COST-BENEFIT ANALYSIS OF KENAF AS BIOMATERIAL FOR AUTOMOTIVE COMPONENTS

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By

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April 2015

Chair: Professor Mohd Shahwahid bin Haji Othman, PhD
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Kenaf is known as a renewable source of material that has various industrial applications. Recognized as a cash crop, it had been brought into Malaysia and was targeted to become one of the major commodities for the country. Among myriads of application, its use as bio-material for automotive components had proved viable in many technical studies. Moreover, by replacing kenaf with conventional fossil based feedstock; it can improve automobile efficiency by weight reduction which in turns brings fuel savings and avoid corresponding CO_2 emission. Furthermore, kenaf is also known for its high carbon absorption ability relative to other plants which can aid in reducing global warming. In conjunction with national kenaf development programs, kenaf venturing into automotive industry seemed encouraging. However, to tap into the restrictive automotive industry; more insights and planning are needed. Thus, the advent of this study is targeted to reveal the feasibility of kenaf applications as bio-material for automotive components with financial and economic viewpoints.

Using cost-benefit analysis, this study has three consecutive objectives. The first is to identify the processes and procedures for kenaf as feedstock for automotive parts in Malaysia. Secondly, is to determine and estimate the relevant cost and benefits involve in the value chain identified. Third, is to assess the financial and economic feasibility of kenaf applications as bio-material for automotive components. This analysis enables the recognition and accounting of direct and indirect costs and benefits in monetary units to uncover the financial and economic feasibility of the project. As a result, the findings suggest that applying kenaf as bio-material for automotive components is generally viable financially and economically. However, looking at the four production stages identified – kenaf cultivation, fibre processing, compounded and non-woven composite sheets production, and utilisation into automobile parcel shelves; the results were mixed. The utilisation of kenaf as bio-material for automotive components can be financially and economically feasible with rising scale of production and with kenaf price reduction. The findings also suggest that more efforts are needed in improving competitiveness of kenaf and kenaf fibre production to enable its penetration to the automotive sector. In addition, policies are needed to promote utilisation of natural fibre in automotive industry.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia Sebagai memenuhi keperluan untuk Ijazah Sarjana Sains

ANALISA KOS FAEDAH UNTUK KENAF SEBAGAI BAHAN-BIO KOMPONEN AUTOMOTIF

Oleh

ONG CHU LEE

April, 2015

Pengerusi: Professor Mohd Shahwahid bin Haji Othman, PhD
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Kenaf dikenali sebagai sumber bahan yang boleh diperbaharui dan mempunyai pelbagai aplikasi industri. Diiktiraf sebagai tanaman tunai, ia telah dibawa ke Malaysia dan disasarkan untuk manjadi salah satu komoditi utama kepada negara. Antara pelbagai aplikasinya, penggunaan kenaf sebagai bahan-bio untuk komponen automotif telah dibuktikan boleh dilaksanakan dalam banyak kajian teknikal. Lebihan lagi, dengan menggantikan kenaf dengan bahan konvension yang mendasarkan bahan fosil, ia boleh meningkatkan kecekapan automobil secara meringankan keberatan serta membawakan penjimatan pengguanan bahan api dan mengurangkan pelepasan karbon dioksida. Tambahan pula, kenaf juga mempunyai keupayaan tinggi dalam penyerapan karbon berbanding dengan tumbuhan lain yang boleh mengurangkan pemanasan global. Sempena dengan program pembangunan kenaf nasional, penerokaan kenaf ke automotif industri dinampakkan sebagai optimistik. Tetapi, untuk mengusahakan kenaf ke dalam industri yang ketat ini; lebih banyak informasi dan perancangan adalah diperlukan. Oleh itu, kemunculan kajian ini adalah disasarkan untuk mengetahui kebolehlaksanaan aplikasi kenaf sebagai bahan-bio untuk komponen automotif dari perspective kewangan dan ekonomi.

Dengan menggunakan analisa kos-faedah, kajian ini mempunyai tiga objektif. Pertama adalah untuk mengenal pasti proses dan prosedur yang diperlukan untuk aplikasi kenaf dalam pengeluaran komponen automotif. Kedua, menentu dan menggngarkan kos dan faedah yang terlibat dalam rantaian proses yang dikenalpasti. Ketiga, menilai kebolehlaksanaan aplikasi kenaf sebagai bahan bio untuk komponen automotif dari segi kewangan dan ekonomi. Analisa ini dapat mangambil kira kos dan faedah langsung dan tidak langsung yang terlibat dan dikira dalam unit kewangan. Dengan itu, kebolehlaksanaan projek ini dalam aspek kewangan dan ekonomi boleh diketahui. Penemuan kajian ini secara umumnya menunjukkan pelaksanaan aplikasi kenaf sebagai bahan-bio untuk komponen automotif adalah positif dari aspek kewangan dan ekonomi. Tetapi, jika melihat ke dalam empat peringkat pengeluaran yang dikenalpasti - penanaman kenaf, pemprosesan gentian, pengeluaran komposit kompaun dan 'non-woven' dan penggunaan gentian dalam 'parcel shelves' automotif; kebolehlaksanaannya bercampur-baur. Penggunaan kenaf sebagai bahan-bio untuk komponen automobil boleh menjadi 'feasible' secara kewangan dan ekonomik dengan peningkatan dalam skala pengeluaran dan jika harga kenaf dapat diturunkan. Lebih

banyak usaha adalah diperlukan untuk meningkatkan daya saing pengeluaran kenaf dan gentian kenaf. Tambahan lagi, polisi untuk menggalakkan penggunaan gentian semula jadi di dalam industry automotif adalah amat diperlukan.

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Last but not least, I thank God for all the blessings.

I certify that a Thesis Examination Committee has met on 27 April 2015 to conduct the final examination of Ong Chu Lee on her thesis entitled "Cost-Benefit Analysis of Kenaf as Biomaterial for Automotive Components" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

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AFTA	ASEAN Free Trade Agreement
BCR	Benefit-Cost Ratio
BNM	Bank Negara Malaysia
CBA	Cost Benefit Analysis
CO_2	carbon dioxide
CO_2 e	carbon dioxide emission
CPI	Climate Policy Initiative
CPMC	Collection, Processing and Marketing Centre
CRES	Centre for Renewable Energy Sources, Biomass Department, Greece.
DAP	Day after planting
DBP	Day before planting
EEV	Energy Efficient Vehicle
EIA	Environmental Impact Assessment
EPA	US Environmental Protection Agency
FAO	Food and Agriculture Organization of the United Nations
FPU	Fibre Preparation Unit
FRIM	Forest Research Institute of Malaysia
ha	Hectare
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
IRR	Internal Rate of Return
JPH	Department of Animal Services
KSC	Kenaf Steering Committee
kWh	Kilowatt hour
MAA	Malaysian Automotive Association
MAI	Malaysia Automotive Institute
MARDI	Malaysian Agricultural Research and Development Institute
MIGHT	Malaysian Industry-Government Group for Higher Technology
MINT	Malaysian Institute of Nuclear Technology
MIROS	Malaysian Institute of Road Safety Research
MRKF	Mechanical retted kenaf fibre
MTIB	Malaysian Timber Industry Board
NAP	National Automotive Policy
NATIP	National Timber Industry Policy
NEAC	National Economic Action Council
NFRC	Natural Fiber Reinforced Composite
NKTB	National Kenaf and Tobacco Board
NPV	Net Present Value
NTB	National Tobacco Board
PP	Polypropylene
QC	Quality control
RM	Malaysian dollar
RTM	Resin transfer molding
SIRIM	Standards and Industrial Research Institute of Malaysia
SMC	Sheet molding compound
TIV	Total industry volume

UKM	Universiti Kebangsaan Malaysia
UNIDO	United Nations Industrial Development Organization
UPM	University Putra Malaysia
USM	Universiti Sains Malaysia
VC	Value chain

CHAPTER 1

INTRODUCTION

1.1 Overview

Kenaf (*Hibiscus cannabinus*) is a plant that grows wildly in Africa known as Guinea hemp. It is from the family of *Malvaceae*, similar with cotton and okra; an herbaceous fast-growing annual crop that can mature quickly growing up to 12-14 feet within four to five months (Encyclopedia Britannica 2013).

Kenaf stalk is rich in cellulose fiber where it can be separated into two fibrous parts which are the inner core and outer bast. The fiber can then processed as materials to manufacture various products including paper, particleboard, animal bedding, bioremediation aids, interior car parts, bio-plastics, soil-less potting mixes,etc (Department of Agriculture, Fisheries and Forestry, Queensland; 2008). It is also able to produce protein-rich, edible leaves as well as yielding vegetable oil for application in cosmetics, industrial goods and as biofuels. It is recognized as a green crop due to the plant's ability to absorb carbon dioxide (CO_2) – the culprit of global warming. Kenaf is distinguished with its ability to do so more than any other type of crop. It has been reported that due to its high photosynthesis rate, kenaf plant is able to absorb twice as much of CO_2 in comparison to tropical rainforest trees (Lam; Hori & Iiyama, 2003).

Being a multi properties and benefits plant, kenaf had been recognized as a new national commodity. It was first brought into Malaysia in early 1970s and has been acknowledged as a cheaper alternative of fibrous material to be used for production of panel products like fibreboard and particle board under the 7th Malaysia Plan (1996 – 2000) (Abdul Khalil et al., 2010). Furthermore, in the 9th Malaysia Plan, RM12 millions was allocated by the government as research and development funds for kenaf-based industry (Edeerozey et al., 2007). Later, in the year 2010 when ASEAN Free Trade Agreement (AFTA) took effect on tobacco control enforcement; cultivation of tobacco was no longer economically viable. This had created the motivation to accelerate the expansion of Kenaf as the commodity of new source of economic growth to replace tobacco. Henceforth, on 1st April 2010 the Parliament authorized conversion of National Tobacco Board (NTB) to National Kenaf and Tobacco Board (NKTB) to engineer the development of Kenaf agronomy and at the same time to reduce the trading of tobacco as commodity.

Moreover, amidst shortage of wood resources and rising concerns on sustainability and climate change; the needs to develop sustainable biomass resources for industrial applications for production of end products are urgent. With continuous research, industrial uses of kenaf derivatives are expanding. The trends and existing application of kenaf products are shown in Table 1.1.

Table 1.1 Market for kenaf products

Product	Fiber form
Sacking, hessian, canvas	Woven fabric/textile
Ropes, cordage	Twined
Composites	Fabric/non-woven/chopped fiber
Non-woven tissue	Non-woven
Geotextile	Nets, non-woven
Insulation	Non-woven
Paper and board	Pulped
Fiber boards	Refined/milled/chipped
Absorbent (moisture/oil)	Core particles/non-woven
Green chemicals	Fermented and bio-refined
Bio-fuel, activated carbon	Combustion and carbonised
Mulch, compost	Composted
(Adapted from: Lips & van Dam, 2013)	

Kenaf as a source of biodegradable fiber and in view of its wide application; can be the bio-resource that can lead towards sustainable development and environmental protection. With careful planning and promotion; kenaf have the opportunity to be one of the dominant commodities in Malaysia which can lead to socio-economic improvement.

1.2 Background of the study

With depletion of fossil resources, hikes in crude oil price and concerns on environmental sustainability, auto makers are faced with pressure and challenges to optimize their costs as well as to produce greener products and improve efficiency in fuel consumption. This motivates them to search for an alternative source to replace petroleum-based feedstock like synthetic fibers and polymers. As a result, natural fibre had gained a revived interest in the automotive industry due to its relative advantages compared to conventional plastics materials (Mohanty, Misra, Drzal, 2002).
According to a handful of literature (Anandjiwala & Blouw, 2007; Mangino, Carruthers & Pitarresi, 2007; Huda, Drzal, Ray, Mohanty & Mishra, 2008; Njuguna, Wambua, Pielichowski & Kayvantash, 2011; Faruk, Bledzki, Fink & Sain, 2014), natural fibre (such as flax, sisal, hemp, kenaf or jute) can serve as reinforcement filler combined with polymer matrices to form composites with desired properties for automotive components. Moreover, this use of natural fibre in automotive application can have several vital direct and indirect benefits; this includes

- Reduction of weight in automotive components thus reduce fuel consumptions
- Greener waste disposal due to natural fibre's carbon neutrality
- Reduction of CO_2 emissions (CO_2 e) when reducing utilization of fossil resources
- Lower material cost compared to glass fiber
- Technical advantages such as lower energy loss and tool wear
- Create growth to agriculture industry as demand of natural fibre in automotive sector is high
- Societal benefits through health improvement of industrial worker when exposure to harmful substances are reduced

In conjunction with the nation's kenaf development program, automotive sector appear as a lucrative segment to tap into. As shown in Table 1.2, from year 2004 to 2013 production of cars domestically has fluctuate within -10 to 20% while global car production has increased steadily except during the financial crisis year of 2008-2009. With the positive trend and stable demand on cars, the automotive sector appears as an attractive market for kenaf to venture into as material for automotive composite. In a survey based in Germany and Austria, Karus, Kaup & Ortmann (2003) found that the average use amount of natural fibres per vehicle is between 5 to 10 kg. Based on Table 1.2 below, the average number of passenger cars produced domestically is 456,413. If automotive industry Malaysia adopts natural fibres in the cars assemblies, this would require approximately 2,282 to 4,564 tonnes of natural fibre annually alone for domestic market. Moreover, with increasing adoption of natural fibre by major car manufacturers worldwide; there is a large market demand that kenaf can penetrate. Figure 1.1 showed the use of natural fibres for composites in the European automotive industry in 2012; where the total volume consumed was 80,000 tonnes. Kenaf was the fourth most used natural fibre in the sector after wood, cotton and flax; consisting of 8 percent from the total and amounting to 6,400 tonnes.

Table 1.2 Number of passenger cars produced in Malaysia

Year	**Number of passenger cars produced**			
	Malaysia	Changes in percentage (%)	World	Changes in percentage (%)
2004	364,852	-	44,554,268	-
2005	422,225	15.73	46,862,978	5.18
2006	377,952	(10.49)	49,918,578	6.52
2007	403,245	6.69	53,201,346	6.58
2008	484,512	20.15	52,841,125	(0.68)
2009	447,002	(7.74)	47,772,598	(9.59)
2010	522,568	16.91	58,341,703	22.12
2011	488,261	(6.57)	59,897,273	2.67
2012	509,621	4.37	63,070,002	5.30
2013	543,892	6.72	65,433,287	3.75
Average production 2004-2013	456,413	-	54,189,316	-
(Source: International Organization of Motor Vehicle Manufacturers)				

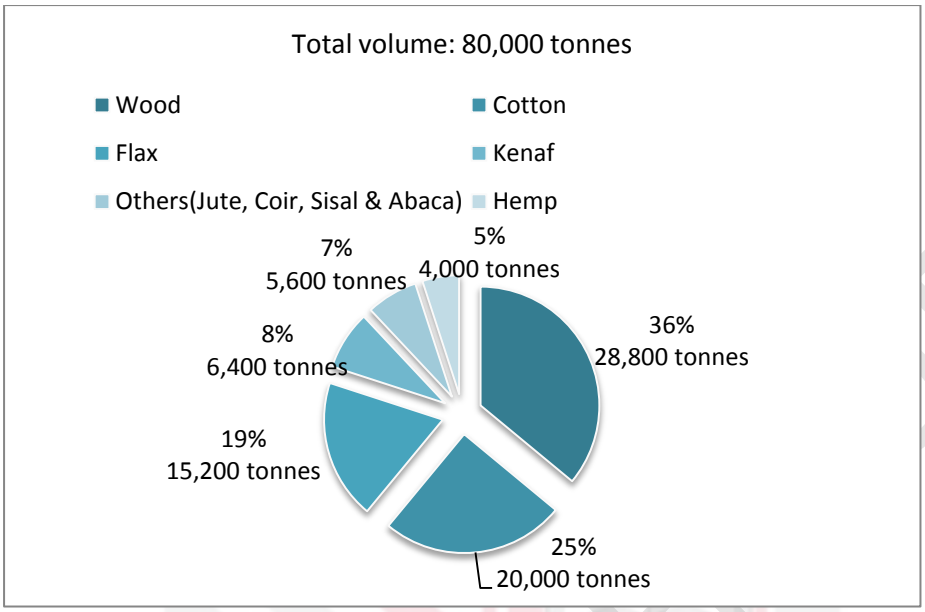

Figure 1.1 Use of Natural Fibres for Composites in the European Automotive Industry 2012
(Adapted from: nova-Institute GmbH, press release, 2013-11-26)

To ride on this bandwagon, formulation of strategy and new investment need to be made. Moreover, with targets of fostering kenaf to become one of the biggest crops cultivated in Malaysia, it is crucial to gather more information for further careful planning before venturing into the regulative and restrictive automotive industry. Thus, this study aims to provide valuable insight to assist in shaping the avowedly valuable commodity – Kenaf as an economically viable material for the automotive industry.

1.3 Problem Statements

In 1970s, Kenaf was introduced to Malaysia and received much attention in late 1990s as a more economical resource to produce panel products including fibreboard and particleboard, textiles and fuel (Abdul Khalil et al., 2010). Since then, Malaysian government is keen to develop Kenaf to become one of the major commodities for the nation. There were continuous efforts and financial support from the government. This could be seen from the ongoing and increasing funds allocated to Kenaf research and development since late 90s as shown in Table 1.3; moreover there was an enforcement of statutory body - National Tobacco Board switched to National Kenaf and Tobacco Board (NKTB) on 1st April 2010 specifically to develop Kenaf as an industry in Malaysia. These had indicated the nation's determination and vision directed to Kenaf.

Table 1.3 Research and development funds allocation from Malaysia government to Kenaf programs

No.	Malaysia Plan	Year	Amount (RM million)
1	7th	1996-2000	2
2	8th	2001-2005	3.2
3	9th	2006-2010	12
4	10th	2011-2015	65
Source: (1) and (2) www.ecerdc.com.my (n.d.) (3) Edeerozey et al., 2007 (4) Utusan Malaysia (2013, May 8th)			

Over the years, NKTB as the spearhead of kenaf development had promoted kenaf planting programs by offering subsidy program and buyback schemes to smallholder farmers. As a result, in year 2005 kenaf plantation for production of stems covered only 39 hectares (ha) in state of Kelantan and Terengganu had compoundedly grown to acreage of 1,824 ha in year 2013 throughout Peninsular Malaysia (NKTB). This had shown the success of Kenaf upstream development and the targeted kenaf cultivation had recently being raised to 10,000 ha by year 2020 (Bernama, Aug 2014). Furthermore, the NKTB had established Kenaf Collection, Processing and Marketing Centre (CPMC) to collect kenaf dried stem from farmers at the same time producing and selling kenaf primary products derived from kenaf bast and core.

Based on data from Statistic Report NKTB – 2012; the recorded demand for kenaf based products in year 2011 involved four companies with total 31,700 tons of kenaf stems, fiber and core. However, this figure had dropped drastically to 3,040 tons from only two companies in year 2012. This scenario had suggested that the market penetration of kenaf into industry application was still in struggles and volatile. Contrary to the growth and vision to kenaf plantation, there is an urgent need to find prominent market for kenaf derivatives to keep up with the growing kenaf cultivation and stems production and to while moving towards the vision of kenaf becoming major commodity of the country.

In searching for kenaf's market, there are many possibilities. According to Lips and van Dam (2013), kenaf had been commercialised with fibre price range from €50 to up to €2000 to produce products like sacking, cordages, composites, non-woven, paper and board, green chemicals and compost. There are other uses as well such as for geotextile, insulation, fibre boards, absorbent and bio-duel, however the price range are unidentified. For these various types of market, there are questions arise on which one is having growing and consistent market demand.

(Dammer, Carus, Raschka, & Scholz, 2013) Looking across the hemisphere, the Europeans are known as adept in growing fibre plants for various applications stemmed from their long standing traditions. In a market survey report, researchers had found that the most important application sector for natural fibres is the automotive industry. As shown in the report, the Europe domestic fibres are flax and hemp, while others were categorised as exotic fibre. Based on the survey, the fibre used for production of composite applied in passenger car in year 2005 was dominant by flax at 64.2%, kenaf/jute at 11.2% while hemp at 9.5% and the remaining are coir, abaca and sisal. In year 2012, the main fibre used was still flax at 50% while the kenaf's share had leap to

the second largest comprising 20% of the market and hemp at 18% and others at 12%. This trend had shown that kenaf have very good potential and viability in automotive market whereby it was just second to the European domestic fibre, flax. Moreover, researchers are foreseeing growing trends on natural fibre used in automotive sector mainly drive by the advantage on fuel efficiency and sustainability (Anandjiwala & Blouw, 2007; Pandey, Ahn, Lee, Mohanty, & Misra, 2010; Lips & van Dam, 2013; Dammer, et. al., 2013; Faruk, Bledzki, Fink, & Sain, 2014).

Turning back our sights to Malaysia, the nation's automotive industry is envisioned to become the regional automotive hub for Energy Efficient Vehicles (EEV) while having initiatives to green the overall domestic automotive supply chain in line with Malaysia's commitment to reduce 40% carbon intensity by 2020 (National Automotive Policy, 2014). The EEV production can be achieve in many ways and the most discussed method is by reducing the vehicle's weight which can lower the energy consumption (Helms & Lambrecht, 2006). In conjunction with kenaf upstream development and current large scale plantation in Malaysia, kenaf fibre could play an important role in the automotive sector not only to achieve Malaysia as the hub of EEV in addition could green the supply chain.

Kenaf fibre is becoming more available in Malaysia with the growing large scale cultivation, while in the global arena it had gained reputation in the application of cars. It seems to have very good potential and suitability to apply in automotive sector. Moreover, the target of kenaf programs and NAP 2014 are compatible to each other and could walk hand-in-hand to achieve respective goals. However, in local automotive industry the application of natural fibre is still very low (MAI, 2012). While for kenaf, throughout almost 10 years of development in Malaysia; it had yet to venture into the automotive sector.

From the phenomena shown above, it suggested that there is apparently an unknown barrier deterring kenaf venturing into automotive sector in Malaysia. This concern had prompted the needs to uncover the underlying problems. On one hand, technical studies had proven kenaf suitability for automotive applications (Parikh et. al., 2002; Davoodi et. al., 2010 & Jeyanthi & Rani, 2012) and on the other; there are track records from abroad on successful commercialised kenaf fibre for automotive composites. Thus, as for this study with both financial and economic perspective, is aiming to discover the mystery by conducting a feasibility study on kenaf as bio-material for automotive industry in context of Malaysia.

1.4 Research Objectives and Hypothesis

This study aims to evaluate the feasibility of using kenaf as bio-material in the automotive industry; and the below objectives would be followed.

a) To identify the production processes and stages from kenaf cultivation to production of automotive components in Malaysia
b) To determine and estimate the cost and benefits elements involved in using kenaf as bio-material for production of automotive components from the cultivation stage
c) To conduct financial and economic feasibility assessment on cultivation and processing of kenaf for automotive components

Thus, the hypothesis to test in this paper is:

- Production and utilization of kenaf as bio-material of automotive components is economically feasible

1.5 Significance of study

To develop kenaf to become the major commodity in Malaysia, it is vital to establish markets for its derivatives. From observation presented in previous sections, the automotive sector has high potential as a prominent market for kenaf.

Furthermore, the application of kenaf fiber in the nation's automotive sector could solidify kenaf's market while assisting Malaysia in reaching vision of regional hub of EEV. Thus, the information obtained from this study can fills the information gaps while provide insights to policy makers and stakeholders for better decision making and aids in devising kenaf market strategy into automotive sector.

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