swiss plastics cluster

Swiss Biomass Waste

A valiable source for renewable plastics

In Switzerland, about 2.8 million tons – 330 kg per inhabitant – of food is wasted every year. This number (2019) reflects the combined amount of food lost across the value chain.

Rudy Koopmans [1]

Considered as non-value-added residues, having little or no nutritional value, or not fit for human consumption, they are wasted as effluents, by incineration, or spilled as fertilizer. These actions have a further negative environmental impact in terms of CO_2 equivalent emissions (CO_2, CH_4, NOx), biodiversity loss and land and water consumption. From a materials engineering perspective, these losses consist for the majority out of proteins and carbohydrates, polymeric molecules that are the building blocks of all organic natural structures in fauna and flora. Accordingly, these natural polymers are in fact a very important local feedstock to be explored as potential replacements for fossil fuel-based chemicals and plastics. As a reference, in Switzerland, about 1 million tons of fossil-fuel based plastics are consumed of which about 0.78 million tons are wasted every year. An estimated 80 % is used as a fuel additive in incineration furnaces.

The numbers suggest that there is plenty of natural biopolymer feedstock available with the potential to replace all currently used plastics, even when only considering the waste produced in the food chain. Typically, there is much reservation using food sources for non-nutritional purposes out of fear it may hamper the availability of food and the associated economics with a direct «perceived as negative» impact for consumers. However, the total amount of biomass produced in Switzerland is estimated to be 57.6 million tons (wet, or 16.1 million tons dry [2017]) when including all sources such as wood and woody products, manure, and other organic waste streams. These amounts of biomass are also seen as a source of renewable energy in particular wood and woody products. About 5.5% of the total Swiss energy production is already provided from biomass.

In contrast to what these annual, available volumes suggest, a direct use of biomass as a source for polymeric materials is not a straightforward exercise. Some of main challenges relate to sourcing i.e., the mixed molecular composition of biomass, and to the non-centralized production of biomass, which both pose an important technical and economic challenge. Interesting polymers or chemicals for material applications will require extraction and adapted processing technology, and the distributed production requires effective logistics and centralization for achieving an economy of scale. The alternative would be a different business and economy concept of creating local, smaller production ecosystems close to the feedstock, which contrasts with the current prevailing paradigm of large, centralized production sites away from feedstock and from which products are distributed. However, looking closer and beyond this high-level perspective, there are several opportunities for industrial biomass «waste» streams that offer avenues to produce natural polymer alternatives for existing fossil fuel-based plastics.

Unique benefits

Proteins such as collagen, casein, whey, hemoglobin, keratin, and other plant-based proteins are highly functionalized polymeric molecules. They have the capacity to self-organize and build functional structures at different length scales to provide unique properties and benefits. Keratin is such a protein better known as hair, nails, and feathers. Specifically, keratin polymers of feathers organize themself into plate-like structures – beta-sheets – that shape the layered structure of feathers. These nanostructures are an ideal barrier against oxygen and water. Accordingly, by taking advantage of this process it is possible to develop a new kind of barrier film with properties that should be similar or better than the fossil fuel-based polyamides (PA) or polyvinylalcohol (PVOH) films, typically used in multi-layer flexible packaging that preserves fresh and processed food.

Renewable natural polymer

In view of the ambitions to reduce food waste, use a renewable natural polymer to produce a high value functional film that is compostable, and to create a carbon neutral circular value chain, PICC initiated a study to turn the promise into a reality. Two development routes were followed, one starting from feather meal and one using chicken feathers. The first step is to extract the keratin polymer form the two feedstocks without destroying (denaturing) the capacity of keratin molecules to self-organize into beta-sheets. Feather meal turned out not to be a good feedstock as the keratin is denatured for the most part during the preparation process. The direct extraction of keratin from chicken feathers provided enough to test the hypothesis of making a film sample using a compression molding approach.

Several approaches can now be followed to process the keratin into a film. Similar approaches are now being pursued in EU Horizon Europe projects KaRMA2020 with an emphasis on upscaling technologies and *unlock* where different applications will be valorized. Several startups are also pursuing the industrialization of chicken feathers. As for Europe, 3.6 million tons are available annually, sufficient to replace current barrier solutions in packaging.

Rethinking how and why society produces organic «waste» that can be avoided or up cycled into valuable materials is a research and development field that needs to be reinvigorated. This requires a paradigm shift for the plastics industry but a realistic avenue to become carbon neutral in a zero-waste sustainable society.

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