Polymeric-Composites Reinforced with Banana Fibers

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Recent manufacturing advancements have led to the fabrication of polymeric composites (PC) reinforced with fibers. However, to reduce the impact on the environment, efforts have been made to replace synthetic fibers (SF) by natural fibers (NF) in many applications. NF, e.g., as banana fibers (BF) possess higher cellulose content, a higher degree of polymerization of cellulose, and a lower microfibrillar angle (MFA), which are crucial factors for the mechanical properties (MP), namely tensile modulus (TM) and tensile strength (TS), and many other properties that make them suitable for the reinforcement of PC. This review paper presents an attempt to highlight some recent findings on the MP of PC reinforced with unmodified or modified BF (UBF, MBF), which were incorporated into unmodified or modified (synthetic (SPM) or a bio (BPM)) polymeric matrices (UPM, MPM). The experimental results from previous studies are presented in terms of the variation in the percentage of the MP and show that BF can improve the MP of PC. The results of such studies suggest the possibility to extend the application of PC reinforced with BF (PCBF) in a wide range, namely from automotive to biomedical fields.

Keywords: banana fibers, polymeric composites

1. Introduction

Banana Fiber (BF) has a hydrophilic nature and high cellulose content. The presence of lignin and hemicellulose components contribute to absorb the water molecule and swell. For this reason, BF can present some incompatibility within the PM which increased the microvoids, thus resulting in microcracks on the IR of the PCBF, which enhances the moisture absorption tendency. However, the hydrophilicity of BF can be reduced with different SCT.

Appendix G (Table A7) summarizes the moisture absorption tendency of PC reinforced with UBF or with MBF from selected authors in different situations. From Appendix G (Table A7), some important conclusions can be drawn. The variation in moisture absorption tendency is positive in all cases. However, the highest variation in moisture absorption tendency was found for PCWUBF (20 vol % of UBF into a polyester PM) in comparison with the pristine PC, which reached a moisture absorption tendency of +2431(%) [137] for a saturation time of 143 h. The authors decreased this moisture absorption tendency with SCT of BF. The lowest mean values in moisture absorption tendency were found for PC with UPC (PP matrix; +1.35(%) of MAT), and MPC (with MA; +0.30(%) of MAT) reinforced with UBF (20 mm in length) at a FL of 10 vol % in comparison with the pristine PC. MAT decreased with the addition of PP_MA in comparison with the PC without MA. The MAT for the PP + PP_MA + UBF mixture was the lowest. The authors justified this result with the presence of hydroxyl groups on the hydrophilic nature of the BF and their interaction with the anhydride groups of the treated PM (PP_MA). In this case, the sequence of the mixture also influenced the MAT results.

Concluding, in all cases, the poor wettability and adhesion into the IR was attributed to the hydrophilic nature of BF, as expected. The entry focused on the direct and indirect surface treatments on the natural fibers and their influence on MAT. Considering the obtained results by selected authors and the information, it can be stated that MBF and MPM get masked into the PCBF with stronger adhesion, resulting in greater hydrophobicity and less MAT.

2. Remarks and Outlook

This entry summarized the most used methods to extract and to treat banana fibers before their incorporation into the polymeric matrices (thermoplastic polymeric matrices or thermosetting polymeric matrices). Using the different information available, which was sometimes difficult to correlate, an attempt was made to understand the effect of the addition of unmodified or modified banana fibers as a function of the fiber loading, or at fixed fiber loading, into synthetic or biopolymeric matrices, or into plasticized starch matrices. Such an effect can improve the mechanical properties, namely the tensile modulus and strength, flexural modulus and strength, and impact strength of untreated polymeric composites reinforced with untreated banana fibers, untreated polymeric composites reinforced with treated banana fibers, treated polymeric composites reinforced with untreated or treated banana fibers (with maleic anhydride), etc. Various studies were analyzed, and some important conclusions can be drawn.

The number of suppliers is still very limited for commercial banana fibers. In fact, the majority of the used banana fibers in the mentioned studies were extracted by local farmers, and after that, they were treated.

Banana fibers are most commonly available in tropical regions of developing countries (e.g., Brazil, Colombia, India, Malaysia, and China). This is why they constitute the best buying locations for the acquisition of commercial products made with banana fibers. In Europe, there are fewer material sources, which are mainly located in the Macaronesian region (e.g., Canary Islands and Madeira Island, respectively a Spanish autonomous community and Portuguese autonomous regions) and geographically located near Africa, where there is a need to make all processes (extraction and manufacturing) more efficient and economical when compared to the previously referred regions of the world.

The utilization of the banana plants reduces the resulting waste of banana cultivation and allows the extraction of hard banana fibers with five to eight different textures (from coarse to fine and from smooth to rough), which after appropriated treatment can be incorporated into usefully biopolymeric matrices to fabricate green polymeric composites.

Similar to natural fibers, banana fibers also are hydrophilic with a moisture absorption tendency, making banana fibers incompatible with the hydrophobic nature of the polymeric composites, causing weak interfacial bonding on the interfacial region (reduction of interactions) and causing failure by intercellular and/or intracellular modes. This is one of the reasons which led, in some cases, to the decrease of the mechanical properties of polymeric composites reinforced with banana fibers, with the addition of banana fibers. To solve this drawback, the research community has developed different surface chemical treatments, which cause morphological changes to the banana fibers and lead to a closer packing of banana fibers. This improves the compatibility between natural fibers (in this case, banana fibers) with the polymeric matrix and induces better mechanical bonding into the interfacial region.

Examples of surface chemical treatments are alkalization or mercerization, silanization, acetylation, cyanoethylation, potassium (e.g., permanganate, metabisulfite, hydroxide) treatments, sodium (e.g., lauryl, hypochlorite, chlorite) treatments, acid (e.g., acetic, oxalic) treatments, benzoylation, etc. On the modified banana fibers studied in this review work, the most used surface chemical treatments were alkalization and silanization.

An indirect method to treat the natural fibers, namely banana fibers, is by the addition of a compatibilizer into the polymeric matrix. Examples of compatibilizers are graft, block copolymers, or graft copolymers by the modification of polymeric matrices. In general, grafting can be done by monomers (e.g., $C_{18}H_{36}O_2$, $C_4H_6O_3$, maleic anhydride, and methylacrylate) and acrylic monomers (e.g., 2-EHA), etc. With this method, it is possible to obtain interactions between the monomers and the hydroxyl group (–OH) of banana fibers, which causes better adhesion into the IR and, consequently, some increases in the mechanical properties (e.g., toughness) of polymeric composites reinforced with banana fibers. In addition, it also causes a reduction in the moisture absorption tendency. In some of the consulted works, the Scanning Electron Microscope images revealed the good quality of the interfacial region (reduction of the crack propagation) and the higher adhesion between the modified polymeric matrices and the modified banana fibers, which were caused by the maleate groups. However, some improvement was also obtained for the modified polymeric matrices with unmodified banana fibers. In these cases, the authors speculated that the selected polymeric matrices were not the best choice. However, from the comparative studies of the mechanical properties of polymeric composites reinforced with unmodified banana fibers and mechanical properties of polymeric composites reinforced with modified banana fibers, it was found that the mechanical properties of polymeric composites reinforced with modified banana fibers are higher than that of polymeric composites reinforced with unmodified banana fibers.

Various techniques and methodologies exist to fabricate polymeric composites reinforced with banana fibers. For the polymeric composites reinforced with banana fibers studied in this review work, the most used was compression molding.

Polymeric composites reinforced with banana fibers with satisfactory behavior on the modulus and strength could be successfully manufactured using unmodified banana fibers as the reinforcing agent. However, some mechanical improvements can be a consequence of the reduction of the banana fiber length. In fact, the highest improvements were observed for the longest unmodified banana fibers at the highest fiber loading. This proves that it is necessary to add a large amount of unmodified banana fibers to make the polymeric composites reinforced with unmodified banana fibers more ductile. However, the shortest unmodified banana fibers improve the mechanical properties of the polymeric composites reinforced with banana fibers, even at a low fiber loading content. It would be interesting to compare the results with the shortest modified banana fibers instead with the shortest unmodified banana fibers.

Modified banana fibers with starch solution caused an increase of mechanical properties because starch was working as a good stiffening agent. It is well known that starch is widely used as a stiffening agent for fibers.