Are Nanoreinforced Natural Fibre Composites the Route Forward?

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Renewable polymers often have inferior properties to their synthetic counterparts against which they have to compete. The development of composites is thus a vital strategy for enhancing the performance of these polymers. To create a new generation of renewable polymer matrix composites, it is also necessary to replace synthetic fillers with renewable ones – hence the re-emergence of natural fibre composites. Renewable or green composites, also often called biocomposites, have regained vast interest in the past decades because of the wide availability of natural fibres, the increased availability of renewable polymers and the biodegradability of the composites.
Natural fibres are already being considered for various applications. Advantages of natural fibres are their low cost, low density, renewability and biodegradability. The main drawbacks are inconsistency in mechanical properties, relatively low tensile strength, and their limited thermal stability resulting in a limited processing routes. The increased availability of nanocellulose, which can be produced top down by the mechanical disintegration/fibrillation of (chemically modified) cellulosic fibres or bottom up by microbial fermentation of suitable carbon sources. These new reinforcing agents may provide a breakthrough in the development of green composites by introducing an additional nanoscale reinforcement into the matrix of traditional natural fibre composites. This should allow for the development of novel composites with much improved properties. We focused on bacterial cellulose (BC), because it's the purest cellulose. BC fibrils have diameters ranging from 10 to 100 nm and a measured Young's modulus of 114 GPa. In addition to its light-weight and attractive mechanical properties, bacterial cellulose is non-toxic, renewable and biodegradable. These intrinsic properties can be used to influence and enhance the surrounding polymer matrix performance.
Nature demonstrates the use of hierarchical structures when high mechanical resistance is needed, e.g. in plant cell walls, animal shells and bones, through the assembly of molecules of different sizes. The application of this concept is markedly improving our engineering of truly green composites. Nanocellulose coated natural fibres were created by cultivating cellulose-producing bacteria in the presence of fibres or by fibre coating resulting in significant coverage of the fibre surfaces by bacterial cellulose. We have created hierarchical structures in natural fibre composites by using these "hairy" fibres to deliver the nanoreinforcement into polymer matrices avoiding troublesome processing issues associated with anisotropic nanofillers. There are many outstanding issues in hierarchically structuring composites: the compatibility between all phases, the arrangement of the nanofiller within the composite, and biodegradability control. The separation of end-of-life waste of truly green composites from the waste streams and compositing is another thorny issue.