UNIVERSITI PUTRA MALAYSIA

PULP AND PAPER MADE FROM SELECTED AQUATIC MACROPHYTES USING WESTERN AND JAPANESE METHODS

ZARITH SOFIA BINTI HAMZAH

FP 2013 120

PULP AND PAPER MADE FROM SELECTED AQUATIC MACROPHYTES USING WESTERN AND JAPANESE METHODS

ZARITH SOFIA BINTI HAMZAH

DEPARTMENT OF AQUACULTURE

FACULTY OF AGRICULTURE

UNIVERSITI PUTRA MALAYSIA

SERDANG, SELANGOR

2013

PULP AND PAPER MADE FROM SELECTED AQUATIC MACROPHYTES USING WESTERN AND JAPANESE METHODS

ZARITH SOFIA BINTI HAMZAH

This research proposal is submitted in partial fulfillment of the requirements for the degree of Bachelor of Agriculture (Aquaculture)

DEPARTMENT OF AQUACULTURE

FACULTY OF AGRICULTURE

UNIVERSITI PUTRA MALAYSIA

SERDANG, SELANGOR

2013

CERTIFICATION OF APPROVAL

DEPARTMENT OF AQUACULTURE

FACULTY OF AGRICULTURE

UNIVERSITY PUTRA MALAYSIA

Name of student : Zarith Sofia Binti Hamzah

Matric number : 157324

Programme : Bachelor of Agriculture (Aquaculture)

Year : 2013

Name of supervisor : Assoc. Prof. Dr. Muta Harah Zakaria

Title of project : Pulp and Paper Made from Selected Aquatic Macrophytes Using Western and Japanese Methods

This is to certify that I have examined the final project report and all corrections have made as recommended by the panel examiners. This report complies with the recommended format stipulated in the AKU4999 project guidelines, Department of Aquaculture, Faculty of Agriculture, University Putra Malaysia.

Signature and official stamp of supervisor & co-supervisor:

_____ _____

Assoc. Prof. Dr. Muta Harah Zakaria
Supervisor
Date :

Prof. Dr. Japar Sidik Bujang
Co-supervisor
Date :

ACKNOWLEDGEMENT

Foremost, highest thankful to Allah for providing me patient and courage to complete this final year project.

I would like to express my sincere gratitude to my supervisor, Assoc. Prof. Dr. Muta Harah Zakaria for the continuous support of my project, for her patience, motivation, enthusiasm, and immense knowledge. Her guidance helped me in all the time of research and writing of this thesis.

Millions of thanks to my beloved parents, Hamzah Abu Bakar and Zainun Zakaria for your affection, advices, guidance, instruction and help in my project, your love is beyond any words. My beloved siblings, Farah, Jannah, Zaleha and also Mr. Mohammad Harith, may Allah always bless you all.

Thanks also to Farahin, Mariah, Aznadia, Naziruddin, Nordiah, Wan Hazma and Emmclan, I really appreciate your helps and cooperation. For lab assistants, Pn. Shafika, En. Jasni and En. Zawawi, thanks for your assistance throughout my experiments.

Lastly, thanks a lot to all my friends and others who are not mentioned here, you are really helpful and supportive. Thank you so much to all.

ABSTRACT

Six (6) species of aquatic macrophytes; *Pandanus odoratissimus*, *Nypa fruticans*, *Cyperus compressus*, *Fimbristylis miliacea*, *Rhyncospora corymbosa* and *Monochoria hastata* were selected to determine their suitability for raw material of pulp in papermaking using Western and Japanese methods. The macrophytes were examined for their fiber dimension and derived value. *Pandanus odoratissimus* was the most suitable aquatic macrophytes for raw material in papermaking based on the highest fiber length (1.49±0.04 mm), fiber lumen (5.52±0.24µm) and cell wall thickness (3.69±0.17µm). All the species were suitable for papermaking with slenderness ratio >60. Based on chemical composition, *Monochoria hastata* stem was suitable species for paper pulp with the highest value of cellulose (72.54±10.41) and <30% of lignin (22.63±7.42). Five speciesof macrophytes were used to produced paper using Western method but only two species were used to make paper using Western and Japanese methods. Paper produced from *Monochoria hastata* using Western method showed the highest breaking length which was 2377.80±0.33 m while paper from *Rhyncospora corymbosa* using Japanese method showed highest tensile strength which was 3.78±0.71 kN/m. The selected aquatic macrophytes in this present study suitable for papermaking using both Western and Japanese methods to produced moderate quality of paper.

ABSTRAK

Enam (6) spesies makrofit akuatik; *Pandanus odoratissimus*,*Nypa fruticans*, *Cyperus compressus*, *Fimbristylis miliacea*, *Rhyncospora corymbosa* dan *Monochoria hastata* telah dipilih untuk menentukan kesesuaiannya sebagai bahan mentah pulpa dalam pembuatan kertas menggunakan kaedah Barat dan Jepun. Makrofit tersebut telah diperiksa dimensi seratnya. Daun *Pandanus odoratissimus* adalah makrofit akuatik yang paling sesuai sebagai bahan mentah dalam pembuatan kertas berdasarkan serat yang paling panjang (1.49±0.04 mm), lumen serat paling lebar (5.52±0.24 μm) dan dinding sel paling tebal (3.69±0.17 μm). Semua spesies tersebut adalah sesuai untuk pembuatan kertas kerana ia mempunyai >60 nisbah kelangsingan.Berdasarkan komposisi kimia, batang *Monochoria hastata* merupakan spesies yang sesuai untuk pulpa kertas di mana ia mempunyai nilai selulosa yang paling tinggi (72.54 ±10.41 %) dan lignin <30% (22.63±7.42 %). Lima spesies makrofit digunakan untuk penghasilan kertas menggunakan kaedah Barat dan hanya dua spesies digunakan untuk penghasilan kertas dengan menggunakan kaedah Barat dan Jepun. Kertas yang dihasilkan daripada *Monochoria hastata* menggunakan kaedah Barat menunjukkan panjang pemecahan tertinggi iaitu 2377.80±0.33 m manakala kertas dari *Rhyncospora corymbosa* menggunakan kaedah Jepun menunjukkan kekuatan tegangan tertinggi iaitu 3.78 ±0.71 kN/m. Makrofit akuatik yang dipilih dalam kajian ini sesuai untuk pembuatan kertas menggunakan kedua-dua kaedah Barat dan Jepun dengan hasilan kertas yang berkualiti sederhana.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATION AND SYMBOLS

l	liter
cm	centimeter
m	meter
°C	degree Celsius
ml	milliliter
g	gram
PCA	Principle Component Analysis
µm	micrometer
g/m^2	grammage
NaOH	sodium hydroxide
H_2SO_4	sulphuric acid
%	percent
kN/m	kilonewton per meter
HNO_3	nitric acid
mm	millimeter

CHAPTER 1

INTRODUCTION

Aquatic plants or aquatic macrophytes are the plants which inhabited the wetland areas such as ponds, lakes, swamps, rivers and oceans. den Hartog and Segal (1964) defined aquatic plants as plants which are able to achieve their generative cycle when all vegetative parts are submerged or are supported by the water, or which occur normally submerged but are induced to reproduce sexually when their vegetative parts are exposed due to emersion. Cook (1990) defines aquatic macrophytes as vascular plants (ferns, fern allies, and seed bearing plants) whose photosynthetic parts are permanently or at least for several months of the year submerged in water or float on the surface of water.

Aquatic plants are commonly divided into categories according to their lifeform. According to Gerber *et al*. (2004), the aquatic plants are categorized as free-floating, floating with leaf attached, submerged with emergent broad leaved and emergent narrow leaved. The aquatic plants can also be divided into two groups either freshwater plants such as *Nelumbo nucifera* and *Monochoria hastata* or marine plants, seagrasses such as *Halophila ovalis*.

Freshwater plants have many roles in aquatic environment. They are the primary producers that can provide food for other organisms, supply oxygen through photosynthesis process, serve as habitat for small aquatic animals and function as filters which help in stabilizing the water clarity and also prevent the erosion of

the river bank. According to Kusuma *et al.* (2012), the male flowers of *Pandanus odoratissimus* are valued for their fragrance and used as hair decoration and used for kewda attar, kewda water in India.

Eventhough these aquatic plants have many benefits, but they also give negative effects to the agricultural sector especially in rice plantation area. Due to that, these aquatic plants are also refer as aquatic weeds. Aquatic weeds are plants which grow and complete their life cycle in water and cause harm to aquatic environment relative surrounding ecosystem (Lancar and Krake, 2002). Bhowmik *et al.* (2012) stated that the aquatic plants negative effect magnify in lakes and waterways by humans intensive use of natural water bodies.

Problem arises when these plants grow too much and destroy the ecosystem at certain place. As a result, the plants need to be removed from the water body mechanically or chemically. If the chemical way is used, the negative effects will become worsen. But, if the aquatic weeds are being removed manually, there must be a problem to dump them as no suitable places are available and this will create more waste. Therefore, the waste can be reduce by using them as raw material for pulp and paper production. Aquatic weeds has been used as source of raw materials for pulp and paper production such as in Indonesia (Joedodibroto *et al.,* 1983) and in India (Bhardwaj, 2005) but still not practised in Malaysia. The papers made from aquatic weeds can be used as decorative papers, bookmarks, crafts, paperbags and others in order to utilize these unwanted plants from becoming waste. According to Johnson (2010), papermaking using invasive plants

can be used as educational tools to create awareness among students zero waste concept.

Bajpai (2010) stated that pulp and paper are manufactured from wood raw materials containing cellulose fibers, recycled paper and agricultural residues. Chemical composition of plant's fiber such as cellulose, hemicellulose and lignin content can determine the possible utilisation of the selected plants in paper production. Paper strength also depends on the lignin and cellulose content of raw materials while pulp mechanical and tensile strength are directly proportional to the cellulose content (Madakadze *et al*., 1999). The combination of aquatic plants and the other fibers can enhance the paper strength as well as make different type of papers. To make the paper more interesting, the paper's colour can also be enhanced by the addition of artificial dye or natural dye such as flower petals during the papermaking process.

Based on the information above, two methods in handmade papermaking which are using both Western and Japanese methods that will be conducted in this study to diversify the paper productions instead of using the papermaking machine which is more expensive. Other than that, utilizing the undesired aquatic plants for 'Go Green' production and avoid wasting in agriculture are the main justification of this study by utilize them for papermaking other than being use as biofilter of heavy metal (Tiwari *et al*., 2007) and as a supplement fish feed (Bag *et al.*, 2012).

Therefore, the objectives of this study are :

1. To examine the physical and chemical properties of the aquatic macrophytes fibers.
2. To determine the suitable aquatic macrophytes species in papermaking.
3. To identify the suitable method between Western and Japanese for papermaking.

REFERENCES

Akpakpan, A.E., Akpabio, U.D., Ogunsile, B.O. and Eduok, U.M. (2011). Influence of cooking variables on the soda and soda-ethanol pulping of Nypa fruticans petioles. *Australian Journal of Basic and Applied Sciences, 5,* 1202-1208.

Aldaba, V.C. (1927). The structure and development of the cell wall in plants bast fibers of *Boehmeria* and *Linum*. *Am. J. Bot., 14,* 16–24.

Amidon, T. (1981). Effect of wood properties of hardwoods on Kraft paper properties. *TAPPI J., 64,* 123-126.

Anonymous (1959). The wealth of India. *The Dictionary of India Raw Materials and Industrial Products, 3,* 219-221. CSIR, New Delhi.

Ates, S., Atik, C., Ni, Y. and Gumuskaya, E. (2008). Characterization and evaluation of Paulownia elongota as a raw material for paper production. *Afr. J. Biotechnol., 7,* 4153-4158.

Awagami Factory. (2013). Papermaking proess (KOZO). www.awagami.com/awawashi/process.html. Retrieved February 19, 2013.

Bag, M.P., Mahapatra, S.C. and Rao, P.S. (2012). Aquatic weed as potential feed for Mozambique tilapia*, Oreochromis mossambicus*. *J. Aquacult Res Dev*., *3*, 154.

Bajpai, P. (2012). Brief description of the pulp and paper making process. *Biotechnology for Pulp and Paper Processing, 2,* 8-14.

Bajpai, P. (2010). *Environmentally Friendly Production of Pulp and Paper*. John Wiley & Sons, Inc., New Jersey.

Bakshi, T.S. (1964). Control of *Vossia cuspidata*. An aquatic weed of growing importance. *Span., 7*, 37-39.

Ballarpur Industries Limited (2013). Properties of paper:A to Z of paper. http://www.biltpaper.com/atoz2.asp#18. Retrieved on December 2, 2013.

Batra, S.K. (1998) Other long vegetable fibers. In Lewin, and Pearce, E.M. (Eds.), *Hand Book Of Fiber Science Technology, 4,* (p. 505-571). New York: Marcel dekker, Inc.

Bektas, I., Tutus, A. and Eronglu, H. (1999). A study of the suitability of Calabrian pine (*Pinus brutiaten*) for pulp and paper manufacture. *Turk. J. Agri., 23,* 589-599.

Bellis, M. (2013). History of papermaking: The invention of paper and the history of papermaking machinery. http://inventors.about.com/od/pstartinventions/a/papermaking.htm. Retrieved March 29, 2013.

Benazir, J.A.F., Manimekalai, V., Ravichandran, P., Suganthi, R. and Dinesh, D.C. (2010). Properties of fibers/culm strands from mat sedge-*Cyperus pangorei* Rottb. *BioResources, 5,* 951-967.

Bhardwaj, K.R. (1989). Chemical constituents and pulping study of *Salvinia molesta* Mitchell. *Indian Fern Journal, 5,* 18-22.

Bhardwaj, K.R. (2005). Potential use of an aquatic weed, *Salvinia molesta*, in paper industry. *Bulletine of the National Institute of Ecology, 15*, 145-151.

Bhowmik, S., Datta, B.D. and Saha, A.K. (2012). Determination of mineral content and heavy metal content of some traditionally important aquatic plants of Tripura, India using atomic absorption spectroscopy. *Journal of Agr. Tech., 4,* 1467-1476.

Brindha, D., Vinodhini, S. and Alarmelumangai, K. (2012). Fiber dimension and chemical contents of fiber from *Passiflora foetida*, L. and their suitability in paper production. *Science Research Reporter, 2,* 210-219.

Brindha, D., Vinodhini, S. and Alarmelumangai, K. (2013). Extraction and characterization of fiber from three plant species of the genus *Cleome*, L. *Asian J. Exp. Biol. Sci., 4*, 69-73.

Byrd, M. and Gratzl, J. (1998). Nonwood fibers offer opportunities and challenges. *Paper Age, 14,* 20-22.

Casey, J.P. (1966). *Pulp and Paper*. New York: Interscience Publishers.

Chandra, M. (1998). Use of Non Wood Plant Fibers for Pulp and Paper Industry in Asia : Potential in China. Virginia Polytechnic Institute and State University, Virginia.

Cook, C.D.K. (1990). Aquatic Plant Book. The Hague: SPB Academic Publishing.

Cronk, J.K. and Fennessy, M.S. (2001). *Wetland Plants, Biology and Ecology*. USA: Lewis Publisher.

Daud, Z., Hatta, M.Z.M., Kassim, A.S.M., Awang, S. and Aripin, A.M. (2013). Analysis the chemical composition and fiber morphology structure of corn stalk. *Australian Journal of Basic and Applied Sciences, 7,* 401-405.

den Hartog, C. and Segal, S. (1963). A new classification of the water-plant communities. *Acta Botanica Neerlandica, 13*, 367-93.

Deniz, I. and Ates, S. (2002). Determination of optimum kraft pulping conditions using bamboo (Pyllotachys bambusoides). *Second National Black Sea Forestry Congress Proceedings (p. 1072-1084).* Artvin, Turkey.

Dutt, D., Upadhyaya, J.S., Singh, B. and Tyagi, C.H. (2009). Studies on *Hibiscus cannibus* and *Hibiscus sabdariff* as an alternative pulp blend for softwood: An optimization of kraft delignification process. *Ind. Crops Prod., 29,* 16-26.

Ekhuemelo, D.O., Oluwalana, S.A. and Adetogun, A.C. (2013). Potential of agricultural waste and grasses in pulp and papermaking. *Journal of Research in Forestry, Wildlife and Environment, 4,* 1-15.

Elzaki, O.T., Khider, T.O. and Omer, S.H. (2012). Pulp and papermaking characteristics of *Cajanus cajan* stems from Sudan. *American-Eurasian J. Agric. & Environ. Sci., 12,* 159-163.

Enayati, A.A., Hamzah, Y., Mirshokraie, S.A. and Molaii, M. (2009). Papermaking potential of canola stalks. *Bioresource, 4,* 245-256.

Garcia, H.J.A. (2007). *Fibras papeleras*. Spain: Edicions UPC.

Gerber, A., Cillers, C.J., Ginkel, C.V. and Glen, R. (2004). Easy identification of aquatic plants. Natural Botanical Institute Pretoria.

Goswami, T., Kalita, D. and Rao, P.G. (2008). Utilization of certain forest weeds and agro-waste materials for pulp and paper making. In *Proceedings of Papertech* (p. 116-123), India.

Gunawardana, S.H.C.S. and Wijetunga, S. (2010). Paper production for rough use from aquatic weeds (*Limnocharis flava*) and its evaluation. In *Proceedings of the 15th International Forestry and Environment Symposium (p. 76-84). Sri Lanka*. Department of Forestry and Environmental Science.

Guntenspergen, G.R., Stearns, F. and Kadlec, J.A. (1989). Wetland vegetation. In D.A. Hammer (Eds), *Constructed Wetlands for Wastewater Treatment (p. 73-88)*. Michigan: Lewis Publishers.

Han, J.S. (1998). Properties of nonwood fibers. *Korean Society of wood and technology annual meeting (p. 3-12). North America, Atlanta: American:* Nonwood Symposium.

Haygreen, J.G. and Bowyer, J. (1996). *Forest Products and Wood Science: An Introduction Third Edition*. Ames: Iowa University Press.

Hiebert, H. (1998). *Papermaking with Garden Plants and Common Weeds*. North Adarns: Storey Publishing.

Hiromi Paper Inc. (2010). History of washi. http://www.hiromipaper.com/hpi_about_washi.htm. Retrieved on August, 31, 2013.

Hosseinpour, R.P., Fatehi, A.J., Latibari, Y.N. and Sepiddehdam, S.J. (2010). Canola straw chemimechanical pulping for pulp and paper production. *Bioresource Technology, 101,* 4193-4197.

Howard County Maryland (2013). Common aquatic plants in Howard county. http://www.howardcountymd.gov/Departments.aspx?id=2392. Retrieved on September 1, 2013.

Hunsigi, G. (1989). Agricultural fibers for paper pulp. *Outlook on Agriculture, 18,* 96-103.

Hurter, R.B. (2001). Nonwood plant fiber characteristics. In *(TAPPI, 1997), Nonwood Fibers Short Course Notes* (p. 1-4). Hurter Consult Incorporated: Canada.

Hurter, R.W. and Riccio, F.A. (1998). Why CEO's don't want to hear about non-wood or should they? *TAPPI North America Nonwood Fiber Symposium (p.1-10). Atlanta, Georgia*: TAPPI Press.

Hurter, A.M. (1988). Utilization of annual plants and agricultural residues for the production of pulp and paper. *Proceedings of TAPPI Pulping Conference 1988. (p. 139-160) , LA, USA*: New Orleans.

India, Council of Scientific and Industrial Research. (1952). *The Wealth of India, vol. 3*. Raw materials. New Delhi: CSIR.

Industrial Studied and Survey Unit (1969). *A preliminary study on pulp and paper from bagasse.* Federal Industrial Development Authority. Malaysia.

Isenberg, I.H. (1967). *Pulp and paper microscopy*. The Institute of Paper Chemistry. Appleton, WI.

International Association of Wood Anatomist (1937). Standard terms lengths of vessel members and wood fibers. *Tropical Woods, 51,* 21.

Jahan, M.S. (2003b). Future fibers of pulp mills in Bangladesh. *XII World Forestry Congress (21-28 September).* Quebec City, Canada.

Jeffrey (1940). *Plant Microtechniques.* New York: McGraw-Hill.

Jensen, C. (1995). Japanese papermaking. http://www.artpaper.com/mm5/merchant.mvc?Screen=JapanPaper. Retrieved February 11, 2013.

Joedodibroto, R., Widyanto, L.S. and Soerjani, M. (1983). Potential uses of some aquatic weeds a paper pulp. *J. Aquato Plant Manage*., *21,* 29-32.

Johnson, J. (2010). Using invasive plant fibers responsibly. *Hand Papermaking Newsletter*, p. 3.

Khalil. H.P.S.A., Alwani, M.S. and Omar, A.K.M. (2006). Chemical composition, anatomy, lignin distribution, and cell wall structure of Malaysian plant waste fibers. *BioResources, 2,* 220-232.

Kirci, H., Usta, M. and Eroglu, H. (1998). Soda-air pulping of Phragmites reed. *The 5th Meeting of Pulp and Paper Industry of Balkan Countries, October 7-9.* Costanta, Mamaia, Romania.

Kusuma, R., Venkat, R.P., Bhaskar, B.N. and Venkatesh, S. (2012). Phytochemical and pharmacological studies of *Pandanus odoratissimus* Linn. *Int. J. Res. Phytochem. Pharmacol., 4,* 171-174.

Lancar, L. and Krake, K. (2002). Aquatic weeds and their management. *International Commission on Irrigation and Drainage*, 1-65.

Langeland, K.A. (2012). *Help Protect Florida's Natural Areas from Non-Native Invasive Plants.* Gainesville: University of Florida Institute of Food and Agricultural Sciences.

Macdonald, G.R. (1970). *Pulp and Paper Manufacture: Papermaking and Paperboard Making.* New York: McGraw Hill Book Company.

Madakadze, I.C., Radiotis, T., Li, J., Goel, K. and Smith, D.L. (1999). Kraft pulping characteristics and pulp properties of warm season grasses. *Bioresour. Technol., 69*, 75-85.

Manzanares, M., Tenorio, J.L. and Ayerbe, L. (1997). Sowing time, cultivar, plant population and application of N fertilizer on kenaf in Spain's central plateau. *Biomass Bioenerg., 12,* 263-271.

Marques, G., Rencoret, J., Gutierrez, A. and del Rio, J.C. (2010). Evaluation of the chemical composition of different non-woody plant fibers used for pulp and paper manufacturing. *The Open Agriculture Journal, 3,* 1-10.

Maureen, G. and Green, S. (2009). Paper history. *Hand papermaking Newsletter 88*, p. 4.

May, S. (2006). Aquatic and Wetland Plants. Science Online. http://www.fvhslibrary.com/Biomes/aquatic%20and%20wetland%20plants.pdf. Retrieved March 30, 2013.

McDougall, G.J., Morrison, I.M., Stewart, D., Weyers, J.D.B. and Hillman, J.R. (1993). Plant fibers: botany, chemistry and processing. *Journal of the Science of Food and Agriculture, 62*, 1-20.

Metcalfe, C.R. (1971). Anatomy of the Monocotyledons: Cyperaceae. Oxford. Clarendon.

Mitchell, D.S. (1969). The ecology of vascular hydrophytes on Lake Kariba. *Hydrobiologia, 34*, 448-464.

Moubasher, M.H., Abdel-Hafez, S.I.I, Abdel-Fattah, H.M. and Mohanram, A.M. (1982). Direct estimation of cellulose, hemicellulose and lignin. *J. Agricu. Res., 46,* 1467-1476.

Nag, B. (1976). The destruction of water hyacinth by utilization in aquatic weeds in South East Asia, In C.K. Varshney and J. Rzoska (Eds.), *Proceedings of a Regional Seminar on noxious aquatic vegetation (p. 383-385).* New Delhi: The Hague.

Nieschlag, H.J., Nelson, G.H., Wolff, J.A. and Perdue, R.E. (1960a). A search for new fiber crops, the suitability of Calabrian pine (*Pinus brutiaten*) *TAPPI J., 43,* 193.

Nieschlag, H.J., Nelson, G.H., Wolff, J.A. and Perdue, R.E. (1960b). Structural characterization of kenaf lignin differences among kenaf varieties. *Ind. Crops Prod., 15,* p. 115-122.

Ogunsile, B.O., Omotoso, M.A. and Onilude, M.A. (2006). Comparative soda pulps from the mid-rib, pseudostem and stalk of Musa paradisiacal. *J. Biol. Sci., 6,* p.1047-1052.

Philip, J. (1992). *Biosynthesis of the major crop products*. UK: John Wiley & Sons.

Pramila, T. and Saka, S. (2013). Chemical characterization of various parts of nipa palm (*Nypa fruticans*). Kyoto Japan, 1-32.

Ralph, J., MacKay, J.J., Hatfield, R.D., O'Malley, D.M., Whetten, R.W. and Sederoff, R.R. (1997). Abnormal lignin in a Loblolly Pine Mutant. *Science, 277,* 235-239.

Reddy, K.R. and DeBusk, T.A. (1987). State the art utilization of aquatic plants in water pollution control. *Wat. Sci. Tec*., *19*, 61-79.

Robert, J.C. (1996). Materials of paper. *The chemistry of paper (p. 20-24)*. United Kingdom: The Royal Society of Chemistry.

Robertson, G., Olson, J., Allen, P., Chan, B. and Seth, R. (1999). Measurement of fiber length, coarseness, and shape with the fiber quality analyzer. *TAPPI Journal, 82,* 93-98.

Robson, D. and Hague, J. (1993). The properties of straw fiber. In: Straw-a valuable raw material. *Pira International/Silsoe Research Institute Joint Conference (3, p. 19)*. Leatherhead, UK.

Rodriguez, A., Serrano, L., Moral, A. and Jimenez, L. (2008). Pulping of rice straw with high-boiling point organosolv solvents. *Biochemical Engineering Journal, 42,* 243-247.

Rottenberg, F. (2013). *Teacher's guide. Washi: Japanese Papermaking Workshop*. Robert C. Williams Paper Museum. Georgia Institute of Technology.

Rowell, R.M. (2012). *Handbook of Wood Chemistry and Wood Composites*. United State of America: CRC Press.

Saheb, N.D. and Jog, J.P. (1999). Natural fiber polymer composites: A review. *Adv. Polym. Tech., 18,* 351-363.

Samariha, A. (2011). Effect of beating value on bagasse CMP pulp fiber characteristics. *World Applied Sciences Journal, 12,* 1987-1988.

Sculthorpe, C.D. (1967). *The biology of aquatic vascular plants*. Edward Arnold, London.

Schweingrubber, F.H., Ernst, A.B. and Schulze, D. (2013). Significance of stem features: the stabilization system. *Atlas of Stem Anatomy in Herbs, Shrubs and Trees Volume* 2 (p. 336). New York: Springer Heidelberg.

Shakhes, J., Rezayati-Charani, P. and Zeinaly, F. (2010). Evaluation of harvesting time effects and cultivars of kenaf on papermaking. *BioResources, 5*, 1268-1280.

Sharma, M., Sharma, C.L. and Kumar, Y.B. (2013). Evaluation of fiber characteristics in some weeds of Arunachal Pradesh, India for pulp and papermaking. *Research Journal of Agriculture and Forestry Sciences, 1,* 15-21.

Shelmati, R.M., Ibrahim, A., Ishak, A., Alaine, D. and Hanieh, K. (2012). Extraction of cellulose nanocrystals from mengkuang leaves (*Pandanus tectorius*). *Carbohydrate Polymers, 88,* 772-779.

Silva, F.A. and Filho, R.D.T. (2013). *Sisal fiber reinforcement of durable thin walled structures- a new perspective*. CBM-CI International Workshop.

Smith, C.J. (1993). Carbohydrate chemistry. In Lea, P.J. and Leegood, R.C. (Eds.). *Plant biochemistry and molecular biology*. (p. 73-111). New York: John Wiley & Sons.

Smith, S. (1992). *Papermaking for basketry and other crafts.* North Carolina: Lark Book.

Sumaila, M., Amber, I. and Bawa, M. (2013). Effect of fiber length of the physical and mechanical properties of random oriented, non woven short banana (*Musa balblsiana*) fiber/epoxy composite. *Asian Journal of Natural and Applied Sciences, 2,* 39-49.

TAPPI (2009). Species identification of nonwood plant fibers, T 259 SP-09. *Standard Specific Interest Group,* p. 5.

TAPPI (1988). Paper testing and strength characteristics. In *TAPPI Proceedings of the 1988 Paper Preservation Symposium (p. 31-40). Washington, DC. Atlanta, G.A*: TAPPI Press.

TAPPI. (1980). Standard and Suggested Methods Technical Association of Pulp and Paper Industries, New York, 2, 14-19.

Taylor, (2007). Oriental Papermaking Fibers. http://culturalconservation.unimelb.edu.au/PapermakingFibres/summarytable.html. Retrieved on Novermber 16, 2013.

Textile Fashion Study (2012). Chemical composition of sisal fiber/ cellulosic fiber. http://textilefashionstudy.com/chemical-composition-of-sisal-fiber-cellulosic-fiber/. Retrieved on December 2, 2013.

Thomas, B.B. (1970). Effect of fibre size and shape. In Britt, K.W (Eds.), *Handbook of Pulp and Paper Technology (p. 225-226).* New York: Van Nostrand Reinhold Co.

Tiwari, S., Dixit, S. and Verma, N. (2007). An effective means of biofiltration of heavy metal contaminated water bodies using aquatic weeds *Eichhornia crassipes*. *Environmental Monitoring and Assessment, 129*, 253-256.

The free encyclopedia. (2013). http://en.wikipedia.org/wiki/Papermaking. Retrieved February 19, 2013.

Todman, T. (1992). *Tonia Todman's Paper-making Book.* Rozelle, Australia: Sally Milner Publishing.

Tsoumis, G. (1991). *Science and Technology of Wood: Structure, Properties and Utilization*. New York: Van Nonstrand Reinhold.

Tutus, A., Deniz, I. and Eroglu, H. (2004). Rice straw pulping with oxide added soda-oxygen-anthraquinone. *Pakistan J. Biol. Sci., 7,* 1350-1354.

Usta, M., Kirci, H. and Eronglu, H. (1990). Soda-oxygen pulping of corn (*Zea mays indurata* Sturt). In *TAPPI Pulping Conference Proceeding Book 1 (p. 307-312).* Toronto, Ontario, Canada.

Ververis, C., Georghiou, K., Christodoulakis, N., Santas, P. and Santas, R. (2004). Fiber dimensions, lignin and cellulose content of various plant materials and their suitability for paper production. *Industrial Crops and Products, 19*, 245-254.

Weidenmuller, R. (1980). *Papermaking: The Art and Craft of Handmade Paper*. Thorfinn International Marketing Consultants Inc. San Diago and Ralf E. Soderholm, London.

Wisconsin Paper Council. (2004). The Invention of Paper. http://www.wipapercouncil.org/invention.htm. Retrieved February 19, 2013.

Wirjahardja, S. (1976). Importance of some aquatic weeds in Rawa Pening. BIOTROP Proc. No. TP/75/161.

Wong, L., Kortschot, M.T. and Dodson, C.T.J. (1996). Effect of formation on local strain and fracture of paper. *Journal of Pulp and Paper Science, 22,* 213-219.

Wood, I.M. (1981). The utilization of field crops and crop residues for paper pulp production. *Field Crop Abstracts, 34*, 557-568.

Xu, F., Zhang, F.C., Sun, R.C. and Lu, Q. (2006). Anatomy, ultrastructure and lignin distribution in cell wall of *Caragana korshinskii*. *Ind. Crops Prod*., 24, 186-193.

Young, J.H. (1981). Fiber preparation and approach flow in pulp and paper. In Casey, J.P. (ed.), *Chemistry and Chemical Technology* (p. 572-598). New York: Interscience Publishers.