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Posted Date: 26 July 2023

doi: 10.20944/preprints202307.1813.v1

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Article

A Review on Agricultural Wastes and Pineapple Leaf Fibers in UAVs Airframe Manufacturing

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Abstract: In the past few decades, the use of agricultural waste has been increasing due to the increasing demand for sustainable materials. This paper aims to review the significance of agricultural waste as a type of wealth and its potential as an alternative material in the composite field. It was found that many agricultural wastes had been utilized in various production of ecological products. The review discusses the physical, mechanical, and chemical properties of the natural fibers made from agricultural waste and the use of Pineapple Leaf Fiber Reinforced Composite to manufacture UAVs (Unmanned Aerial Vehicles). The extracted waste fibers' physical, mechanical, and chemical properties show that these agricultural wastes can produce better advanced composite materials suitable for structural applications. The use of pineapple leaf fiber in Unmanned Aerial Vehicles manufacturing has the potential to revolutionize this industry and contribute to a more sustainable future.

Keywords: UAV; aircraft airframe; agricultural waste; natural fiber composites; waste composites; pineapple; reusing waste; natural waste

1. Introduction

The growth of the agricultural sector highly affects human development and economic development. Due to the ever-increasing human population, awareness of increasing agricultural production has been growing. However, the growth of agricultural production comes with the increment of farming activities, which produce large amounts of agricultural waste.

One of the major problems with having an abundant supply of agricultural waste is the disposal method. Due to the massive amount of waste generated, it is not easy for farm owners to dispose of the accumulated waste. Moreover, these wastes are usually improperly managed in developing countries because little information is available on their potential and benefit as raw material if appropriately managed. Improper handling of agricultural wastes will lead to economic loss and threaten human health due to environmental and air pollution [1].

The current disposal method used by the farm owners is through burning. This method could quickly dispose of the waste without spending a large amount of expenses. However, the effect of this method is severely detrimental to the environment and society. One of the side effects due to open burning is air pollution. The burning of agricultural wastes will increase the emission of green gases, which contributes to global warming, increasing the particulate matter and smog that are

 doi:10.20944/preprints202307.1813.v1

detrimental to human health, as well as the deterioration of soil fertility. In addition, the contaminated soil that contains the smoke and dust residue may be channeled to the nearby water source, thus polluting the aquatic environment.

Another common method of disposal is by dumping. Although this method requires little labor and expenses, it increases the landfill area. Furthermore, indiscriminate dumping of agricultural wastes on the farm site will attract a lot of predators and pests, which could compromise the workers' safety. The accumulation of agricultural wastes in the farms could provide ideal conditions for rodents and pests' breeding grounds and adequate hiding spaces for snakes. Rodents are known to be a carrier for various diseases and crop destroyers. Meanwhile, snakes like to prey on workers or farm animals.

Although having a balanced population of these creatures is incredibly beneficial on farms, an unhealthy population could also threaten workers' safety. Another effect of indiscriminate dumping is flooding. Flooding occurs due to blocked waterways caused by solid agricultural wastes. Due to this, many lives and properties were lost during a high flood. Dumping at the landfill site is also another option for agricultural waste disposal. However, unlike indiscriminate dumping, this type is quite expensive due to the need for labor and transportation. This kind of dumping also requires a licensed pickup service, and each landfill needs to be checked earlier to ensure that the agricultural wastes match the landfill requirements.

Burying agricultural waste is also one of many common disposal methods. It is one of the easiest disposal methods depending on the soil condition. However, the problem with this method is that it is labor and energy intensive. Thus it is much more expensive compared to the dumping and burning method. Furthermore, burying a massive amount of animal waste could negatively impact the soil and water quality near the burial site. Table 1 shows some of the disposal methods used for agricultural wastes.

Table 1. Agricultural waste disposal methods.

Agricultural activity	Wastes produced	Disposal method	Ref
Pineapple production	Leaves, crown, core, peels, stems	Dumping, burning, burying, decomposing	[2]
Banana production	Peels, stems, trunks	Dumping, burning, burying, decomposing	[3]
Animal production	Left-over feed, wastewater, hatchery wastes, manure, carcasses	Dumping, burning, buried	[4]
Leather tanning	Hair, bristle, flesh side, splits, trimmings, fleshing, splits trimmings, shavings, sludge	Dumping	[5]
Sugar processing	Bagasse, cane trash, press mud, molasses	Dumping, burning, buried	[6]

Based on the Table 1, it can be concluded that the current disposal method significantly impacted the health of society and the environment. Thus, current researchers have studied various ways to change the existing forms of disposal that would lessen the negative impact on the economy, society, and environment. One such method is recycling agricultural waste and converting it into an alternative income for the locals [7,8]. Therefore, an alternative income generation could be established instead of losing money due to improper means of waste management. This will also keep the environment and society safer. Hence, this paper aims to review the significance of agricultural waste as a type of wealth and its potential as an alternative material in the composite field.

2. Converting agricultural waste to wealth

In recent years, many researchers have explored the possibility of recycling agricultural waste instead of using the traditional disposal method. This effort is more prevalent in developing countries since it offers an alternative source of income for the population living below the poverty line [9]. Another reason is that there is still no organized waste management in third-world countries, contributing to uncontrolled waste in landfills [10]. Currently, three types of agricultural wastes identified could be utilized and converted into an alternative income generation, as shown in Figure 1. Thus, this section discusses the possibility of using agricultural wastes in different types of applications based on the type of agricultural waste.

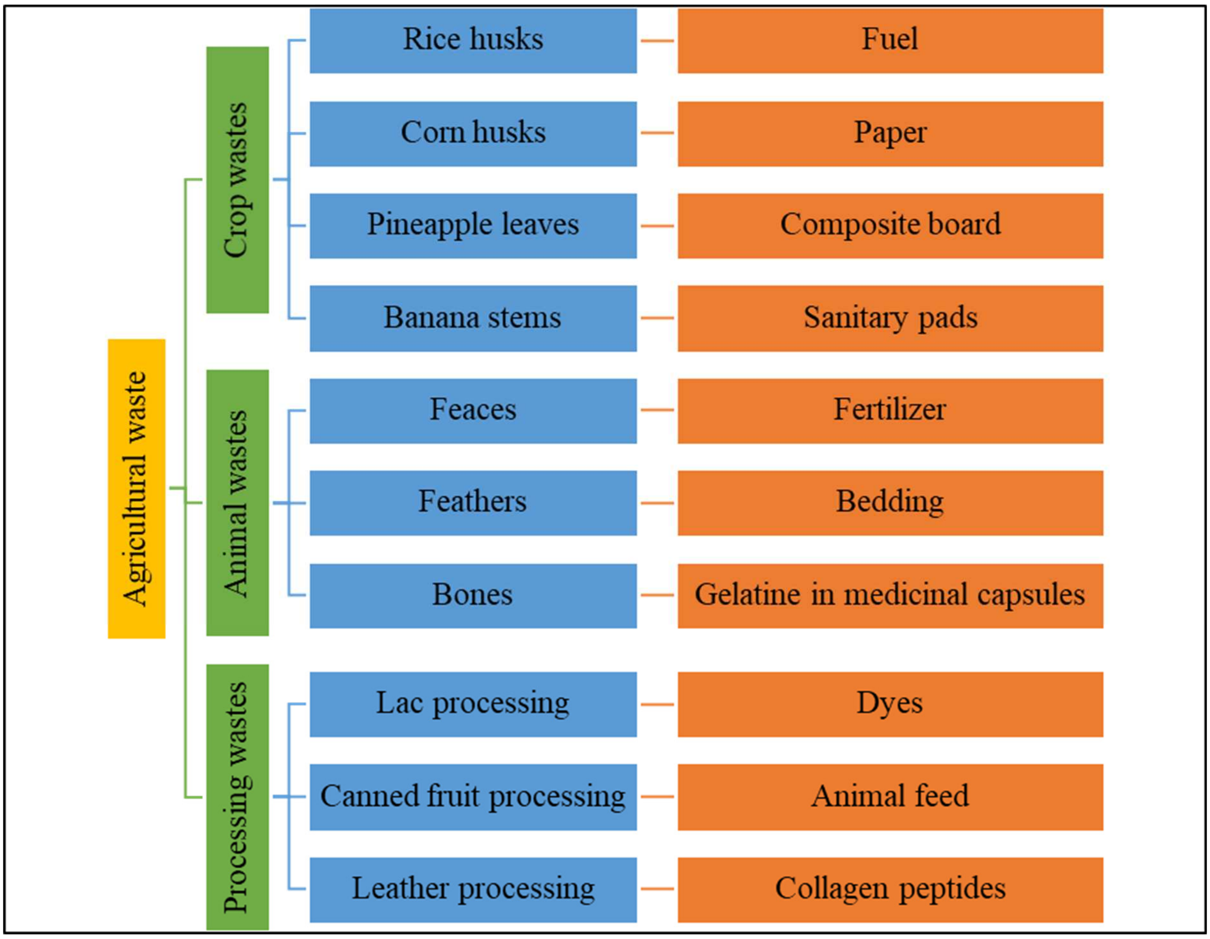

Figure 1. Types of agricultural wastes and some examples of wastes that can be utilized to generate wealth.

2.1. Crop waste

Crop wastes from plants consist of cellulose, hemicellulose, and lignin. Due to the advances in the manufacturing field, current technologies can extract these components into their pure structural form. Figure 2 shows the basic structure of plant fiber.

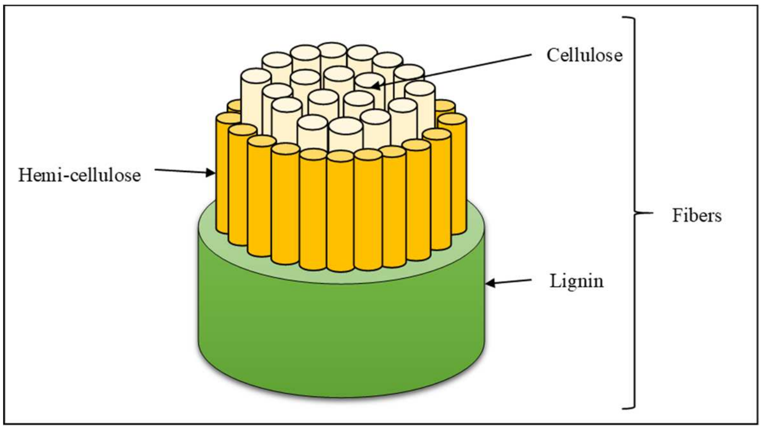

Figure 2. Basic architecture of plant fiber.

Cellulose is mainly used to produce textiles [11], papers [12], and pharmaceuticals [13]. Cellulose is mainly used in these industries due to the presence of fibrils, which are small thread-like structures that could be exposed by beating or refining to provide a large area for bonding. Therefore, cellulose fiber could develop physical and chemical bonding with other fibers when its condition changes from wet to dry. Biofuel is also one of the applications made from cellulose or lipids to replace gasoline and diesel, respectively. Many modern vehicles are designed to operate on biofuels developed from plants.

As for hemicellulose, it provides support and strength to the cellulose structure [14]. The unique characteristics of cellulose fibers are high tensile strength, flexible, water-insoluble, and chemically stable. Hemi-cellulose is also commonly used to ferment alcohol that can be applied in cosmetics, coatings, and pharmaceuticals [15]. Hemicellulose is biodegradable, non-toxic, and has a lower molecular weight than cellulose.

Lignin's characteristics are similar to cellulose and hemicellulose, with good biocompatibility and low toxicity. However, lignin is unique because it has high carbon content [16]. Therefore, lignin can be transformed into a composite or carbon material by extracting the carbon in this construction. The materials made from lignin are not only cost-efficient, but it is also environmentally friendly. In the most recent studies, lignin is used to produce epoxy resin suitable for printed board circuits in the electrochemical industry [17], wound dressing in the medical industry [18], 3D printing lignin-polymer composite materials in the manufacturing industry [19], and much more.

Besides its structural form, crop wastes can be used in fiber form, which is widely used in the composites field as a reinforcement material. In composites, fibers are found in two primary forms: short and long. Some of the products that were made by using the powdered or short-fibered form are briquettes made from charred coconut husks and shells [20], bio-packaging made from bagasse [21], and biogas from rotting vegetables [22]. Meanwhile, for long fibers, there are products such as clothing or textiles made from corn husks [23], sanitary pads made from banana stems [24], and plastics made from avocado pits [25].

2.2. Animal waste

Generally, animal waste means any substances emitted by animals in solid or liquid states. Some examples of animal solid wastes are feces, animal bedding, animal carcasses, and many others. Liquid wastes include urine, blood, and wastewater. Reusing animal waste is not new in agricultural management and is usually pre-treated before application. The most common ways solid waste was applied is as fertilizer and animal feeds [26]. Another method is converting them into energy [27] and biogas [28]. However, with the current technology, more applications are being proposed to utilize animal wastes in product manufacturing, especially in the form of fibers. One such example was using poultry feathers, hair, fur, and much more by extracting fibers from these materials [29]. These fibers are valuable as reinforcement material in composites or fabrics in textiles.

Cashmere fiber is a fine, soft hair collected while dehairing goats [30]. The fibers were obtained from goat hairs during its combing process during the spring season when the goats naturally shed their winter coat. It is composed of keratin, a protein with high sulfur content, which gives cashmere its softness and warmth. The cashmere is eight times warmer than ordinary wool. The fine texture of the fibers makes them softer than wool.

Chicken feathers are a waste product obtained when birds are molted during the molting season or after the chicken has been processed into meat [29]. The most interesting property of feathers that attracted much attention is their extremely low density and hydrophobic nature. Due to its hydrophobic nature, feather composites have high resistance to decay fungi and termites. This fiber also has high tensile strength, compressive strength, and impact resistance, with thermal and sound insulation properties, which are highly suitable for structural materials.

2.3. Processing waste

Processing waste can be defined as the end products obtained from various processing industries, which were discarded and not utilized. These wastes could be turned into valuable products if the proposed utilization could generate revenues exceeding its cost for reprocessing. Processing waste is the main reason for the high accumulation of landfills and environmental pollution [31]. There are mainly two types of processing waste based on their properties, which are biodegradable and non-biodegradable. Biodegradable processing waste comprises rotting fruits and vegetables, papers, and wool waste, while non-biodegradable processing waste comprises plastics, bottles, cans, and much more.

In the lac processing industry, lac, the resinous secretion of the lac insect (*Kerria lacca*), was used to produce several types of products such as lac dye, lac mud, and gummy mass. The sticklac was converted into a seedlac with the lac resin (shellac) and the water-soluble lac dye [32]. The dye has a deep red color suitable for use as a coloring material, and due to its non-toxicity, it is also used as a food colorant [33]. As for the lac mud, it was produced from the primary processing of lac. Lac mud is usually discarded due to the lack of a proper disposal method. Currently, in India, lac mud is used as an organic manure for vegetable production [34]. It was reported that there was an increased yield rate for vegetable production. This shows that lac mud could improve soil fertility and help sustain the lac production system. The gummy mass produced in the lac industry is the by-product waste obtained from Aleuritic acid production [35]. It is a sticky material that will not dry at ambient temperature. Therefore, this material was proposed as a coating material, gasket cement compound, and composite board.

Processing wastes could also be found significantly within the canned fruit processing industry. The pineapple processing factories produced many by-products from processing canned pineapple fruits. The factories usually discard around 80% of pineapple parts, including the fruit core, crown, peels, leaves, stems, and wastewater from washing fruit and juice production [36]. Most pineapple parts were pulverized into smaller bits for animal feeds, whereas the wastewater was processed into alcohol and sold to the pharmaceutical company to produce medicinal products.

Wool waste fibers are a by-product that comes from different steps in wool processing, which is unsuitable for textile use [37]. However, due to its unique properties, it is being applied in different applications. The chemical properties of wool waste fibers include a high nitrogen content, which makes them useful as a fertilizer. It is also composed of keratin, a protein with high sulfur content, which makes wool naturally flame resistant and resilient to stretching and compression. The mechanical properties of wool waste fibers include high elasticity and good resistance to compression. Meanwhile, the physical properties of wool waste fibers include a fine texture and a natural crimp, with a soft and fluffy feel that makes them helpful to act as thermal and sound insulators or as pillow stuffing.

Like wool, silk waste fibers refer to short silk fibers obtained during silk processing, which cannot be reeled due to technological constraints [38]. Due to its high protein content, silk waste fiber is usually processed into animal feeds. The silk waste fibers can be incorporated into composites to fabricate a high strain to failure composites with good deformability and resist impact. Silk waste fiber also contains amino acid structures most similar to human skin and has an antibacterial function. These features are a unique characteristic of silk waste fibers that are highly beneficial in cosmetic applications.

3. Agricultural waste as fiber polymer-reinforced material

In recent years, the effort exerted by researchers to develop greener products has significantly increased. Ecological awareness has started to sprout and is a significant factor driving more sustainable and environmentally friendly research. One of the most significant growth and application is within the composites field as reinforced material. Due to the rapid growth of manufacturing technology, extracting fibers from agricultural waste and developing green products is now possible. These agricultural waste fibers have a range of chemical, mechanical, and physical properties that make them useful for various applications, such as clothing, textiles, composites, and packaging. This section will discuss the physical, mechanical, and chemical properties of agricultural waste in its fiber form.

3.1. Physical and mechanical properties of fibers

Fiber reinforcement materials are generally used to add rigidity and restrain the propagation of cracks within composites. These fibers enforce the mechanical strength of the matrix while retaining or reducing the weight of the composites. Plant fibers from crop waste can be extracted in various ways, such as retting, scraping, decortication, or steam explosion after harvest season. Meanwhile, animal fibers are collected by shearing during the shedding season. As for processing waste fibers, it is collected from discarded materials due to plant or animal processing. The physical and mechanical properties of fibers extracted from agricultural waste are summarized in Table 2.

Table 2. Physical and mechanical properties of fibers extracted from agricultural waste.

Types	Materials	Density (g/cm^3)	Tensile strength (MPa)	Young's Modulus (GPa)	Ref
Crop waste	Pineapple leaf fiber	0.95 – 1.53	460.00 – 1244.30	4.4 – 43	[39–42]
	Banana stem fiber	0.22 – 0.96	210 – 914	16.36 – 32	[43–46]
	Bamboo fiber	0.6 – 1.4	206.5 – 630	17 – 36	[47–50]
	Corn husk fiber	1.16 –1.49	180 – 256	4.57 – 15.87	[51–53]
	Sugarcane bagasse fiber	0.88 – 1.2	20 – 290	3 – 27.1	[54–56]
Animal waste	Milk protein/casein fiber	1.30	37 – 116	2.08 – 7.4	[57–59]
	Chicken feather fiber	0.78 – 0.90	130 – 220	3.0 – 4.5	[60–63]
	Yak fiber	1.32 – 3.41	270.05	45.09	[64]
	Gelatin fiber	1.2 – 1.58	91 – 170	2.0 – 3.1	[65–68]
Processing waste	Wool waste fiber	1.29 – 1.31	130 – 210	2.6 – 3.6	[61,69,70]
	Silk waste fiber	1.32 – 1.33	165.27 – 248.77	3.82 – 6.10	[71]
	Recycled cotton fiber	1.5 – 1.6	287 – 597	5.5–12.6	[72]

Table 2 shows that the mechanical strength of animal fibers and processing waste fibers are much lower compared to plant fibers. As for the fiber densities, plant-based fibers are much lower compared to animal-based fibers. Therefore, it can be concluded that plant fibers have a higher specific strength, which is highly significant in structural applications. This shows that plant fibers work better in composites than animal fibers and processing waste fibers. Therefore, to understand better how the fibers could affect the mechanical properties of the composites, knowing the fibers' chemical composition is essential, which will be further discussed in Section 3.2.

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3.2. Chemical properties of fibers

The chemical properties of fibers will differ from one fiber to another. The chemical composition of the fibers will help determine the suitability of the fibers for their chosen application.

In structural applications, the amount of cellulose and hemicellulose in plant fibers and protein in animal fibers will determine the strength and stiffness of the fibers as a reinforcement material [73]. Fibers with more cellulose/hemicellulose or keratin will help reinforce and strengthen composites.

As for lignin in plant fibers, it provides rigidity to the fiber, further strengthening its tensile strength. In addition, lignin is also hydrophobic. This specific characteristic provides the water resistivity of composites. Therefore, a higher amount of lignin will have better water resistance. Thus, it can be used as a resin to produce printed board circuits or as a replacement for polymer films. Furthermore, lignin has high carbon content, which could be used to make carbon fibers.

Similar to lignin, pectin increases the mechanical properties of the composites. Due to its unique characteristic as an adhesive in plant cell walls, it is highly suitable for gel making or coating. In addition, pectin is well known for its biocompatibility and anti-microbial characteristics. Thus, it is highly applied in food, biomedicine, and drugs. Table 3 shows the chemical composition of agricultural waste fibers.

Table 3. Chemical properties of agricultural waste fibers.

Types	Materials	Chemical Properties (%)	Ref
Crop waste	Pineapple leaf fiber	Cellulose: 64.4 – 72.14 Hemicellulose: 4.86 – 21.73 Lignin: 4.28 –13.55 Pectin: 1.3 – 1.6 Ash: 0.8 – 5.01	[3,39,40,42,74]
	Banana stem fiber	Cellulose: 39.2 – 64 Hemicellulose: 10.2 – 27.8 Lignin: 11.40 – 27.77 Pectin: 2.1 – 2.78 Ash: 3.88	[43–46,75]
	Bamboo fiber	Cellulose: 36.1 – 55.68 Hemicellulose: 11.4 – 19.15 Lignin: 16.93 – 28.5 Pectin: <1	[76–78]
	Corn husk fiber	Cellulose: 43 – 45.7 Hemicellulose: 31 – 40 Lignin: 2 – 22 Ash: 0.36 – 6.4	[51,52,79]
	Sugarcane bagasse fiber	Cellulose: 30 – 55 Hemicellulose: 20 – 28.25 Lignin:18 – 26 Pectin: 0.6 – 0.8 Ash: 3 – 10	[55,80]
Animal waste	Milk protein/casein fiber	Carbon: 53.0 Hydrogen: 7.50 Oxygen: 23.0 Nitrogen: 15.0 Sulfur: 0.70 Phosphorous: 0.80	[81]

	Chicken feather fiber	Protein: 82 – 91 Carbon: 64.47 Nitrogen: 10.41 Oxygen: 22.34 Sulfur: 2.64	[63,82,83]
	Yak fiber	Protein: 65–95 Carbon: 51.09 – 58.3 Nitrogen: 13.47 – 18.2 Oxygen: 20.7 – 32.06 Sulfur: 2.09 – 2.3	[84,85]
	Gelatin/protein fiber	Protein: 98 – 99 Carbon: 47.98 – 50.5 Nitrogen: 14.42 – 17 Oxygen: 25.2 – 29.44	[86–88]
Processing waste	Wool waste fiber	Protein: 33 Carbon: 50 Nitrogen: 14 – 25 Oxygen: 10 Sulfur: 0.1 – 0.2	[89,90]
	Silk waste fiber	Protein: 78 – 95 Nitrogen: 16.35 Sulfur: 3.65	[89,91]
	Recycled cotton fiber	Cellulose: 90 – 94 Moisture: 6 – 7 Protein: 1 – 1.5 Pectin: 0.9 Ash: 1.2	[92]

From Table 3, it can be seen that the difference between plant fibers and animal fibers is their main composition, where plant fibers are mainly made up of cellulose, whereas animal fibers are mainly made up of protein. Meanwhile, processing waste fibers are discarded products processed from their primary source or have fully served their purpose as packaging or fabrics.

Due to the increasing animal welfare awareness, current research is mainly directed toward plant fibers. Although there are several innovative ways to collect animal fibers that could avoid killing them (such as peace silk), the process requires complicated procedures that end up making the materials more expensive. Similar to animal fibers, innovations in converting processing waste into recycled fibers were also researched and proposed. However, the additional procedure to convert them into useful fibers also requires higher production costs. However, unlike animal fibers and recycled fibers, the extraction of plant fibers is much cheaper. The raw materials can be transformed directly into valuable fibers without undergoing complicated extraction procedures. Therefore, there is an increasing trend for the innovation of animal fibers using plant fibers such as wool (made from a blend of cotton and calotropis) and silk (made from lotus, agave, or aloe vera).

Plant fibers are renewable, cruelty-free, and have a lower carbon footprint. Therefore, it is much preferable, especially among vegan enthusiasts. Some plant fibers are derived from stems and leaves of a plant or tree that was harder to extract in high amount due to the absence of proper equipment. However, with the current technology, the extraction of these fibers has become possible. One such example is the pineapple leaf fibers.

4. Reinforced Pineapple Leaf Fiber in UAV Construction

Pineapple plantations can be found worldwide, and the three top producers are the Philippines, Costa Rica, and Brazil. However, a high amount of production will also result in a high amount of agricultural waste. In Malaysia especially, due to the lack of proper equipment, the pineapple leaf

 doi:10.20944/preprints202307.1813.v1

waste will usually end up being dumped or buried underground at the plantation site to degrade naturally. Figure 3 below shows the accumulation of pineapple leaf waste. Over time, this will compromise the workers' safety at the plantation site. Thus, instead of discarding these leaves, they can be turned into valuable fibers widely used in composites.

Figure 3. Accumulation of pineapple leaves at the plantation site.

Pineapple leaf fiber is a natural textile fiber extracted from the leaves of the pineapple plant. It is a sustainable material that has been gaining attention in recent years for its potential applications in various industries, including fashion and textiles. The fiber is strong, flexible, and lightweight, making it a versatile material for various applications, including structural applications, due to its unique properties.

Pineapple leaf fiber can be used in structural applications in various ways, such as reinforcing material, building material, furniture, and textiles. In composites, pineapple leaf fiber can be used as a reinforcing material. When mixed with a resin matrix, the fiber can add strength and stiffness to the composite material. The resulting material can be used in various structural applications, such as building materials, automotive components, aerospace airframes and constructions formed by bolted connections [93–96]. As a building material, pineapple leaf fiber can be used to create eco-friendly building materials such as tiles, panels, and insulation. These materials can be used in construction and provide a sustainable alternative to traditional building materials. Pineapple leaf fiber can also be manufactured into chairs, tables, and lamps. The fiber can be woven into different patterns to create a unique look and strengthen the furniture. Finally, pineapple leaf fiber can be transformed into clothing, bags, and accessories in textiles. The fiber is lightweight, breathable, and has natural antibacterial properties, making it an attractive option for fashion designers.

Pineapple leaf fiber is a sustainable and environmentally friendly material that can be used in various structural applications. Its unique properties make it a versatile material that can be used in different ways to provide strength, durability, and style to various products. As the demand for sustainable materials increases, pineapple leaf fiber is likely to become an even more critical material for structural applications in the future.

Currently, studies have also been exploring the use of pineapple leaf fiber in UAV applications. One of the main advantages of using pineapple leaf fiber in drones manufacturing is its lightweight and high strength-to-weight ratio. This makes it an ideal material for constructing UAVs frames, which must be strong and lightweight to achieve optimal flight performance [97,98]. Additionally, pineapple leaf fiber has been shown to have good mechanical properties, such as high tensile

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strength, making it resistant to deformation and breakage. This is a crucial feature for multirotor copters frames, which must withstand flight stresses and potential crashes [99].

Another advantage of using pineapple leaf fiber is its biodegradability, which makes it an environmentally friendly option for many kinds of UAV construction. Pineapple leaf fiber can decompose naturally, unlike other synthetic materials commonly used in drones manufacturing, which can take hundreds of years to break down. Table 4 below shows the mechanical properties of pineapple leaf fiber composites.

Table 4. Mechanical properties of pineapple leaf fiber composites.

Fiber	Matrix	Fiber treatment	Composition of fiber	Density	Tensile strength	Young's Modulus	Ref
			(%)	(g/cm^3)	(MPa)	(GPa)	
Pineapple leaf fiber	Polypropylene	None	40	-	58	1.67	[100]
Pineapple leaf fiber	Epoxy	Alkaline (NaOH) treatment	40	1.18	93.82	4.24	[101]
Pineapple leaf fiber	Natural rubber	None	25	1.09	11.14	0.33	[102]
Pineapple leaf fiber	Polylactic acid	None	25	-	96.78	-	[103]
Pineapple leaf fiber	Polyester	Silane treatment	-	-	55	2.3	[104]
None	Polylactic acid	None	0	1.27	56	3.37	[105]
None	Acrylonitrile-Butadiene-Styrene	None	0	1.05	26-31	2.18 –2.23	[105]

From Table 4, it can be seen that depending on the matrix, the mechanical properties of the composites will differ. By comparing composites of the same amount of composition (40%), epoxy yields better mechanical properties compared to polypropylene. Furthermore, with the addition of fiber treatment, the mechanical properties of the composites have been further enhanced. As for natural rubber and Polylactic acid with 25% fiber, it shows that Polylactic acid composite has better tensile strength, whereas natural rubber composite has better elasticity. In addition, with a proper fiber treatment and compatible matrix, the mechanical properties of the pineapple leaf fiber composites could exceed a pure polymer that is frequently used for UAVs manufacturing, as shown in Table 4.

In conclusion, using pineapple lead fiber in drones manufacturing shows promise as a sustainable and lightweight alternative to traditional materials. While further research and development are needed, this material has the potential to revolutionize the UAV's industry and contribute to a more sustainable future.

5. Conclusions

The rapid growth of manufacturing technology has opened endless possibilities for using agricultural waste as another source of wealth. It can be said that there is no such thing as agricultural waste, but only things that science still has not found a way to utilize. Each of these materials has unique advantages that could help solve an existing problem. The review found that many agricultural wastes had been utilized in various production of ecological products. As manufacturing technology progresses, more waste can be converted into valuable products. The extracted waste fibers' physical, mechanical, and chemical properties show that these agricultural wastes can produce better advanced composite materials suitable for structural applications. This also holds true for pineapple leaf fiber composites. Fiber extraction, done through scrapping, made the extraction tedious for farmers. Thus, plantation owners prefer to discard the leaves instead of utilizing them. However, acquiring a large amount of pineapple leaf fibers at a shorter time has become much easier with the emerging extraction technology. As studies on the utilization of agricultural waste progresses, more manufacturing and extracting technology are being developed. Thus, this will create a sustainable economy that will benefit a country's development.

Supplementary Materials: Not applicable.

Author Contributions: Conceptualization, F.S.S.; writing—original draft preparation, F.S.S.; writing—review and editing, F.S.S., M.T.H.S., A.L., and R.G.; visualization, F.S.S.; supervision, M.T.H.S and A.L..; project administration, F.S.S, A.L., and R.G.; funding acquisition, M.T.H.S., A.L. and R.G. All authors have read and agreed to the published version of the manuscript. Authorship must be limited to those who have contributed substantially to the work reported.

Funding: The Malaysian Ministry of Higher Education funded this research through the PENJANA KPT–CAP (Career Advancement Programme).

Institutional Review Board Statement: Not applicable.

Data Availability Statement: Data sharing does not apply to this article as no new data were created or analyzed in this study.

Acknowledgments: The authors would also like to express their gratitude to the Department of Aerospace Engineering, Faculty of Engineering, Universiti Putra Malaysia, and the Laboratory of Biocomposite Technology, Institute of Tropical Forestry and Forest Product (INTROP), Universiti Putra Malaysia (HICOE) for their close collaboration in this study.

Conflicts of Interest: The authors declare no conflict of interest.

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