THE NEW WHEY OF PACKAGING

PACKAGING CONSTITUTES A MAJOR MARKET SHARE OF THE PLASTIC INDUSTRY DESPITE ITS OFTEN SHORT TERM APPLICATION. WITH GROWING CONCERNS ON THE ENVIRONMENT AND RESOURCES, WHEY COATED PACKAGING CAN BE THE SOLUTION FOR THE FUTURE THAT IS MADE FROM WASTE MATERIALS AND IS RECYCLABLE. BY ELODIE BUGNICOURT, INNOVACIÓ I RECERCA INDUSTRIAL I SOSTENIBLE (IRIS)

As opposed to standard plastics derived from petroleum, bio-sourced polymers, hereafter referred to as biopolymers are from renewable biomass sources. The use of this class of materials is in fact nothing new.

For example, back in the 40s, Ford introduced an all-plastic motor car body made of cellulose fibre and resin extended with a by-product of the soybean oil extraction process. However, the subsequent interest in this class of materials faded out with the development of more durable and resistant petro-chemical plastics.

Now, having reaching a new breakeven point, research has recently been intensified in that field, revealing a large range of possible resources and extending the spectra of applications biopolymers can fulfil. This can be attributed to the improvement of their performance, making them more competitive with their synthetic counterparts.

The feedstocks for naturally occurring biopolymers range from proteins (from animal and vegetal sources) to lipids and polysaccharides (eg: starch and cellulose based biopolymers). Some biogenic polymers such as polyhydroxyalkanoates (PHAs) are naturally accumulated in microbial cultures.

Others biopolymers, such as polylactic acid (PLA), are obtained from bio-derived monomers, (eg: from corn starch) which are then polymerised through standard routes. This is also the case for the new commercially available bio-based polyethylene terephthalate (PET) or polyethylene (PE), which now covers the biggest segment in terms of production volume among biopolymers.

HUGE MARKET SHARE

While generally used for short term application, packaging is the biggest market for the plastic industry with an increasing share of over 40 percent of all plastic produced (even accounting for over 70 percent for bioplastics).

In consideration of the legislation and market requirements, factors such as weight reduction, recyclability, waste reduction, used of sustainable/renewable raw materials have driven new developments in the sector.

While maintaining good food preservation just like their synthetic counterparts, biodegradable plastics stands out as a solution for conserving depleting fossil resources, reducing carbon dioxide emissions and environmental pollution at the end of their packaging lives.

Research enabling the development of tailored made solutions for this sector is important because most biopolymers do not meet the requirements of packaging for sensitive food due to their insufficient barrier properties, which are unable to guarantee product quality throughout its shelf life.

Such requirements in terms of barriers against light, moisture, water vapour and gases are specific to the type of food packed. To fulfil the optimal combination of properties, multilayer laminates are generally used. However, due to the challenge of separating the different materials during recycling operations, multilayer flexible packaging is often unrecyclable.
**WHEY PROTEIN SOLUTION**

In this context, the development of a biopolymer-coating within the framework of the EC funded Whey-layer project (FP7 n°218340) for plastic films based on whey protein has the potential to replace current synthetic oxygen barrier layers used in food packaging, such as ethylene vinyl alcohol copolymers (EVOH) and is expected to be far reaching in the market.

Whey is a by-product of cheese manufacturing and therefore, as opposed to certain controversial biopolymers, it does not create direct food competition. For example in Europe, about 20 million tonnes of whey produced annually is not currently valorised. In addition, the generated waste can be highly polluting if not properly handled due to the high organic content of whey.

A recent study, which demonstrated the scale-up ability of the production of the whey-based coating as a preliminary requirement for its commercialisation, built on past academic literature which had not been routed to the industry yet, showing that edible coatings made of whey proteins offered good aroma, fat, humidity and oxygen barriers.

The new bio-coating solution was formulated using whey protein isolates (WPI of high purity above 90 percent) and plasticisers to prevent brittleness. The most promising formulations among those evaluated at pilot scale were selected for scaling up.

The coating solutions were applied at semi-industrial rates using a tailor made application and drying prototype, which optimises speed and energy consumption to minimise the environmental impact of this manufacturing stage. The process also allowed for the correct structuring of the protein-based coating on the film and governed the barrier properties. Resulting coated films were either directly characterised or assessed after lamination with PE as a sealing layer.

**BARRIER PROPERTIES**

The oxygen transmission rates (OTRs) were measured for the laminates. The coating showed a good oxygen barrier (e.g., a whey coating of approximately 12 μm in a PE/PET sandwich allowed an improvement by a factor of 30 of the entire OTR).

The calculated average Q100 values (OTR normalised to 100 μm)
**WHEY-BASED COATING CAN REDUCE CARBON DIOXIDE EMISSIONS AND CONSUMPTION OF RESOURCES IN PACKAGING PRODUCTION.**

The potential to substitute other synthetic barrier layers used for food packaging.

These results together with the different previously reported thermo-mechanical, optical, adhesion properties of coated PET films, consequently determine the suitability of the whey protein-based coatings for packaging application and show the potential to substitute other synthetic barrier layers used for food packaging.

In terms of validation of the obtained material for food packaging, laminates derived from whey protein-coated films were tested for storing butter cheese in comparison with fully synthetic reference multilayer films (a PE/PA based laminate of 60 µm).

The overall shelf life was comparable in both cases and exceeded the duration of the tests that was specified by the cheese manufacturer. Further tests also showed that those laminates fulfilled food contact compliance regulations according to the EU regulation 10/2011 in terms of global migration.

In terms of end of life, whey proteins can be hydrolysed by different enzymes in specific conditions to make multilayer films recyclable as a result of the separation of the layers made up of conventional plastics.

**RECYCLABILITY**

The recycling process consists of the shredding of the films, the washing and the separation of plastic flakes thanks to the difference in density between the layers assembled by the whey coating, such as PE and PET, before each can be recycled independently.

The possibility of reusing the recovered films was tested by performing mechanical tests showing not too significant changes in properties for the separated PE and PET films.

Finally, preliminary life cycle analysis (LCA) showed that the use of whey-based coating can reduce carbon dioxide emissions and consumption of resources in packaging production. Data regarding the difference in the production stage of the whey-coating indicates a 15 percent reduction of environmental impact compared to synthetic counterparts such as EVOH or PA at similar weight.

These figures were obtained on prototype production and could be improved at higher production speed. Nevertheless, in a multilayer film, the layer acting as a barrier is relatively thin (thickness depending on the food to be packed and nature of the barrier layer), leading to a ‘dilution’ of this advantage.

In the previously reported food storage validation, the PA-based
reference films used had a higher thickness than the film based on the whey coating (60 µm compared to 45 µm). The further saving due to weight reduction resulted in a 60-65 percent lower impact during production and processing of the multilayer films, while still competing in terms of food preservation.

When comparing the two laminated materials previously used for food packaging throughout their life cycles, no obvious differences can be identified during the transport, use and manufacturing processes since the impact of co-extrusion and lamination are not significantly different.

The reduction of emissions and energy consumption due to the possibility of recycling the polymeric layers of the multilayer film, which are conventionally incinerated, facilitate a benefit of 19 percent for human health, 35 percent on ecosystem quality and 14 percent on resources when multilayer films based on whey-coating were compared with those based on EVOH.

In the case of the multilayer films of 45 µm based on the whey coating compared with PA-based films of 60 µm, the difference in impact is over 60-80 percent reduction in the impact categories.

It seems that, especially in the field of packaging, the environmental advantages of biopolymers, such as whey protein based coatings, are tremendous over traditional plastics.

**ENVIRONMENTALLY FRIENDLY OPTION**

Bioplastics can be produced from an increasing range of renewable resources, including an increase utilisation of waste materials which are of non-food competing sources as opposed to bioplastics which diverted full corn fields for the production of ethanol leading to starvation and ethical questionings.

Although the research in bioplastics is very dynamic, there are still much to be done ahead. The whey protein based coatings developed in the study exhibited excellent barrier properties, outperforming most existing biopolymers and therefore, appear as promising replacements for synthetic barrier used for food packaging applications.

Coated films were validated for storing various food products. The developed whey coating can be removed inside the multilayer films to make them recyclable. A LCA has been performed and showed a significant reduction in the environmental impact of the packaging thanks in particular to the possibility of recycling the materials as opposed to incinerating those containing EVOH or PA and also the use of bio-sourced raw materials that are by-product of the industry.

All in all, the whey protein coating safeguards the performance of packaging and improved the uses resources throughout its life cycle. As a result of this, there are a lot of new opportunities to close the loop between the food and packaging industries with the development of sustainable biopolymers that will help save food and reuse wastes.

*L Source of the coauthors of this work and article whereby the present results are further described: E Bugnicourt, M Schmid, O Mc Nemey, J Wildner, L Smykala, A Lazzeri, P Cinelli, Processing and Validation of Whey-Protein-Coated Films and Laminates at Semi-Industrial Scale as Novel Recyclable Food Packaging Materials with Excellent Barrier Properties, Advances in Materials Science and Engineering, volume 2013, Article ID 496207, 10 pages, 2013.*

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