UNIVERSITI PUTRA MALAYSIA

PAPERMAKING USING JAPANESE METHOD FROM AQUATIC MACROPHYTES

EMMCLAN LAU SHENG HANN

PAPERMAKING USING JAPANESE METHOD FROM AQUATIC MACROPHYTES

EMMCLAN LAU SHENG HANN
152964

DEPARTMENT OF AQUACULTURE
FACULTY OF AGRICULTURE
UNIVERSITI PUTRA MALAYSIA
SERDANG, SELANGOR

2012

PAPERMAKING USING JAPANESE METHOD FROM AQUATIC MACROPHYTES

EMMCLAN LAU SHENG HANN
152964

This project report is submitted in partial fulfilment of the requirements for the degree of Bachelor of Agriculture (Aquaculture)

DEPARTMENT OF AQUACULTURE
FACULTY OF AGRICULTURE
UNIVERSITI PUTRA MALAYSIA
SERDANG, SELANGOR

2012

CERTIFICATION OF APPROVAL

DEPARTMENT OF AQUACULTURE

FACULTY OF AGRICULTURE

UNIVERSITI PUTRA MALAYSIA

Name of student	: Emmclan Lau Sheng Hann
Matric number	: 152964
Programme	: Bachelor of Agriculture (Aquaculture)
Year	: 2012
Name of supervisor	: Assoc. Prof. Dr. Muta Harah Zakaria
Title of project	: Papermaking using Japanese method from aquatic macrophytes.

This is to certify that I have examined the final year project report and all corrections have been made as recommended by the panel of examiners. This report complies with the recommended format stipulated in the AKU 4999 project guidelines, Department of Aquaculture, Faculty of Agriculture, Universiti Putra Malaysia.

Signature and official stamp of supervisor:

____

Assoc. Prof. Dr. Muta Harah Zakaria

Date:

ACKNOWLEDGEMENT

This thesis has benefited greatly from the support of many people, some of whom I would sincerely like to thank here.

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

Besides my advisor, I would like to thank the Head of Department of Environmental Sciences, Prof. Madya Dr. Puziah Abdul Latif and other lectures especially to Dr. Rasmina Binti Halis from the Faculty of Forestry and Dr. Suraya Bin Mohd Tahir from Faculty of Engineering for allowing me to use the apparatus in their laboratory to run my experiments. Without their permission and support, I will not be able to accomplish my research.

I thank my fellow friends for the stimulating discussions, for the sleepless nights we were working together before deadlines, and for all the fun we have had in the last four years. I also thank the laboratory staff of Department of Agriculture, Mrs. Zaiton Basar, Ms. Norazlina Nordin, Ms. Nurul Shafika Maulad Abdul Jalil and Mr. Jasni Mohd Yusoff for their support and assistance since the start of my research.

I would like to thank to my best friend Mr. Mohd Salim Bin Mohamed from the Faculty of Science, University of Malaya for his guidance, support and all the discussion that we had. Last but not the least; I would like to thank my family especially both of my parents, Mr. Lau Fook Ming and Mrs. Katherine Lawrence for supporting me spiritually throughout my life. For any errors or inadequacies that may remain in this work, of course, the responsibility is entirely my own.

ABSTRACT

Eight (8) species of aquatic macrophytes; *Eichhornia crassipes*, *Cyperus digitatus*, *Cyperus halpan*, *Cyperus* sp., *Limnocharis flava*, *Nelumbo nucifera*, *Nymphaea* sp. and *Scirpus grossus* were explored for their usage as alternative source in papermaking. This study was conducted to determine the potential species and the suitable plant part as source in papermaking using Japanese papermaking method. The macrophytes were examined for fibre dimension and derived values for species selection. The stem part of *C. digitatus, Cyperus* sp. and *S. grossus* which have higher dry weight compared to leaf and root was used for paper production. The stem fibre was the most suitable part for papermaking compared to leaf fibre and petiole fibre. The stem of *Cyperus* sp., *C. digitatus* and *S. grossus* have highest slenderness ratio value of more than 60 which are 113.46, 105.54 and 99.05 respectively. The three selected macrophytes have unsatisfactory flexibility coefficient (<50) and Runkel ratio (>1). The stems chemical composition of *C. digitatus* and *Cyperus* sp. have higher content of cellulose compared to *S. grossus* with the value of 44.82%, 44.60% and 42.13%, respectively. The lignin content was lowest in *Cyperus* sp. which was 10.63% followed by *C. digitatus* (11.81%). and *S. grossus* (11.44%) The paper produced from *C. digitatus* has the highest value of tensile strength and breaking length of 2.61 kN/m and1.20, km respectively. The stems of the three selected macrophytes were suitable to produce moderate quality of paper using the Japanese papermaking method.

ABSTRAK

Lapan (8) spesis makrofit akuatik; *Eichhornia crassipes*, *Cyperus digitatus*, *Cyperus halpan*, *Cyperus* sp., *Limnocharis flava*, *Nelumbo nucifera*, *Nymphaea* sp. dan *Scirpus grossus* telah diterokai penggunaanya sebagai sumber alternatif dalam penghasilan kertas. Kajian ini telah dijalankan untuk menentukan potensi spesis dan bahagian tumbuhan yang sesuai sebagai sumber penghasilan kertas mengunakan pembuatan kertas kaedah Jepun. Bahagian batang *C. digitatus*, *Cyperus* sp. dan *S. grossus* yang mempunyai berat kering yang tinggi berbanding daun dan akar telah digunakan untuk menghasilkan kertas. Fiber daripada batang adalah lebih sesuai untuk penghasilan kertas berbanding daun dan tangkai. Fiber daripada batang *Cyperus* sp., *C. digitatus*. dan *S. grossus* mempunyai nisbah kelangsingan yang tinggi iaitu 113.46, 105.54 dan 99.05. Ketiga-tiga makrofit tersebut mempunyai pekali fleksibiliti (<50) dan nisbah Runkel (>1) yang kurang memuaskan. Komposisi kimia daripada batang *C. digitatus* dan *Cyperus* sp. mempunyai kandungan selulosa yang lebih tinggi berbanding *S. grossus* dengan nilai masing-masing iaitu 44.82%, 44.60% dan 42.13%. Kandungan lignin adalah paling rendah bagi *Cyperus* sp. iaitu 10.63% berbanding *S. grossus* (11.44%) dan *C. digitatus* (11.81%). Helaian kertas yang dihasilkan dari *C. digitatus* mempunyai nilai kekuatan tegangan dan panjang pemecahan masing-masing 2.61 kN/m dan 1.20 km. Batang untuk ketiga-tiga makrofit yang dipilih adalah sesuai untuk menghasilkan kertas yang berkualiti sederhana dengan menggunakan pembuatan kertas kaedah Jepun.

TABLE OF CONTENTS

Contents	**Page**

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATION AND SYMBOLS

CO_2	carbon dioxide
NaOH	sodium hydroxide
H_2SO_4	sulphuric acid
HNO_3	nitric acid
g	gram
g/m^2	grammage
kg	kilogram
ml	millilitre
l	litre
%	percent
cm	centimetre
mm	millimetre
^oC	degree celsius
kN/m	kilonewton per metre
km	kilometre

CHAPTER 1

INTRODUCTION

Paper is one of the most important products from the forest. Indeed, almost every human activity requires paper. However, logging activities in papermaking industry have greatly destroy the nature when forest recovery does not happen in the same frequency. In 2005, Malaysia's papermaking industry has produced at over one million tons of paper (Roda and Rathi, 2006). This figure depicts that the papermaking industry in Malaysia has produced large amount of paper which require logging activities. Globally, paper consumption in 2010 is 400 million tons and this figure is expected to increase for about 25% by 2020 (WWF, 2012).

It is estimated that 8 to 10% of the total global wood production is illegally produced for domestic and international trade in 2002. Malaysia denotes 35% of illegal logging for wood production and 35% of the product has been illegally exported in 2002 (SCA and WRI, 2004). Illegal logging activities have greatly destroy the forest without proper management and inspection from the authority, and thus disturb the efforts in sustaining the forest. Comprehensive and strict guidelines are needed to ensure the mission of sustainable development can be achieved.

Presently, the issue of forest destruction has been tremendously increased in Malaysia which includes both in protected forests as well as production forests.

According to the special report by Intergovernmental Panel on Climate Change (2000), deforestation and forest degradation contribute 24% of all anthropogenic carbon emissions and 18% of all greenhouse gas emissions. Furthermore, the impact is getting more serious with elimination of forests' capacity to absorb carbon in the future (Schoene and Netto, 2005).

The shortage of conventional raw materials for pulping as well as the increasing awareness of forest destruction, some alternatives have been searched since 1980s to replace wood sources with non-wood materials (Davies, 1980; Joedodibroto *et al*., 1983; Ashori 2006). Indeed, Malaysia is currently struggling to find a new fibre source to improve the quality of recycled paper (Roda and Rathi, 2006). In highly industrialized countries, problems such as shortage of supply as well as expensive costs of wood resulted in the use of non-wood as a new alternative source in papermaking (Sabharwal and Young, 1996). Due to the limited wood resources, China has utilized the agricultural residues and non-wood plants especially straw material, bagasse and bamboo as an alternative source for pulp and paper productions (Hammett *et al.*, 2001). In addition, canola (Ekhtera *et al.*, 2009), oil palm residues (Bahari, 2010), kenaf (Shakhes *et al.* 2010) and other non-wood material can also be utilized in pulp and paper production.

Another important source of non-wood plants is aquatic macrophyte. The term aquatic weed is commonly used to refer aquatic macrophytes especially in agriculture sector. Aquatic macrophytes have some advantages such as short growth cycles, modest irrigation and fertilization requirements and low lignin content which are able to reduce energy and the need of chemicals use during pulping (Hurter and Riccio, 1998). Therefore, the alternative material for pulp to non-wood sources has become important.

According to Chambers *et al.* (2008), aquatic macrophytes can be defined as living aquatic organism that are able to undergo photosynthesis, large enough to be seen by naked eye and grow permanent or periodically submerged, floating or growing up through the water surface. The use of aquatic macrophytes as a source for papermaking is not something novel and it has been extensively discussed since 1980s and much attention has been given to the utilization of aquatic macrophytes as a fibre source (Davies, 1980; Joedodibroto *et al.*, 1983). The important characteristics that are being observed in the aquatic macrophytes are their fibre morphology and length (Davies, 1980; Joedodibroto *et al.*, 1983). In recent years, the fibres are further identified and analyzed to determine their physical, chemical and mechanical (tensile) properties and morphology. This process is important to evaluate the properties of the fibre (Reddy *et al.*, 2012).

The large areas of wetlands which occupy many species of aquatic macrophytes that can be used in the papermaking industry are available all over the world. Since Malaysia is located in the tropics and with a long shoreline, it has a large area of wetlands. According to the Wetlands International Malaysia (2012), there are currently 105 wetland sites. The main wetlands ecosystem found in Malaysia consists of mangroves, river system, and tropical peat swamp forest. The aquatic macrophytes grow well in the wetland ecosystem.

There are few species of aquatic macrophytes such as water hyacinth that has harmful effects to aquatic population and boating activity since they have very rapid growth rate under tropical condition (Joedodibroto *et al*., 1983). Therefore, these harmful plants should be manipulated in order to see their benefits in another aspect. Based on the study by Joedodibroto *et al*. (1983), in comparing to wood source, the aquatic plants have shorter life cycle and more productive in a sense of industry productivity. Reddy *et al*. (2012) stated that the management cost of the aquatic plants is also comparatively cost effective than those wood sources which require higher maintenance, manpower, and more complicated management. Moreover, the method of producing pulp from non-wood source is more environmental friendly because the production consumes less energy and applies less polluted method (Reddy *et al*., 2012).

In this study, traditional Japanese method of papermaking will be used to observe how paper can be produced from aquatic macrophytes. In relation to the above issue, it is imperative for researchers to explore and manipulate the potential of aquatic macrophytes to be utilized in such a practical and economical-effective ways. Therefore, this research aims to examine how the suitability of aquatic macrophytes or non-wood sources of pulp as paper. The objectives of this study are:

i. To investigate the potential use of aquatic macrophytes as significant resources in papermaking using Japanese method.
ii. To determine the suitable part of aquatic macrophytes for papermaking.
iii. To investigate the paper quality using the Japanese papermaking method.

REFERENCES

Akgul, M. and Tozluoglu, A. (2009). Some chemical and morphological properties of juveniles woods from beech (*Fagus orientalis* L.) and pine (*Pinus nigra* A.) plantations. *Trends in Applied Sciences Research*, ***4***, 116-125.

Ashori, A. (2006). Non-wood fibers – a potential source of raw material in papermaking. *Polymer-Plastic Technology Engineering Journal*, ***45***, 1133-1136.

Bahari, M.A.M. (2010). *Oil Palm Trunk (OPT) as an Alternative Cellulosic Material for Brown Paper Production.* Thesis Degree of Bachelor of Chemical Engineering.

Bakar, B. (2004). Invasive weed species in Malaysian agro-ecosystems: species, impacts and management. *Malaysian Journal of Science*, ***23***, 1–42.

Baker, C.A. (2000). *By His Own Labor. The Biography of Dard Hunter*. Oak Knoll Press, NewCastle.

Banik, A., Sen, M. and Sen, S.P. (1993). Methane emission from water hyacinth-infested freshwater ecosystems. *Chemosphere*, ***27***, 1539-1552.

Barrett, T. (2005). *Japanese Papermaking: Traditions, Tools, Techniques*. Floating World Editions, Warren.

Bektas, I., Tutus, A. and Eroglu, H. (1999). A study of the suitability of Calabrian pine (*Pinus Brutiaten*) for pulp and paper manufacture. *Turkey Journal of Agriculture and Forestry*, ***23***, 589-599.

Biggs, S. and Messerschumidt, D. (2005). Social responsibility in the growing handmade paper industry of Nepal. *World Development*, ***33***, 1821-1843.

Bornette, G. and Puijalon, S. (2011). Response of aquatic plants to abiotic factors: a review. *Aquatic Sciences*, ***73***, 1-14.

Byers, M. and Sturrock, J.W. (2006). The yields of leaf protein extracted by large-scale processing of various crops. *Journal of the Science of Food and Agriculture*, ***16***, 341-355.

Cappelletto, P., Mongardini, F., Barberi, B. Sannibale, M., Brizzi, M. and Pignatelli, V. (2000). Papermaking pulps from the fibrous fraction of Miscanthus x Giganteus. *Industrial Crops and Products*, ***11***, 205-210.

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

Chambers, P.A., Lacoul, P., Murphy, K.J. and Thomaz, S.M. (2008). Global diversity of aquatic macrophytes in freshwater. *Hydrobiologia*, ***595***, 9-26.

Chandra, M. (1998). *Use of Nonwood Plant Fibers for Pulp and Paper Industry in China.* Thesis Master of Forestry.

Chase, L.M. (1991). Process for Continuous Determination of Paper Strength.United States Patent. May 7, 1991. Patent Number: 5103403.

Citizendia. (2012). Washi. http://www.citizendia.org/Washi. Retrieved March 1, 2012.

Colodette, J., Gomide, J.L., Girard, R., Jaaskelainen, A-S. and Argyropoulos, D.S. (2002). Influence of pulping conditions on eucalyptus kraft pulp yield, quality, and bleachability. *TAPPI Journal*, ***1***, 14-20.

Davies, G.W. (1980). Fibre measurement of some aquatic species with a view to new sources of papermaking fibre. *Aquatic Botany*, ***8***, 381-383.

Dinwoodie, J.M. (1965). The relationship between fibre morphology and paper properties: a review of literature. *TAPPI Journal*, ***48***, 440–447.

Ekhtera, M.H., Azadfallah, M., Bahrami, M. and Mohammadi-Rovshandeh, J. (2009). Comparative study of pulp and paper properties of the canola stalks prepared by using dimethyl formamide or diethylene glycol. *BioResources*, ***4***, 214-233.

Gao, W.H., Chen, K.F., Li, J., Yang, R.D., Yang, F., Rao, G.H. and Tao, H. (2011). Effects of beating on tobacco stalk mechanical pulp. *Cellulose Chemistry and Technology*, ***46***, 277-282.

Garner, L. (2006). *The Complete Book of Papercraft*. St.Martin's Press, New York.

Goyal, G.C., Fisher, J.J., Krohn, M.J., Packood, R.E. and Olson, J.R. (1999). Variability in pulping and fiber characteristics of hybrid popular trees due to their genetic makeup, environmental factor and tree age. *TAPPI Journal*, ***82***, 141-152.

Hamaguchi, K., Misu, K. and Iwasaki, M. (1997). *The Pulping and Fiber Characterization of Papyrus and Reed Used for Water Purification of Japanese Lakes and Ponds,* Oji Paper Company Limited, Japan.

Hammett, A.L., Youngs, R.L., Sun, X. and Chandra, M. (2001). Non-wood fiber as an alternative to wood fiber in China's pulp and paper industry. *Holzforschung*, ***55***, 219-224.

Han, J.S., Mianowski, T. and Lin, Y. (1999). Validity of plant fibre length measurement - a review of fibre length measurement based on kenaf as a model. In: Sellers, T., Reichert, N.A. (Eds.), *Kenaf Properties, Processing and Products* (p. 149–167). Mississippi State University.

Han, Y-H, Enomae, T., Isogai, A, Yamamoto, H., Hasegawa, S., Song, J.J. and Jang, S-W. (2006). Traditional papermaking techniques revealed by Fibre Orientation in Historical Papers. *Studies in Conservation*, ***51***, 267-276.

Hiebert, H. (2006). *Papermaking with garden plants and common weeds*. Storey Publishing, North Adams.

Hori, H. (1991). Sheet formation and paper machines: Present state of small-scale papermaking in Japan. *Japan Pulp Paper*, ***29***, 29-37.

Horn, R.A. and Setterholm, V.C. (1990). Fibre morphology and new crops. In: Janick, J., Simon, J.E. (Eds.), *Advances in New Crops* (p. 270-275). Timber Press, Portland.

Hubbe, M.A. (2006). Bonding between cellulosic fibres in the absence and presence of dry-strength agents-A review. *Bioresources*, ***1***, 281-318.

Hubbe, M.A. (2007). Water and papermaking. *Plant Technology*, ***48***, 18-24.

Hubbe, M.A. and Bowden, C. (2009). Handmade paper, review. *Bioresources*, ***4***, 1736-1792.

Hughes, S. (1978). *Washi, the World of Japanese Paper*. Kondasha International, Tokyo.

Hunter, D. (1978). *Papermaking: The History and Technique of an Ancient Craft.* Dover Publication, Inc., New York.

Hurter, R.W. and Riccio, F.A. (1998). Why CEOS don't want to hear about nonwoods—or should they? In R.W. Hurter and F.A. Riccio (Eds.), *TAPPI Proceedings, NA Nonwood Fibre Symposium (p.1-11), Atlanta, GA, USA*: TAPPI.

Ilvessalo-Pfaffli, M-S. (1995). *Fiber Atlas: Identification of Papermaking Fibers*. Springer, New York.

Intergovernmental Panel on Climate Change. (2000). Land use, landuse change and forestry. Special report. Cambridge University Press, Cambridge, UK. http://www.grida.no/c1imate/ipcc/land_use/index.htm. Retrieved March 1, 2012.

Jahan, M.S., Chowdhury, N. and Ni, Y. (2010). Effect of different locations on the morphological, chemical, pulping and papermaking properties of *Trema orientalis* (Nalita). *Bioresource Technology*, ***101***, 1892-1898.

Jimenez, L.A., Baldovin, F.L. and Herranz, J.L.F. (1993). Evaluation of agricultural residues for paper manufacture. *TAPPI Journal*, ***76***, 169–173.

Joedodibroto, R., Widyanto, L.S. and Soerjani, M. (1983). Potential Uses of Some Aquatic Weeds as Paper Pulp. *Journal of Aquatic Plant Management*, ***21***, 29-32.

Kern, M.E. (1980). *The Complete Book of Handcrafted Paper*. Coward, McCann & Geoghegan, New York.

Kouris, M. (1996). *The Dictionary of Paper*. Tappi Press, Atlanta.

Kousar, H. and Puttaiah, E.T. (2009) Application of Trapa biniposa for the treatment of pulp and paper industry effluent. *Journal of Environmental Biology*, ***30***, 659-66.

Lee, P.F.W. and Lindstrom, T. (1989). Effects of high molecular mass anionic polymers on paper sheet formation. *Nordic Pulp Paper Research Journal*, ***4***, 61-70.

Leitner , C. (2005). *Paper Textiles.* A&C Black, London.

Lopez, F., Ariza, J., Perez, I. and Jiminez, L. (2000). Comparative study of paper sheets from olive tree wood pulp obtained by soda, sulphite or kraft pulping. *Bioresource Technology*, ***77***, 1-7.

Machida, S. and Nishikori, S. (1958). Chemical studies on wood hemicellulose. II. On the hemicellulose of ganpi bast fibers. *Bulletin of the Chemical Society of Japan*, ***31***, 1021-1024.

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

Mauseth, J.D. (1988). *Plant Anatomy*. The Benjamin/Cummings Publishing Company Inc., Calif.

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

Michel, A., Arias, R.S., Scheffler, B.E., Duke, S.O., Netherland, M. and Dayan, F.E. (2004). Somatic mutation-mediated evolution of herbicide resistance in the nonindigenous invasive plant hydrilla (*Hydrilla verticillata*). *Molecular Ecology*, ***13***, 3229–3237.

Morrison, T.A., Jung, A.G., Buxton, D.R., Hatfield, R.D. (1998). Cell wall composition of maize internodes of varying maturity. *Crop Science Journal*, ***38***, 455-460.

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

Mwaikambo, L.Y. (2006). Review of the history, properties and application of plant fibres. *African Journal of Science and Technology*, ***7***, 120-133.

National Research Institute for Cultural Properties. (2003). International Course on Conservation of Japanese Paper, Tokyo, 1-18 October 2002. http://www.tobunken.go.jp. Retrieved March 1, 2012.

Ndimele, P.E., Kumolu-Johnson, C.A. and Anetekhai, M.A. (2011). The Invasive Aquatic Macrophyte, Water Hyacinth (*Eichhornia crassipes* (Mart.) Solm-LAubach: Pontedericeae): Problems and Prospects. *Research Journal of Environmental Sciences,* ***5***, 514.

Ndukwe, N.A., Jenmi, F.O., Okiei, W.O. and Alo, B.I. (2009). Comparative study of percentage yield of pulp from various Nigerian wood species using kraft process. *Journal of Environmental Science and Technology,* ***3***, 21-25.

Ogbonnaya, C.I., Roy-Macauley, H., Nwalozie, M.C. and Annerose, D.J.M. (1997). Physical and histochemical properties of kenaf (*Hibiscus cannabinus* L.) grown under water deficit on a sandy soil. *Industrial Crops and Products*, ***7***, 9–18.

Oluwadare, A.O. and Sotannade. (2007). The relationship between fibre characteristics and pulp-sheet properties of Leucaene leucocephala (Lam.) De Wit. *Middle-East Journal of Scientific Research,* ***2***, 63-68, 2007.

Peel, J. (1999). *Paper Science and Paper Manufacture*. Angus Wilde Publiction Inc., Vancouver.

Pietzcker, E. (2012). Japanese papermaking-Kami-suki. http://www.druckstelle.info/en/papier.htm. Retrieved March 1, 2012.

Plowman, J. (1997). *The Craft of Handmade Paper. A Practical Guide to Papermaking Techniques.* Knickerbocker Press, New York.

Plummer, M.L. (2005). Impact of invasive water hyacinth (*Eichhornia crassipes*) on snail hosts of Schistosomiasis in Lake Victoria, East Africa. *EcoHealth*, ***2***, 81–86.

Reddy, K.O., Maheswari, C.U., Shukla, M. and Rajulu, A.V. (2012). Chemical composition and structural characterization of Napier grass fibres. *Material Letters, **67***, 35-38.

Robert, J.C. (1996). *Paper Chemistry*. Champion and Hall Press, London.

Roda, J.M. and Rathi, S. (2006). *Feeding China's Expanding Demand for Wood pulp: A Diagnostic Assessment of Plantation Development, Fiber Supply, and Impacts on Natural Forests in China and in the South East Asia Region. CIRAD*, Vietnam.

Sabharwal, H. S. and Young, R. A. (1996). International agro-fiber research initiative. *TAPPI Journal*, ***79***, 66-67.

Saijonkari-Pahkala, K. (2001) Non-wood plants as raw material for pulp and paper. *Agricultural and Food Science in Finland*, ***10***, 101.

Saikia, S.N., Goswami, T. and Ali, F. (1997). Evaluation of pulp and paper making characteristics of certain fast growing plants. *Wood Science and Technol*ogy, ***31***, 467–475.

Schmitz, O.J., Grabowski, J.H., Peckarsky, B.L., Preisser E.L., Trussell, G.C, and Vonesh, J.R. (2008). From Individuals to Ecosystem Function: Toward an Integration of Evolutionary and Ecosystem Ecology. *Ecology*, ***89***, 2436–2445.

Schoene, D. and Netto, M. (2005). The Kyoto Protocol: What does it mean for forests and forestry? *Unasylva*, ***222***, 3-11.

Seneca Creek Associates (SCA), LLC and Wood Resources International (WRI), LLC. (2004). *"Illegal" Logging and Global Wood Markets: The Competitive Impacts on the U.S. Wood Products Industry*. American Forest and Paper Association, Maryland.

Seth, R.S. and Page, D.H. (1988). Fibre properties and tearing resistance. *TAPPI Journal*, ***71***, 103–107.

Seth, R.S., Janturen, J.T. and Moss, C.S. (1989). The effect of grammage on sheet properties. *APPITA*, ***42***, 42-48.

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

Shen, J., Zhou, X., Wu, W. and Ma, Y. (2012). Improving paper strength by gelation of native starch and borax in the presence fibers. *Bioresources*, ***7***, 5542-5551.

Sithole, B. (2005). *New Method of Measuring the pH of Wood Chips*. Springer-verlag, Berlin.

Sreekala, M.S., Kumaran, M.G. and Thomas, S. (1997). Oil palm fibers: Morphology,chemical composition, surface modification and mechanical properties. *Journal Applied Polymer Science, **66***, 821-835.

Sunakar, P., Chandra, P.J. and Prasad, T.U. (2012). A comprehensive approach for the characterization of pulp and paper industry post oxygen stage effluent. *Research Journal of Chemical Sciences*, ***2***, 41-46.

Szabo, L., Soria, A., Forsstro, J., Keranen J.T. and Hytonen, E. (2009). A world model of the pulp and paper industry: Demand, energy consumption and emission scenarios to 2030. *Environmental Science and Policy*, ***12***, 257–269.

Tamolong, F.N., Lopez F.R., Casin R.F., Semanta J.A. and Espiloy Z.B. (1980). Properties and utilisation of Philippine bamboos. In Lessard G. and Chouminard A. (Eds.)*, Proceedings of Bamboo Research in Asia (p. 189-200), Ottawa:* IRDC.

Taori, K. (2002). *Green and Gramin: The Ecofriendly Handmade Paper Industry*. Regency Publication, New Delhi.

TAPPI. (1992). Tensile breaking strength and elongation of paper and paperboard (using pendulum-type tester)(T 404 cm-92). http://www.tappi.org/zziMIS-Data/Products/Tensile-Breaking-Strength-and-Elongation-of-Paper-and-Paperb.aspx. Retrieved July 1, 2012.

TAPPI. (2007). Solvent extractives of wood and pulp (Proposed revision of T 204 cm-97). http://www.tappi.org/content/sarg/t204.pdf. Retrieved July 1, 2012.

Thorp, B.A. and Kocurek, M.J. (1991). *Pulp and Paper Manufacture Volume 7: Paper Machine Operations, Joint Textbook Committee of the Paper Industry*. TAPPI, Canada.

Tuncturk, M., Tunturk, R., Yildirim, B. and Ciftci, V. (2011). Changes of micronutrients, dry weight and plant development in canola (*Brassica napus* L.) cultivars under salt stress. *African Journal of Biotechnology*, ***10***, 3726-3730.

Turner, S. and Skiold, B. (1983). *Handmade Paper Today: A Worldview Survey of Mills, Papers, Techniques, and Uses*. Humphries, London.

Usuda, M. (1984). The current trend of book preservation and the mechanisms of degradation of paper (in Japanese). *Japan TAPPI, **38***, 48-58.

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

Vogel, S. (1994). *Life in Moving Fluids: The Physical Biology of Flow*. Princeton University Press, Princeton.

Wetlands International Malaysia. (2012). Wetlands of Malaysia. http://malaysia.wetlands.org/OurWetlands/WetlandsofMalaysia/. Retrieved March 10, 2012.

Wilkie, A.C. and Evans, J.M. (2010) Aquatic plants: an opportunity feedstock in the age of bioenergy. *Biofuels*, ***1***, 311-321.

World Wildlife Fund (WWF) (2012). About Pulp and Paper production and use.http://wwf.panda.org/what_we_do/footprint/forestry/sustainablepulppaper/aboutpulppaperproductionuse/. Retrieved September 4, 2012.

Wu, Z. and Tanaka, H. (1998). Permanence of wood-free paper I: Paper making additives in naturally degraded wood-free papers. *Journal of Wood Science*, ***44***, 111-115.

Yamauchi, T. and Usami, N. (2005). Characteristic mechanical properties of washi papers. *Japan TAPPI Journal*, ***59***, 112–116.

Yan, H.W., Lindstrom, T. and Christiernin, M. (2006). Some ways to decrease fibre suspension flocculation and improve sheet formation. *Nordic Pulp Paper Research Journal*, ***21***, 36-43.

Yonenobu, H., Tsuchikawa, S. and Oda, H. (2003). Non-destructive near infrared spectroscopic measurement of antique washi calligraphic scrolls. *Journal of Near Infrared Spectroscopy*, ***11***, 407–411.

Zar, J.H. (1984). The normal distribution. In: Kurtz, B. (Eds.), *Biostatistical Analysis* (p.93-95). Prentice-Hall, Inc., New Jersey.

Zauscher, S. and Klingenberg, D.J. (2001). Friction between cellulose surfaces measured with colloidal probe microscopy. *Colloids Surface*, ***178***, 213-229.