DEGRADABLE PLA/KENAF FIBER WIPES: A QUR'ANIC APPROACH TO SUSTAINABILITY

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ABSTRACT

Wipes are versatile items and the most commonly used items in life. Somehow wipes often be flushed down causing blockage to the sewage systems as well as flows into the ocean resulting the clogged waste lines and damaging the ecosystems that require a lot of time and money to recover. Moreover, there is an opportunity to develop non-woven biodegradable wipes to overcome this pollution issue and decrease its carbon footprint. Thus, this research aims to fabricate biodegradable non-woven fiber using the electrospinning method. The biopolymer, polylactic acid (PLA) is incorporated with Kenaf fiber and investigated for absorption, morphological and degradation properties. PLA and grinded Kenaf fiber were mixed with chloroform in various ratios and successfully fabricated with the Kenaf fibers ranging from 0 wt% (P100), 5 wt% (P95K05), 10 wt% (P90K10), 15 wt% (P85K15) and 20 wt% (P80K20). Through morphological study and the absorbency test, the findings showed higher porosity of electrospun fiber mats leads to higher absorbance. The oil absorbency test shows that P95K05 is the most suitable to be used as wipe application, specifically in absorbing hydrophobic substances. The ultraviolet (UV) degradation of PLA/Kenaf electrospun fibers showed the degradation behaviour of the non-woven composites. Additionally, this work aligns with the Qur'anic Principles of environmental stewardship (*Khilāfah*) and waste reduction (*Isrāf*), aiming to promote sustainability and minimise harm to Allah's creation. By integrating biodegradable materials into everyday products, the research addresses ecological challenges while emphasising the Islamic responsibility of protecting the environment.

Keywords: *PLA, electrospinning, Kenaf, non-woven, biodegradable, composite, Qur'an, Sustainable.*

1.0 INTRODUCTION

Environmental degradation and resource exhaustion have become pressing global issues demanding immediate attention. Waste generation, particularly from non-biodegradable materials, are among the contributing factors, significantly harming ecosystems [1]. Islamic guiding principles such as *Khilāfah* (stewardship) and avoidance of *Isrāf* (wastefulness) ensure that one's actions align with the responsibility of safeguarding Allah's creation [2]. Prophet Muhammad ﷺ also constantly reminds us that "*The purity is half of faith*" (Muslim). This research integrates such principles by developing biodegradable non-woven materials using electrospinning technology, with applications in hygienic wipes. It aims to provide an environmentally sustainable solution while fulfilling Islamic ethical obligations.

Over the past years, the production of nonwoven fiber through electrospinning has gained a lot of attention due to its versatility including all-purposed applications. Electrospun fibers have a very high surface area to volume ratio, thus very flexible to fit specific applications. Electrospun fibers have been reported in utilizing in enzyme immobilization, active food packaging, tissue engineering, filtration device and electronics [3]. This present study focuses on hydrophobic electrospun fibers that can be used as wipes, as well as exploring other potential applications as oil absorbent for oil spills, filtration devices, drug delivery, catalysis, and packaging.

Kenaf (*Hibiscus cannabinus* L.) is commonly known in history as a cordage crop, which later, more applications such as absorbents, paper products, building materials and animal feedstock were discovered. Kenaf plant has a single, straight, and branchless stalk and is made up of an inner woody core and an outer fibrous bark surrounding the core [4]. Recently, kenaf plant is used as a component in biocomposite manufacturing [3]. Due to the rapid growth and ability to harvest high yield of raw materials in a short time, kenaf is chosen as an ideal alternative material in the biocomposite industry [5]Although scientists agree that kenaf is a crucial raw material for biocomposite research, further research on kenaf for biocomposite applications can be explored. Wipes can be found everywhere and the increase of usage is now causing a huge global environmental and drainage issues which cost money and years to solve [6]. Globally, the wipes infiltrate riverbeds before discharge into the ocean, often harming marine creatures. After the sewers were discharged, many wipes were released into the sea. Wipes also contribute to microplastic in the environment due to its non-biodegradability [7]. Wipes are made up of a combination of cotton, rayon, and plastic fibers, that in turn make the wipes durable enough to complete the task at hand, but in doing so means they are unable to disintegrate or tear.

This is where the advantages of biocomposite can be exploited,and this study can incorporate the polylactic acid (PLA) and Kenaf fibers through electrospinning. This study focuses on developing biodegradable, non-woven material from PLA incorporated with Kenaf Fibers using electrospinning for wipes application, which has hydrophobic properties. The development of hydrophobic nonwoven materials also extends their application as oil absorbents for oil spills, filtration devices, drug delivery, catalysis, and packaging. Moreover, the development of nonwoven material made from PLA incorporated with Kenaf

Fibers are less extensively studied. Hence by analysing the morphology, absorbance and degradation properties of this material, more information can be found, and the applications can be further explored. The potential of nonwoven fibers made from PLA incorporated with natural fiber can be used in many applications, from commercials to medical uses. The incorporation of natural fiber (Kenaf) increases the biodegradability of the material which furthermore could decrease the plastic pollution problems that occurs globally. Utilization of natural fiber also decreases the carbon emissions of the whole process.

This present study aligns with the Sustainable Development Goal Number 9 (Industry, Innovation, and Infrastructure), Number 11 (Sustainable Cities and Communities), Number 12 (Responsible Consumption and Production) and Number 13 (Climate Action). This study investigates PLA's morphological and absorption properties incorporated with Kenaf fibers in various ratios prepared through electrospinning. Later, the ultraviolet degradation of PLA/Kenaf electrospun fibers was studied.

By aligning Qur'anic guiding principles with global sustainability goals, this endeavour demonstrates the potential of biodegradable materials to address critical ecological challenges while upholding religious and ethical responsibilities. This integration reflects a holistic approach to environmental stewardship, benefiting humanity and the planet as well as contributing to a sustainable future.

1.1 First Qur'anic Guiding Principle: Environmental Stewardship (*Khilafah*)

The role of a man as a *Khalīfah* (steward) on earth entails protecting the earth, preserving the natural world, sustaining resources, and safeguarding ecological balance. The earth and its resources are a trust from Allah and a *Khalīfah* must use them responsibly and sustainably [8]. Prophet Muhammad ﷺ demonstrated environmental mindfulness, emphasising sustainable living. He ﷺ discouraged excessive use of resources, even during acts of worship like ablution (*wuḍū*'), heﷺ said "*Do not waste water, even if performing ablution at a flowing river*." (Muslim). By creating biodegradable materials, this research addresses modern environmental challenges while adhering to the spirit of *Khalīfah*.

1.2 Second Qur'anic Guiding Principle: Avoiding Wastefulness (*Israf*)

In Islam, avoiding *Isrāf* (wastefulness) is essential to sustainable living. Allah warns in the Qur'an: " *Indeed, the wasteful are brothers of the devils, and ever has Satan been to his Lord ungrateful*." (Surah al-Isrā', 17:27) [9]. This verse accentuates that wastefulness is not merely an environmental issue but rather a spiritual deterioration, reflecting ingratitude toward Allah's provisions. Practices such as the excessive use of single-use synthetic wipes have become a prevalent example of *Isrāf* in modern times. These products are commonly disposed of after minimal use, and contribute to marine pollution and growing landfills, with devastating long-term ecological consequences [10]. Islam encourages solutions that balance human needs with environmental care [11].

1.3 Third Qur'anic Guiding Principle: Sustainability (*Istidamah*)

In simple terms, the concept of sustainability (*Istidamah*) means meeting the needs of the present generation without compromising the ability of future generations to meet their own needs. [12] Another verse in the Quran states, *"O sons of Adam, attire yourselves at every time of worship; eat and drink, but do not be wasteful, for Allah does not love the wasteful."* (Surah Al A'raf 7:31), *"And do no mischief on the earth after it has been set in order: that will be best for you, if ye have Faith"* (Surah Al A'raf, 7:85). Environmental preservation and conservation is a religious duty and social obligation. The misuse of any natural resources is forbidden in Islam. Prophet Muhammad ﷺ also emphasises that caring for the environment is a form of charity: *"If a Muslim plants a tree or sows seeds, and then a bird, or a person or an animal eats from it, it is regarded as a charitable gift (sadaqah) for him."* (al-Bukhari).

2.0 MATERIALS AND METHODOLOGY

2.1 Chemicals

Kenaf fibers were obtained from the National Kenaf and Tobacco Board, Kota Bharu, Kelantan. The Kenaf fibers were cut into smaller pieces using a scissor. Then, the Kenaf fibers were grinded and then strained using an 80µm sieve. The strained Kenaf fibers were stored inside a desiccator to avoid any excess moisture. Polylactic acid (PLA) 2003D in the form of pellets was supplied by NatureWorks Co. Ltd. PLA pellets were kept in vacuum oven overnight to remove the moisture. Chloroform was purchased from Sigma and used as it is.

2.2 Preparation of PLA/Kenaf fiber composites

The percentage of PLA/Kenaf to solvent was 10 wt%. The calculation for each composition was done by varying the ratio of Kenaf fiber to PLA while maintaining the total percentage below 10%. The compositions were denoted as P100 (10g PLA), P95K05 (9.5g PLA + 0.5g Kenaf), P90K10 (9g PLA + 1g Kenaf), P85K15 (8.5g PLA + 1.5g Kenaf) and P80K20 (8g PLA + 2g Kenaf).

The PLA and Kenaf fibers were weighed according to the respective solution compositions and mixed in a flask. Chloroform was added up to the final volume of 100ml and stirred using the magnetic stirrer. The mixtures were stirred overnight until the PLA pellets completely dissolved.

2.3 Electrospinning of Non-Woven Fiber

Electrospinning setup consisted of a high voltage supply, a diffusion pump, a 10 ml syringe with the polymer solution as stated, a blunt metallic needle, and a glass collector attached onto a metal sheet. The fixed parameters were the voltage difference of 10.0 kV, the distance between the needle tip and collector was 10cm, the solution flowrate was 10 µL/hour and the total duration time was four hours. The formed fiber mat was left to dry up for one hour and carefully peeled off from the glass collector. The fiber mat was then cut into 5cm x 1cm strips and transferred into a sealed bag. All the samples were stored in the desiccator for further characterization.

2.4 Characterizations

Scanning Electron Microscopy (SEM)

The surface morphology and fiber diameters of the grinded Kenaf fibers and the electrospun fibers were observed using Scanning Electron Microscope (InTouchScope™ JSM-IT100) accelerated at 7kV. The samples were coated with Palladium (Pd) in a sputter coating (QC7620, Quorum Ltd. London) and secured with Nisshin EM conductive carbon tape onto the sample brass holder to allow conductivity.

Absorbency Test

The Absorbency test was conducted following a modified Standard Test Method for Water Absorption of Plastics (ASTM D-570) where the samples were immersed in various oils for 2 hours. ASTM D-570 were modified for this oil absorbency test [13]. The sample was weighed before placed into each container that containing water, corn oil, mineral oil, and silicone oil respectively. The samples were allowed to sit in the fluids for two hours before it was patted dry and weighed again. The absorbency of the fiber mats were determined by the Equation (1):

$$\text{Absorption (\%)} = \frac{\text{initial weight} - \text{final weight}}{\text{initial weight}} \text{x} 100\% \tag{1}$$

UV Degradation Test

A series of ultraviolet (UV) degradation chamber was carried out as shown in Figure 1. The sample was arranged as in Figure 2. The UV degradation test was conducted for 11 days. The samples were weighed on the first, third, fourth, sixth, eight, tenth and eleventh day. The degradation was studied by calculating the weight percent of the samples for each stated day following Equation 2. The UV light was set up to be on 16hr on and 8hr off cycle.

$$\text{Wt \% loss} = \frac{\text{initial weight} - \text{final weight}}{\text{initial weight}} \text{x} 100\% \tag{2}$$

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Figure 1: UV degradation setup

Figure 2: Samples arrangement for UV Degradation Test

3.0 RESULTS AND DISCUSSION

3.1 Morphological Characterization

The surface morphology was investigated to observe the surface morphologies of the non-woven PLA/Kenaf fiber composites is shown in Figure 3. Through SEM, the fibers were visualized, and the PLA/Kenaf diameters were measured using the "ruler" tools in the SEM software, as shown in Table 1. The average range of fiber diameters was calculated and shown in Table 1. P90K10 mat was brittle and could not be peeled off easily from the glass collector. The peeled P90K10 mat for fiber visualization was not intact and had to be scrapped off the collector. It also has poor fiber uniformity and large bead formation as compared to other compositions. Hence, P90K10 is not feasible and is unable to be further analyzed. This could be due to various factors, such as the concentration of this composition and the distance of the needle and collector. P80K20 also has poor fiber formation and this could be due to the low concentration of the electrospinning solution (PLA 80%). Hence, no fiber diameter was taken. In electrospinning, lower solution concentration leads to poorer fiber formation. Similar findings were observed, where there was poor fiber formation as the solution concentration decreases. Kulpreechanan et al (2014) and Zeng et al (2003) observed the formation of beaded fibers (poor fiber uniformity) combined with reduced fiber diameters as their electrospinning solution decreases [14]. Since the Kenaf fiber was sieved through a 80 µm siever, and the PLA/Kenaf fiber diameter ranges from 0.50 µm - 10.76 µm, it is assumed that the Kenaf fiber is placed perpendicularly in the PLA/Kenaf fibers.

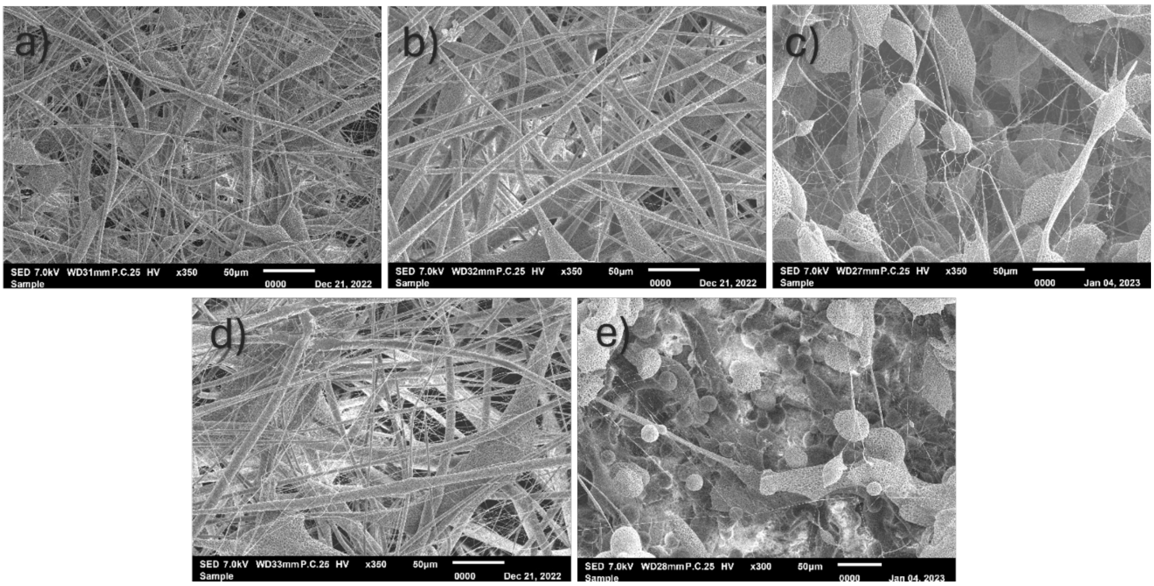

Figure 3: Surface morphologies of non-woven PLA/Kenaf Fiber Composites, a) P100, b) P95K05, c) P90K10, d) P85K15, and e) P80K20 (in x350 magnification**)**

Table 1: Range of Fiber Diameters.

Sample Code	**Fiber Diameter Range (µm)**
P100	0.55 – 6.55
P95K05	0.50 – 10.45
P90K10	0.16 – 24.93
P85K15	0.29 – 10.76
P80K20	**

** Poor fiber formation hence the no fiber diameters taken.

3.2 Absorbency Test

The Standard Test Method for Water Absorption of Plastics ASTM D-570 were modified for this absorbency test [13]. However, water absorbency was also included compared to the oil absorbency. In other studies, Kenaf fiber was found to have higher oil absorbance

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capacity compared to other natural fibers such as sisal, coir, and loofa sponge [15]. Kenaf fiber also able to absorb oil up to 5-6 times its weight [16]. From Figure 3, it can be concluded that P95K05 has the highest oil absorbency for corn oil (470%) and mineral oil (344%), and it is the second highest absorbency for silicone oil (593%). Hence, P95K05 is chosen as the most oil absorbent. It was predicted that water will be poorly absorbed by the fibers in this study due to its hydrophobic property, and it is confirmed by the low percentages of water absorbance. The oil absorbance was also presented by wiping off droplets of corn oil, silicone oil and mineral oil respectively using the P95K05 electrospun fiber mat. Most of the oils were quickly absorbed by the fiber mat, with a little residue left behind (Figure 4).

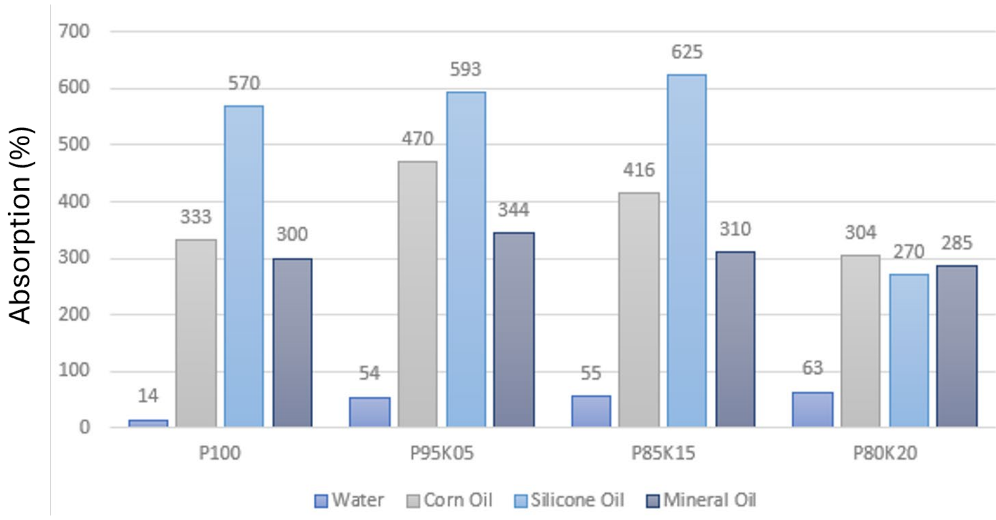

Figure 3: Absorbency Test results of PLA/Kenaf fiber composites.

Figure 4: Screen Captured from video of removal of oil using PLA/Kenal Composite (P95K05).

3.3 UV Degradation Test

Based on observation of the PLA/Kenaf fiber mats before and after 11 days of UV irradiation, the electrospun fibers becomes crumpled and chalky with formation of holes and disintegrate as it was picked up for weighing. UV radiation causes photo-oxidative degradation, leading to the breaking of polymer chains. This process generates free radicals, reduces molecular weight, deteriorates mechanical properties, and ultimately results in materials becoming useless over an unpredictable timeframe [17]. According to Rapisarda (2019), the longer exposure to UV irradiation, higher weight loss percentage of samples [18], as shown in Figure 5. As the content of Kenaf fiber increases, the degradation rate also increases as the natural compund decomposes faster and assisted in the degradation of the composites.

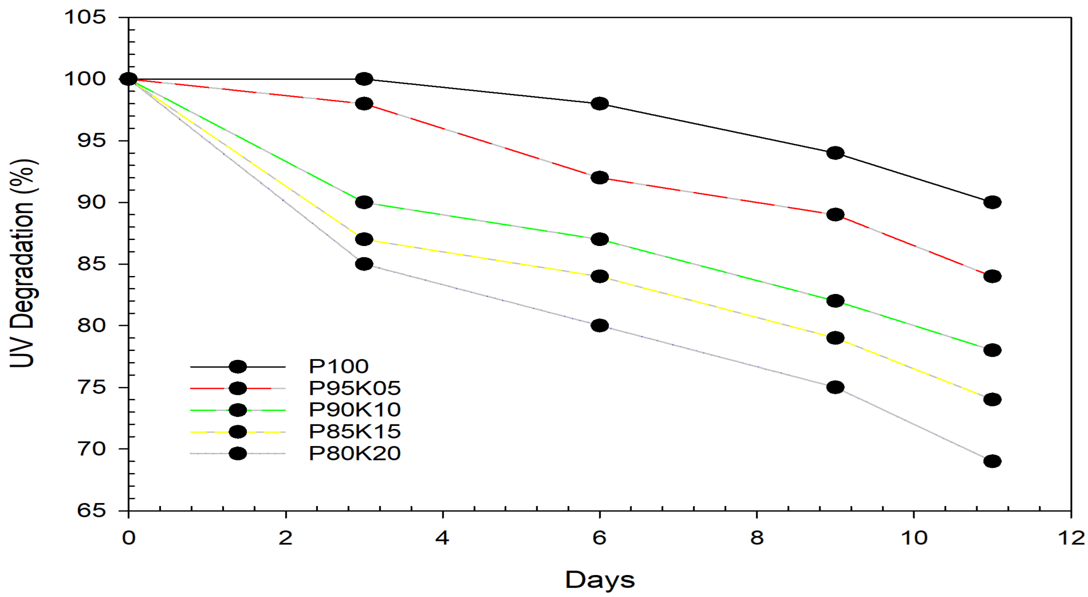

Figure 5: UV Degradation Test of PLA/Kenaf fiber composite

4.0 CONCLUSION

This work establishes the seamless integration of Qur'anic guiding principles with contemporary scientific advancements in addressing environmental degradation and challenges. Qur'an and Sunnah highlight the significance of balancing human rights with responsibilities and duties as a *khalifah*, successor and custodian of resources on the earth. All humankind is accountable before Allah for conserving the environment and avoiding *Israf* (wastefulness). The innovation of biodegradable wipes made from non-woven electrospun fibers offers a practical advantage and solution to modern environmental challenges, fulfilling human hygiene needs without compromising environmental sustainability and integrity.

High fiber uniformity can be observed in P100, P95K05 and P85K15, however severe bead formations occurred on P90K10, and low fiber formation on P80K20, making them infeasible for further analysis with P95K05 has the lowest average fiber diameter. Through absorption test, it can be concluded that P95K05 has the highest oil absorption, followed by P85K15, which both fiber compositions have the lowest average fiber diameter. Oil absorbency test showed that P95K05 is the most suitable to be used as wipes application. Furthermore, ultraviolet (UV) degradation of PLA/Kenaf electrospun fibers exhibited degradation of composites faster than the pristine polymer.

This research emphasizes the potential for modern innovation aligning with Quranic teachings and environmental sustainability. Both Qur'anic ethics and global environmental sustainability goals are realized through the invention of biodegradable materials into everyday products. This study serves as a step towards a sustainable future for the world. In a nutshell, this initiative demonstrates that faith, science and technology should be together as the drives for a significant change of the whole of humanity and the planet.

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