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PFAS (per- and polyfluoroalkyl substance)-free molded fiber: The future is already here FREE

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ABSTRACT

With renewed interest in food packaging materials that can be both recyclable and compostable and the environmental concerns about plastic pollution in the terrestrial and aquatic ecosystems, molded fiber food packaging is experiencing an unprecedented demand around the globe. However, the phase-out of per- and polyfluoroalkyl substances (PFASs), commonly used as a water/grease resistant agent in food contact molded materials in many jurisdictions, has posed a significant challenge to the industry. This perspective outlines a recently developed solution to replace PFASs through the application of a layer of cellulose nanofibrils on the surface of molded fiber objects.

Like many issues humankind has caused for the earth and the environment, we did not break our habit and did it again. Per- and polyfluoroalkyl substances (PFASs) are so ubiquitously used in so many products—as if our lives depend on them—that it seems to be too late to talk about alternative ways to avoid them in the first place. However, any action is better than no action and perhaps better late than never. Although the exact adverse effects of PFASs on human health are yet to be determined, there is no doubt about human exposure pathways and the need to find solutions.[1] It is time to seriously consider removing PFASs from products that science has proven can perform better without them!

Molded fiber is a pulp-based product that is made by molding a low-consistency slurry of pulp into a usable shape: a plate, a bowl, a serving tray, or a clam-shell food container. While molded fiber products are a viable solution to mitigate the world's single-use plastic waste problem, they come with two inherent shortcomings: molded fiber is neither water nor oil/grease resistant, and not surprisingly, most foods have water and/or oil in them and a level of protection is expected in service. Here is where PFASs come to the rescue by imparting both water and oil/grease resistance to molded fiber. Today, PFASs are commonly used in the food packaging industry. A recent study found that 56% of bread and dessert wrappers, 38% of sandwich and burger wrappers, and 20% of paperboard food packaging had detectable fluorine, indicating food contact packaging can be a significant contributor to human exposure to PFASs.[2] Finding a viable, renewable, and economically feasible replacement for PFASs in food packaging seems to be an inevitable requirement with increasing public awareness and potential FDA phase-out.

The Laboratory of Renewable Nanomaterials at the School of Forest Resources at the University of Maine has been actively working on the research and development of alternative ways to make molded fiber to both reduce our reliance on expensive pulp fiber and avoid using PFASs to achieve oil/grease and water resistance. The key enabling technology in our lab is cellulose nanomaterials (CNMs). CNMs are roughly classified into cellulose nanocrystals, which are often a product of acid hydrolysis of wood pulp, and cellulose nanofibrils (CNFs), which are generally produced by the mechanical disintegration of wood pulp.[3] Among their many applications, CNMs have a great potential to solve issues related to oxygen and oil/grease barrier properties of packaging systems.[4] We had also previously shown that CNFs can be effectively used to bind wood and other lignocellulosic particles together to form strong wood-based panels and can be a good alternative for formaldehyde-based resins in the formulation of such panels.[5] Similar panels can be laminated with two layers of paper to produce what can be a viable replacement for gypsum-based drywalls.[6] The question now was how we could combine the

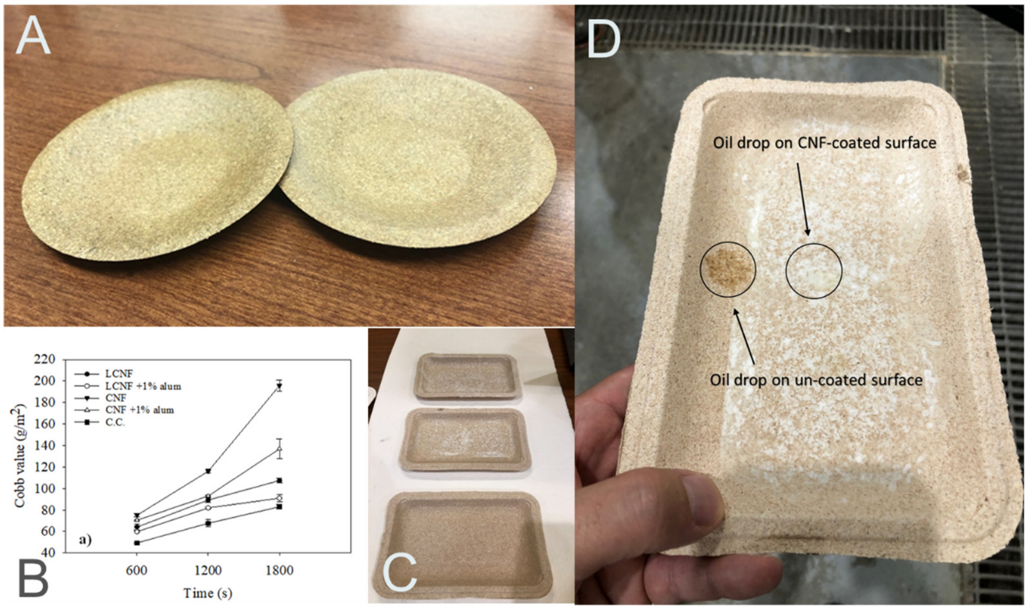

FIG. 1. Sustainable molded fiber alternatives enabled by cellulose nanomaterial technology. (a) First prototypes, (b) enhancement of water resistance by adding alum, (c) molded fiber trays made on pilot scale using a thermoforming machine, and (d) effect of CNF coating on oil resistance.

excellent grease barrier properties of CNFs with their remarkable binding properties into one single product. Here is when our molded fiber products were born.

Instead of forming a plate using bleached Kraft pulp—the industry standard for making molded fiber objects—we use wood particles, i.e., wood flour, that are bonded using CNFs into a thin sheet. Then to impart oil/grease resistance, we apply a thin layer of CNFs to the surface.[7] Figure 1(a) shows an example of the first prototypes made in the lab. While oil/grease resistance of CNF coatings is a given, water resistance is not automatic. Figure 1(b) shows the improvement in water resistance of such coatings compared to commercial containers by the addition a small amount of alum. These molded fiber sheets can be enhanced to have acceptable water resistance and more importantly, they are fully recyclable.[8] In addition, we have recently shown that it is possible to produce such formulations of molded fiber using thermoforming machines designed for the production of thin-walled molded fiber objects [Figs. 1(c) and 1(d)]. Current research involves developing technologies to apply the CNF coating layer on the pilot scale.

There is much to do to eliminate the need to use PFASs in food packaging applications but the outlook is promising. One hindrance is the fact that CNF production needs to be scaled up commercially for such a technology to be adopted. For that to happen though, a good and viable application needs to exist. I think that application is already here.

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AUTHOR DECLARATIONS

Conflict of Interest

The author has no conflicts to disclose.

Ethics Approval

Ethics approval is not required.

Author Contributions

Mehdi Tajvidi: Conceptualization (equal); Methodology (equal); Project administration (equal); Writing – original draft (equal); Writing – review & editing (equal).

DATA AVAILABILITY

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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