. 23(1): p. 22-27.

40. Mohanty, A. K., Khan, Mubarak A, Hinrichsen, G, *Surface Modification of Jute and its Influence on Performance of Biodegradable jute-Fabric/Biopolymer Composites. Composites Science Technology.* Composites Science and Technology, 2000. 60(7): p. 1115-1124.

41. Ahsik, Ahmad, *Pineapple Leaf Fibre* 2013: Muzium Nanas, Pontian, Johor.

42. John, Maya Jacob and Anandjiwala, Rajesh D., *Recent developments in chemical modification and characterization of natural fiber-reinforced composites.* Polymer Composites, 2008. 29(2): p. 187-207.

43. Shyamal Banik, Debasis Nag, Sanjoy Debnath, *Utilization of pineapple lead agro waste for extraction of fiber and the residual biomass for vermicomposting.* Indian Journal of Fibre & Textile Research, 2011. 36: p. 172-177.

44. Sapuan, S. M., Mohamed, A. R., Siregar, J. P., and Ishak, M. R., *Pineapple Leaf Fibers and PALF-Reinforced Polymer Composites*, in *Cellulose Fibers: Bio- and Nano-Polymer Composites*, Susheel Kalia, B. S. Kaith, and Inderjeet Kaur, Editors. 2011, Springer Berlin Heidelberg. p. 325-343.

45. Faruk, Omar, Bledzki, Andrzej K., Fink, Hans-Peter, and Sain, Mohini, *Biocomposites reinforced with natural fibers: 2000–2010*. Progress in Polymer Science, 2012. 37(11): p. 1552-1596.

46. Susheel, K., Kamini, T., Annamaria, C., Marjorie A., K., Caroline L., S., *Surface modification of plant fibers using environment friendly methods for their application in polymer composites, textile industry and antimicrobial activities: A review*. Journal of Environmental Chemical Engineering, 2013. 1(3): p. 97-112.

47. Ragoubi M, Bienaimé D, Molina S, George B, and A., Merlin, *Impact of corona treated hemp fibres onto mechanical properties of polypropylene composites made thereof*. Industrial Crops and Products, 2010. 9(31): p. 344.

48. Sinha E and S., Panigrahi, *Effect of plasma treatment on structure, wettability of jute fiber and flexural strength of its composite*. Journal of Composite Materials, 2009(43): p. 1791.

49. Abdul Khalil HPS and H., Ismail, *Effect of acetylation and coupling agent treatments upon biological degradation of plant fibre reinforced polyester composites*. Polymer Testing, 2000(20): p. 65-75.

50. Nayan N. H. M., Razak S. I. A., Rahman W. A. W. A., Majid R. A., *Effects of Mercerization on the Properties of Paper Produced from Malaysian Pineapple Leaf Fiber*. International Journal of Engineering & Technology, 2013. 13: p. 1-6.

51. J. P. Siregar, S.M. Sapuan, M.Z.A. Rahman, H.M.D.K. Zaman, *Effects of Alkali Treatments on the Tensile Properties of Pineapple Leaf Fiber Reinforced High Impact Polystyrene Composites*. Pertanika Journal Science & Technology, 2012. 20(2): p. 409-414.

52. Threepopnatkul, P., Kaerkitcha, N., and Athipongarporn, N., *Effect of surface treatment on performance of pineapple leaf fiber–polycarbonate composites*. Composites Part B: Engineering, 2009. 40(7): p. 628-632.

53. Sricharussin, Wimonrat, Ree-iam, Preechaya, Phanomchoeng, Wanvichit, and Poolperm, Siwapol, *Effect of enzymatic treatment on the dyeing of pineapple leaf fibres with natural dyes.* ScienceAsia, 2009. 35(1): p. 31-36.

54. Tangjuank, S., *Thermal insulation and physical properties of particleboards from pineapple leaves.* International Journal of Physical Sciences, 2011. 6(19): p. 4528-4532.

55. Rakesh Kumar, Sangeeta Obrai, Aparna Sharma, *Chemical modifications of natural fiber for composite material.* Der Chemica Sinica, 2011. 2(4): p. 219-228.

56. Mishra, S., Mohanty, A. K., Drzal, L. T., Misra, M., Parija, S., Nayak, S. K., and Tripathy, S. S., *Studies on mechanical performance of biofibre/glass reinforced polyester hybrid composites.* Composites Science and Technology, 2003. 63(10): p. 1377-1385.

57. Jayamol George, R. Janardhan, J. S. Anand, S. S. Bhagawan, Sabu Thomas, *Melt rheological behaviour of short pineapple fibre reinforced low density polyethylene composites.* Polymer, 1996. 37(24): p. 5421-5431.

58. Blue, Michele, *Methods of Extraction*, in *A Textile Life*. 2014.

59. *Pina Fibre Fact Sheet*, in *Philippine Pina Fibre Industry*, Philippine Fiber Industry Development Authority, Editor. 2013: Philippine.

60. C.M. Chan, S.S. Ch'ng, *Preliminary Study of S-Wave Velocity and Unconfined Compressive Strength of Cement- PALF Stabilised Kaolin.* International Journal of Integrated Engineering p. 27-34.

61. Kalia, S., Kaith, B.S., and Kaur, I., *Cellulose Fibers: Bio- and Nano-Polymer Composites: Green Chemistry and Technology*. 2011: Springer.

62. FIDA, Fiber Industry Development Authority;, *Pina*. 2011, Department of Agriculture Republic of Philippines: Philippines.

63. D.Paul *Extracting pineapple leaf fibre*. 1998.

64. Panyasart, K., Chaiyut, N., Amornsakchai, T., Santawitee, O. , *Effect of Surface Treatment on the Properties of Pineapple Leaf Fibers Reinforced Polyamide 6 Composites.* Energy Procedia, 2014. 56: p. 406-413.

65. Hidayat, Pratikno, *Teknologi Pemanfaatan Serat Daun Nanas Sebagai Alternatif Bahan Baku Tekstil.* Teknoin, 2008. 13(2): p. 31-35.

66. Yusri Yusof, Anbia Adam, *Review on PALF Extraction Machines for Natural Fibers.* Advance Materials Research, 2013: p. 781-784.

67. Tran, Ai Van, *Chemical analysis and pulping study of pineapple crown leaves.* Industrial Crops and Products, 2006. 24(1): p. 66-74.

68. Chin, Liew Shan, *Characterization of Natural Fibre Polymer Composites for Structural Application*, in *Fakulti Kejuruteraan Awam.* 2008, Universiti Teknologi Malaysia: UTM. p. 136.

69. A U Nair and Nachane, R P, *Comparative study of different test methods used for the measurement of physical properties of cotton.* Indian Journal of Fibre & Textile Research, 2009. 34: p. 352-358.

70. Learning, National Programme on Technology Enhanced. *E-Learning Courses from the IITS & IISC.* Fibre Length 2011 [cited 2014.

71. Ilankeeran, Prasanna Kumar, Mohite, Preetamkumar M, and Kamle, Sudhir, *Axial Tensile Testing of Single Fibres.* 2012.

72. *ASTM C1557-03 Standard Test Method for Tensile Strength and Young's Modulus of Fibers.*

73. Cherian, Bibin Mathew, Leão, Alcides Lopes, de Souza, Sivoney Ferreira, Thomas, Sabu, Pothan, Laly A., and Kottaisamy, M., *Isolation of nanocellulose from pineapple leaf fibres by steam explosion.* Carbohydrate Polymers, 2010. 81(3): p. 720-725.

74. Santos, Roni Marcos dos, Flauzino Neto, Wilson Pires, Silvério, Hudson Alves, Martins, Douglas Ferreira, Dantas, Noélio Oliveira, and Pasquini, Daniel, *Cellulose nanocrystals from pineapple leaf, a new approach for the reuse of this agro-waste.* Industrial Crops and Products, 2013. 50: p. 707-714.

75. Ikiz, Yuksel, *Fiber Length Measurement by Image Processing*, in *Fiber and Polymer Science*. 2000, North Carolina State University.

76. Mohanty, A. K., Misra, M., and Hinrichsen, G., *Biofibres, biodegradable polymers and biocomposites: An overview.* Macromolecular Materials and Engineering, 2000. 276-277(1): p. 1-24.