Jurnal Kejuruteraan 31(1) 2019: 65-76
https://doi.org/10.17576/jkukm-2019-31(1)-08

Kenaf Fiber Composites: A Review on Synthetic and Biodegradable Polymer Matrix

(Komposit Gentian Kenaf: Satu Ulasan bagi Sintetik dan Biodegradasi Polimer Matrik)

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Received 24 July 2018, Received in revised form 23 November 2018
Accepted 10 January 2019, Available online 30 April 2019

ABSTRACT

This review paper deals with the previous and current works published on the kenaf fiber composites. Kenaf is grown commercially in South East Asia country and widely used in the construction and infrastructure as well as in the automotive industry. Kenaf fiber is usually reinforced with synthetic based polymer resin such as polypropylene. However, recent studies tend to concern towards the environmental issues which kenaf fiber act as an alternative natural fiber competitor. Moreover, the combination of the natural fiber and the biodegradable polymer able to reduce the negative impact on human health. Hence, researcher-initiated the interest focusing on the biodegradable materials obtained from the renewable sources. A huge attention gave to the kenaf fiber reinforced bio-polymer materials such as polylactic acid. The processing technique and the fiber orientation within the composite materials are discussed extensively in order to obtain the maximum composite performance. Results indicated that the mechanical properties; tensile strength and tensile modulus, are improved as the kenaf fiber was aligned in uni-direction. Therefore, this paper overview on the kenaf retting types in the common form of kenaf fibers and discussing the thermoplastic polymer matrices types used in the fabrication processes. In addition, the challenging of using kenaf fibers composites and its application in the automotive industry also highlighted.

Keywords: Natural Fiber; Thermoplastic Polymer; Biodegradable Polymer; Automotive Components

ABSTRAK

Kertas ulasan ini membincangkan tentang kajian terdahulu dan terkini bagi komposit yang terhasil daripada gentian kenaf. Kenaf telah ditanam secara komersial di negara Asia Tenggara serta digunakan dengan meluas dalam bidang pembangunan dan juga insdustri automotif. Gentian kenaf kebiasaanya dijadikan sebagai salah satu bahan diperkuat bagi sebatian polimer seperti polipropilena. Walau bagaimanapun, kajian terkini lebih cenderung terhadap isu alam sekitar yang menjanjikan gentian semula jadi sebagai satu bahan alternatif yang berdaya saing. Tambahan lagi, kombinasi antara bahan gentian semula jadi dan polimer terbiodegradasi turut mengurangkan implikasi terhadap kesihatan manusia. Oleh itu, penyelidik terdorong untuk mengkaji bahan terbiodegradasi seperti asid poliatilik. Proses penyediaan dan orientasi gentian dalam bahan komposit turt dibincangkan secara mendalam bagi memperoleh prestasi bahan yang maksimum. Keputusan menunjukkan sifat mekanik; kekuatan tegangan dan tegangan modulus dapat ditingkatkan apabila bahan gentian kenaf disusun pada keadaan satu arah (uni-direction). Oleh itu, keseluruhan ulasan kajian dilalkukan keatas jenis kenaf yang direndam serta perbincangan jenis polimer termoplastik yang digunakan semasa proses pembuatan. Tambahan lagi, cabaran penggunaan gentian kenaf komposit dan aplikasi dalam bidang industri automotive turut ditekankan.

Kata kunci: Gentian Semuala Jadi; Polimer Termoplastik; Polimer Terbiodegradasi; Komponen Automotif

INTRODUCTION

For the past years, the natural fibers have become a major attraction for many researchers. The environmental issues awareness and the petroleum shortage resources encourage the exploration of the natural fibers as an alternative resource. Natural fibers often derived from renewable sources consist of plants, animals and minerals (Akil et al. 2011). However, the fiber selections depend on the fiber types, application and the production cost. Studies suggested that the natural fibers offered a huge advantage when compared to the conventional reinforcement or synthetic fibers. The natural fibers able to benefit both in economic and environment friendly. On top of that, these natural fibers also offered an excellent in mechanical and physical properties. Researchers suggested that the natural fibers are more cost-effective in terms of raw material due to its renewable resources with abundantly and cheap that reflected the maintenance cost reductions (Akil et al. 2011). Moreover, the natural fiber benefits as its release the CO_2 neutrally at the end of its life cycle. Hence, its poses no negative side effects towards human health as the particle is inhaled, and biodegradable.

In comparison to the conventional materials, lower density of the natural fiber results in the lightweight fiber for polymer composites. Despite that, the excellent tensile modulus and specific modulus results in enhancement of mechanical properties. These indicated that the natural fibers have a huge tendency in fabricating low costs and lightweight materials, high strength and good in stiffness. These features further make the natural fibers widely developed due to the intention of producing a lightweight composite (Nabi S D. and Jog J P 1999). Recent publications reported that these natural fibers were applied extensively in various of application including the construction, sports and leisure, furniture and consumer goods, pipes and tanks, as well as automotive industry (Low, Ghanbari, Rahman & Majid 2018).

Hence, kenaf fiber is one of the natural fiber which often and extensively used over the past few years. Kenaf fibers have gained so much interest among the researchers due to its unique properties and availability. The study reported that kenaf fiber is a good alternative to wood in the pulp and paper industry (YA El-Shekeil, Sapuan & Khalina 2012). Therefore, this review paper will focus on the kenaf fiber reinforced in variety thermoplastic matrices. There is a different type of thermoplastic materials discussed which is the petrochemical based; polypropylene (PP) and the bio-based; polylactide acid (PLA). These studies will be focusing on the production of the automotive parts using the kenaf fiber materials.

KENAF FIBERS

Kenaf or (Hibiscuss cannabinus L.) Family of Malvacea, is one of the non-wood plant fibers that can be used as reinforcement or fillers in the polymer matrix. Theoretically, kenaf fiber is a traditional third world crop after wood and bamboo which originated from Asia and Africa. Kenaf plant grows quickly around four to five months after sowing the seeds. The kenaf plant growth under a wide range of weather conditions. The plant able to reach the height of more than 3 m with a base diameter of 3 to5 cm (Akil et al. 2011). The kenaf plant can be divided into several parts including the long stem which provides the long fiber. Meanwhile, the kenaf stem consists of two types of fibers known as bast fiber and the core fiber for the outer and inner layer, respectively (Mutasher et al. 2011). Besides that, a thin central pith layer known as a sponge-like tissue are non- ferrous cells. Studies reported that about 35% dry weight of the kenaf stalk consists of the bast fiber which often used to produce paper, textiles and rope. Meanwhile, 65% of the kenaf fiber consists of its core which suitable for animal bedding and potting media. Details of the kenaf fiber will be discussed extensively in the subsequent topics.

KENAF RETTING

Research in 2012 shows that the kenaf bast fiber encounters an excellent flexural strength and good tensile strength when compared to the other kenaf fiber parts (El-Shekeil et al. 2012). Referring to these properties results in researchers tend to choose kenaf bast fiber in a wide range of processing materials. These include the extruded, molded and non-woven products as widely discussed. While the core fiber is light and porous make it easy to crunch into a lightweight particle. However, the ratio of bast to core fiber is (40: 60), it is more economical to use both fiber for the production (Paridah et al. 2009). After harvesting, the kenaf stem was processed in order to produce the bast and core fiber. These were due to the fact that the kenaf fiber unable to be used in its natural state. The basic cellulose fibers must be separated out from the pectin resin that connects them to the woody core of the stem. Meanwhile, the initial retting will expand the fibers which result in the bigger surface area for better kenaf bonding with the matrix (Marsh 2003). Studies demonstrate that there are several types of retting process including dew, enzymatic, mechanical, chemical and water. Hence, for the dew retting process, the plant stems are cut out and vacate to decay. The dew retting will reduce the fiber strength, low and inconsistent quality because of climatic change (Md. Tahir et al. 2011; Jankauskienė & Gruzdevienė 2013). While enzymatic retting is the retting where enzymes such as pectins and xylanases are used to detach the gum and pectin material in the bast. However, the mechanical retting encounters a high cost retting which produces a lower fiber quality. Hence, the fiber are separate by decorticator and generally used to prepare the short fiber or twisted fiber (Mahjoub et al. 2014).

The chemical retting is the high cost retting in which the chemicals were used to dissolve the pectin and separate the component. Yet, these ensured a more efficient way in order to produce a clean and consistent long and smooth surface of bast fiber. Moreover, its ensure the bast fiber to be produced within a short period time but low in tensile strength and generates costly wastes. Despite these, the most popular and traditional method is water retting or microbial retting which known as bacterial retting (Gita et al. 1994). According to Lee et al. (2010), the bacterial retting able to increase the length of the natural fibers. Therefore, these become an alternative way to improve the natural fiber reinforcement. (Shah 2013) had conclude that, the water retting gives the least energy intensive, followed by dew retting and bio-retting. Hence, it can conclude that, the dew, enzymatic, chemical and water retting are the suitable retting process in order to produce a long kenaf fiber.

KENAF COMMON FORMS

Kenaf bast and core fibers are used in different forms as reinforcement in the polymer composites referring to the application needs. There are several kenaf fibers commonly used such as long fiber in a form of continuous and discontinuous yarn, woven or non-woven mat as shown in Figure 1. The continuous form refers to the long fibers which is lengthy compared to the short fibers. Usually the short fibers growth in average of 30 mm in length (B.-H. Lee, Kim & Yu 2009). In contrast, the long, continuous fibers are easy to orient and process compared to the short fiber. These are due to the fact that the appropriate orientations are hard to obtain and controlled when using the short fiber (Mohd Radzuan et al. 2016). Hence, these further lead to other beneficial features of the long fiber including good impact resistance, low shrinkage, improved surface finish, and dimensional stability. However, one should note that short fibers provide a low cost materials and fast cycle time of the fabrication procedures (Kaw & Group 2006).

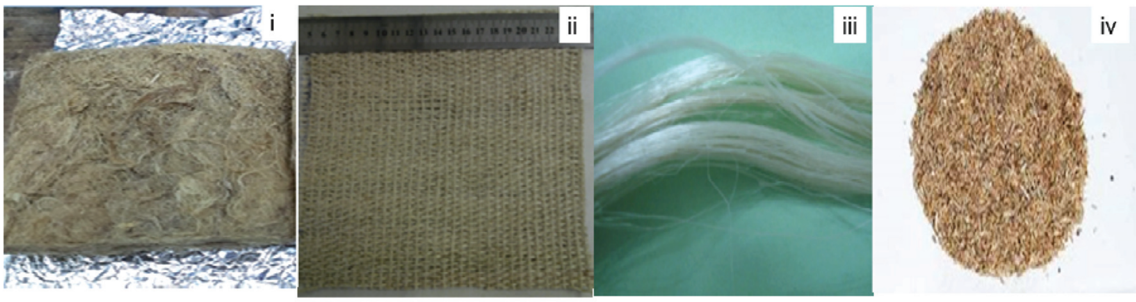

FIGURE1. Kenaf fibers in different form (i) Non-woven, (ii) woven, (iii) long (iv) core

Therefore, these exhibited that woven form produced from the long kenaf fiber are more attractive reinforcements materials. (Alavudeen, Rajini, Karthikeyan, Thiruchitrambalam & Venkateshwaren 2015). A. E. Ismail & Hassan (2014) prepared the woven kenaf from the kenaf yarn using the in-house developed machine while, Kobayashi, Takada & Nakamura (2014) use the woven fabric from the micro-braiding technique that weaved on a loom. The form of the non-woven mat will ensured that the fiber arranged homogenously and exhibit better mechanical properties compared to composites produced using randomly oriented materials (Salim, Ishak & Abdul Hamid 2011).

However, the mechanical properties of the composites itself are depending on several factors such as fiber length, fiber loading and also fiber orientation in the matrices (Chua et al. 2013). Studies suggested that as the fiber oriented in one direction, the stiffness and the strength of the materials improved. Meanwhile, as the fibers oriented such as in mat-directions, the fibers experience a highly stiff structure which improved in strength (Kaw & Group 2006). Table 1 shows that the most commonly applied methods in order to fabricate the unidirectional composites are hot pressing, compression molding and hand lay-up (Tholibon et al. 2016). Researcher demonstrates that the long fiber will initially be combed. These are crucial in order to lean and untangle the strong bonding between the individual fiber and to ensure that the fibers are relatively parallel (Chen et al. 2005: Bernard et al. 2011: Paridah et al. 2009). Aziz & Ansell (2004) noted that the long unidirectional orientation gives higher mechanical properties compared to short fiber with the random orientation. These were supported by the experiment conducted in which the flexural modulus of the short fiber composites was much lower compared to the aligned long fiber (Sulong et al. 2011). Despite that, Alomayri et al. (2014) determine the effect of cotton fabric orientation in which as the fabrics aligned in the horizontal orientation the higher load and greater resistance to the deformation were achieved when compared to the vertically-aligned materials.

KENAF COMPOSITES

In composite materials, theoretically the polymer matrix will dominate the composites shape, surface appearance, and overall durability while the fiber carries most of the structural load. The most popular matrix materials in thermoplastics materials included polypropylene (PP), polyethylene (PE), polystyrene (PS), and PVC (polyvinyl chloride). Meanwhile, the thermoset materials such as polyester, epoxy resin, phenol formaldehyde, and vinyl esters which also acted as the binder. Due to the ideas in replacing the conventional petroleum-based metrics for the purpose of public awareness many new polymers were developed from renewable resources. These materials include the bio-based plastic such as polylactic acid (PLA), PHA (PHB (polyhydroxybutyrate) and starch.

PETROCHEMICAL BASED: POLYPROPYLENE

Polypropylene is thermoplastic polymer arise from polymerizing propylene molecules which possess an excellent high heat distortion temperature, transparency, flame resistance, dimensional stability that can be used in the wide application. The composite fabrication of PP with natural fiber is one of the most suitable routes to develop natural – synthetic polymer composites (Shubhra, Alam

TABLE 1. Literature survey on research of unidirectional composites

Author(s)	Fiber	Fiber content (%)	Matrix	Processing	Direction (^{0})
Lee et al. (2010)	Long kenaf	40	Polypropylene (film)	Hot pressing	0, 45, 90
Mahjoub et al. (2014)	Long kenaf	40	Epoxy	Hand lay-up	Continuous and parallel
Khondker et al. (2006)	Jute (yarn)	20	PLA	Compression	Parallel molding
Shibata et al. (2008)	Bamboo Kenaf	-	Corn-starch	Press forming	-
(Brahim & Cheikh 2007)	Long Alfa fiber	40	Polyester	Wet lay up Cold press	Parallel
(Van de Velde & Kiekens 2003)	Flax	-	Polypropylene	Hot pressing	Parallel
(Ochi 2006)	Long Manila Hemp	70	Starch	Hot pressing	-
(Nishino et al. 2003)	Kenaf sheet	-	PLLA	Wet impregnation	Parallel and perpendicular
(Ochi 2008)	Long kenaf	70	PLA	Hot pressing	-
(Deka et al. 2013)	Long kenaf	20	PFA	Compression Molding	-
(Kobayashi & Takada 2013)	Long hemp (yarn)	-	PLA	Microbraiding	- technique
(Lodha & Netravali 2005)	Ramie sheet	-	Soy protein	Hot pressing	Parallel
(Chabba & Netravali 2004)	Flax yarn	-	Soy protein	Hot pressing	
(Oksman et al. 2003)	Long Flax (roving)	30	PLLA	Compression molding	-
(Hamzah, Taib & Baka 2013)	Long kenaf (yarn)	30	Unsaturated polyester	Cold press hand lay-up	-
(Ben et al. 2007)	Kenaf sheets	-	PLA	Hot pressing	0 , 45, 90

& Quaiyyum 2011). Natural fiber reinforced PP polymers composites are becoming typical by the development of new production techniques and processing equipment.

BIO-BASED: POLYLACTIC ACID (PLA)

Latest environmental concern on the use of non-renewable resources are encouraging industry to develop an ecologically friendly bio-based composites. Hence, nowadays the new bio-based polymeric matrices were extensively applied. These biodegradable polymers can be classified into four types according to their origin which naturally available (e.g. casein, gelatin, collagen), microbial synthesis (e.g. PHA, PHB), renewable resources (e.g. PLA, starch) and petrochemical synthesis (e.g. PCL, PVA). Besides that, in general these biodegradable materials tend to degrade through the enzymatic reactions in certain environments such as with representative of suitable humidity. However, polylactide (PLA) and polyhydroxyalkanoates (PHA) are the most important among its group.

PLA is currently the most promising materials which produced from lactic acid through the fermentation of agricultural products including corn, rice or sugar beet/cane (Bajpai et al. 2014). The PLA possesses a relatively high melting point and offered a good mechanical performance, good aesthetics, biocompatibility and easy processes in most equipment. However, the PLA has its own limitations including its low elasticity modulus at the glass region and slow crystallization rate which retard its performance (Terzopoulou et al. 2014). Therefore, in order to overcome these issues, the PLA was reinforced with the natural fibers to develop an environmentally beneficial green composites materials (Mukherjee & Kao 2011).

MANUFACTURING PROCESS

Different polymer composites manufacturing techniques can be applied based on the type of matrix used. The suitable manufacturing process will transform the material to the shape without affecting the product. To date, injection molding, extrusion, compression molding, and hot pressing are the major manufacturing processes (Emeka et al. 2018). Generally, the processing methods for the biodegradable polymer such as PLA are similar to those developed for conventional composite materials. According to (Barkoula et al. 2010), composites manufactured through injection moulding exhibited lower impact strength than compression molding (Hamimah et al. 2010; Muhammad et al. 2008).

Bodros et al. (2007) also reported that the film stacking process in term of the heating and compressing materials in which the fiber mats were inserted within the polymers film aid in reducing the fiber degradations. Despite that the press temperature during film stacking also crucial as its effect the mechanical properties of the composite materials. Experimental conducted to demonstrate that as the press temperature increases, the flax fibres wettability and the adhesion between molten matrix and fibres are improved. However, these further results in limitations encounter by the composite materials such as water evaporation, chain degradation and oxidation of the flax fibres. This further decrease and deteriorate the composite materials mechanical properties. For instance, the viscosity of the matrix must be concerned especially for producing thick sample during pressing and heating process. For the purpose of producing quality composite, apart from controlling the viscosity, pressure time, holding time, temperature based on types of fibers and matrix also the sample size should also be considered. Inability to control the processing parameters will cause the reduction in mechanical properties of the composite. For this study, the authors' focus is only to the processing of kenaf reinforced PP and PLA composites using hot pressing or compression molding.

BIO-COMPOSITE SYSTEM

Currently, there are numerous studies on kenaf fiber reinforced polypropylene (PP) composites using hot pressing or compression molding method. Some techniques are conducted to ensure that the proper matrix fusion and a good fibre impregnation. Zampaloni et al. (2007) in their study, focused on the fabrication of kenaf fiber reinforced (PP) in order to get a good fiber distribution. Firstly, using long kenaf fiber (130 mm) sandwiching between the two layers of PP sheets but it showed the poor fiber distribution. Due to uneven fiber distribution in the sandwiching, the chopped kenaf (20 mm) was used where its mechanically mixed with powder PP in a kitchen mixer. This method creates a swirling pattern, causing clamping and void, make it difficult to achieve an even fibers distribution. Lastly, the optimal fabrication method that produce the better fiber distribution has proven to be the layered sifting of a microfine polypropylene powder (20µm compared original PP size 400µm) and chopped kenaf fiber.

Based on Figure 2, results exhibited that at 30 wt.% and 40 wt.% of the fiber content able to provide adequate reinforcement which aid in improved and strengthen the composite materials. Despite that, the use of the coupling agent, 3% Epolene G3015 (MAPP) is recommended to give successful fiber–matrix adhesion improved the flexural and tensile strength of composite materials. According to Saad (2011), the tensile strength, impact strength, and thickness swelling for samples that treated with MAPP give better performance compared to the untreated composite. Lee et al. (2010) had use the hot-pressing technique to evaluate the effect of kenaf long fiber orientation and the properties of laminates. Findings indicated that the mechanical properties improved as the fiber content increase and oriented parallel to the loading direction. Studies reported that the highest tensile strength was obtained for the composites with a 50 wt.% kenaf content at 0^0 fiber orientation.

In another, other research done by Shibata et al. (2006) shows that the number of kenaf layers, heating time and kenaf weight fraction will give effects on the flexural modulus of the lightweight laminate composite. That process resulted in better wetting between the polypropylene materials with the kenaf fiber which was observed by the SEM. Meanwhile, Hao et al. (2013) produced the kenaf reinforced PP materials with the ratio of 50/50 by the carding and the needle-punching techniques. The results indicated that at high temperature, the mobility of melt polypropylene will increase. These further related to the excellent fiber bonding which formed within the matrix. Besides that, the 6 mm thickness sample are too thick as the time processing duration of 1 minutes are insufficient for the heat to transfer from the sample surface towards the inner sample.

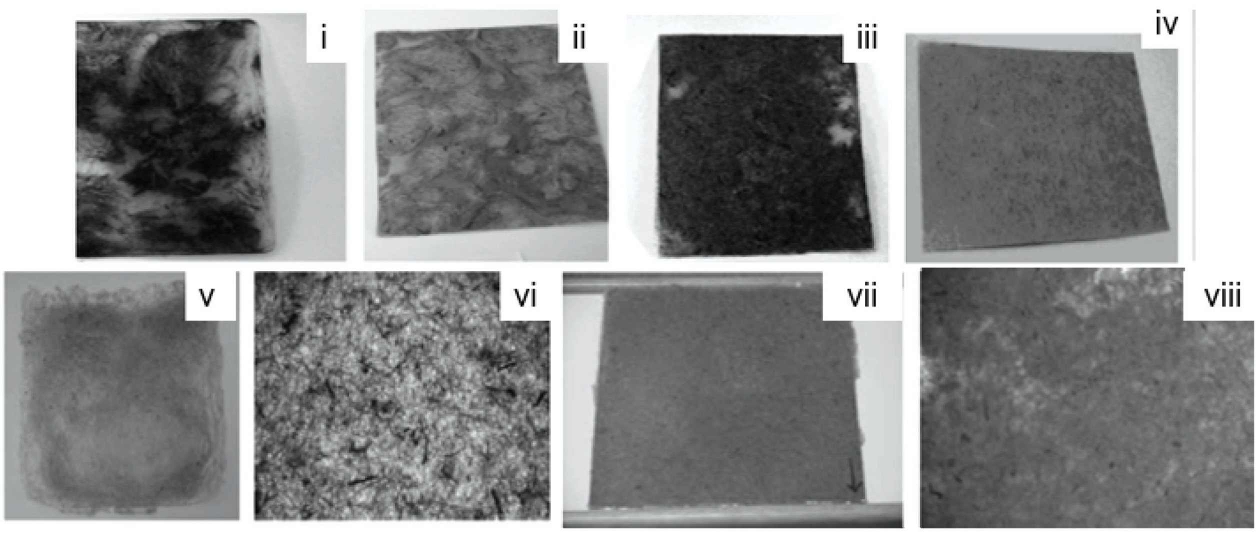

FIGURE 2. The kenaf fiber materials at various types and conditions (i) long fiber (ii) chopped fibers (iii) kenaf/PP composites fabricated by dry mixing (iv) kenaf/PP composites fabricated by multiple layering of powder and fiber (v)&(vi) kenaf/PP composite fabricated by multiple layering of powder and fiber (vii) & (viii) final kenaf/PP composites with 30% fiber by weight (Zampaloni et al. 2007)

Asumani et al. (2012), fabricate the kenaf fiber reinforced polypropylene composite using the compression molding as illustrate in Figure 3. The studies categorized into several fabrication process which compaction are, fiber impregnation, compression, release of the compaction and cooling process. The compaction stage starts at the pressure of 7.5 MPa and the temperature of 250^{o}C for 20 minutes. The pressure then reduces and maintain to 5 MPa in order to minimize the uneven fiber distribution. In another, study conducted by (John et al. 2010) had use the needle-punched techniwue towards the non-wovens kenaf fibers that was treated with the zein coupling agent. The polypropylene used in the studies consists of a sheet form structure which used to fabricate the composites. The kenaf mats were cut in square form (30 cm × 30 cm) before being dried in the oven at 110°C for 7 hours. Later, the kenaf mats were sandwiched between the weighed polypropylene sheets and wrapped in the Teflon® sheets. The compression pressure is about 3.5MPa for 20 minutes at 210°C were applied during the processing. The materials were later cooled under pressure for 3 minutes.

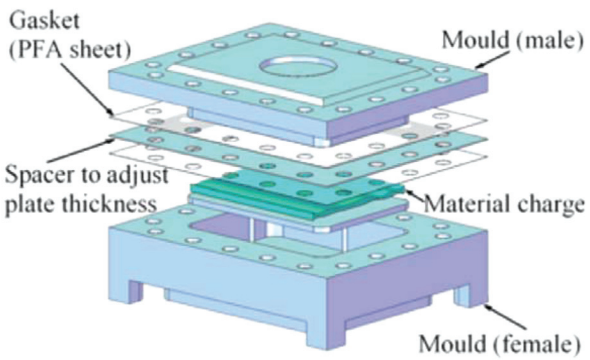

FIGURE 3. Detail mold assembly for compression molding (Asumani et al. 2012)

BIOCOMPOSITES KENAF FIBER

(Ben et al. 2007) investigate the mechanical properties and molding conditions for the kenaf fiber yarn bundles form. These kenaf fiber yarn bundle were obtained from the kenaf textiles and reinforced with the PLA polymer resin using the hot press method. Results indicated that the combination of the temperature at 185°C for 15 min gave the highest tensile strength of the composite. Ochi (2008) studies on the long kenaf fibers fabrication in the uni-directional direction reinforced PLA composites using the hot-pressing method. At the temperature of 160°C, the tensile strength of the heat-treated kenaf fibers tend to decrease, even with longer heating times. The tensile strength of kenaf fibers heat-treated at 180°C for 30 min was similar to that of non-heat-treated fibers but later decreased at 200°C. Figure 4 shows the processing temperature which kept below 160°C for 60 min or 180°C for 30 min to prevent the strength reduction due to the thermal degradation.

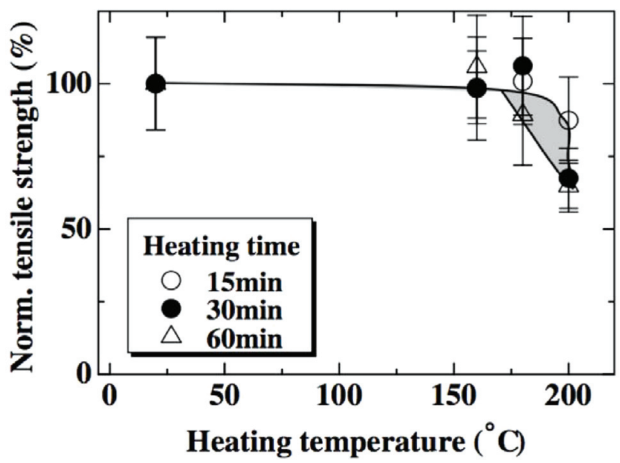

FIGURE 4. Relationship between tensile strength of kenaf fibers and heating temperature

Results as in Figure 4 show that the tensile strength, flexural strength and the elastic moduli of the kenaf fiber-reinforced composites increased as the kenaf fiber content increase till 50 wt.%. However, as the kenaf fibers content increase at 70 wt.%, the unidirectional fiber-reinforced composites showed the tensile strength and flexural strengths of 223 MPa and 254 MPa, respectively. These exhibited that the maximum kenaf fiber content of 70 wt.% are required to performed an excellent composite properties. (B.-H. Lee et. al. 2009) explore the use of carding process in the production of bio-composites of kenaf fibers combined with PLA fibers prior to compression molding as shown in Figure 5. Results indicated that the tensile strength, elongation and flexural strength are certain with the automotive industry standard.

A similar work by Graupner & Müssig (2011) using the carding process in order to produce the multilayer webs of the PLA at 40 wt.% of kenaf fibres prior to the compression molding process. Results indicated that the fibre reinforcement leads to a significant increase in the tensile strength. The tensile strength of 82.0 N/mm^2 was measured for the kenaf reinforced PLA composites which is high compared to the pure PLA matrix at 51.9 N/mm^2. W. Liu et al. (2007) studied the impact of the fiber length and the processing method on the thermal and the mechanical properties of the composites from kenaf fiber and soy-based bioplastic. Taib et al. (2010) studied the kenaf fiber as reinforcement in plasticized polylactic acid (p-PLA) as a matrix component. In the study, polyethylene glycol PEG was added in the composite formulations to plasticize PLA to improve the brittleness of PLA itself. Results showed that the tensile strength and kenaf composites modulus is increased with the increasing of the fiber loading. Moreover, the highest tensile strength was obtained at 40 wt.% of fiber loading with the unplasticized PLA as listed in Table 2. This indicated that the presence of the PEG materials might have disturbed the fiber-matrix interaction in the p-PLA/kenaf composites. Nevertheless, the presence of PEG improved the impact strength of p-PLA/kenaf composites.

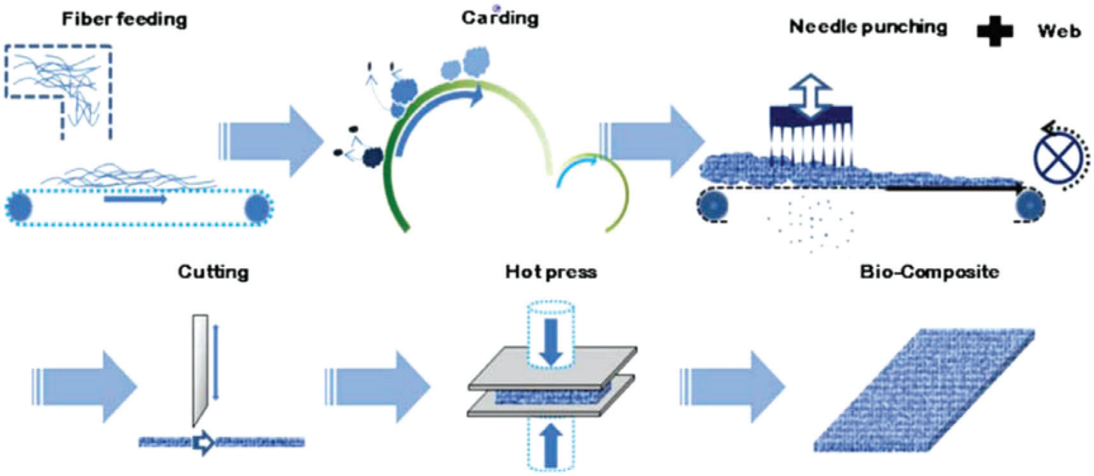

FIGURE 5. Carding process (kenaf and PLAs fibers) for manufacturing bio-composites (Lee et al. 2009)

TABLE 2. Mechanical properties of PLA, p-PLA and their composites[a] (Taib et al. 2010)

Materials	Tensile strength/MPa	Tensile modulus/GPa	Strain at break/%	Impact strength/kJ/m^2
PLA	41.06 (1.21)	1.66 (0.11)	4.24 (0.61)	11.00 (3.67)
p-PLA	17.58 (3.73)	1.35 (0.51)	42.29 (20.28)	14.57 (3.77)
p-PLA/10KF	10.10 (2.05)	2.13 (0.22)	6.17 (0.60)	8.34 (3.03)
p-PLA/20KF	29.00 (1.63)	2.71 (0.31)	2.03 (0.45)	8.51 (1.63)
p-PLA/30KF	35.02 (3.38)	3.56 (0.19)	1.47 (0.18)	6.36 (1.32)
p-PLA/40KF	38.45 (2.68)	4.22 (0.13)	1.46 (0.08)	7.02 (1.52)
PLA/40KF	60.95 (1.41)	5.73 (1.20)	1.48 (0.05)	5.89 (1.54)

[a] Standard deviation in parentheses

(Shukor et al. 2014) investigated the effects of the ammonium polyphosphate (APP) content on the flame retardancy, thermal stability and the mechanical properties of the alkali treated kenaf fiber filled PLA bio-composites materials. The PLA was initially blended with the kenaf core fiber, polyethylene glycol (PEG) and ammonium polyphosphate (APP) using the dry blending. The compound was later underwent the twin screw extrusion and compression molding process techniques in order to fabricated the composite materials. Results indicated that incorporation of the APP materials is shown to be very effective in improving the flame retardancy properties. These was measured using the limiting oxygen index measurement which often increased char residue at higher temperatures. However, the APP addition will decreased the compatibility between the PLA and kenaf fiber. These further results in the significant reduction of the mechanical properties of PLA bio-composites (Figure 6(a) and Figure 6 (b)).

With recent growth in the field of nanocomposites, (Lasat et. al,2011) investigated the effect of the kenaf nanofiber loading in 3%, 5%, 8%, and 10% concentration on the composites mechanical performance. The 3% of nanofiber loading showed that the tensile strength is slightly reduced with no significant increase for modulus tensile compared to the pure PLA. However, the tensile strength as well as the modulus tensile was increased gradually as the amount of nanofiber increased from 5% to 10%. The tensile strength of 10% nanofiber loading was increased by 28% compared with neat PLA from 33 MPa to 42 MPa. The modulus tensile was increased by 83% with 10% of nanofiber loading from 482 MPa to 884 MPa. In contrast Ogbomo et al. (2009) studied several kenaf fiber loading of 1 wt.%, 3 wt.%, and 5 wt% reinforced with the Poly(L-lactide). Results showed the storage modulus kenaf composites are higher than the PLLA matrix shown in Figure 7(a). These indicated a potential of kenaf reinforcement due to the strong interaction that exists between the PLLA and kenaf. In addition, the peak also increases with the concentration indicating a higher energy absorption capability in the composites when compared with the pure PLLA. The glass transition, as indicated by the peaks in the loss modulus-temperature curve as show in Figure 7(b), showed a modest increase with increased in kenaf concentration.

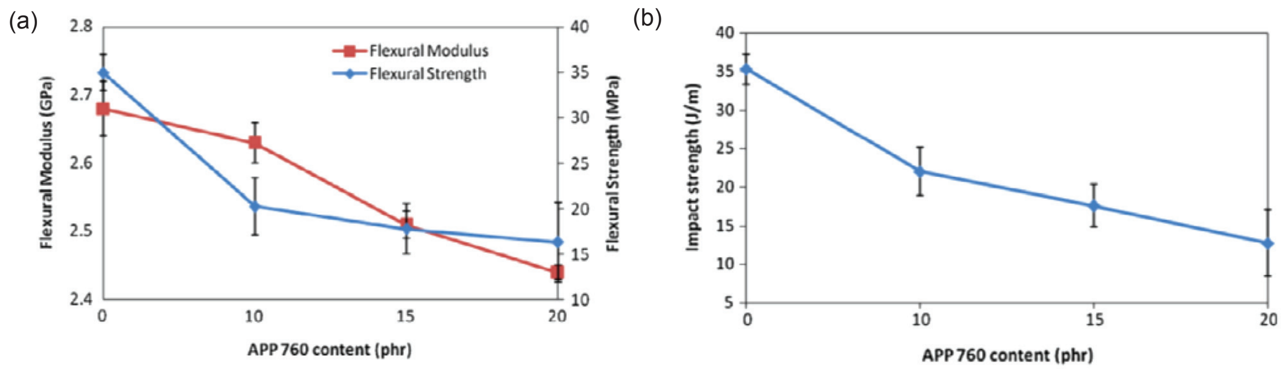

FIGURE 6. (a) Variation of flexural properties PLA bio-composites at different APP content. (b) Variation of impact strength of PLA bio-composites at different APP content.

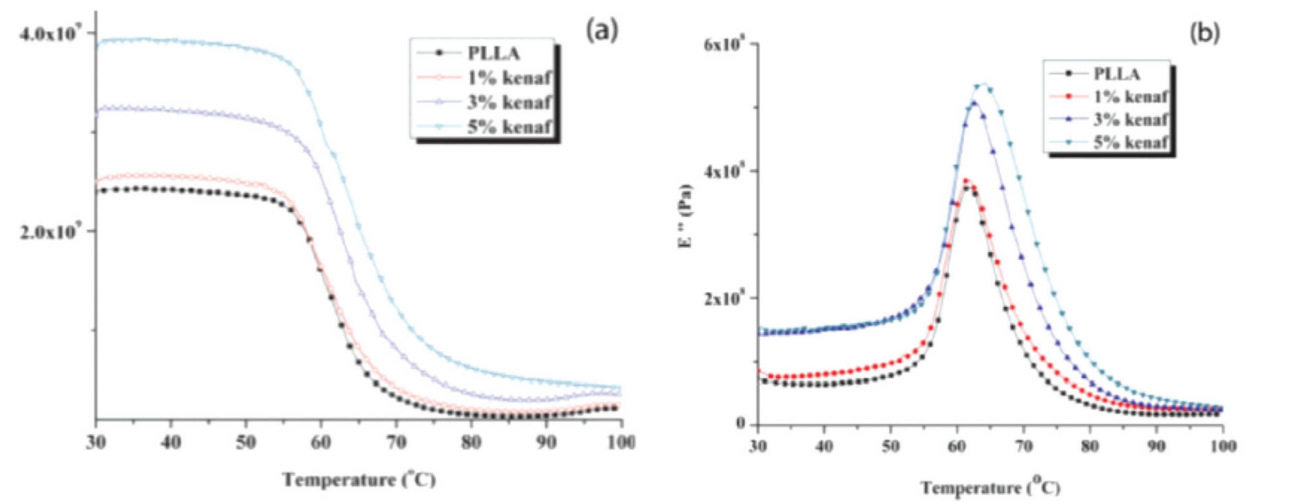

FIGURE 7. (a) Storage modulus of PLLA and kenaf composites showing enhanced glassy plateau moduli with kenaf concentration and (b) loss modulus as a function of temperature for PLLA and kenaf composites showing slight increase in glass transition and E” maxima with kenaf concentration

CHALLENGES AND SOLUTIONS OF KENAF COMPOSITE REINFORCEMENT

Based on the previous research conducted, the main limitations of the natural fibers as the reinforcement in composites are lack in interfacial adhesion between the fibers and the polymeric matrices. These phenomenon results in the poor properties of the final product fabricated (Akil et al. 2011). The natural fibers behaved as a hydrophilic materials due to the presence of the hydroxyl-group. These we differ from others polymeric matrices which often behave as a hydrophobic materials (Ismail et al. 2010). The fibers with hydrophilicity properties results in high moisture absorption. These will lead to swell and presence of voids at the composites interface. The occurrence of the voids results in poor mechanical properties and reduces the dimensional stability of the composites materials (Jawaid et al. 2011). The difference of this characters contributes to the fibers does not wet or interact with hydrophobic polymers that cause poor wettability of the hydrophobic polymer and weak bonding between fibre and matrices interface.

Therefore, it is necessary to use a coupling agent in order to enhance the adhesion between natural fiber and the polymer matrices (Hashim et al. 2012). The coupling agent acts as compatibilizers between matrices that provide better bonding besides increase the strength and rigidity of the composites by improving the fibers wettability. Viet Cao et al. (2011) had investigate the use of compatibilizer, maleic anhydride grafted polyethylene (MAPE), on the tensile properties and water absorption of the bio-composites. It was found that the addition of MAPE will increase the tensile strength, elongation and modulus of the composites due to good adhesion between the fibers and matrices besides reduction in the water absorption of the composites. Meanwhile, Zampaloni et al. (2007) also noticed that, the use of coupling agents malleated polypropylene (MAPP) immensely improving the adhesion between natural fibers and polypropylene.

Besides that, the most common methods to reduce the moisture absorption from the fibers and improve the fiber-matrix adhesion are the alkaline treatment and acetylation. The alkaline treatment also known as mercerization usually performed using the Pottassium Hydoxide (KOH), Lithium Hydoxide (LiOH) or Natrium Hydroxide (NaOH). During these mercerization, the other non-cellulose materials such as hemicellulose, lignin, pectin and impurities such as wax, ash and natural oil in the fibers are removed. These encounter a rough surface of the composite materials (Hashim et al. 2012).

KENAF COMPOSITES IN AUTOMOTIVE APPLICATION

In recent years, the automotive industry faced the fuel-efficient and low-polluting vehicles revolutions which enquired more sustainable constructions in automotive industry. These further play an important role as a driving force toward the sustainable materials' use. Studies indicated that the automotive industry has usage about 30,000 volumes of the natural fibers such as flax, kenaf, hemp and jute. These was mainly used and applied in the passenger cars and kenaf itself compromise about 20% among of the total usages (Dammer et al. 2013).

However, for several years, the natural fibers are also being applied to exterior components. Research by (Rahim et al. 2014), Malaysia with multinational companies agreed to invest in kenaf downstream activities and take participate in research and development, fiber separation processing, production of kenaf powder until commercialization. Currently, local automotive manufacturer such as Proton and Perodua used kenaf composites in automotive trim components such as door panels, seatbacks, headliners and package trays. Table 3 shows the kenaf reinforcement in composites used as automotive parts.

TABLE 3. Kenaf fibers as reinforcement in automotive part

Matrix	Part	Manufacturer
Poly-lactic Acid	Spare tire cover, floor mats	Toyota Raum
Polypropylene	Interior door panel	Chrysler Sebring
Polypropylene	Interior door panel	Ford Fiesta and Ford Focus

CONCLUSION

Due to the increasing environmental awareness on carbon emission and depletion of petroleum resources, the natural fibers, and also biopolymers gain attention from scientist, manufacturers and industrials as an alternative for the future. Kenaf fibers are the one of the promising natural fibers owing to good mechanical and physical properties. The matrix selection, the kenaf fiber composites can be used for non-structural and structural applications. However, focuses on finding the challenges associated using the natural fiber itself or combination with the biodegradable polymer before can be established.

ACKNOWLEDGEMENT

The authors gratefully thank the Ministry of Higher Education Malaysia (MOHE) for funding under grant number LRGS/TD/2012/USM-UKM/P1/05 and Universiti Kebangsaan Malaysia under grant number MI-2017-004.

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