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Adding plant fibers improves thermomechanical properties of poly(lactic acid) matrix

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New Zealand flax leaf fibers, traditionally used for weaving mats and ropes, can reinforce a poly(lactic acid) matrix, making it more desirable for plastics and composite applications.

Compostable polymers derived from renewable sources are a potential solution to relieve solid-waste disposal problems and dependence on petroleum-based plastics. Poly(lactic acid), or PLA, derived mainly from starch and sugar, until recently has been used principally in the biomedical field because the body can absorb it. Other current applications for PLA are packaging, disposable cups, and shopping bags. Fiber-reinforced PLA used in injection-molded plastics and composites would considerably broaden interest in this polymer, which is highly desirable due to ever-increasing environmental awareness.

In recent years glass fibers have been used to reinforce PLA. But one of the most investigated solutions involves processing PLA with natural fibers to produce truly 'green' composite materials suitable to compete with their non-biodegradable counterparts based on fiberglass for non- or semi-structural applications. PLA-plant fiber composites have been fabricated mainly using fibers from herbaceous species and bast (skin, or inner bark) fibers. Leaf fibers appear promising for obtaining long stretches of aligned fibers. Their inherent limitation is that they are formed by bundles of many fiber cells, only a small portion of which contribute effectively to fiber-matrix adhesion. Nonetheless, adding 30% abaca fibers by weight to PLA yielded promising results both in improved work of fracture and tensile strength.[1] Fibers extracted from the leaves of *Phormium tenax*, a flax plant indigenous to New Zealand, have traditionally been used by the Maori people for weaving mats and ropes.[2] However, the industry is declining to the point where there is just one mill that still extracts these fibers. Consequently, there is an interest in finding new uses and applications to revive the sector, such as the production of composites.[3–5]

We characterized composites of *Phormium tenax* fibers in a PLA matrix with fibers content of 20, 30, and 40wt% produced by injection molding and twin screw compounding. Mechanically, we performed tensile, dynamical-mechanical analysis and Shore-D hardness tests. Thermally, we used differential scanning calorimetry and thermogravimetric analysis, and morphologically, we inspected fracture surfaces using scanning electron microscopy (SEM).

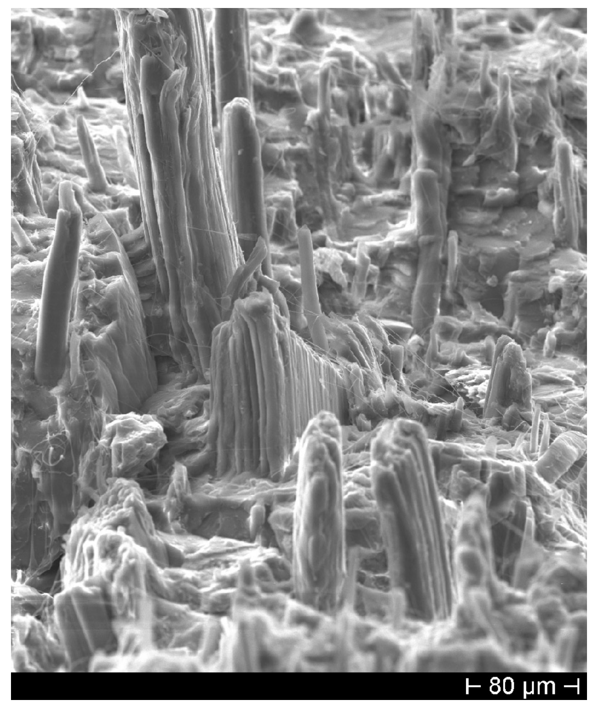

Figure 1. *Fracture surface of poly(lactic acid)/phormium (30wt%) showing extensive fiber pull-out.*

We saw a considerable increase of stiffness in phormium fiber-reinforced composites. Some decrease of the tensile strength also occurred, with limited difference between tensile strength measured for composites with different reinforcement content. SEM micrographs

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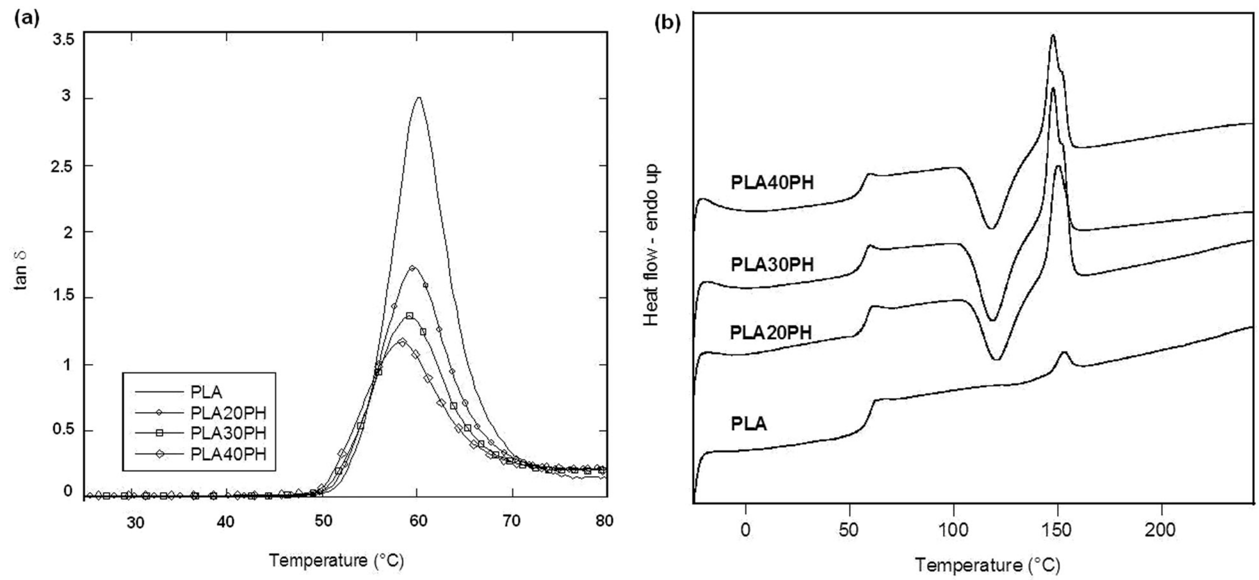

Figure 2. *(a) Tan δ vs. temperature curve (dynamic mechanical analysis), and (b) differential scanning calorimetry curves for all composites. PLA: Poly(lactic acid). PH: Phormium content.*

of fracture surfaces highlighted composite failure modes, including a diffuse presence of fiber pull-out and debonding (see Figure 1). This suggests that the fiber adhesion to the matrix must be improved to enhance this material's profile. We also saw an increase in hardness because lignocellulosic fiber is considerably harder than thermoplastic polymer matrix, suggesting that introducing more fibers improves the composite's wear properties.

Dynamic mechanical analysis showed that the addition of phormium fiber did not significantly affect the glass transition temperature and therefore the service temperature of PLA. It reduced the area under the tan δ curve representing the viscous component of PLA behavior. Thermal analysis by differential scanning calorimetry showed the cold-crystallization peak shifted to lower temperatures with increasing fiber content, confirming that adding phormium fiber promotes crystallinity (see Figure 2).

We produced promising results applying these composites to obtain larger stiffness and lower damping properties. In general, using short phormium fibers in a randomly oriented arrangement results in a highly positive effect on composite tensile modulus and hardness, and a limited modification of PLA's thermal profile for growing contents (up to 40wt%) of reinforcement. The principal challenge going forward is improving the interface strength of PLA/phormium composites.

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