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Biodegradable biocomposites with antimicrobial properties for food packaging

Intan S. M. A. Tawakkal, Marlene J. Cran, and Stephen W. Bigger

A novel ternary composite comprising a biopolymer, natural fibers, and an essential oil extract is a promising active material for extending the shelf-life of food products.

Single-use food contact packaging materials are typically made from common plastics, including polyethylene and poly(ethylene terephthalate). Although these materials are recyclable, vast quantities of them end up in landfill sites, where they resist degradation for long periods of time. Bioderived polymers are now gaining popularity as replacements for these traditional packaging materials. In particular, poly(lactic acid)—PLA—is one of the more promising biopolymers for these applications. In terms of cost, however, PLA cannot rival the traditional packaging materials. Creative solutions are therefore needed to make PLA a more financially viable packaging alternative.

PLA is highly compatible with many natural fibers, which means that composites of the two can be used to substantially reduce the costs of PLA-based packaging materials (often without degrading the mechanical integrity of the resulting products).[1] For example, filling PLA with abundant, natural plant fibers such as kenaf (*Hibiscus cannabinus*) is a common practice that can lower production costs and reinforce the naturally brittle polymer.[2] To use kenaf fibers within PLA composites, the use of an alkaline chemical treatment is required to remove surface impurities and to increase the compatibility of the fibers with the PLA matrix. In recent years, PLA has also emerged as an important polymer in the field of active food packaging materials, i.e., where systems are designed specifically to interact with the food product as well as the environment inside and outside the package. Antimicrobial (AM) packaging is one example in which PLA is beginning to be successfully used. In AM packaging, agents such as thymol—an essential oil extract (EEO) obtained from the thyme plant—is used to inhibit microbial growth that can eventually result in food spoilage.

In our work we are focused on a relatively new and promising aspect of PLA packaging that involves the use of both fillers and AM agents to form ternary composites.[3,4] We have thus produced ternary composite systems that consist of PLA, alkali-treated kenaf (TK), and thymol. For these composites we typically use fibrous filler (i.e., TK) contents of 30–40% w/w and up to 10% w/w thymol (required to impart adequate AM activity). To assess their potential for AM packaging material applications, we have investigated various characteristics of these composites, including their rheological, mechanical, and decomposition properties.

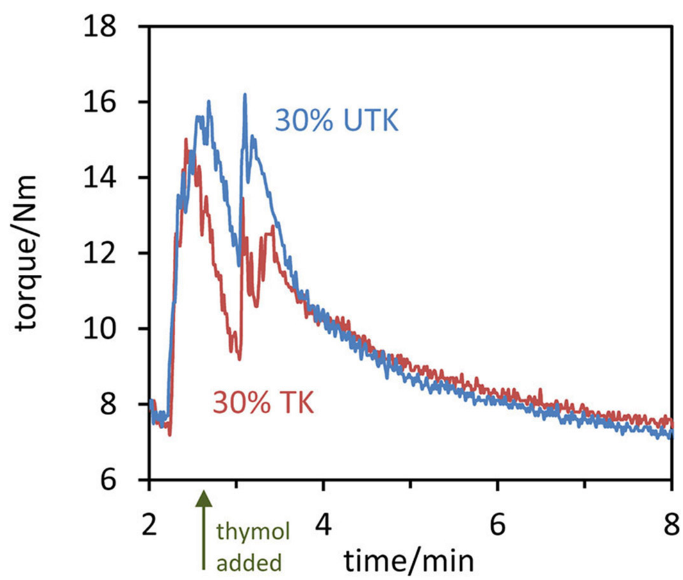

Figure 1. *Effect of addition of thymol on the rheological properties of poly(lactic acid)/kenaf (PLA/kenaf) composites that contain 30% of either alkali-treated (TK) or untreated (UTK) kenaf fibers.*

The results of our study show that the rheological properties of our PLA composites are affected by the addition of thymol (see Figure 1). We find that the processability of the PLA composites containing 30% kenaf is improved following the addition of thymol. In particular, the composites that contain treated fibers become slightly easier to process

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than those that contain untreated kenaf (UTK) fibers. In these cases, the addition of thymol imparts a desired lubricating effect and thus reduces the processing energy required to form the composite.[4]

In addition, we find that the mechanical properties of our ternary PLA composites are appropriate for their intended use as rigid, compostable food containers or trays. In particular, our results show that the tensile strength is improved with both increasing kenaf content and with alkali treatment of the fibers (see Figure 2). However, we observe a slight decrease in tensile strength when thymol is added to the composites. This may be caused by the plasticizing effect, which has previously been suggested, and by potential slippage of the fibers within the PLA matrix.[3]

Unlike conventional, rigid food trays that can be either recycled or disposed of in landfill, our PLA/kenaf/thymol composites are suitable for composting. Under typical compost conditions, we find that our ternary composite completely disintegrates into the compost medium within 48 days (see Figure 3).[4] The volatile nature of EEOs (e.g., thymol) assists in their liberation, particularly under the relatively high temperatures that are encountered in compost environments. When the AM agents are released, the composting micro-organisms can flourish, decompose, and assimilate the composite.

In summary, we have recently demonstrated the potential of PLA composites to compete with conventional, rigid packaging materials. In our ternary composites we include alkali-treated kenaf fibers for reinforcement and thymol as an antimicrobial agent. There is still, however, considerable scope for further development of such biocomposites for food packaging applications. This is particularly the case in the areas of active and AM packaging, i.e., where extending the shelf-life of food products is becoming a vital issue, but where environmental sustainability and resource management are equally important. In our current studies we are using PLA and other biomaterials as carriers for a range of natural agents to impart AM and/or antioxidant activity in biopolymer packaging films. We aim to show that encapsulation of these additives in compatible materials offers protection through the processing stages, and controlled release into the packaging environment to extend the shelf-life of food products.

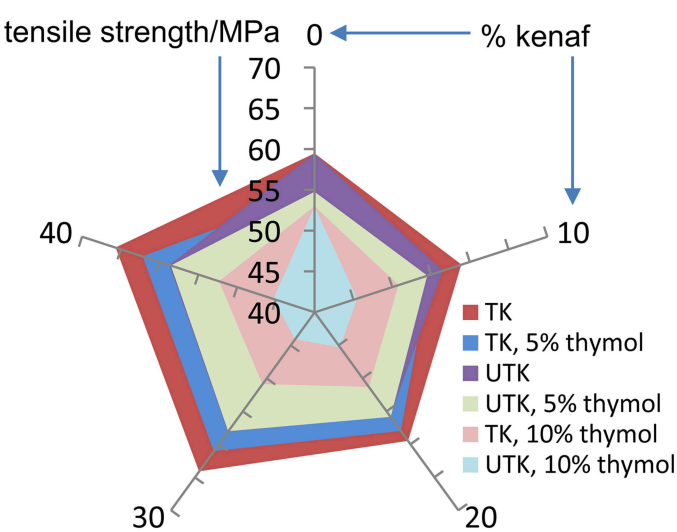

Figure 2. *Tensile strength of the PLA/kenaf composites as a function of kenaf content, fiber treatment, and thymol content.*

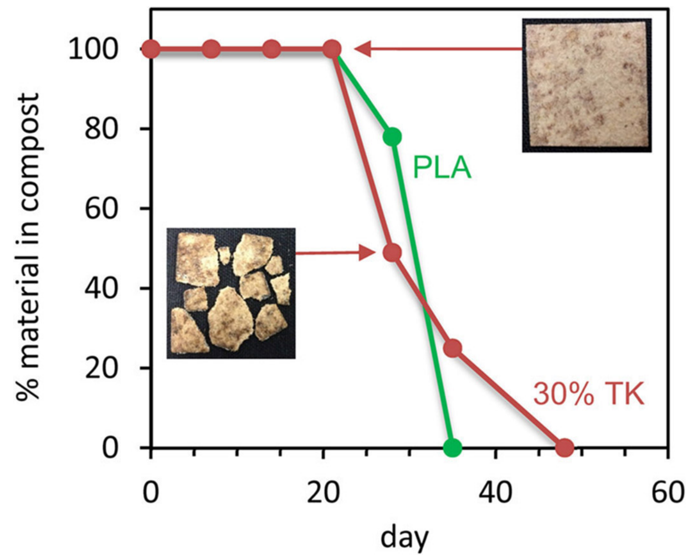

Figure 3. *The amount of PLA (green line) or PLA/kenaf/thymol composite (red line) in a typical compost environment as a function of time.*

Author Information

Intan S. M. A. Tawakkal
Department of Process and Food Engineering
Universiti Putra Malaysia (UPM)
Serdang, Malaysia

Intan Tawakkal graduated with a BEng and MSc in packaging from UPM. She recently completed a PhD at Victoria University in the field of active PLA composites and has now returned to UPM as a tutor in the Faculty of Engineering's Department of Process and Food Engineering.

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Marlene J. Cran and Stephen W. Bigger
Victoria University
Melbourne, Australia

Marlene Cran is a BSc(hons) and PhD graduate from Victoria University with majors in environmental management and polymer science, respectively. Her research is in the fields of water and wastewater treatment, membrane science, and active packaging, with a particular focus on the synthesis of nanomaterials for use in these areas.

Stephen Bigger graduated with a BAppSci and PhD from the University of Melbourne, Australia. He has published widely in the fields of polymer degradation and stabilization, as well as in the refereed educational literature in chemistry. He currently holds a professorial position in the College of Engineering and Science.

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