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ABSTRACT

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This paper reports a compressive study on the utilization of rice husk (RH) as an important agro waste and reinforcement for composites fabrication. It also reports in details, a review of the physical and mechanical properties of RH composites and it intensively highlighted the knowledge gaps that need to be filled in the respective research areas. Furthermore, it discusses the potential of RH composites to be used in photonics, construction materials, and automotive and furniture applications, based on their strength and thermal characteristics. It also revealed that, extensive efforts can make rice husk a material for sustainable development since it has the potential to reduce greenhouse emissions, reduces material costs and abundantly affordable.

Keywords: Rice Husk, Composites, Matrix, Reinforcement

1. INTRODUCTION

Due to the present Nigerian economic situation, government is encouraging farmers and other Nigerian to improve the level of productivity of food and other farm product. This make the rice production more ruminant and making its husk available in abundance without proper utilizations where part of it is taking to farm in mixture of fertilizer and little of it was utilize in animal food. Among the different existing residues and by-products, the possibility of using rice husk (RH) has attracted more attention of the researchers than any other crop residues. Overcoming these problems gave the motivation for this work; hence this study tends to look at rice husk as a potential reinforcement for all composite fabrication by analysing its properties, uses, application as well as the process involved. The development of science and technology has created a need to develop engineering materials having light weight, high strength with specific properties as per service requirement at low cost and minimum energy consumption. Thus, the concept of composite materials has come into existence partially replacing existing metals, non-metals and alloys in various engineering applications. The idea of composite materials however is not a new or recent one but has been around thousands of years. [1] Since the early 1960s, there has been an increase in the demand for stronger, stiffer and more lightweight materials for use in the aerospace, transportation and construction industries. Demands on high performance engineering materials have led to the extensive research and development in the field of composite materials. Many composites used today are at the leading edge of materials technology, enabling their use in advanced applications such as aircraft and aerospace structures [1]. Just as mankind has moved from Stone Age to the composite age, so have composites evolved from the chopped straw bricks of primitive times to today's sophisticated ceramic matrix composite and metal matrix composite. There has been an extraordinary explosion in composite usage, research and application. Now composites find unusual and exotic applications such as stealth aircraft and superconductive composite.

Composite materials are multiple phase materials achieved from non-natural mixture of dissimilar materials in order to get properties that the individual component by themselves cannot obtain and different phases are formed naturally by reactions, phase transformations, or other phenomen [2].

Generally, a composite material is made up of reinforcement (fibers, particles, flakes, and/or fillers) embedded in a matrix (polymers). The reinforcement materials provide strength to the composites whereas the matrix holds the fibre in desired shape and transfer the load from one fibre to other. [2] Composites are one of the fastest growing industries and continue to demonstrate a significant impact on the material world. In recent years, there has been growing environmental consciousness and understanding of the need for sustainable development, which has raised interest in using natural fibers as reinforcements in polymer composites to replace synthetic fibers such as glass. The advantages of natural fibers include low price, low density, sustainable availability and low abrasive wear of processing machinery. Further, natural fibers are recyclable, biodegradable and carbon dioxide neutral and their energy can be recovered in an environmentally acceptable way [2].

Composite materials can be modified for a variety of properties by suitably choosing proportions, distributions, and morphologies, degrees of crystallinity, crystallographic textures, as well as the structure and composition of the interface between components. Therefore, composite materials can be designed to suit the needs of technologies relating to the aerospace, automobile, electronics, construction, energy, biomedical and other applications [2,3,4]. As a result, composite materials comprise most commercial engineering materials in the engineering applications. Recent interest on the environmental impact of polymer-based materials has led to the development of new products prepared with recycled polymers and/or containing biodegradable materials. Lignocellulosic plastic composites constitute an important set within this kind of materials showing several advantages over traditional mineral-filled plastic composites: low density, low production costs, biodegradability, renewability, etc. Stiffness, hardness and dimensional stability of plastics have also been improved by incorporation of lignocellulosic fillers. [3, 4]

The main benefits that composite components offer are reduced weight and assembly simplification. Furthermore, composites differ from traditional materials in that composite comprises two distinctly different components reinforcement/filler and a matrix; a matrix can be polymeric, ceramic or metallic material (most often a polymer resin) that, when combined, remain discrete but function interactively to make a new material whose properties cannot be predicted by simply summing the properties of its components [5].

However, the use of agro-fibers shows some drawbacks such as degradation at relatively low temperature due to the presence of cellulose and hemicellulose. This early thermal degradation limits the allowed processing temperature to less than 200°C and restricts the type of thermoplastics that can be used with agro-fibres to some commodity plastics such as Polyethylene, Polypropylene, Polyvinyl chloride and Polystyrene [5]. Natural fiber/PP composites have been used in automotive applications and recently they have been investigated for use in construction, such as building profiles, decking, railing products, etc. [3, 6] Other factors should be considered when designing composites made of lignocellulosic fibers for specific applications, among them its poor resistance to moisture [6]. Outdoor applications have raised the interest on this property since moisture absorbed by the composite led to dimensional changes and to decreasing mechanical performance [7]. These negative effects can be reduced if the fibers are encapsulated in the plastic with good adhesion between the fibers and the matrix. The addition of a compatibilizer has been a useful tool for achieving such adhesion. Maleic anhydride-grafted PP (MAPP) is the most common compatibilizer used to improve interfacial adhesion for bio-fillers/a polar thermoplastic matrices even so new alternatives are being currently studied. [8, 9] The use of natural fibers as particulate fillers is known to have different effects when combined with different thermoplastics, and in most cases, improve the impact strength, stiffness, heat distortion temperature and cost reduction [10].

2. COMPOSITION OF RICE HUSK AND ITS UTILIZATION

Rice husk (RH) is one of the major agricultural residues produced as a by-product during rice processing. Usually, it has been a problem for rice farmers due to its resistance to decomposition in the ground, difficult digestion and low nutritional value for animals. [11]. According to Marti-Ferrer [12] the lignin and hemicellulose contents of rice husk are lower than wood whereas the cellulose content is similar. For this reason, Rice Husk Flour can be processed at higher temperatures than wood. Therefore, the use of rice husk in the manufacture of polymer composites is attracting much attention. It is one of the most widely available agricultural wastes in many rice producing countries of the world. They are the hard protecting coverings of grains of rice and removed from rice seed as a by-product during the milling process. It is essentially free as waste product from agriculture sector and forest residues. [12, 13]

2.1. Composition of Rice Husk

Rice husk contains 75-90% organic matter such as cellulose, lignin etc. and rest mineral components such as silica, alkalis and trace elements. [14] Rice husk is unusually high in ash compared to other biomass fuels in the range 10- 20%. The ash is 87-97% silica, highly porous and lightweight, with a very high external surface area. Presence of high amount of silica makes it a valuable material for use in industrial application. [15] Other constituents of Rice Husk Ash (RHA), such as K_2O, Al_2O_3, CaO, MgO, Na_2O, Fe_2O_3 are available in less than 1%. Rice husk having bulk density of 96-160kg/m^3, oxygen 31-37%, nitrogen 0.23- 0.32%, sulphur 0.04-0.08%. In the year 2016, TATYANA et al., in their work reported the presence of K_2O to be greater than 1%.

2.2. Utilization of Rice Husk

The interest in the utilization of rice husk as fillers in thermoplastics has increased recently mainly due to the needs in overcoming the environmental problems caused by agricultural by-products. [1] Kumar S et al [16] in his review reported the various utilization and application of rice husk, depending upon their physical and chemical properties like ash content, silica content etc. Rice Husk is used as a Fertilizer and Substrate as it can be composted, due to their high lignin content, the process is slow, but in few months, they are converted to organic manure, and it does not affect plant growth regulation. [14, 17]. It is also used as alternative fuel for household energy. [18]. Due to the lignocellulosic property of rice husk, rice husk can be applied in the preparation of activated carbon for effective adsorbents due to their complex microporous structure. [19, 20]. It can also be used in brewing beer to increase the lautering ability of a mash. However, it was used for over centuries in cleaning mouth before toothpaste replaced it. Rice husks are used as pillow stuffing. The pillows are loosely stuffed and considered therapeutic as they retain the shape of the head. One company announced plans to use rice husk ash as a source for tire additive. It serves as a source of fibre that is considered a filler ingredient in pet foods. [21]. Rice husk is used in making bricks, if there is more percentage of rice husk in the bricks, the brick will be more porous and have better thermal insulation. [22]. For generation of process steam, rice husk is used as a fuel. In small sector process industries, rice husk is used as a fuel in low-capacity boilers. For producing 1MWH (million-watt hour) electricity, 1 tonne of rice husk is required.

2.3. Other Uses

Rice husk is used for production of xylitol, furfural, ethanol, acetic acid, etc. It is used as a cleaning and polishing agent in metal and machine industries. It is also used as building material [23] and also used as industrial raw material example-as an insulating board material, filler in plastics, filling material, for making panel board etc [24].

Rice (Oryza sativa L. genus) is the primary source of daily food intake and has become the world’s second most important cereal crop sector due to the demand of billions of human beings. In 2019, approximately 756 million metric tons of rice were produced globally, and 90% of the total output came from Asia [13]. In Malaysia, about 700,000 hectares of paddy are planted on the extensive agricultural land, yielding more than 800,000 tonnes of rice husk (RH) and stalk waste annually [14]. These wastes should never be burned, due to various reasons, such as the ashes, harmful gases, and fumes that contribute to air pollution [15].

Typically, the RH can be used as biochar, extracted silica, or husk itself. In general, RH is a hull to protect seeds or grains. It is formed from rigid materials, is water-insoluble, and is abrasive, with a high level of cellulose–silica structures. The exterior of the hulls consists of silica covered with a cuticle, with a small amount of silica content at the innermost epidermis. Recently, several attempts have been made to utilize these waste materials in composite structures. The study of RH as a filler has been of interest to researchers since the 1970s.

Rice Husk Plastic Composites Several works on the application of rice husk as the reinforcing agent in plastic composites have been reported. Atuanya C. U [71] in his work investigated the effect of rice husk filler loading on the mechanical properties of recycled low-density polyethylene (RPE) and mixed with a fraction of virgin polyethylene (MPE) composites it was observed that tensile strength increased up to 10 percent weight fraction of rice husk filler in the composites and later decreased above 10 percent filler loading. Tensile modulus, flexural strength and modulus, and Brinell hardness increases with increased filler loading, but impact strength decreases with increased in filler loading. Nwanonenyi, S. C and Obidegwu, M. U I [72] analysed the Mechanical Properties of Low-Density Polyethylene/Rice-Husk Composite using Micro Mathematical Model Equations and the result showed that there is a distinct variation between the experiment results and results from micro mathematical model equations, the mechanical properties of the composite indicate that it may be useful in some applications that require low strength, high stiffness and hardness Nwanonenyi S. C [73]

3. MECHANICAL PROPERTIES

3.1 Tensile Strength of RH Composites

The exploitation of RH residues in bio composites offers multiple advantages, for example, reducing the relative number of constituents derived from synthetic polymers, such as resin polymers and some additives. The tensile strength is mainly used to evaluate the strength behaviour of a composite material. The behaviour of composites is dependent upon the filler type, matrix material, concentration, size, dispersion, and the adhesion between the filler and the matrix material. Various studies have been conducted on the variation of tensile properties of RH-reinforced composites at different filler loadings using different types of matrix materials as polymer matrices.

Using RH as a reinforcement has offered significant enhancements to the tensile properties of composites, as reported by Abdulkareem et al. [16]. They clarified that the young’s modulus of RH/waste polystyrene (PS) composite increased with increasing the RH content; up to 40 wt % compared to pure PS. A similar improvement in strength was also discovered by Zafar et al. [17] when studying an RH reinforced polypropylene (PP) matrix composite. The maximum tensile strength was achieved at 5 wt % of RH loading, with the size of the RH filler being 355–500 micron. In contrast, this contradicted the findings mentioned by Zhang et al. [18], where increasing the RH filler to 70 wt % decreased the tensile properties due to fiber agglomeration in the matrix. Zhang et al. [19] also studied the tensile strength of RH in a high-density polyethene (HDPE) matrix for different RH loadings, and the best level of tensile strength was attained at 40 wt % loadings. This was the result of the uniform distribution of RH in the matrix, making the matrix tightly wrap the RH, and thus improving the interface bonding. In another study, a unique type of RH, called hydrochar, was reinforced with polylactic acid (PLA) as the matrix, and it was observed that the tensile modulus improved from 2.63 GPa in virgin PLA to 4.24 GPa after blending with hydrochar. Xue et al. [20] used the ball milling technique to enhance the filler–matrix interaction by refining the particle size. They found that the tensile strength increased 44% compared to unmilled RH. While studying the performance between unfilled and filled epoxidized natural rubber (ENR) with RH ash, it was shown that the filled ENR provided a higher tensile strength than the unfilled ENR. A study of the differences in mechanical properties between RH ash filler and high-purity silica in an epoxy matrix composite by Fernandes et al. [21] found that similar characteristics were observed. They claimed that RH ash could replace silica with little loss of desirable properties. Pongdong et al. [22] indicated a similar conclusion, Polymers 2021, 13, 2391 4 of 19 whereby they found that RH ash filler exhibited a similar reinforcement compared to conventional siliceous earth for epoxidized natural rubber matrix composites. In order to reduce the level of alkalinity of the pore water in a synthetic polymer, matrix modification has been promoted. This method can typically enhance the durability of the fiber–matrix interaction by using cementitious materials. The tensile strength of the RH reinforced hybrid recycled HDPE/polyethylene terephthalate (PET) composites was optimum at 70 wt % of filler loading, as reported by Chen et al. [23]. In a similar study, Raghu et al. [24] used maleic anhydride grafted polypropylene (MAPP) and m-isopropenyl α–α-dimethylbenzyl-isocyanate grafted polypropylene (m-TMI-g-PP) as coupling agents. They found that the tensile properties of the RH/PP composites were better than the control samples. They observed that at 50 wt % RH loading, the tensile strength increased by 52% as compared with another type of filler, which were encouraging results. Several researchers evaluated the improved tensile strength properties between RH and the matrix resin using surface modification techniques such as esterification, silane treatment, fiber mercerization, or fiber surface modification. For example, Rajendran et al. [25] treated RH with ultraviolet-ozonolysis and found that the treated RH composites improved the tensile strength by 5% compared to the composite with untreated RH. Bisht et al. [26] used a mercerization treatment on RH flour and studied the effect on the tensile strength of RH/epoxy composites. The tensile strength of the composite improved by 36% with treated sodium hydroxide (NaOH) solution, by up to 8%. Santiago et al. [27] compared the tensile strength of RH powder in a recycled acrylonitrile butadiene rubber/PP hybrid matrix between a silane treatment and anhydride (AC) treatment of the fillers. Again, the AC treatment exhibited better tensile strength compared to the silane treatment. Zhang et al. [28] analyzed an extracted RH biochar reinforced HDPE composite at different pyrolysis temperatures using injection moulding. The best tensile properties of the composites were obtained in the temperature range of 500–600 ◦C, due to their outstanding physical interlocking structures. A similar pyrolysis of RH work was conducted by Moreno et al. [29]. It was shown that the increased RH content in the PP matrix led to a proportional decrease in the tensile strength. However, the decrease in tensile strength was less significant for the pyrolysis composites, as verified by the fracture surface. In addition, Boonsuk et al. [30] mentioned that an alkaline treatment with 11% w/v of NaOH removed the hemicellulose layer of RH and offered an outstanding tensile strength improvement, by a factor of 220%, compared to the neat thermoplastic starch. It improved the matrix-filler load transfer capabilities due to the loss of hemicellulose and the rougher outer surfaces after alkaline treatment. By contrast, the combination between untreated and 5% RH loading in a flexible polyurethane (PU) was found to have the best tensile performance of the composites [31]. The treated RH with 10% w/v NaOH adversely affected the surface of the filler and decreased the tensile behavior. Some researchers fabricated hybrid RH composites by combining two or more different types of fillers within a common matrix. For example, Shubbar [32] evaluated the tensile properties of RH combined with fumed silica nano powder in an epoxy matrix. The tensile properties increased by 50%, just by adding 5 wt % RH, compared to the sample with pure resin. Furthermore, Awang et al. [33] evaluated RH combined with titanium oxide (TiO2) and zirconium oxide (ZnO) in the PP matrix and proposed that the addition of TiO2 gave a higher tensile strength and Young's modulus compared to the addition of ZnO. From the scanning electron microscope (SEM) images, they concluded that this higher tensile strength was due to a better interaction between the matrix and the RH particles. Additionally, Kumar et al. [34] assessed a combination of RH/bauhinia-vahilii-weight/sisal filler with epoxy as the matrix and concluded that the addition of RH improved the tensile strength by 34.42% compared to not using the RH filler loading. The application of RH as a filler in polymer matrix composites increased the tensile strength in all the research that was reviewed in this paper. RH could replace silica and other fillers; however, some of the research showed that the tensile strength increment had a maximum point after a certain amount of RH loading. Some researchers conducted additional studies on the improvement of the interface properties of the filler–matrix, either by surface modification of RH or to the matrix formulation. It is believed that this is the way forward for increasing the usage of RH in polymer matrix composites.

3.2 Flexural Strength of RH Composites

In order to characterise the bending properties of the composite material, the most classical test used to characterize this behaviour is the flexural test (three or four points). A study by Zhang et al. [18] reported that the bending strength of a RH biochar/HDPE composite reached 53.7 MPa, which was far beyond wood–plastic composites. It was indicated that the biochar behaved as a rigid grain and locked the movement of a particle in the polymer chains. Hidalgo-Salazar et al. [35] analyzed a RH-reinforced PP composite and recorded an increase of 75% in flexural strength for the RH/PP composite compared with neat PP. They attributed the increase in bending properties to the stiffening effect of RH in the PP matrix. Singh et al. [36] also measured the flexural strength of a fully recycled RH-reinforced corn starch matrix composite and mentioned that the maximum flexural strength was 19.60 MPa for a RH/corn starch composite with 15 wt % RH content. Flexural modulus is a material characteristic that is significantly influenced by the morphology and crystallinity of polymers. In particular, the heterogeneous structure of the surface layers is important for high values of flexural modulus. Using a compatibilizer, Chen et al. [23] used an ethylene-glycidyl methacrylate (E-GMA) copolymer as a compatibilizer between recycled HDPE and recycled PET, and maleic anhydride polyethene (MAPE) as a coupling agent between the filler and matrix. They reported an increase in flexural strength of 62% with the increase of RH concentration in the polymer blends of recycled HDPE and recycled PET. It was discovered that the use of a compatibilizer increased the strength of the RH composite with the matrix blend. The coupling agent also improved the flexural strength of the RH/PP composites, and an increase of 46% was reported by Raghu et al. [24]. Moreover, when comparing the effect of silane coupling and compatibilizer MAPE on interfacial adhesion properties in RH/HDPE composites, Sun et al. [37] found that the bending strength and flexural strength were improved by 11.5% and 40.7%, respectively. It was observed that the flexural modulus increased with the increase in RH and the technical cellulose fiber amount. It was obvious that the flexural modulus reached higher values at higher quantities of cellulose fibers (20–30 mass%). Furthermore, there was no positive effect on the flexural modulus with a variety of plasma surface treatments of technical cellulose fibers or grafted maleic anhydride (PLA-g-MAH/PLA/30CeF). The smallest effect on the flexural modulus was noted for ozone-treated fillers [38]. Kumar et al. [34] reported an increase of 33% in the flexural strength for RH/bauhiniavahilii-weight/sisal epoxy composites compared to unfilled composites at all filler loadings. The effects of hybridized RH with groundnut shell (GNS) reinforced with PP were obtained by Guna et al. [39]. The maximum flexural strength of the hybrid composites was obtained with a 20/60/20 GNS/RH/PP ratio, which was 40% higher than the non-hybrid composites. This could suggest that a higher loading of small fillers was inclined to extensive delamination, and the misalignment of the filler in the matrix thus decreased the strength properties.

3.3 Impact Strength of RH Composites

Singh [36] reported that the impact energy of RH/corn starch composites increased with the increase of the amount of RH content. The impact strength reached 0.362 J for composites with 15 wt % RH content. The mercerization of fibres improved the impact strength, and Bisht et al. [26] reported that the impact strength of RH flour–epoxy composites were highest at 8% NaOH concentration. The reason for the increase of the impact strength was due to the mercerisation treatment, which improved the adhesion between the matrix and fiber by way of removing the voids on the surface of the untreated RHs. Surface modification by silane treatment of a PVC matrix in RH–PVC composites also increased the impact strength to 44%, as reported by Petchwattan et al. [40]. The use of coupling agents, as studied by Raghu [24], showed that the impact strength of RH–PP composites decreased with increasing filler loadings. Jiang et al. [41] explored the possibility of reinforcing RH–PVC composites with basalt fibres (BF) and found a noticeably increase in impact strength, whereby the BF acted as a reinforcing agent and strengthened the mobility of the matrix chains. Additionally, the aspect ratio of BF was higher than RH, thus the shift of the stress from the matrix to the fiber was more effective.

3.4 Water Diffusion Behavior of RH Composites

The water diffusion behavior of fiber-reinforced composites is dependent on the relative mobility of penetrants between the water molecules and polymer parts. In general, this obeys Fick’s diffusion theory, and three classes of diffusion can be determined [45,46]. The measurement of the kinetic diffusion mechanism was evaluated based on Fick’s theory and the fitting of experimental values, as follows:

$$\log \log(\frac{Mt}{M\infty}) = loglogk + n\ loglogt$$

where Mt and M∞ are the water absorption at time t and the saturation point, respectively. k and n are constants. The diffusion mechanism is reflected in the value of n. When the rate of diffusion of the infiltrate is less than the polymer part, Case I of the Fickian diffusion mechanism is obtained. For this case, the value of $n = 0.5$, where the saturated condition corresponding to a time is rapidly gained and conserved inside the composite [47]. However, when $n = 1.0$, this indicates that the diffusion activity is faster than the relaxation process [48]. The mechanism is distinguished by the progressive barrier between the bulging outer part and the inner glassy part of the synthetic polymer. In Case II, an equilibrium penetration diffusion is reached at a constant velocity. The non-Fickian is justified at a $0.5 < n < 1.0$ diffusion mechanism and does not obey the Fickian laws. At this condition, Melo et al. [49] used a Langmuir-type model to closely interpret the physical phenomenon of water absorption relaxation of natural fibre composites. In some cases, when n is larger than 1, it is known as Super Case II kinetics [50]; however, when $n < 0.5$, this can be classified as ‘Less Fickian’ behaviour. Table 3 summarises the water absorption kinetics of an RH-reinforced synthetic polymer. Chen and Ahmad [51] reported that the water absorption and swelling showed a linear increase with the increase of RH content. The higher water absorption and swelling with higher RH fiber content were due to the hydrophilicity of RH. This finding agreed with the finding of Abdulkareem et al. [16], where it was observed that the percentage of water absorbed increased with the addition of RH. Abdulkareem et al. [16] attributed the increase in water absorption to the pores and gaps in the RH structure. A different mechanism was observed in the epoxy matrix by Shubbar [32], whereby it was reported that due to the swelling of the composite as a result of water absorption, the epoxy matrix cracked, which in turn generated a capillary effect and caused further water absorption.

The RH was found to be better in terms of its water absorption properties when it was compared with other types of fillers. Muthuraj et al. [64] found that composites containing RH showed lower water absorption compared to other types of fillers, such as wheat husk, wood fibres, and textile waste. This observation was explained by the higher hydrophobicity of RH compared to other fillers. Yusuf et al. [65] compared composites containing RH with composites containing bamboo stem fiber. They found that composites with RH were better in terms of their lower water absorption and swelling thickness due to the lower affinity of RH to water. Sheykh et al. [52] compared RH and bagasse ash in an HDPE composite. The RH–HDPE composite was found to have lower water absorption and thickness swelling properties. This was due to the lower accessible -OH group on the surface of RH compared to bagasse fibres. Mohamed et al. [55] compared the water absorption properties of different contents of hybrid kenaf–RH in a polypropylene composite. Similarly, other researchers found that a higher RH content exhibited lower water absorption properties. This is because kenaf has larger voids and has more hydroxyl groups that can interact with water. Antunes et al. [66] studied the ability of RH panels (to be used as wall panels) to absorb and desorb moisture using the moisture buffer value test. They found that the higher RH content panels had a better ability for absorbing and desorbing moisture compared to panels with a lower content of RH, which makes them excellent for high humidity applications. Akindoyo et al. [58] presented that all composite structures massively absorbed more water than neat PLA due to a natural fiber composite, which contained a higher abundance hydroxyl group and easily interacted with water molecules. The increase in water absorption was higher in the reinforced blends, which could be credited to the water uptake properties of natural fibers. In general, all the composites conformed with Fickian’s law, where there was an initial rapid water uptake before reaching a saturation plateau region, with further increases in the soaking period. The effect of nano-silica particles extracted from RH on the water absorption characteristics was evaluated by Daramola [59]. An enhancement of the moisture absorption resistance of a nano silica-reinforced HDPE composite was observed at a lower particle weight fraction. However, increasing the filler loading resulted in an increase in the void content, interfacial bonding, and exposure surface between the filler and blend. Similar work was also reported by Hamid et al. [60].

In contrast, they reported that the silica concentration had no significant effect on the water moisture kinetic. Additionally, a nano-silica crystalline composite offered a higher water resistance than a nano-silica amorphous coupon. Both composites had a more hydrophobic resistance compared to epoxy resin. Furthermore, Norhasnan et al. [62] evaluated a hybridized RH/coco peat reinforced ABS, which showed reduced water-resistance biocomposite structures. Figure 1 shows the moisture absorption behaviour of the RH/CP reinforced ABS, and a maximum water kinetic behaviour for 20 wt % of coco peat composite composition was found, due to the higher hydrophilicity of the coco peat particle. Fiber surface treatment and matrix modification improves the water absorption properties of RH composites. This was confirmed by several kinds of research that used NaOH and silane treatments on RH and coupling agents on the matrix. Huner [53] used 10% NaOH, while Nabinejad et al. [67] used 5% NaOH. Both found that NaOH decreased the water absorption of the RH–PP composite. NaOH treatment caused the surface of the RH to be polar. The same result was also produced by silane treatment of RH. Water absorption decreased by up to 38%, as reported by Petchwattana et al. [40], due to the silane reacting with free OH groups and due to the elimination of voids. Huner [53] reported that the tendency for reaction was lower than NaOH, causing the water absorption rate for silane treated composite to be lower. The use of MAPP decreased the water absorption rate due to the decrease of micro gaps in the interface, as a result of enhanced bonding between the filler and matrix [53]. The comparison between NaOH treatment and UV/O_2 treatment by Rajendran Royan et al. [25] showed that the NaOH-treated RH exhibited higher water absorption properties. The reason for this was due to the dry treatment with UV/O_2, where the RH was not soaked in any liquid and as a result, there was no fiber swelling that could give access to water in the reactive region. Saidi et al. [54] used a titanate coupling agent for a RH–PVC composite. Titanate coupling improved the interfacial adhesion between the RH and PVC matrix, preventing the diffusion of water molecules. As a result, the water absorption was reduced by 26%.

Researchers have also used hydrophobic materials to increase the water resistance of the composite structure. As an example, Chalapud et al. [61] used a tung oil in RH that was adhesively bonded by a soy protein composite to improve the moisture resistance of particleboard. The impregnation of the composite panel with tung oil decreased its moisture absorption capacity and reduced the volume of voids, as obtained by surface microscopy. Since the oil was hydrophobic, a longer time period was required to reach saturation conditions, and this reduced the water kinetic mechanism, diffusing inside the hydroxyl groups of the RH and matrix to form hydrogen bonding. Moreover, a gamma radiation post-treatment was also employed by Chen et al. [63] and proved that the irradiation process increased the moisture kinetics and swelling effect on the composites. However, increasing the filler content after post-treatment also increased the moisture absorption, due to a huge quantity of carbonyl and hydroxyl groups in the composite, which allowed more molecule water to be diffused via the capillary effect.

4. SURFACE TREATMENT METHODS

Adekunle K. F [68] reported that for reinforcement to take place, the natural fibres have to be suitably treated to elevate their properties if they are to be used in technical applications, the effects of various fibre surface treatments actually improve the interfacial adhesion between the fibre surface and the matrix, thereby giving good mechanical properties to the resulted polymer composites, so we look briefly at the two methods of treatment

4.1. Physical Method

Physical methods such as stretching, calendaring, thermo treatment and the production of hybrid yarns have no effect on the chemical composition of the fibres but however they change the structural and surface properties of the fibre and thereby influence the mechanical bonding to polymers [69].

4.2. Chemical Methods

Zeynab Emdadi et al [70] reported a case of replacing chemical desiccants with rice husk, and the rice husk is been treated with alkali and acid solution, after characterization, the composite samples showed higher water absorbance which is attributed to the porosity and improvement of adhesion properties in the prepared samples. The point is that before rice husk is used, as reinforcement for plastic composites for instance, it was treated chemically, to make it compatible for composite preparation by introduction of a third material that has properties intermediate between those of the other two materials. This includes the following concepts; the morphology of the interface, the acid-base reactions at the interface, surface energy and the wetting phenomena. [69]

Another research was conducted were the Effect of Rice-Husk Filler on Some Mechanical and End-use Properties of Low-Density Polyethylene investigated and the Results showed that tensile modulus and hardness increased with increase in filler loading, while tensile strength and % elongation decreased with increase in filler loading. In addition, it was also observed that end-use properties such as water absorption, specific gravity and flame retardant properties increased as filler loading increases. Dimzoski [74] studied properties of rice-hull-filled polypropylene (PP) composites. Using the concept of linear elastic fracture mechanics, Introduction of rice hulls in the PP matrix resulted in a decreased stress at peak, together with increase of composites tensile modulus and modulus in flexure. Patricio Toro [75] investigated the increase of the rice husk charge as natural filler in the PP matrix decreases the stiffness, and in the presence of PP-g-MMI as compatibilizer in PP/rice-husk, the tensile modulus and water absorption of the composite were improved. Simone Maria Leal Rosa et al [76] studied on the Properties of Rice-Husk-Filled-Polypropylene composites with Maleic anhydride modified propylene as the coupling agent, it was verified that tensile strength decreased with filler loading. The presence of MAPP improved this property showing a strong dependence on the MAPP/RHF ratio Nak-Woon. Choi et al [77] developed a new recycling method for rice husks and waste expanded polystyrene, with a view of using the styrene solution of waste expanded polystyrene as a binder for rice husk-plastic composites, their water absorption and expansion in thickness are decreased with increasing binder content and filler-binder ratio, since the composites formed have a high flexural strength and water resistance, their uses as building materials are expected.

Dr. Shivappa et al [78] carried out a research on rice husk reinforced with vinylester polymer composite, though the work showed a lot of fluctuation on the tensile and flexural strength of the composites, it increased but not steady Vasanta V Cholachagudda et al [79] used rice husk as an additional fiber with coir fiber to reinforce vinyl ester from observations, there were improvement in mechanical properties of the composite material formed (both in tensile and flexural strength) From the works reported, it was observed that polyethylene reinforced with rice husk exhibited increase in tensile modulus, flexural strength and hardness during the loading of the filler but tensile and impact strength dropped at the early stages of the loading, then for the polystyrene and polypropylene their tensile modulus, flexural strength increased but showed improvement when a compatibilizer was used on polypropylene composite. polyethylene composites have higher elongation at break more than other polymer composites, that is why rice husk exhibited more useful mechanical properties in its composites both in recycled form, also the tensile strength of rice husk composites increased when used as an additional fiber to coir in reinforcing vinyl ester, showing that they are gradually substituting synthetic fibres and the tensile strength of the composites is not falling.

5. Rice Husk Composite Production Method

The rice husk fibres were separated from undesirable foreign materials (matter) and pith and then ground with hand grinding machine. The ground rice husk was then sieved to get very smooth fine textured particles. Then the composite was formed by integrating selected rice husk with a matrix. The mixture of reinforcement/resin does not really become a composite material until the last phase of the fabrication, that is, when the matrix is hardened [80] The characteristic of composites depends on the nature of the reinforcement, the ratio of resin to reinforcement, and the mode of fabrication, so the basic methods applicable to rice husk composite fabrication include: extrusion process, injection moulding and compression moulding, the extrusion process is preferable to other methods due to its ability to create very complex cross-sections and to work on brittle materials. [80, 81].

6. Problems and Challenges Facing Biocomposites

This effort to develop biocomposite materials with improved performance for global applications is an ongoing process, it has been proved that it has low density, easily affordable, biodegradable, renewable and environmentally friendly it is faced with a whole lot of problems like Low impact strength (high concentration of fiber defects), Problem of stocking raw material for extended time, UV resistance– not better than plastics, Fiber degradation during processing and Fiber orientation and distribution. [82] Nwanonenyi, S. C and Obidegwu [72] in their research showed that tensile strength and percentage elongation of the composite exhibited a gradual decrease with increase in filler loading while tensile modulus and hardness showed gradual improvement with increase in filler loading. The mechanical strength of a biocomposite could not match that of synthetic composites and the natural fibres would not replace synthetic fibres in all applications. For the last decades, extensive research is ongoing in order to improve the mechanical properties of biocomposites, while the intrinsic properties of the natural fibres such as biodegradability and low specific gravity of the fibers remain unchanged. [83].

5. CONCLUSION

From the various works reviewed in this study so far, rice husk has proven to be very important agro waste and suitable candidate material for reinforcement in plastic composites, once they are suitably prepared and treated as the society still regard rice husk as a non-economical viable material, and dwell on synthetic fibres which is costly, non-renewable and releases greenhouse gases that causes variation in the climate which is a global problem. Extensive effort needs to be made to portray rice husk as a material for sustainable development since it has the potential to reduce greenhouse emissions, reduces material costs and abundantly affordable.

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