Kenaf For Biocomposite: An Overview

[1]Izran Kamal*, [2]Mohd. Zharif Thirmizir [3]Guenter Beyer, [4]Mohamad Jani Saad, [5]Noor Azrieda Abdul Rashid, and [6]Yanti Abdul Kadir

[1]Advanced Processing and Design Programme, Timber Technology Centre, Forest Research Institute Malaysia (FRIM), 52109 Kepong, Selangor Darul Ehsan, Malaysia
[2]Science and Engineering Research Centre (SERC), Universiti Sains Malaysia, Engineering Campus, 14300 Nibong Tebal, Penang, Malaysia
[3]Physical and Chemical Laboratories, Kabelwerk EUPEN AG,B-4700 Eupen, Belgium
[4]Rice and Industrial Crops Research Center, Malaysian Agricultural Research and Development Institute (MARDI), Persiaran MARDI-UPM, 43400 Serdang, Selangor Darul Ehsan
[5] Wood Mycology Laboratory, Forest Research Institute Malaysia (FRIM), 52109 Kepong, Selangor Darul Ehsan, Malaysia
[6]Furniture Design Laboratory, Forest Research Institute Malaysia (FRIM), 52109 Kepong, Selangor Darul Ehsan, Malaysia

**Corresponding email:eastrun84@gmail.com*

Abstract

Increase of the awareness on the importance of protecting the environment has urged researchers around the globe to find ways to produce goods that can minimize harm to the environment. Biocomposite is a product that has been shown to be helpful in achieving this objective. Biocomposite is produced using natural or semi-natural materials, therefore it can easily be disposed, thus, minimize harm to the environment. Kenaf is a natural plant which has began to gain attention as a material in the production of biocomposite. Kenaf is selected as an additional alternative material for producing biocomposite because of its fast-growing properties which makes it capable to deliver a large volume of raw material in a short period of time. This paper reviews the use of kenaf as a material for biocomposite which is used for construction and non-construction purposes. Input from a variety of researches related to kenaf biocomposite as well as its uses are used for this review.

Keywords: structural; non-structural; uses; green technology

1. INTRODUCTION

Kenaf is a non wood lignocellulosic material because it is formed mainly by cellulose, hemicelluloses and lignin. The word Kenaf came from a Persian word *kanab* which is derived from the word *Cannabis sativa* (hemp or marijuana) [1]. However, Kenaf and hemp are not related each other even though they have almost similar agricultural requirements [2]. Kenaf is a part of Malvaceae, whereas hemp is under Moraceae . Therefore, it is more precise to classify Kenaf as a cousin to okra (*Hibiscus esculentus*), cotton (*Gossypium hirsutum* L.), hibiscus (*Hibiscus hibiscum* L.), hollyhock (*Althaea rosea*) [3] and Hawaii flower [2]. Kenaf has various names such as mesta (Bengal, India), palungi (Madras, India), deccan hemp (Bombay, India), bimli jute (Andhra Pradesh, India), ambali (Taiwan), till, teel / teal (Egypt and Northern Africa), Java Jute (Indonesia) , papoula de Sao Francisco (Brazil), stokroos (South Africa), dah, gambo and rama (West Africa) [4]. Kenaf can grow up to a height of 8 to 20 feet with a period of maturity up to 150 days [5]. It is believed to be a native to east-central Africa [6] or western Africa [7] where it was widely used as a source of food and fiber since thousands of years ago. From the regions, the crop was believed to spread to Asia by sea or caravans through Mesopotamia territory [7]. Until today, there is no literature to confirm who is the founder of Kenaf.

Recently, due to the increase of environmental awareness, concern of environmental sustainability, growing global waste problem, initiation of ecological regulations as well as regulations, decrease of fossil fuels, increase of crude oil price have created interest to renewable resources like Kenaf. Kenaf is an environmental-friendly industrial organic material which is recognized by Kyoto Protocol to be effective in reducing global warmness [8]. Due to the recognition, in Malaysia, Kenaf was then encouraged by the government to be planted to replace tobacco. The other issue which caused tobacco to be replaced with Kenaf was the Asean Free Trade Area (AFTA). Under AFTA, Malaysia needed to reduce duties on tobacco imports by 2010. The reduction of duties has decreased the competitiveness of Malaysian tobacco, because its price was much higher than Thailand's and Indonesia's tobacco, even though its price actually dropped almost half of its initial price [9]. Though, market for Kenaf is still uncertain, because it is very new in Malaysia, but it has potentials to be commercialized as biocomposite which can be used for many purposes. Therefore, this paper reviews the cultivation, anatomy, production, as well as uses of kenaf especially in the production of biocomposite.

2. KENAF CULTIVATION

Kenaf is cultivated actively in Southeast and East Asian countries like India, Bangladesh, China, Thailand, Indonesia, Vietnam, Nepal, Myanmar and Cambodia [10]. Other countries who are actively cultivating kenaf are Brazli and Cuba [11]. The average suitable temperature to grow kenaf is 25^0C because kenaf cannot tolerate frost. The planting process starts by dispersing kenaf seeds at a seedling rate of 22.5 to 30 kg per hectare at a soil depth of 2 cm. Soils that can be used as mediums to plant kenaf are acid, peat, alluvial, silt loam, sandy loam, clay loam, alkaline and saline soils [10] with a pH from 4.4 to 6.5 [13]. Seeds are brown in colour, wedge-shaped and 5 mm long [12] (Figure 1).

Figure 1: Kenaf seeds

The composition of a kenaf seed is as demonstrated in Table 1. Kenaf can tolerate with many types of soils because it grows with primary root system like hemp which facilitates the plant to search for moisture deep into the soils [14,12]. It does not need irrigation to grow but irrigation can help to produce better kenaf quality. A study done by [15] recorded that irrigated kenaf has better growth rate, thicker stems, higher lignin content and higher hemicelluloses content compared to kenaf that is not irrigated. Proper irrigation can help to double the volume of kenaf yield [16].

The other important factor that needs to be taken care of when planting kenaf is fertilizer. Fertilizer with added nitrogen can increase kenaf biomass yield [17,18]. It was suggested that, since kenaf rooting system is deep tap root and widespreading lateral, it is best to fertilize kenaf using residual nutrients from previous crops such as leaves. It has been reported that the leaves from the previous crops that left on the plantation site can produce about 50 to 100 pounds of nitrogen / acre, which is very essential for kenaf growth [6]. This methodology not only helps in increasing kenaf yield, but at the same time it helps to preserve the environment as less chemical involved to grow kenaf. The effects of fertilizer to kenaf growth at dry and wet seasons were studied by [19]. For the study, they used a fertilizer with the following formula (NPK with a ratio of 12:12:36 + 2MgO + TE + micronutrient compositions such as Boron, Cuprum, Iron, Manganese, Molybdenum and Zinc).

Table 1: Kenaf seed composition

Components	Percentage (%)
Moisture content (MC)	9.6
Ash	6.4
Fatty Oil	20.4
Palmatic oil	19.1
Oleic acid	28.0
Linoleic acid	44.9
Stearic acid	6
Alpha-linoleic acid	0.5
Nitrogenous matter	21.4
Saccharifriable matter	15.7
Crude fiber	12.9
Other matter	13.9

Source: [20]

The fertilizer was used to treat three different plots to plant kenaf at three different fertilizer levels i.e high (1960 kg/plot), medium (1260 kg/plot) and low (700 kg/plot). The fertilizer was sprayed for 16 s per liter to the plots every day. The effects of the fertilizer to kenaf growth were accessed by looking at the: 1) diameter and height, 2) leaf number and leaf area and 3) biomass. The study revealed that the kenaf growth went well during wet season at all fertilizer level, which this has given a sign that kenaf, like other plants needs adequate irrigation to survive and keep the cells in good conditions at the early stage of its development, so that they can produce new tissues and cells continuously to facilitate better kenaf growth. The fertilizer has not given significant effects to kenaf growth during dry season [19]. According to [18], the recommended fertilizer rate for good kenaf growth with high biomasss production is 80-100 kg N/ha, 40 kg P205 and 60 kg K20. The fertilizer should be dispersed in between kenaf rows. All P and K fertilizers should be applied at two weeks after sowing

Harvesting time affects kenaf properties in term of chemical composition especially its lignin content.A research was undertaken by [20] to study the effect of harvesting time to the production of lignin in kenaf. The study was to determine the best harvesting time to harvest kenaf at the lowest lignin content, where delignification, pulping and bleaching can be done easier to the harvested kenaf, which later will be used for papermaking. Five harvesting times were applied for comparisons in the study i.e. 76 days, 116 days, 152 days, 185 days, and 226 days after planting. The study indicated that the best harvesting time is 152 days (5 months after planting), where after that period no further lignin production occurred in kenaf. This study can help manufacturers especially papermakers (who are always working with delignification, pulping and bleaching processes to make papers) to buy kenaf at the suggested age from the suppliers to minimize the usage of energy for the said processes .

Since the last 6000 years, kenaf has been hand-harvested. The harvesting is done by cutting the stalks at or near ground using a curved blade, while the trees are still growing or nearly flowering [21]. Recently, it was discovered that the easier ways to harvest kenaf are by chopping it with a forage chopper or by cutting the stalks using an 8-row harvest machine, which is at the same time lays the stalks in the plantation area to dry by the sun [6]. Until now, innovation on creating kenaf harvesting equipments seems endless to facilitate increment of kenaf yield. However, like other kenaf cultivation factors mentioned previously, kenaf harvesting technique may be vary, depending on the production location, the availability of equipment, processing method as well as the final product use [22].The world production of kenaf and allied fibers has experienced a decrease from year 2003 to 2010 (Table 2). The highest total world production was in year 2009. The highest producer for kenaf and allied fibers for the period of time is India, followed by China, Thailand, Africa, Vietnam, Brazil, Cuba, Indonesia, Pakistan and Cambodia. The statistic shows, even though there was a slight decrease of the total world production for kenaf and allied fibers, but still the demand for the fibers is still undeniable. By referring to the total world production, it is clear that kenaf and allied fibers are available at a very huge volume and can be utilized to many areas which are working with natural fibers. These fibers are no doubt as substitutes for wood which is commonly obtained from natural forests. Damages to the forests due to the process of obtaining wood source from them could be minimized if these fibers are fully utilized as alternative materials to wood.

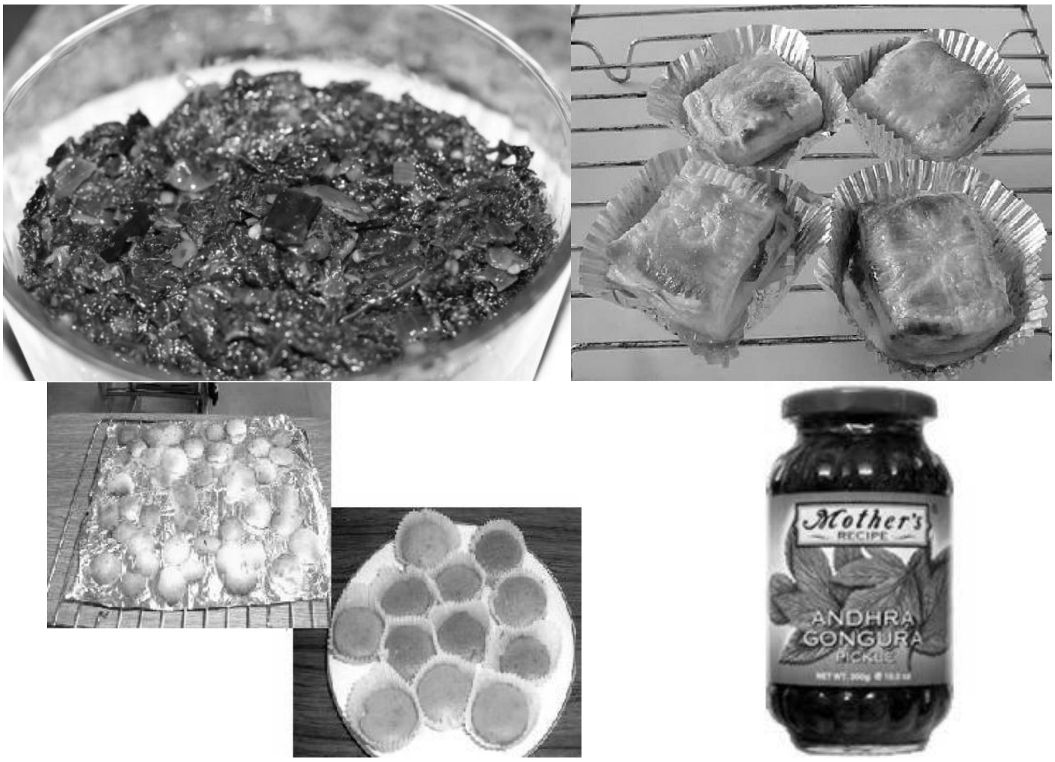
Table 2: World production of kenaf and allied fibers from year 2003 to 2010

Kenaf & Allied Fibers	2003 to 2004	2004 to 2005	2005 to 2006	2006 to 2007	2007 to 2008	2008 to 2009	2009 to 2010
World	377.29	351.83	327.58	314.4	329.12	279.8	290.1
Developing countries	370.29	344.83	320.58	307.40	322.12	272.8	283.1
Far East	329.88	302.2	264.32	250.51	266.06	217.3	227.6
China	99.78	86.92	82.82	68.8	86.8	80	80
India	167	156.4	153	144	139.7	120	131.2
Indonesia	7	7	7	3.1	4	3.8	3.8
Thailand	41.33	35.66	4.6	3.6	2.2	2.9	1.8
Vietnam	12.5	14.2	15	10.6	31	8.8	9.0
Cambodia	0.65	0.65	0.65	0.83	0.85	0.3	0.3
Pakistan	1.62	1.19	1.25	1.59	1.51	1.5	1.5
Latin America	24.01	25.91	39.37	39.91	39.07	38.5	38.5
Brazil	10.5	12.65	26.1	25.95	25.66	25.1	25.1
Cuba	10	10	10	10	10	10	10
Others	3.51	3.27	3.27	3.96	3.41	3.3	3.3
Africa	12.7	13.2	13.19	13.29	13.29	13.3	13.3
Near East	3.7	3.7	3.7	3.7	3.7	3.7	3.7
Developed countries	7	7	7	7	7	7	7

Source: Food and Agriculture Organization (FAO)
The values are in ‘000 tonnes (1 tonne is equal to 1000 kilogramme)

3. KENAF APPLICATIONS

Kenaf is a very versatile material. Each part of kenaf can be utilized for different usages. Its leaves can be consumed by human and animal because they contain high content of digestible protein [22] . It was revealed that the average protein content in kenaf leaves range between 18 to 30% [22]. Usually the leaves are consumed raw or boiled to greens [23]. The leaves can be eaten as early as 10 days after planting and it was reported that 80 servings of kenaf leaves can be made from a single plant [23]. The leaves are also can be main ingredient for preparing delicious foods (Figure 2).



Source: [24, 25, 26]

Figure 2: From left to right: Kenaf leaves fried with chillies and kenaf apple pie; below: Kenaf cakes and kenaf leaves pickle

However, kenaf is mostly known for its fibers as these are the largest fractions of kenaf. In a kenaf stalk, there are two fibers; the inner and the outer fibers namely core and bast, respectively. The characteristic of having two different regions of fibers in a stalk is similar to flax straw, jute and hemp [27, 28]. These two fibers are so versatile because they can be used for many purposes such as to be converted to pulp, paper, cardboard, panels, traditional cordages, absorbent agent, packing materials, soil-less potting mixes, grass and flower mats and natural fuels [4].

4. KENAF FIBERS

The bast contains average cross and bevan cellulose between 47% to 57%, alpha cellulose between 31% to 39%, lignin between 15% to 18%, pentosans between 21% to 23% and ash between 2% to 5%. The fiber has an average length of 2740µm which is superior to wood (840µm) and an average diameter of 20µ. As for the core, they contain average 34% alpha cellulose, 17.5% lignin, 19.3% pentosans and 2.5% ash. The average fiber length of the core is 600µ [29]. However, these information are vary based upon where, when and how a Kenaf is grown and harvested [30]. According to [30], the fiber length increases with the increase of kenaf height. However, it wasfound that the fiber length decreases as the plant matured [30]. Different view on the fiber length was shared by [27]. Their research found that, the fiber length increases with kenaf age, but at three different phases i.e. increase in the initial stage of growth, decrease in the middle stage and then increase again at the end stage. It was also discovered from the same study by [27] that, kenaf bast fibers grow much more active than kenaf core fibers. This is the possible reason why kenaf bast fibers are longer and relatively stronger than kenaf core fibers. The growth process may be related to several factors such as the development of protein, extractives, cellulose and cell wall of the fibers [27]. According to [31] the difference of fiber length may also influenced by genetic of the tree as well as external factors like light, water and nutrient.

The fibers are formed by a combination of many cellulose cells (multicellular) which are bonded with non-cellulose materials [32]. A study conducted by [33] found that the vessels of the fibers are almost the oval and round shapes; with simple perforation, moderately large size, solitary and sometimes in pairs. The cell walls of the bast fibers appeared to be much thicker than that of core fibers. Conversely, the lumens of the core fibers were found to be larger than that of bast fibers.

4.1 Fiber Separation

Since the bast and the core fibers have different purposes of usages, hence, separation process to separate the fibers is not exclusion. The bast fibers can be separated from the core fibers using processes called decortating and retting. Decortating is an action of separating the bast fibers from the core fibers using decorticator [34]. The process is much easier and faster than retting. Several advantages that can be obtained by using decorticating process in kenaf fiber separation are: i) It is cheaper than fiber separation using hands, 2) longer fibers can be obtained [34]. In the other hand, retting can be done in three different ways. It can be done with involvements of mechanical process, chemical and water. Mechanical retting is conducted by first soaking the fibers to be retted in water for at least 5 days. The soaking is to soften the fibers before the fibers are separated through decorticating process. The separated bast fibers are then washed, cleaned, dried, hackled and combed after the decorticating process. As for chemical retting, it is usually done by boiling decorticated stalks into a weak alkali solution for an hour before the fibers of the stalks are washed with hot water and neutralized. After neutralized, the fibers are washed once again with hot water and subsequently air dried and combed to obtained straight and hair-like long fibers [35]. Like mechanical retting, this retting method is significantly affecting the properties of the fibers like loss in firmness, colour and shine. These disadvantages could be avoided if water retting is used, instead. However, water retting is a time-consuming process. Normally a water retting process would take more than 22 days to complete (include washing, drying and combing processes of the fibers). Therefore, the decision of selecting correct retting process should be carefully done by considering the final products that may be produced using the retted fibers, especially when the final products involved strength.

Figure 3: Kenaf bast (left) and grounded kenaf core (right)
Source: [36] and [37]

5. BIOCOMPOSITE

Biocomposite is defined as a material formed from a combination of matrix (resin) and natural fibers (wood or non-wood) (filler) which are obtained from plants. Usually, in the fabrication of a biocomposite, important parameters that need to be taken seriously are pressing pressure and pressing temperature (heat). The pressing pressure is needed to assist adhesion between filler and matrix, whereas the pressing heat is to assist curing of the matrix, so that the adhesion is stronger and a compact biocomposite could be produced. Examples of biocomposite are particleboard, fiberboard (Figure 2), oriented strand board (OSB), and wood flour composite. By looking at the examples given, the term 'biocomposite' is actually interchangeable based on the type of incorporated filler. Biocomposite becomes popular when market demand for environmental friendly products increased and urge of finding alternative materials to cover up the demand of natural fibers from forest resources. Apart of that, biocomposite got a lot of great reputations to offer which makes this technology now is gradually accepted to be applied commercially. This technology: 1) able to reduce environmental pollution, 2) it has good mechanical properties, 3) biodegradable, and 4) good appearance [38]. Biocomposite can be divided into two main groups for its application: structural and non-structural. A structural composite is defined as one that is required to carry a load in use. In the housing industry, for example, these represent load bearing walls, roof systems, subflooring, stairs, framing components, furniture, etc. Structural wood-based composites, intended for indoor use, are usually made with a low cost adhesive which is not stable to moisture while exterior grade composites contain a thermosetting resin that is higher in cost but stable to moisture. Non-structural composites are not intended to carry a load in use. These can be made from variety of materials such as thermoplastics, textiles, and wood particles, and are used for such products as doors, windows, furniture, gaskets, ceiling tiles, automotive interior parts, molding and etc [39].Biocomposite is currently used widely for packaging (Figure 4), agriculture, medicine and other areas.

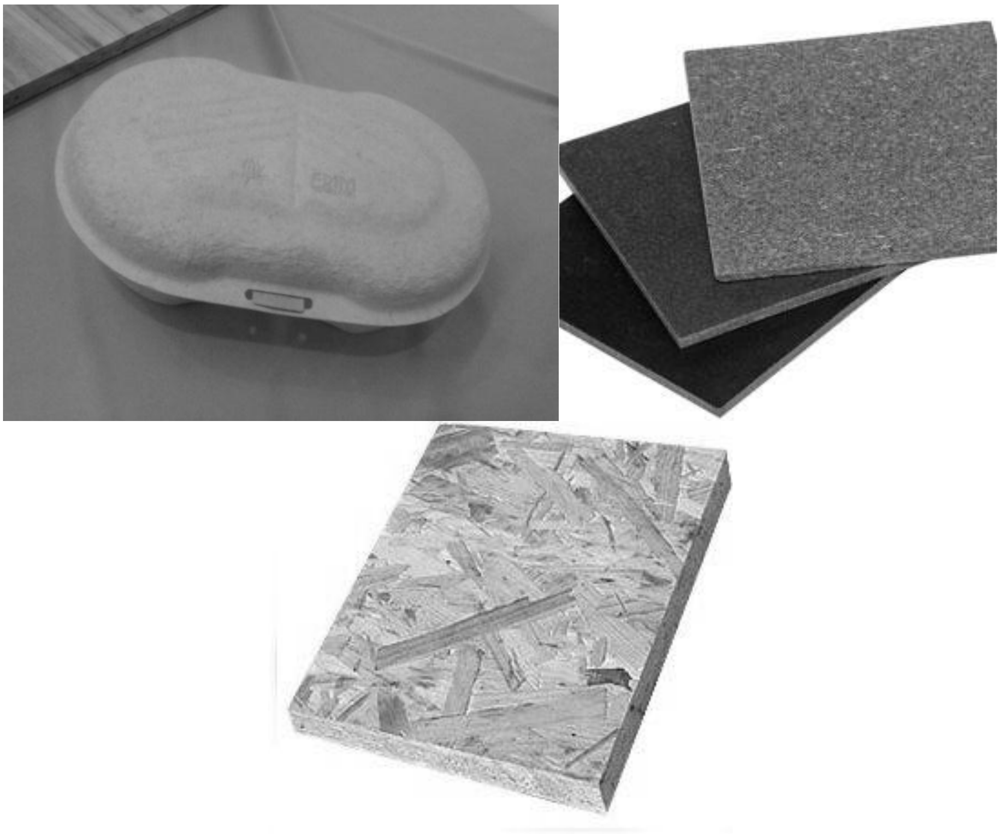


Figure 4: Biocomposite, from left to right : food packaging, particleboard and oriented strand board

Biocomposite can be divided into two groups: 1) fully biodegradable and 2) partially biodegradable. The biodegradability is subject to the type of matrix or filler used. According to [40], the fully biodegradable biocomposite is made of materials that can be degraded by biodegradation agents such as heat, moisture, ultraviolet (UV) and microorganism like fungi. The fully biodegradable biocomposite is made of polymer matrix derived from natural sources and reinforced with natural fibers. Both components of the biocomposite can be degraded by microorganisms and the byproducts of the degradation process are carbon dioxide (CO_2) and water (H_2O). As for partially biodegradable biocomposite, it is fabricated with a combination of chemical-based matrix and natural fibers. The biodegradable component in the combination is natural fibers [40]. When this type of biocomposite is exposed to the environment, microorganisms will penetrate into the biocomposite and consume natural fibers. As the natural fibers in the biocomposite are consumed, the biocomposite becomes more porous and the matrix will also gradually degrade [41].

6. MATRIX

Matrix is an important fraction of a biocomposite. As mentioned earlier, it is responsible to provide a good adhesion between filler in a biocomposite. Matrix is usually classified into two different categories namely thermoplastic and thermostatic. Thermoplastic matrices are those can be uncured by heat after they are cured (when cooled). Whereas thermoset matrices are otherwise which they cannot be uncured by heat once they are cured (when cooled). The matrix can either comes from chemical-based or natural-based materials. More and more researches are done to prove the advantages of using biodegradable (natural-based) matrices over the chemical-based ones in making biocomposite [41,42,43,44,45] in line with the demand of producing environmental friendly products that seems endless.

Several natural-based matrices are starch, poly-lactic acid (PLA), polycaprolactone (PCL), polyesteramide (PEA), poly (butylene succinate adipate) (PBSA), polyhydoxyalkanoate (PHBV) [46]. Examples of chemical-based matrices are urea formaldehyde (UF), phenol formaldehyde (PF), melamine formaldehyde (MF), polypropylene, polystyrene, polycarbonates, polysulphone and polyamides [47]. The chemical-based matrices are resistant to degradation, hence difficulty of disposing them has actually create an awareness to produce more and more natural-based matrices. The chemical-based matrices are impenetrable by microorganisms, which makes them so hard to be degraded [40]. However, matrix is not limited to petroleum-based materials only.

7. KENAF BIOCOMPOSITE

The statement, 'Kenaf for biocomposites' sounds very natural nowadays. In Malaysian scenario, kenaf plants scientifically known as *Hibiscus cannabinus* was identified by the Malaysian Government to be the 7th commodity plant . There are a lot of incentives provided by Malaysian government in attempt to optimize the utilization of kenaf products. The researches on kenaf for biocomposite is still in the introductory stage, even though researchers from around the world have successfully built confidence to include kenaf as one of important raw materials for biocomposite researches for so many years before. Examples of researches that imposed kenaf as a raw material are researches on textile technology [48], plastic composite [49,50,51,52]. Owing to the good mechanical properties and abundant local supply and relatively cheaper cost of the kenaf fiber (RM4.00/kg) as compared to glass fibers (RM7.00/kg), it will be a perfect choice for composite products especially for automotive applications. The bast fiber which is extracted from outer bark of kenaf plant has equivalent strength compared to other natural fibers such as jute, hemp and flax. The cellulose components play the major role in providing good mechanical properties of kenaf plants. High α-cellulose content especially in kenaf bast was reported to provide high strength in kenaf-based products [53,54,55]. An attractive feature of kenaf is that up to 40% of the stalk yields usable fiber, roughly twice that of jute, hemp and flax, which makes the fiber quite economical. Kenaf reinforcement in polymer matrix can be used in the form of particulate fillers, short, continuous fiber, non-woven and woven fabrics. However, to utilize kenaf for the production of automotive components several fundamental issues are confronted:

i. Consistent, good quality and sustainable

One of the main requirements of kenaf utilization in automotives is sustainable supply of good and consistent quality of industrial grade fibers. Different parts of a plant have different physical and chemical properties. The chemical and physical morphology of bio-fibers, their cell wall growth patterns and thickness, dimensions and shapes of the cells, cross-sectional shapes, distinctiveness of lumens, etc, besides their chemical compositions (cellulose, hemi-cellulose and lignin contents), affect the properties of the fibers [56, 57]. The variability in the fiber properties can lead to variability of mechanical properties of the resulting bio-composites. This could give rise to serious reliability issues in the application of bio-composites for automotive components.

ii. Wettable and interactive bio-composites

One of the main challenges in producing high performance bio-composites is to improve the degree of interaction or interfacial bonding between hydrophilic BF and hydrophobic or apolar nature of various types of polymer matrices i.e. thermoplastic and thermosetting resins [58].A clear disadvantage of this apolar character for composite applications is its limited wettability as well as poor interfacial bonding with reinforcing fibers. Thus a critical assessment of the interfacial bond is needed for a successful design of the final component.

iii. Durable bio-composites

The presence of hygroscopic bio-fibers (due to high content of hydroxyl groups) in bio-composites resulted in composite products to absorb moisture over time, causing functional and durability concerns [59]. In addition, this could give rise to odour and smell of the automotive components. This is extremely crucial in the context of Malaysia which experience high relative humidity throughout the year. A fundamental study is thus needed to find the cost-effective means of increasing the moisture resistance and durability of bio-composites

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iv. Odourless bio-composites

One of the problems in combining kenaf with a polymeric matrix as polypropylene, PP, is the poor thermal stability, which results in degradation of the fiber at the common processing temperatures of the composites. This process leads to a darkening of the material and formation of low molecular weight compounds that are released producing undesirable odours. This issue is very pertinent in the context of market acceptance and consumer perception. It is interesting to examine the effect of fiber chemical treatments and chemical modification of polymer matrices could restrain the emission of odourous volatile organic compounds (VOC).

v. A fully green bio-composites

The challenge for the automotive industry is to produce lighter, inexpensive, environmentally sustainable vehicles that are safe, attractive, energy efficient and economical to operate. The social push and increasing environmental awareness of consumers have provided the ground for increasing the use of so called “green” materials in the automotive sector [57]. The current trend is towards using fully green bio-composites which involve combination of kenaf with biodegradable polymers. Several natural resin systems (both thermoset and thermoplastic) have been considered as candidates for the automotive industry. Thermoplastic bio-resins such as polylactic acid (PLA), polyalkanoates (PHA) and poly(butylene succinate) (PBS) have potential applications because of their biodegradable nature. However, market penetration of these bio-resins in automotive industry is presently restricted by cost-performance flexibility of the resins. In order to achieve the wide use of bio-resins, the controlled synthesis of resins with a wide range of properties to suit different applications is required. Thus extensive R & D efforts are being directed towards lowering the cost of production and diversifying the properties in order to make these bio-plastics competitive with conventional plastics.

vi. Realizing a high performance and competitive bio-composites

In order to be able to compete with glass-fiber-reinforced composites and gradually become a replacement materials for automotive components, the performance of bio-composites need to be uplifted in several ways. One of the key aspects that need to be focussed is finding means of having highly filled biocomposites with high aspect ratio (length to diameter ratio) of kenaf fiber. From a practical point of view, kenaf fiber has dimensions that are limited by their anatomical restrictions [56,57] . In terms of length, it has been found that many natural fibers have average values that are sufficient to be considered as long and continuous reinforcement for the fabrication of bio-composites [60,59]. The use of conventional melt-processing methods for the production of short fiber reinforced compounds such as extruders will not be acceptable since it will results in serious degradation of fiber length. High fiber aspect ratio is very crucial in achieving high performance bio-composites. Considerable R & D efforts are now given in finding means of producing bio-composites with high fiber loadings and high fiber aspect ratios albiet the fact that both variables will affect the rheology and limit the processability of such composites. Thus a fundamental research is essential to achieve a balance between mechanical performance and processability.

7.2 Kenaf Biocomposite Applications

7.2.1 Non Structural Application

i. Current bio fiber composite application in automotive components.

Table 3 shows the interior parts that are potential to be replaced by biodegradable composites. However, the biodegradability aspect need to be further explored, so that the material can be used without failure during service life. The next study will focus on tailoring the biodegradability of the composites for specific purposes or applications particularly as automotive components.

Table 3: Uses of biocomposite as automotive components.

Application	Status/Note
Front end module/carrier	Major near-term D-LFT and LGF-PP pellet driver in N. American Market Established in Europe
Door hardwere module	Facilities strong trend towards hardwere consolidation Brose is early leader
Instrument panel substrate	Started in Europe (Faurecia and JCI) Both D-LFT injection and compression
Underbody shield	Will come from Europe with OEM transplants Add-on acoustic layer being offered
Running board	Started in N. America
Hatchback door	2012 Forrd Escape Combination with talc/PP exterior
Overhead console/ Headliner structure	Stimulated by changes in overhead design and construction
Instrument panel structural ducts	Early Chrysler innovation Requires vibration welding
Load floor	Early GMT application
Spare tare well/storage module	Competes with SMC, GMT, natural fiber candidate
Seating	Competes with SGF-TPs
Engine cover	Starting in natural fiber
Battery carriers	Stimilated by trend to electric drive vehicles

D-LFT = Direct long-fiber thermoplastic composite
LGF-PP = Long Glass Fiber – Polypropylene composite
JCI = Johnson Controls Inc.
OEM = Original Equipment Manufacturer
SMC = Short Fiber Moulding Composite
GMT = Glass Mat Thermoplastic Composite
SGF-TP = Short Glass Fiber – Thermoplastic Composite

Many published studies have proven that kenaf biocomposite is suitable to be used as automotive components [61,62]. However, in Malaysia, though the studies are published, but it seems greater guts are needed to make the studies commercialized and accepted by the industry. People are still depending on petroleum-based biocomposite. However, it seems that the acceptance is improving progressively though it is quite slow.

In year 2011, as the interest on Kenaf biocomposite seemed expanding, Malaysian Agricultural Research and Development Institute (MARDI) made use of the expansion of interest to commercialize Kenaf biocomposite namely Kenaf Polymer Composite (KPC) for building construction material and industrial applications [63]. Earlier in year 2008, a local company, Malaysia's Symphony Advance Sdn Bhd has collaborated with Samsung Cheil (under Samsung Group) to commercialize KPC too [64]. Both collaborative works are aiming not only to commercialize KPC for automotive application and building construction material, but also to promote kenaf planting among farmers which are previously planting tobacco as their source of income. These promising collaborative works are expecting to accelerate the commercialization of kenaf biocomposite and at the same time as a support to the Malaysia's government initiative on green technology launched on 24th July 2009.

But in Japan, this practice is no more an alien. In the country, Toyota Boshoku Corporation became a pioneer to include kenaf as a raw material for their interior automotive components [65]. The company uses kenaf biocomposite for lighter weight door trim and seat back board. The reasons of choosing kenaf biocomposite are to improve fuel efficiency and minimize carbon dioxide (CO_2) emission by reducing weight of the vehicles installed with the biocomposite. A study has recorded that a reduction of 25% of a weight of an vehicle is equivalent to a savings of crude oil about 250 million barrels and reduction of CO_2 emission about 220 billion pounds per annum [66]. Thus, it is environmental-friendly and helps users to save more money for other more important matters. Currently, kenaf-based automotive components are attached in the latest model of vehicle manufactured by Toyota Motor Corporation namely Lexus GS [65]. Actually, the usage of kenaf biocomposite as a material for automotive components in Toyota vehicles has started since year 2000. The first Toyota vehicle, which has used kenaf biocomposite (kenaf and polypropylene composite) as automotive components, was Celsior. Then it was followed by Brevis in year 2001 and Harrier in year 2003 [67].
The other organization in Japan which is using kenaf biocomposite as their product component is Panasonic Electric Works. The organization has chosen kenaf for structural application. Kenaf fibers were used to produce of structural wall board to replace plywood which is usually fabricated using timber. The structural wall board made of kenaf composite was found to be much lighter than the one made with timber [63]. Lighter structural wall is more preferable because it eases installation work, where, less man power is needed in handling the structural wall compared to the heavier one, thus reducing operation cost. The commercialization proved that to use kenaf biocomposite as automotive components is not just a vain dream. In fact, if it is successfully commercialized, it can help in generating national income.

ii. Kenaf biocomposite as furniture components

Usually, when talk about the use of biocomposite as furniture components, the main things that need to be taken into account are their strength, fire resistance and durability. These are important because they determine the quality and lifespan of furniture. A research done by [68] showed that kenaf core particleboards possessed feasible stiffness that makes them suitable to be utilized as furniture components. The research showed that kenaf core particleboards were able to achieve stiffness more than 1800 N/mm^2 although the kenaf core fibers were incorporated with treatment chemical prior to the production of the particleboards. In fact, the same research revealed that untreated kenaf particleboards surpassed all the mechanical (modulus of rupture, internal bond) and physical test (thickness swelling) requirements for furniture components.

As for fire resistance, although, many people may not consider this as a very important subject to talk about, especially for furniture components, but it is actually very necessary to be accounted. In the United Kingdom, UK Furniture and Furnishings (Fire Safety) Regulations were introduced mainly to reduce the rate of deaths and injuries caused by fire that started in upholstered furniture in the home, often through a dropped cigarette [69]. Treating furniture components with fire retardant shall not be able to prevent the fire from occurring. The main purpose of performing fire retardant treatment is to make furniture components burn slowly, thus delaying proliferation of fire. Slower fire proliferation will give sufficient time to occupants of a building to save themselves. A research by [70] revealed that untreated kenaf core particleboards exposed to fire were able to survive for 13 min. The survival time was greater when the particleboards were treated with phosphorous-based (monoammonium phosphate, diammonium phosphate) and boron-based (BP®) fire retardants. These findings may strengthen the ability of kenaf core particleboards to be used as furniture components, especially in high-rise buildings. In Malaysia, there are numbers of factories use kenaf biocomposite as an input to their furniture manufacturing. One of them is called GreenComposite International Sdn Bhd. It is located in Bangi, Selangor.

7.2.2 Structural Applications

Normally, plastic-based materials are not suitable for structural / load-bearing applications. This is because; plastic-based materials are lack of strength, elasticity and dimensional stability. However, the disadvantages of the plastic-based materials can be reduced by incorporating them with natural fibers. Natural fibers are known for high strength and elasticity, but they are not suitable to be used in structural applications, when they are used alone. Biocomposites that have good strength and elasticity, which are suitable for structural applications can be formed, when natural fibers are mixed with suitable matrix.

Unfortunately, until now, acceptance of biocomposites as structural applications is still low, due to the lack of production procedure standardization as well as quality of the produced biocomposites [71]. However, it has been recorded that biocomposite such as oriented strand board (OSB) is widely used in North

America and Europe for load-bearing applications. Kenaf biocomposite on structural applications commercially is still limited even though many researches have proved the abilty of kenaf biocomposite for such applications (Paridah and Juliana, 2008)[76].

7.3 Kenaf Biocomposite vs Common Petrol-Based Composite

There are many reasons why kenaf biocomposite should receive better attention over petrol-based composite. The main reason is related to the efforts to improve and preserve the environment. The other reason is because manufacturing cost of kenaf biocomposite production is considerably lower. Knowing the cost of manufacturing is important because this is the main thing of concern to the industry before they can accept innovation of a research. According to the industry, even though an innovation is capable of helping them to produce good products, but if the manufacturing cost is high, they will think twice to accept it. They prefer innovation or idea that can help them to create a good manufacturing process at a lower cost. A research conducted by [72] has found that to produce a piece of kenaf core particleboard with a size of 340 mm x 340 mm x 12 mm, the cost that is required is around RM 3.65. This means, if the production volume is in cubic meter, the production cost would be as much as RM 2629.13. This cost is still low when compared with the manufacturing cost of a petrol-based composite. The manufacturing cost is cheaper because natural fibers such as kenaf fibers are cheaper than materials that are commonly used in petrol-based composite, for example, glass fiber [73].

Kenaf natural fibers are light in weight and they are also easy to be processed. Biocomposites made of kenaf fibres have mechanical and physical properties comparable to glass fibre-based composites and they are also biodegradable [74].

Study on the cost of manufacturing biocomposite using kenaf fiber is still very limited and unpopular. This might due to the thought that it is not necessary for us to make a 100% substitution for petrol-based composite with biocomposite. Now, even though biocomposite is seen as a potential substitute to petrol-based composite, but it is impossible to replace all the applications involving petrol-based composite with biocomposite [75].

8. CONCLUSIONS

Based on the review made, biocomposites made of kenaf fibres seem have been receiving progressing acceptance by the industry around the world, even though it is not rapid. Kenaf biocomposite has a good potential to replace petrol-based composite like glass-fibre composite because it has comparable mechanical and physical properties to the latter. In Malaysia, biocomposite technology is a relatively new; however it has a bright future to develop through continuous research and development as well as well-planned commercialization strategy. Approaching manufacturers and helping them to implement good biocomposite production process, in order to obtain high quality biocomposite is essential. To ensure continuous supply of good quality kenaf fibers to meet the uprising demand of kenaf biocomposite, the upstream also needs to practice good kenaf plantation procedures. Both upstream and downstream need to work together closely to ensure unstoppable development and acceptance of kenaf fibre-based biocomposite in various applications.

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