

Study on Pineapple Leaves Fibre and its Polymer based Composite: A Review

Yogesh M¹, Hari Rao A N²

¹Department of Mechanical Engineering, GSSS Institute of Engineering & Technology for Women, Mysore 570016, Karnataka, India

²Department of Mechanical Engineering, Sri Jayachamarajendra College of Engineering, Mysore 570006, Karnataka, India

Abstract: *Pineapple leaf fibre (PALF) is one of the abundantly available waste materials in India and has not been studied yet as it is required. A detailed study of chemical, physical, and mechanical properties will bring out logical and reasonable utilization of PALF for various applications. From the socio-economic perspective, PALF can be a new source of raw material to the industries and can be potential replacement of the expensive and nonrenewable synthetic fibre. However, few studies on PALF have been done describing the interfacial adhesion between fibres and reinforcement compatibility of fibre but a detailed study on PALF properties is not available. In this review, author covered the basic information chemical, physical, and mechanical properties of PALF. Furthermore, it summarizes the recent work reported on physical, mechanical, and a thermal property of PALF reinforced polymer based composites with its various applications.*

Keywords: Pineapple leaf fiber (PALF), Natural fibre, Polymer matrix composites, PALF based Hybrid composite, Reinforcement

1. Introduction

Industries are widely using plant fibres for numerous applications from many resources. In the middle of 20th century, synthetic fibres are drastically used, and natural fibres industries collapse its market shares. For promoting natural fibre as material, year 2009 is considered as international year of natural fibre (IYNF), which is highly supportive to farmers, agriculture, environment and market demand. The most important property of natural fibre is biodegradability and non-carcinogenic which bring it back into fashion, with an advantage of being cost-effective. The versatile nature of it makes it suitable for automobiles, railway coach, building construction, partition wall cabinets, furniture for machinery uses and packaging. Natural fibres are important agricultural biomass contributing to Indian economy. The huge and wide range availability of natural fibre can reduce the pressure on forest and agriculture. The usage of diverse raw materials will help to keep an ecological balance in nature. Generally agriculture materials and forest product produce 30-40% waste materials, which can also be used in value added processing. The low density natural fibres can also be utilized as per the aim of utility. For example, a grass fibre can be a good alternative for low load bearing products [1]. It has cumulative advantage of light weight (low density), cheaper source, low wages, being non-carcinogenic, and biodegradability [2-4]. Scientists and engineers are having great interest to find out new sources of raw materials that possess comparable physical and mechanical properties to synthetic fibres. Various other parameters to be considered while selecting raw materials are cheap and eco-friendly [5], absence of health hazards, high degree of flexibility [6], lower plant's age, easy collection, and regional availability which directly influence the suitability of natural fibres [7]. The natural fibres are renewable resource, thus providing a better solution of sustainable supply, like it has low cost, low density, least processing expenditure, no health hazards and better mechanical and physical properties [8-11]. The main drawback of natural fibre is moisture absorption, so it is bound to change its surface property by using chemicals

[12]. Synthetic fibre reinforced polymers were costly and have an impact on environment [13]. There are many plant fibres available which has potential to be applied in industries as raw materials such as pineapple, kenaf, coir, abaca, sisal, cotton, jute, bamboo, banana, Palmyra, talipot, hemp, and flex [14-16]. Among them Pineapple leaf fibre (PALF) is one of the waste materials in agriculture sector, which is widely grown in India as well as Asia. After banana and citrus, Pineapple (*Ananas comosus*) is one of the most essential tropical fruits in the world [17]. Commercially pineapple fruits are very important and leaves are considered as waste materials of fruit which is being used for producing natural fibres. The chemical composition of PALF constitute holocellulose (70- 82%), lignin (5-12%), and ash (1.1%). Pineapple (PALF) has tremendous mechanical properties and can be applied in making of reinforced polymer composites [18, 19], low density polyethylene (LDPE) composites, and biodegradable plastic composites. Physical and mechanical properties of composites like viscoelastic behaviour processing, tensile strength, flexural strength, and impact are dependent on length of fibre, matrix ratio, and fibre arrangement [20, 21]. The main drawback PALF is hydrophilic nature; it does not make good bonding with hydrophobic matrix, particularly at high temperatures [22]. Interfacial quality between PALF and polymer could be enhanced by using chemical treatments like dewaxing, treatment with NaOH, cyanoethylation, and grafting of acrylonitrile monomer onto dewaxed PALF. Moreover, the surface modification by chemicals like sodium hydroxide (NaOH), 2, 4-dinitrochlorobenzene, benzoyl peroxide (BPO), and BPO / acetylation can minimize water absorption and improves the mechanical properties [23]. The moisture absorption of chemically modified PALF reinforced LDPE composites shows considerably less moisture content [24]. Bonding agent resorcinol (reso), hexamethylenetetramine (Hexa), and silica have good affinity for PALF-natural rubber (NR) and exhibits better adhesion [25].

Nowadays, bio-composite reinforced materials are widely accepted in place of traditional materials in high strength

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and several light weight applications. Such composite materials exhibit good strength by weight ratio, high tensile and flexural strength, high creep resistance, and high compactness. Natural fibres reinforced into bio-plastics are a good example of green composites, which is easily degradable by bacteria and enzyme [26]. The major problem of natural fibres as a reinforced material is improper contact of adherent surface and polymer matrix with a bad interaction load transformation from matrix to fibre [27]. Thus, to enhance the adhesion property of fibres, it needs surface modification by using appropriate chemicals. These modification methods can be alkaline treatment [28] grafting with maleic anhydride copolymer [29] and using saline coupling agent [30].

2. Pineapple Plant

Pineapple is perennial herbaceous plant with 1-2m for height and width belongs to family Bromeliaceae [31]. It is chiefly cultivated in coastal and tropical regions, mainly for its fruits purpose. In India, it is cultivated on about 95 million hectares of land and is continuously increasing its production. Figures 1(a) and 1(b) show a pineapple plant in the ground; it is a short stem with dark green colour. First sprout of leaf looks decorative; later it converts into 3 ft. long, 2 to 3 inch wide sword shaped and numerous spirally arranged fibrous leaves edges as well as curved towards the cross section to maintain the stiffness of the leaf [32]. Each pineapple fruit has equal number of hexagonal sections on outer shell and does not depend on the size or shape. India is a large country to produce pineapple plant in Asia. It produces a huge amount of waste material, currently; India produces 1.53million Tonnes of pineapple with productivity of 15.3 tonnes/hectare in 2013. Productions of Pineapple leaf fibres are plentiful for industrial purpose without any supplementary addition and of easy availability [33]. Pineapple is

very rich Source of bromelain and other cysteine proteases are present in different part of pineapple [34]. Commercially, bromelain has been used in many food industries, cosmetics, and dietary supplements.

2.1. History

Pineapple is a native plant of America, first seen by Columbus and his companion in 4th November 1493, at an island of West Indies. When the new world was discovered, pineapple has been spread all over South America coastal region as well as in tropical regions. A Spanish government officer, De Oviedo, came to America in 1513; he handed over first written documents of some varieties of pineapple, and he added some Indies varieties also. The plant is called “pineapple” because of its fruit which look like pine cone. The native Tupi word for the fruit was *anana*, meaning “excellent fruit;” this is the source for words like *ananas*, common in many languages. The pineapple is an old emblem of welcome and can often be seen in stamped decorations. In 17th century Americans imported pineapple from Caribbean because of its apparently exotic features and rareness; pineapple began to be considered as an icon of wealthy people in America. The Portuguese contributed their important role in introducing the fruit throughout the whole tropical regions and major parts of world like south and east Coast of Africa, Madagascar, south India, China, Java, and Philippines. Nowadays, varieties of pineapple plants are available which are used in various applications such as edible, medicinal, and industrial applications. For example, bromelain is an enzyme extracted from its leaves and helps in respiratory ailments. A mixture of pineapple juice and sand is powerful cleaner for boat decks. Dehydrated waste material of pineapple is used as bran feed for cattle, chicken, pigs, and so forth [35].

2.2. Pineapple Leaf Fibre

Every year tonnes of pineapple leaf fibres are being produced, though very small portions are being used in the field of feedstock and energy production. The expansion of bio-composites has amplified industrial usage that would release the possibilities to minimize the wastage of renewable materials. It promotes a non food based market for agricultural industry [36]. It is white in colour, smooth, and glossy as silk, medium length fibre with high tensile strength. It has a softer surface than other natural fibres and it absorbs and maintains a good colour [37].

However, PALF has high specific strength and stiffness; it is hydrophilic in nature due to high cellulose content [38, 39]. Extraction of fibres from pineapple leaf fibre is carried out by mechanical method, exhibited in Figure 1(c). Fresh leaves yield about 2 to 3% of fibres [40]. Fibrous cell of PALF consists of vascular bundle system in the form of bunches which is obtained after mechanical removal of the entire upper layer after harvesting. PALF is composed of many chemicals constituents. It is multicellular lignocellulosic fibre containing polysaccharides, lignin in major amount, and some minor chemicals like fat, wax, pectin, uronic acid, anhydride, pentosan, colour pigment, inorganic substance, and so forth [41]. Fibre is collection of thin and small multicellular fibres which appears like a



Figure 1: Production of pineapple leaf fiber

thread. These cells are tightly joined with the help of pectin [42]. PALF constitute cellulose (70–82%) and arrangement of fibres is the same as in cotton (82.7%) [43, 44].

In all the collection, pineapple leaf fibre is more compatible natural fibre resource and constitutes a good chemical composition. PALF has better mechanical strength than the jute when it is used in making of fine yarn [45, 46]. The cellulosic molecules model of PALF is a three-dimensional structure and parallel to crystalline region of the fibre. Remaining parts of molecular structure are supposed to associate with in amorphous regions. Pineapple leaf fibre (PALF) is vital natural fibre, which have high specific strength, rigidity, and flexural and torsional rigidity as much as jute fibres. Considering these exclusive properties of PALF, industries can use it as an outstanding alternative raw material in the prospect of reinforcing composite matrixes.

2.3. Extraction of Pineapple Leaf Fibres (PALF)

Pineapple natural fibres have excellent mechanical strength but due to lack of knowledge it is still not utilized properly. It can be used in various applications like artificial fibres, as a sound absorber and thermal insulator, and so forth. There are various methods to extract the PALF from leaves of pineapple.

2.3.1. Scrapping Method of Extraction

Scrapping machine is the machine used for scrapping the pineapple leaf fibre [47]. The machine is the combination of three rollers: feed roller, leaf scratching roller, and serrated roller. Feed roller is used for the feeding of leaves into the machine; then leaves go through the second roller that is called scratching roller. It scratches upper layer of leaf and removes the waxy layer. And at last leaves come to the dense attached blade serrated roller, which crushes leaves and makes several breaks for the entry passage for the retting microbes [48].

2.3.2. Retting of Pineapple Leaves

In retting process, small bundles of scratched pineapple leaves are immersed in a water tank which contains substrate: liquor in 1:20 ratio, urea 0.5%, or diammonium phosphate (DAP) for fast retting reactions. Materials in water tank are regularly checked by using finger to ensure fibre are loosened and can extract many chemical constituents like pentosans, lignin, fat and wax, ash content, nitrogenous matter, and pectin. After retting process, fibres are segregated mechanically, through washing in pond water. Extracted fibres are dried in hanging place by air. Both ball mill and disc mill can be used to extract PALF from chopped fresh pineapple leaf [49]. The methods not only are simple but also provide higher fibre yield and smaller fibre than the conventional methods. Among the two mechanical grinding methods studied, wet ball milling is much slower but provides PALF with a greater number of elementary fibres [50].

2.4 Chemical Composition

Technical Association of Pulp and Paper Industry (TAPPI) [51] standards reported that the chemical constituents and extractive like holocellulose, α -cellulose, lignin, and ash

content of PALF were analysed from different source of fibres, age of fibres, and climatic conditions. The procedure to extract the fibres may attribute the factor of various types of chemical composition and cell wall structure [52]. In a transmission electron microscopy, PALF cell wall shows distinct different layers as primary, secondary, and tertiary (S1, S2, and S3) layers. Pineapple leaf fibres have many chemical constituents like α -cellulose, pentosans, lignin, fat and wax, pectin, nitrogenous matter, ash content, degree of polymerization, crystallinity of α cellulose, and antioxidants [53, 54]. PALF has a large quantity of α -cellulose (81.27), low quantities of hemicelluloses (12.31%), and lignin content (3.46%) [42]. PALF has higher cellulosic content as compared to other natural fibres like oil palm frond, coir, and banana stem fibres [52]. The higher quantity of cellulose in PALF supports the higher weight of the fruit [55]. The chemicals composition fibre directly affects performance of fibres [56].

2.5 Physical and Mechanical Properties

Reinforced natural fibres composite plays a huge share in bio-composite and material science. PALF has been proved as a good substitute of synthetic fibres, because of its economical and renewable nature. Specific strength of natural fibres supports in enhancing the physical and mechanical strength of polymer matrix without using any additional processing. The superiority of PALF mechanical properties is related with the high content of alpha cellulose content and low microfibrillar angle (14°). Due to extraordinary qualities of PALF, it can be used as reinforcing composite matrix [25]. The physical and mechanical properties of any natural fibres depend on fibre-matrix adhesion, volume fraction of fibre, aspect ratio, orientation, and stress transfer efficiency at interface. The result of PALF based polymer composites shows excellent stiffness and strength compared to other cellulose based composite materials. Strange characteristics of PALF are noticed; that is, a wet PALF bundle exhibits lower strength by 50%, but when it converts into yarn, its strength increases up to 13%. The PALF exhibits a modulus range from 34.5 to 82.51 GN·m⁻², tensile strength ranges from 413 to 1627 MN·m⁻², and an elongation at breakpoint ranges from 0.8 to 1.6%. PALF can sustain abrasiveness [57]. Datta et al. [58] studied many different types of properties and behaviour like morphology of surface structure, tensile behaviour, and dielectric property. PALF shows good elastic property in cellulose type I structure. In comparison to other natural fibres PALF has high strength. The electrical properties show high anisotropy.

3. Challenges for PALF as Reinforcement

PALF shows lower degree of compatibility with hydrophobic polymers due to its hygroscopic nature. Existence of natural waxy substance on surface of fibre layer provides low surface tension, which does not allow a strong bond with polymer matrix. However, the literature suggests various methods to improve the fiber surface to make it suitable for good interfacial fibre/matrix bonding. Natural fibres reinforced polymers are susceptible to humidity and water absorption that causes a physical degradation of final product. High moisture content in fibre

can cause swelling or dimensional defect at the time of composites preparing that affect the physical and mechanical property of the final product. At low temperature, water molecule faces obstacle by stiffness of polymer chain segments. Moisture diffusion into polymer depends on various factors such as molecule structure, polarity, crystallinity and the hardeners used in composite making [59].

4. PALF Based Hybrid Composite

Natural fibres are focused study among researchers and industries, as a replacement of glass fibres to natural fibres. The rapid growth in research on environmental issues is acceleration factors to utilize natural fibres in coming decades. Recently, PALF is being utilized effectively in polymer matrix to develop composites with improved mechanical strength [60]. The outstanding mechanical properties of individual PALF are reflected in its ultimate product. Various research has been done to reinforce PALF with thermoset, thermoplastic, biodegradable plastics [20, 21], and natural rubber [61].

4.1. Epoxy Based PALF Reinforced Composite

Epoxy resin has excellent properties like adhesion, strength, low shrinkage, corrosion protection, and many other properties [62]. Although it is expensive resin, its mechanical and chemical properties are very good. Natural fibres like jute, flax, sisal, and bamboo fibres with epoxy reinforced have been studied [63-66]. In case of PALF there is no work done yet. PALF has a major problem related to adhesion with many polymer matrices. PALF is hydrophilic in nature and it does not have good compatibility with hydrophobic polymer. PALF contains waxy substance on its surface causing low surface tension which negatively affects the bonding with polymer matrix. To overcome this issue PALF surface is modified to improve bonding. In surface modification process reagents make fibres hydrophobic in nature and graft the fibres surface with resin matrix and some compatible polymers [67]. A number of researches have been carried out to improve the adhesion between PALFs and matrix, for example, cyanoethylation, alkalization, dewaxing, and grafting of acrylonitrile monomer [68]. These methods have been proved to be a very effective modification to enhance the adhesion property of PALFs with polymer matrix. Benzoylated PALF with alkali treatment is used to enhance the adhesion and tensile properties. The alkalization process makes the fibres surface rough and improved mechanical hold. A rough surface improves the affinity of epoxy matrix and interfacial adhesion made strong due to deposition of DGEBA resin on fibres surface. Furthermore PALF-epoxy composites will exhibit a positive result in interfacial bonding when combination of alkalization and DGEBA solution will be used. Such kinds of surface modification will enhance the flexural, tensile, and impact properties of epoxy composite.

4.2 Polyethylene Based PALF Reinforced Composites

A pineapple leaf fibre reinforced with polyethylene exhibits high performance composites [7]. In comparison to other natural fibres, pineapple leaf fibre (PALF) shows excellent

mechanical and physical properties but the hydrophilic nature of PALF causes a negative impact. Thus, a chemical treatment such as alkali, isocyanate, saline, and permanganate was carried out to improve the water resistance. Peroxide modification is very helpful to reduce the hygroscopicity of fibres [67].

4.3 Polypropylene Based PALF Reinforced Composites

Pineapple leaf fibres (PALF) are renounced as possible and plentiful substitutes for the high-priced and nonrenewable synthetic fibres. PALF enhances the mechanical properties of the polymer matrix through its own high specific strength. PALF is multicellular, lignocellulosic and has very good mechanical properties. In study of stress behaviour of PALF reinforced polyethylene composite; stress is inversely proportional fibre content. Mechanical properties of polypropylene pineapple leaf fibre reinforced composites are reported. The tensile and flexural properties of composites are depending on volume fraction. The recent study showed very useful composites with high-quality strength. PALF is being used as a reinforced agent in polypropylene matrix in the place of pure resin, to improve the mechanical properties. Flexural modulus and flexural stress are directly related to the volume fraction. Though, value is insignificant due to fibre-to-fibre repulsion and dispersion problems. Researchers are mainly focused on improving the mechanical properties of PALF-PP composites and interfacial relation.

4.4 Vinyl Ester Based PALF Reinforced Composites

Currently natural fibres are widely used in the research as a substitute of glass fibre (GF) in fibre reinforced plastics (FRP). In comparison to glass fibre, these natural fibres have lower densities, are economical, consume lesser energies during production, cause less or no abrasion to machines, and are not hazardous to health when inhaled [68]. In spite of these properties, pineapple leaf fibres are untouched in research areas especially for reinforcing plastics although this application is now becoming an important research area. Now polymers composite is focused on using pineapple leaf fibres for developing value added applications. Despite several merits, PALF possesses inherent demerits such as poor interfacial fibre-matrix adhesion and absorbing water. In the last two decades, a lot of researches have been carried out to optimize the problem of the interfacial adhesion between natural fibres and polymer matrices. There is not much literature available on PALF Vinylester composites. Vinyl esters are strong, flexible, and less hydrophilic in nature [69]. Moreover, interfacial shear stress (IFSS) is the measurement of fibre-matrix adhesion which is always higher for natural fibre-vinyl ester compared to those of other matrices [70]. Most of the work on PALF reinforced thermoset composites used hand lay-up method in sample preparation and very few if any reported the use of liquid compression moulding process. As reinforced matrix, both untreated and bleached PALF are using in the form of random and unidirectional PALF mats. To evaluate the viability of PALF-vinyl ester eco-composites, there are many criteria of measurement, for instance, mechanical properties, water absorption, and thermal stability.

4.5 Polyester Based PALF Reinforced

PALF is obtained from the pineapple plant's leaves. Major compounds of PALF are cellulose (70–80%), lignin (5–12%), and ash (1.1) [71]. The recent study proved that by using different surface modified pineapple leaf fibres as reinforcing material can be used for polyester matrix. PALF fibre loading up to 30% by weight with polyester showed significant increment in flexural strength, tensile strength, and impact strength. Toughness of composite material is reached up to the benchmark of engineering materials. Surface modification by chemical treatment can enhance the strength of individual fibers and it can help to develop better mechanical strength PALF/polyester composite for commercial purpose.

4.6 Polycarbonate Based PALF Composite

A poor contact between PALF and matrix are prone to moisture intake and ultimately degradation through insects and pests [26, 72]. Thus, fibre surface modification is an important and necessary step to reduce the polarity of fibre. There are many methods like alkaline treatment [73], grafting with maleic anhydride copolymer [29], saline coupling agent such as *c*-aminopropyl trimethoxy silane (Z-6011) and *c* methacrylate propyl trimethoxy saline (Z-6030) [74,75]. Polycarbonate (PC) is an amorphous thermoplastic resin. It provides numerous vital and important characteristics such as lucidity, dimensional strength, high impact strength, and high heat resistant and flame resistance. Though there are some limitations of using the PALF in some applications. At low temperatures, it becomes softer and easy to remove from mould [76]. There are very few research works published on the PALF reinforced with polymers [77].

4.7 Low Density Polyethylene Based PALF Composite

Melt mixing and solution mixing techniques have been used in preparation of PALF reinforced LDPE composites. Solution mixed technique shows a better tensile strength than melt mixed technique. Relation of fibre size, loading %, and orientation with mechanical properties has been studied. Through fibre distribution curve and scanning electron micrographs, it is possible to analyze fibre rupture and damage during composite making. Fibre length of 6mm length was found to be suitable for PALF reinforced with LDPE. Mechanical properties are found to be improved and elongation at break is inversely proportional to fibre loading. In comparison to random and transverse orientation, longitudinal orientation of fibres showed better mechanical properties of composites. PALF-LDPE composites are eco-friendly, biodegradable and exhibit superior performance than any other cellulose-fibre reinforced LDPE systems.

5. PALF Based Hybrid Composites

Various combinations of natural lignocellulosic composite are promising interest of researchers. It provides wide range of results and properties which is very difficult to achieve through a single type of reinforcement. This type of matrix is generally used for the fibre having good interaction between matrix and fibres and together gives a better

mechanical performance [78, 79]. Thus, hybrid composite is the mixture of two different types of fibres reinforced into a matrix. It has various improved qualities which help to make it best composite. Individual strength of fibres is combined to achieve improved composite with better efficiency. Many researches are in progress for partially or fully replacement to glass fibres (GF) by natural fibres. GF has very good quality of reinforcement along with natural fibres like sisal, jute, pineapple, hemp, and so forth [80, 81]. Mechanical characteristic of hybrid composite and GF is studied by Thomas et al. [82, 83]. Idicula et al. studied the well mixed random orientation of banana/sisal hybrid fibre reinforcement with polyester composite [84]. Transformation maximum stress between fibres and matrix has been calculated for the composite of banana and sisal fibre ratio 3: 1, showing lowest impact strength. There is another composite of natural fibre reinforced with short carbon and kenaf fibre hybrid system [85].

On the basis of these studies and the aim of this research is to develop a high performance, cost-effective and lightweight pineapple leaf fibres and GF as the reinforcement based hybrid composites. Utilization of pineapple leaf with disposable chopsticks is very popular [86, 87]. Pineapple leaf fibre (2.3–3.9 mm) and recycled disposable chopstick fibres were integrated into PLA and PBS. The optimum ratio and content of the hybrid fibres were investigated in order to obtain the best thermal and mechanical properties.

6. PALF Applications and Future Prospects

PALF is generally used in making threads for textile fabrics from several decades. Present application of PALF for various purposes is textile, sports item, baggage, automobiles, cabinets, mats, and so forth. Surface modified PALF is introduced for making machinery parts like belt cord, conveyor belt cord, transmission cloth, air-bag tying cords, and some cloths for industry uses [88]. PALF is very good for carpet making because of its chemical processing, dyeing behaviour, and aesthetically pleasing fabric. The use of pineapple leaf fibre can be considered relatively as new in the paper manufacturing industry in India. PALF can be suitable for various other applications such as cosmetics, medicine, and biopolymers coating for chemicals. The pineapple leaf fibre is one of the natural fibres, having highest cellulosic content nearly 80%. Its density is similar to the other natural fibres while Young's modulus shows highest tensile strength when compared to other natural fibres. These properties are suitable for its application as building and construction materials, automotive components, and furniture. From this review it is clear that limited work has been done on thermal, electrical, dynamic, and mechanical properties. PALF is widely accepted in textile sector and already used in our daily life materials but we attribute that further study will enhance the application in various other exiting products.

7. Conclusions

Pineapple leaf fibre is very common in tropical regions and very simple to extract fibres from its leaves. The utilization of pineapple leaf fibre in composite material is a new source

of materials which can be economic, eco-friendly, and recyclable. However, the main issue of PALF is its hydroscopic nature, which makes a big hurdle for fibre utilization as a reinforced material in polymer composites. Surface modification of PALF is required to improve for good interfacial adhesion of PALF with polymers in fabrication of polymer composites. Synthetic fibres can be replaced or partially substituted with PALF in fabrication of composite products for different applications. It is observed that recent works have reported on chemical modification of PALF, physical and mechanical properties of PALF reinforced polymer composites and its hybrid. Pineapple is one of the natural fibres having highest cellulosic content nearly 80%. Density of PALF is similar to other natural fibres while Young's modulus is very high, and tensile strength is highest among the related natural fibres. These properties are suitable for its application as building and construction materials, automotive components, and furniture. From this review it is clear that limited work has been carried out on thermal properties such as, electrical properties, thermal conductivity, dynamic mechanical analysis, and modelling of mechanical properties of PALF reinforced polymer composites. In most of the examples, PALF fibres are reinforced with PP and unsaturated polyester only, so it is required to study the behaviour of PALF with other resins to get it wider application in bio-composites and hybrid composites manufacturing. PALF is widely accepted in textile sector and already used in our daily life materials but we attributed that further study will enhance its application in development of various existing products.

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