Study suggests converting agri-food waste into feedstock to leverage circular bioeconomy

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Source: Embrapa

Agri-food losses and waste generated in massive volumes from agroindustrial operations and consumption could be transformed into several products with high added value, such as bioplastics and advanced materials, to boost the so-called circular bioeconomy. This is shown in a joint study conducted by researchers from Embrapa, the Federal University of São Carlos (UFSCar), and institutions from Finland, Austria, and Canada.

Part of the biomass from agri-food waste (Food Loss and Waste, FLW) is currently reused, but usually for low value-added inputs, such as cattle feed. This can be considered a suboptimal utilization of FLW, since its versatility allows for its reuse for the production of advanced materials, with potential applications in biomedical devices, sensors, actuators and energy conversion and storage devices.

The study highlights the importance of agri-food waste for the packaging market, especially for food packaging. This is a quite promising avenue due to the sustained growth of the sector and the subsequent increase in demand for convenience foods, in the context of an overall increase of the urban population.
From linear to circular

According to the researchers, bioeconomy is based on the transformation of renewable resources into final products, including materials. However, proponents of the circular economy aim at transforming the current linear supply chain ('take, make, use, dispose') into a circular model ('take, make, use, recycle') that focuses on optimising resource and process efficiency, through reusing and recycling of different types of product.

Circular economy would thus enable a cycle ever closer to being closed, ideally leading to a waste-free system and thus counterbalancing the socio-economic and environmental shortcomings that exist in the current linear model.

For Daniel Souza Corrêa, engineer of materials at Embrapa Instrumentação (São Carlos - SP) and one of the authors of the study, FLWs allow producing food from waste of resources, including water, labor and energy.

The three axes that comprise the water-energy-food nexus require more efficient, equitable and appropriate resource use, considering the possible depletion of resources in the ecosystem of production. Until recently, water, energy and food were managed independently, but in an emerging approach, they are now treated in a connected way.

The concept 'nexus'- a word of Latin origin - suggests an integration between the three elements, rational use and governance of different sectors, considering that the overuse of one of the variables causes loss of another and, consequently, losses in the overall production chains.

"In addition, agri-food waste contributes to worsen the climate change scenario, increasing the emission of greenhouse gases (GHG). Methane gas, for example, the main contributor to the formation of ozone, is released during the decomposition of organic matter (such as food waste found in dumps and landfills)," says the researcher.

Generation of bioplastic

The study "The food-materials nexus: next-generation bioplastics and advanced materials from agri-food waste", was published in 2021, on the back cover of Advanced Materials, issue n. 43. This journal has one of the highest impact factors in the field. In this publication, the scientists assessed recent advances in the valorization of FLWs.

In addition, they explored sustainability aspects associated with the manufacturing demands of advanced and functional materials and devices, as

well as the challenges and strategies to obtain bioplastics from these agri-food residues.

Among the applications mentioned in the study, the transformation of agri-food losses and waste into "green" materials is an emerging option, one which uses waste biomass and secondary streams from the food supply chain.

Professor Caio Otoni, first author of the study, from the Department of Materials Engineering at UFSCar, explains that most are 'first-generation bioplastics' are currently the most abundant. These are produced from plants rich in carbohydrates or proteins that, at least in some cases, could be used as food or animal feed. These include corn, sugarcane, soy, wheat and potato, resulting in different applications in food and non-food production.

On the other hand, the researcher says that 'second-generation bioplastics' are derived from raw materials not intended for food use, including wood cellulose and FLW. A third generation of bioplastics, still under development, involves the direct production of plastics, or their building blocks, from living organisms.

"Therefore, the use of agri-food waste (FLW) to obtain materials is compatible with second and third generation bioplastics, representing a sustainable alternative to the current strategies of massive production of plastics, especially the so-called single-use ones," assesses Otoni.

According to the Brazilian Association of Public Cleaning and Special Waste Companies, Brazil produces almost 37 million tons of organic waste annually, but only 1% of what is discarded is reused. Untreated organic waste generates methane gas, harmful to the atmosphere, when it decomposes in landfills.

Global Challenge

Food loss and food waste are considered widespread problems across the globe, a challenge to food security, the economy and environmental sustainability.

Reducing global per capita food waste is one of the targets of the Sustainable Development Goals, set by the United Nations (UN), which aims to decrease FLW by 50% by 2030 (the target was set in 2015).

According to the global Food Waste Index study, released in March last year, an estimated 931 million tonnes of food, or 17% of the total food available to consumers in 2019, was dumped by households, retailers, restaurants and other food services.

Promising initiatives

At Embrapa Instrumentação, research on the use of agri-food by-products has been conducted for more than two decades, often in partnership with groups from UFSCar, other Embrapa units -including Embrapa Tropical Agroindustry-, and other institutions in Brazil and abroad, such as the U.S. Department of Agriculture, USDA.

According to Embrapa food engineer Henriette M. C. Azeredo, co-author of the study, in addition to the reuse of by-products or waste, there are cases in which the edible parts of food are used to produce materials, in this case, edible materials. An example is the edible films based on fruits, vegetables and vegetables.

These thin films have the potential to serve as primary packaging for all sorts of products, from pizzas to sushi. Moreover, depending on the formulation, they may feature physical characteristics similar to conventional plastics, such as mechanical resistance and barrier capacity, as well as a similar food protection capacity. This line of research, initiated at Embrapa by researcher Luiz Henrique Capparelli Mattoso, can help reduce food waste.

The use of packaging is fundamental for the protection of food, to avoid deterioration agents, mechanical damage, dehydration, among others. Thus, the main objective should be the minimization of FLW with the use of long-lasting materials, considering the circularity and pervasiveness of natural resources within the economic cycle.

Barriers to use

However, economic costs and performance differences remain major barriers to the use of agri-food waste. According to Azeredo, even though FLWs-based products may be more advantageous from an environmental point of view, most bioplastics have inferior performance in their properties compared to conventional plastics.

"In addition to presenting challenges in processability, requiring engineering adaptations or new methods, these materials generally have lower mechanical and barrier properties than conventional plastics. These are challenges to be addressed with research and creativity. On the other hand, food-derived materials may have functional properties (such as antimicrobial and antioxidant properties, for example) that are not present in conventional plastics," says the food engineer.

Azeredo explains that the complex and heterogeneous chemical composition of biomass derived from agri-food residues is a challenge, but it can also offer great opportunities, for example if appropriate partition techniques are applied.

Bruno Dufau Mattos, researcher at Aalto University in Finland and also co-author of the study, adds that state-of-the-art strategies used to recycle FLWs into multifunctional and advanced materials rely on deconstructing and reassembling, synthesizing and engineering monomeric, polymeric and colloidal building blocks derived from agri-food waste.

Azeredo emphasizes, however, that bioplastics represent only a small fraction, about 1% of the total production of plastics. The main application is packaging, more than 53%, which amounted to 1.14 million tons in 2019.

For the researcher, bioplastics could replace traditional non-renewable counterparts or create solutions to current technological challenges, thus improving the sustainability and circularity aspects of materials manufacturing.
The study conducted by Embrapa, UFSCar, and international institutions points out that, in general, there is a growing need to consider new strategies to prevent and valorise FLWs. Therefore, the concepts of bioeconomy and circular economy have been presented as sustainable alternatives to the traditional development model.