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Producing environmentally friendly biodegradable plastics from vegetable waste

Using vegetable waste to produce bioplastics can provide sustainable alternatives to non-biodegradable plastic, new research has found. The biodegradable plastic developed for this study, produced using parsley and spinach stems, cocoa pod husks and rice hulls, have a range of mechanical properties comparable to conventional plastics which are used for products from carrier bags to kitchenware and computer components.

Global plastic production has risen from 1.5 million tonnes per year in the 1950s to 288 million tonnes a year in 2012. This staggering increase has been driven by the low cost and range of mechanical properties that plastics can provide. However, the waste generated can be devastating to ecosystems. All five major oceanic gyres contain substantial amounts of plastic waste, which can injure or kill wildlife and spread invasive species. Furthermore, plastic does not biodegrade but remains in the environment for hundreds of years.

While biodegradable alternatives to plastic cannot solve this problem, they may help to reduce these harmful impacts on a longer time scale. In this study, researchers investigated the possibilities of using agricultural vegetable waste. Europe alone produces 24 million tonnes of vegetable waste, such as stems or husks, every year. This material contains cellulose, a natural polymer—or chain of molecules—that can be used to mimic non-biodegradable plastics.

The researchers used parsley and spinach stems, cocoa pod husks and rice hulls from local industrial producers. These were dried and then soaked in trifluoroacetic acid. Once dissolved, the researchers were able to use the solutions to produce both plastic film coatings and plastic which can be used, for example, to make carrier bags. Trifluoroacetic acid occurs naturally and other research has found it to be biodegradable under the right conditions. It has a relatively low toxicity, although more research is needed and in a similar way to other commonly used chemicals, such as detergents or paint thinners, it may have damaging impacts if released into the environment in large quantities. Importantly, however, after use the acid can be recycled via condensation and then reused. Recent experiments also indicated that human cells grown on these bioplastics remain healthy and proliferate, suggesting that these materials have very low toxicity, if any.

The researchers also investigated the mechanical properties of the bioplastics. Strain measurements (the amount a material can be stretched, divided by its original length) showed parsley and spinach bioplastics had the best stretch properties, with strains of 45% and 60% respectively. Cocoa and rice performed much less well in this category with strain measurements of only 10% and 3%.

However, the strength, or the amount of stress a material can take before breaking, was highest for cocoa pod husks, at 30 megapascals (MPa). Rice, parsley, and spinach films displayed 7, 5 and approximately 1 MPa, respectively.

The researchers then compared the bioplastics against different non-biodegradable plastics incorporating both measures of stiffness (how much a material will stretch under a given amount of stress) and ultimate tensile strength (maximum stress before breaking). Parsley, spinach and rice bioplastics were comparable to low-density polyethylene thermoplastic, which is commonly used to make plastic carrier bags, bottles, tubing and some computer components. Bioplastics made from cocoa pod husks showed similar properties to high-density polyethylene and polypropylene, which are used for applications such as kitchenware, bottle caps and pipelines.

Finally, the researchers also examined how well these bioplastics would degrade in the environment. They showed that when soaked in water for a week all types of bioplastic swell and begin to fragment. After a month they had disintegrated completely. They conclude that these materials could play an important role in replacing conventional plastics and reducing harmful non-biodegradable waste from polluting ecosystems.