24th IAPRI World Packaging Conference: Recyclable Packaging with Good Functional Properties Predominates

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By **Erik Kruisselbrink**

The **24th IAPRI World Packaging Conference** was held in Valencia from 17 to 24 June. This time the host was the Spanish scientific institute **ITENE**, which at the same time celebrated its 30th anniversary. The conference had no fewer than 150 speakers from various universities and other institutes from 32 countries involved in packaging research. The conference was attended by 300 listeners, many of whom work in the same field.

The opening of the 24th IAPRI World Packaging Conference took place at the Oceanographica, close to the conference rooms at the SH Hotel in Valencia. Photo: IAPRI/ITENE

The enormous range of scientific presentations was divided into five segments, each presented during as many parallel sessions. For that reason alone, it was impossible to physically attend all presentations. However, the perfect organization had an equally perfect solution for this with an extensive reference book with all presentations.

The five segments mentioned were divided into:

1. Packaging materials;
2. Packaging design and development;
3. Packaging distribution for products;
4. Packaging machines; and
5. Sustainability of packaging in the supply chain and product conditioning and packaging technologies.

Although interesting insights were presented in each area, the focus in this article is mainly on developments in the field of packaging materials. Partly to blame for this is the **Packaging & Packaging Waste Regulation**, which sets a number of strict requirements for packaging to be placed on the market in the European Union (EU) from 2030. This applies to packaging produced in the EU and abroad. Although only the main points are now known and further details will not be known until 2026, packers will still have to get to work. *(See sidebar at bottom of page.)*

Despite the scientific content, there was of course also laughter. The speakers could explain their projects on posters. Photo: IAPRI/ITENE

Biobased dominates research

A number of common threads were identified in Valencia when it comes to the development of new packaging materials or modifications of existing packaging materials. For example, adding a barrier to

a material to ensure that the packaging meets the minimum functional requirements, particularly to prevent food spoilage. In particular, many solutions could be found for biological and biodegradable materials. Possibly in combination with a comparison of the functional properties with those of an oil-based plastic packaging material.

Comparison PE with compostable

A good example of the latter was a study led by Prof. Mieke Buntinx from UHasselt. In that study, a comparison is made between two different laminates for thermoforming: an oil-based and a biodegradable multilayer. On the one hand to determine the maximum dilution and on the other hand the associated permeability (permeability) of gases.

Prof. Mieke Buntinx from UHasselt. Photo: IAPRI/ITENE

The thermal and tensile properties of two commercial multilayer films were compared: an oil-based PE/EVOH/PE laminate and a compostable Ecovio/G-Polymer/Ecovio (~85 µm). Ecovio is the brand name of a PLA/PBAT bioplastic from BASF. Tensile tests were then carried out at selected temperatures to determine the maximum elongation based on the elongation at break. The 70×60 mm2 films were then stretched in the machine and/or cross direction (MD, CD, MD+CD) or 45 degrees. The microscopic thickness resulting from these situations was compared to the thinning in the bottom, walls, and corners of thermoformed trays.

WVTR increases

The results show that for both films, as they become thinner, there is a proportional increase in the water vapor transmission rate (WVTR). The PE layers provide a better solution in terms of water vapor barrier than the compostable layers.

In contrast, the oxygen transmission rate (OTR) is not proportional to the thinning of the overall film, nor to the thickness of the barrier layer. Here, an improved oxygen barrier can even be seen compared to the base films due to a reorientation of the polymer chains in the barrier layer. This especially applies to PE laminate. This makes it possible to use less EVOH, making the multi-layer film more recyclable.

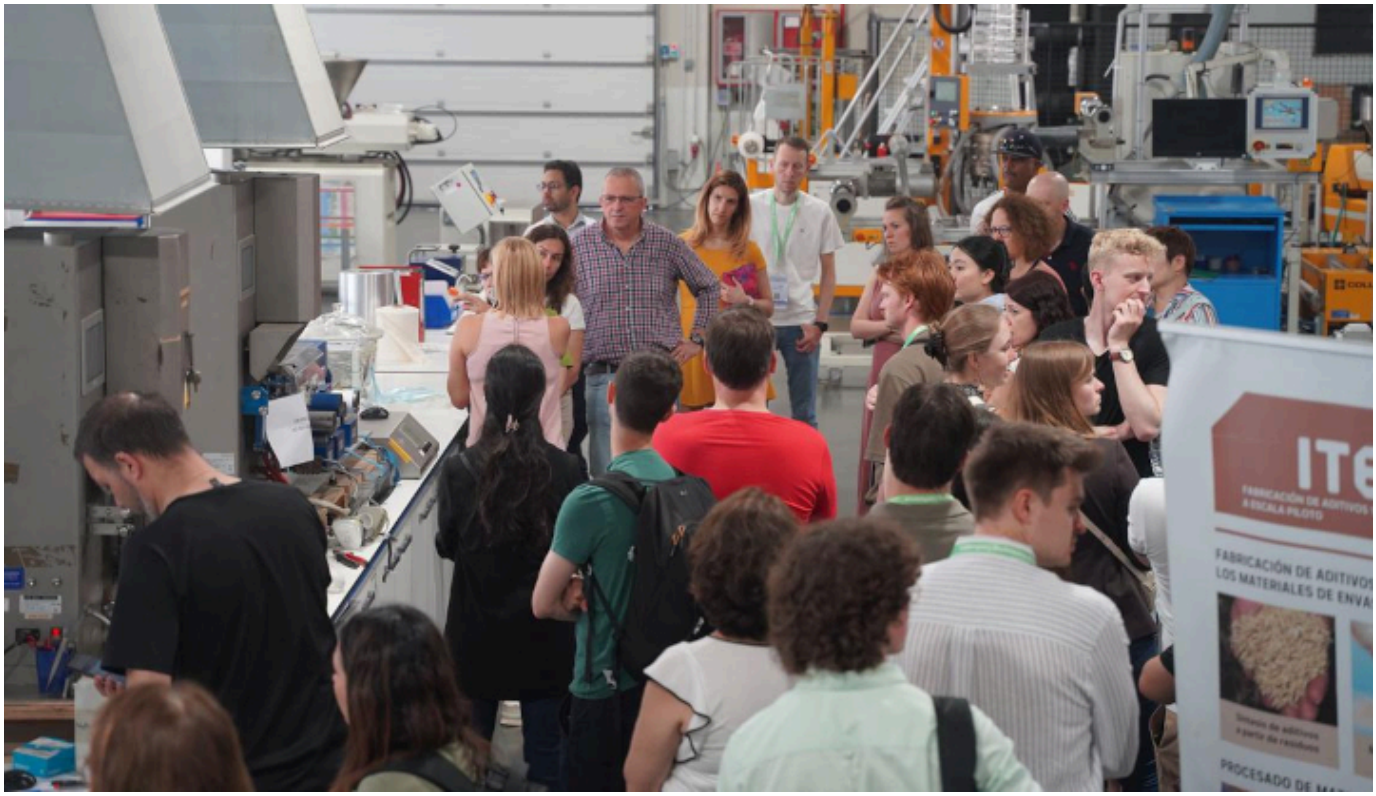
According to Buntinx, this leads to the ultimate conclusion that the biocompostable combination is preferable in dry conditions, because the G-Pol barrier achieves very high oxygen barrier properties at low relative humidity. EVOH in the petroleum-based laminate, on the other hand, is less sensitive to relative humidity compared to G-Pol. Therefore, this is the preferred material for packaging food products with a high/higher(er) moisture content.

No collection structure

Buntinx and her team also choose to consciously involve bio-monolaminates in their research for another reason — and despite the fact that there is not yet a collection structure for this in Europe. “Multi-layer packaging materials are still considered highly efficient and environmentally friendly solutions compared to alternatives,” according to Buntinx. “This is because of the sophisticated balance between mechanical performance required for logistics and handling and thermal stability for filling and/or thermal treatment. But also because of the optics for customer attractiveness and sealability, the gas, water, or aroma barrier properties necessary for content retention and a lightweight design. In this way, we can achieve a reduction in raw materials.”

However, at the end of their life, multi-layer packaging is currently largely incinerated because it cannot (yet) be recycled in the existing waste management infrastructure based on traditional mechanical recycling.

“This contradicts the core principles of a circular economy, especially within the European Union (EU), where plastic packaging is a top priority within circularity initiatives,” Buntinx said. “Given only 39.6% of plastic packaging waste was recycled in 2021, the need for circularity is reinforced by the upcoming entry into force of the PPWR, which sets a 55% recycling target for plastic packaging by 2030.”



The visitors of the conference could also take a tour of the laboratory spaces of the celebrating ITENE. Photo: IAPRI/ITENE

Design for recycling

To comply with these new regulations, design for recycling must be used to reduce multi-layer complexity. “However, when a less complex mono-material solution shows better recyclability but is associated with a higher material use or a shorter shelf life compared to a multi-layer solution, this is actually not environmentally friendly either,” Buntinx noted.

She continued, “Today there is a shift towards minimizing multi-layer material diversity, with a particular preference for polyolefins with limited use of ethylene vinyl alcohol copolymer (EVOH), metallized aluminum layers and aluminum oxide (AlOx) or silicon oxide (SiOx) coatings to provide some height to improve barrier properties.”

To meet the recycling standards according to the Ceflex or RecyClass guidelines, laminates must consist of at least 90% polyolefin to qualify as a mono-material suitable for recycling. Buntinx:

“Coextrusion or lamination with EVOH is preferred over AlOx and SiOx, as these coatings are generally less suitable for sterilizable packaging or thermoforming applications.”

Recyclability testing shows that EVOH has a small impact on the recycled material, at a threshold of up to 5% of the total weight of the PE film. Above this limit, an immediate impact on the extrusion process is observed with yellowing of the material, an increase in haze, membranes and black spots, and a frequent bubble break.

Biobased is sometimes the only option

Another way to meet circularity for multilayers is better recycling technologies. Buntinx again: “In the near future, a mix of different recycling technologies (that is, high-quality material recycling, chemical recycling into hydrocarbons, and downcycling) will develop in different parts of the world. This evolution will be highly dependent on local regulations and availability of technology.”

But even though developed countries have the most efficient technology to recycle multi-layer materials, much of the world will still lack basic waste management and conventional recycling systems.

This is what Buntinx and her team conclude: “Therefore, the use of biobased materials in laminates still offers an opportunity to reduce carbon emissions in the short term and decouple them from the fossil economy. Furthermore, biodegradable food packaging can be thrown away together with food waste and further processed through composting or organic recycling. Biodegradable films also offer better compatibility with compostable fiber-based materials and are ideally suited as a barrier layer for paper packaging. After all, the barrier effect with regard to the packaged product, especially after material processing, remains of primary importance.”

A view into one of the conference rooms. Photo: IAPRI/ITENE

From study to market

Fuensanta Monzo Sanchez from the Spanish research center **CETEC** in Murcia also opts for the option of bio-based/biocompostable materials. “As society transitions to a more sustainable way of life,” he said, “it is crucial to ensure the well-being of future generations.”

In that context, he currently sees the replacement of fossil fuel-based plastics with bio-based materials as a promising strategy to reduce the impact of plastic on the environment.

“Within the upPE-T project, we focus on the production of poly 1 (3-hydroxybutyrate-co-3-hydroxyvalerate), also known as PHBV, with a high molecular content of 3-hydroxyvalerate monomer and the development of PHBV-based formulations applied in the food packaging sector,” Sanchez said. “To date, we have produced a range of composite films with other biodegradable polyesters suitable for processing by injection, cast extrusion and blown extrusion. In addition, thermoformed trays are also available.”

To ensure complete biodegradability of the materials developed during the project, all additives used were biobased and biodegradable, reports Sanchez. “We hope that the efforts invested in this work will contribute to PHBV’s transition beyond academia into the real market.”

Halving food loss

According to Jesus Paluenzula Conde of the organizing Spanish scientific institute ITENE, tackling sustainable developments and reducing food loss and waste (FLW) are two of the most important challenges.

Jesus Paluenzula Conde of the organizing Spanish scientific institute ITENE. Photo: IAPRI/ITENE

“These are recognized by the United Nations in the 2030 Agenda for Sustainable Development. In line with these objectives, the EU-funded **ZeroW project** has set itself the ambitious goal of playing a key role in the transition of current food systems. This includes halving food loss and waste (FLW) by 2030 and reaching near-zero FLW by 2050.

ITENE contributes to ZeroW through the technical development of packaging technologies to effectively address the problem of FLW in fresh fish packaging. A key role has been the development of a multi-compartment tray that eliminates the need to use absorbent pads to retain fish moisture. These serve to extend the shelf life and at the same time increase the durability of the tray.

Furthermore, ITENE is developing a coating for the closing lid that improves the oxygen barrier compared to the original material.

A freshness indicator label with color-changing ink adds the finishing touch. The label responds to changes in metabolites and microbiology in the food. It then provides an indication of the remaining shelf life of the product, which reflects its actual condition. This label can be read with a mobile application, which is also being developed as part of the project.

Recyclable PE/PA film

According to Jordy Montfort, researcher and developer with a special focus on polyamides at the Japanese multinational **UBE**, his employer mainly focuses on PE-based laminates when it comes to sustainability.

“Multiple organizations such as APR, How2Recycle, CEFLEX, Cyclos-HTP, RecyClass, and others have provided guidelines to design packaging structures while ensuring their recyclability in the corresponding stream,” Montfort said. “In the case of flexible packaging, this is usually the polyethylene flow.”

The use of mono-material PE structures was therefore the first, rapid step to tackle the sustainability problem. “But sometimes this has been accompanied by a loss of some essential packaging performance, including protecting the food,” Montfort said.

UBE is therefore currently fully committed to PE films that contain such a small amount of PA that the laminate is compatible in the PE flow. That is why, according to Monfort, a sustainable film becomes possible without sacrificing performance. At UBE this is a recyclable PE/PA film, introducing UBE Nylon 5036B, a new generation of UBE’s Copolymer 6/66 family. According to Montfort, this has even better recyclability due to its low melting point.

Biobased dispersion coating for paper

Rajesh Koppolu from the **VTT** technical research institute in Finland presented the latest development of a bio-based barrier coating for paper. It is a polyester found in plant cell walls, called Suberin. Koppolu: “Suberin can be hydrolyzed and recovered as fatty acids from the bark — birch bark — and could be a promising material for barrier packaging.” This substance protects the plant against moisture loss and therefore automatically has a moisture-repellent effect.

“Currently used moisture barrier layers in packaging are primarily made from fossil-based materials, a finite and non-renewable resource,” Koppolu said. “It is expected that bio-based barrier coatings will increase the sustainability of products and reduce the use of environmentally hazardous resources and the production of waste.”

In VTT’s research, aqueous dispersions of Suberin were prepared using a thermo-mechanical approach. “It is inexpensive and environmentally friendly and uses mild processing conditions that

minimize polymer degradation during dispersion preparation," Koppolu said.

The application of the Suberin dispersion coating was first tested on a laboratory scale on two different paper and paperboard substrates. The coating formulations and application process were optimized before production was moved to a semi-pilot scale (VTT's pilot line for surface treatment concepts). The test coated paper and paperboard were examined for their barrier performance under varying humidity conditions. A water vapor transmission rate (WVTR) of 10 – 18 g/m2 was obtained at 23°C and 50% RH. WVTR was still maintained below 80 g/m2/day at higher humidity conditions (23°C and 80% RH), and this performance was comparable to that of some fossil-derived dispersion coatings. The grease and oil barrier performance of suberin coatings was also found to be competitive. Finally, the heat-seal performance of suberin-coated substrates also stood up to scrutiny in flexible form-fill-seal packaging and die-cutting processes.

Main role for potato peelings

Swiss researcher Susanna Miescher of **Zurich University of Applied Sciences** reported on her search for a film based on whole potato peels. Herein, potato peels (PP) and bio-based polybutylene succinate adipate (BioPBS) in ratios of 1:0, 3:2, 1:1, and 2:3 were used to produce films. This was done in a two-stage extrusion process using a co-rotating twin-screw extruder. Maleic anhydride and tartaric acid were added for better adhesion of the different layers and carnauba wax to improve the film, which was then assessed for its mechanical properties, water vapor permeability, and thermal properties.

Films with a high content of 50%-100% potato peels showed microcracks and weak mechanical properties. However, increasing the BioPBS content to PP:PBS 2:3 resulted in a significant increase in tensile strength and elongation. In addition, it significantly reduced the water vapor permeability of the film.

The use of 1% maleic anhydride to improve interfacial adhesion of the components had no significant effect on tensile strength (6.23 MPa), but further increased elasticity to 65.48% with no additional effect on barrier properties. Addition of 0.15% tartaric acid showed similar elongation at break (56.23%), but significantly increased the tensile strength to 6.56 MPa. The incorporation of 5% carnauba wax significantly increased the surface water barrier temperature from 69.5° to 99.7°, but at the expense of mechanical properties.

Potato peel with citric acid barrier

According to German researcher Katharina Miller (**KU Leuven, Belgium**), the valorization of potato peels as a barrier for use in food packaging is becoming increasingly important in the context of the circular bioeconomy.

Katharina Miller (KU Leuven) won the prize for the best starting researcher. Photo: IAPRI/ITENE

“In a previous study, we have already shown that the physicochemical properties of films based on potato peels are comparable to those of films based on starch, proteins, and polyamide,” Miller said. “However, to increase the application potential of potato peels, their packaging-related properties need to be further improved.”

To reduce the oxygen permeability of potato peel-based coatings and films and overcome bottlenecks including water sensitivity and low tensile strength, modification with citric acid (CA) was applied.

Potato peel suspensions, containing 10%-50% CA, were coated on PLA substrate after which films were cast.

With increasing or decreasing CA concentration, increasing permeability and transmittance values were observed. “The use of low CA concentrations in potato peel-based barrier layers may be beneficial for their barrier properties at high RH, but their flexibility may be insufficient for multilayer application. This is what the research showed.”

Miller concluded: “Overall, potato peel-based coatings and films containing 10%-50% CA demonstrated similar barrier properties to EVOH, even though extensive industrial purification or fractionation of potato peels was not performed. The incorporation of potato peels as an oxygen barrier into laminates will be assessed in future studies. This includes looking at sensitive foods such as meat.”

Barrier layer of pulses

Carolina Peñalva, researcher at the Spanish technology center **Aitiip in Zaragoza**, is looking for pulse residues as a possible barrier layer for bio-based and biodegradable PLA films. “The proteins of soybeans, peas and lentils can be the basis for thin bio-films with barrier properties, protecting food against moisture and gases,” Peñalva said. “The barrier properties can help reduce microbial growth, improve food safety and extend the shelf life of food.”

The barrier layer is applied by roll-bar coating on PLA film substrates. An alternative methodology based on surface activation with atmospheric plasma for effective adhesion of the coating to the biobased and biodegradable films was also investigated. The surface modification had a maximum improvement of 29% due to the added barrier layer.

PLA/TPS laminate

The research of Hayden McGreal, a graduate of **Toronto Metropolitan University**, focused on a possible combination of polylactic acid (PLA) and thermoplastic starch (TPS) as a coextruded laminate. And how efficient multilayer films of PLA and TPS are in terms of mechanical and barrier properties.

Hayden McGreal, Toronto Metropolitan University, investigated the combination of polylactic acid (PLA) and thermoplastic starch (TPS) as a coextruded laminate. Photo: IAPRI/ITENE

To answer that question, a custom-built three-channel coextrusion device was used to fabricate laboratory-scale samples of the films, which were also tested under compression molding conditions. The films consisted of a central layer of TPS, between the two outer PLA layers. “This design is strategically important and takes advantage of the oxygen barrier capabilities of TPS and the moisture barrier properties of PLA,” said the Canadian researcher.

The prepared films were analyzed before and after each experiment for their tensile properties, adhesion strength, and morphological and thermophysical properties. The shear and extensional rheological properties of the films were also studied to investigate the processability of the film components.

“It was shown that the tensile properties of the layered film are a cumulation of the properties of the components,” said McGreal. The bond strength of the films depended on the processing conditions and the amount of adhesive used in the TPS formulation. “The thermophysical studies confirmed the thermal stability of the developed films at high temperatures, suitable for most packaging

applications," McGreal said. "The data showed that the layered films could be suitable for strain-dominant processes such as thermoforming."

Reusable meal packaging

William Snyder, also Canadian and a graduate of Toronto Metropolitan, showed a small-scale study of reusable meal boxes on his university campus.

William Snyder graduated from Toronto Metropolitan University with his research into single- and multi-use meal packaging. Photo: IAPRI/ITENE

"Reusable packaging systems are an emerging trend in foodservice on college campuses in North America due to growing environmental concerns about packaging," said Snyder.

The study aimed to assess the environmental and economic performance of the reusable and multi-expandable food packaging systems offered in canteens on university campuses: single-use polypropylene (PP) meal packaging, reusable and reclosable polypropylene (PP) meal packaging and a compostable variant. A life cycle assessment (LCA) was carried out to quantitatively analyze the environmental impact of these three different packaging formats. The scope of the LCA included raw material extraction and production, transportation, use, and end of life.

The LCA results showed that the reusable PP packaging has the lowest environmental impact compared to the two other single-use packaging alternatives for nine out of 10 environmental impact categories. Single-use PP packaging had the greatest environmental impact due to material extraction, manufacturing processes, and end-of-life emissions.

The sensitivity analysis showed that the reusable packaging scored favorably compared to the disposable variants in nine of the 10 impact categories when reused at least 37 times.

Finally, a cost analysis was conducted on the total costs of these three packaging formats, which related to packaging material, operational costs, energy and disposal costs. The scope of the cost analysis was from the time of purchase to disposal. The results of the cost analysis showed that the reusable packaging format was financially most favorable when reused at least 16 times.

Chemical recycling expanded

Marianne Gravendeel, research technologist from the **Dutch company Ioniqa**, shared in her presentation that Ioniqa has expanded its scope from the chemical recycling of PET bottles to that of multi-layer trays. Ioniqa originated as a startup from **Eindhoven University of Technology**.

“Current environmental needs make developments in plastic recycling increasingly urgent, as plastic consumption continues to increase while government-set recycling targets are far out of reach,” Gravendeel said.

In addition, impurities make even a mono-PET stream difficult to recycle mechanically. Impurities in the raw materials can be of any nature. This may involve food residues that hinder sorting efficiency, but also additives and breakdown products with a high or low molecular weight. These impurities in the raw material mean that traditional mechanical recycling is only applicable to a certain percentage of the plastic waste flakes available on the market.

Chemical recycling can be a solution to this challenge as it can process higher impurity levels in waste plastic flakes. This opens up opportunities for recycling raw materials, such as waste streams from sorters, polyethylene terephthalate (PET) that is difficult to recycle, and multi-layer trays.

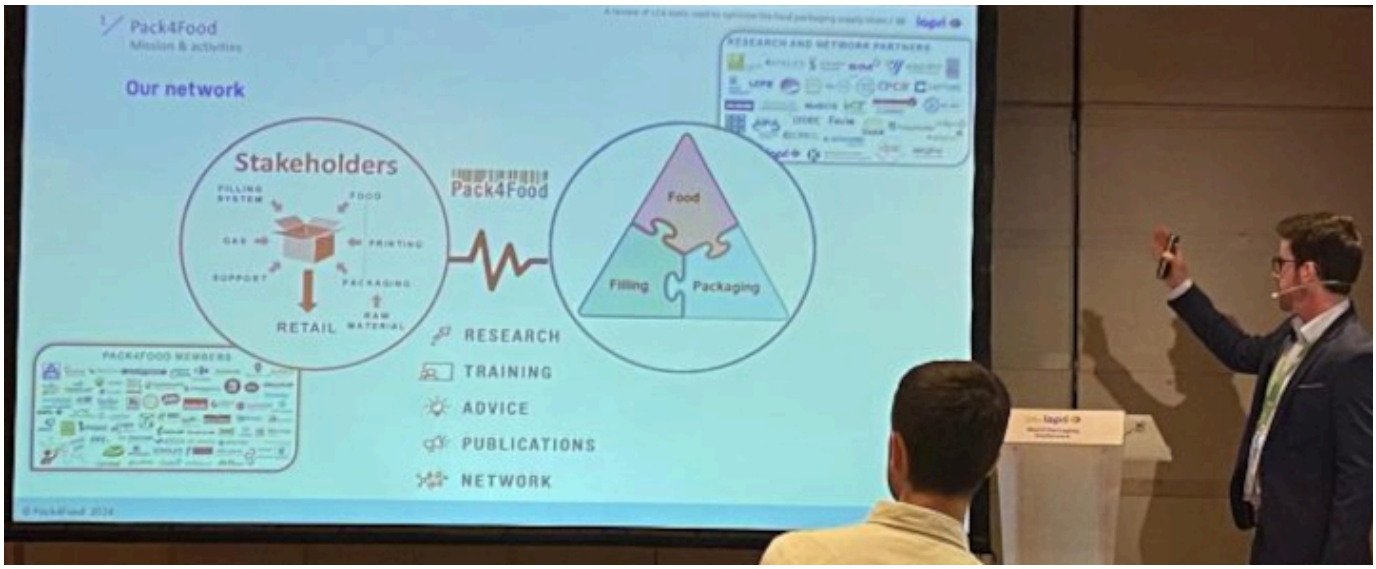
Ioniqa’s glycolysis technology breaks down PET into monomers, making it much easier to remove impurities than isolating impurities from mixtures containing oligomers. In the PET glycolysis process, the ester bonds in PET are cleaved by monoethylene glycol (MEG) to form Bis(2-Hydroxyethyl) terephthalate (BHET). BHET is a monomer and an intermediate in current PET polymerization processes using oil-based raw materials. The glycolysis process is generally carried out at temperatures around the boiling point of MEG and in the presence of a catalyst. The four main steps that can be distinguished in the Ioniqa process are: (1) reaction, (2) inert and catalyst separation, (3) purification, and (4) product isolation.

Multi-layer trays add another challenge due to the presence of other polymers in packaging. Ioniqa wants to remove this in the near future prior to the main process.

LCAs far from adequate

To better understand the capabilities and scientific limitations of commercial LCA tools for packaging systems, the TACTIC project inventoried and analyzed LCA tools currently on the market for (food) packaging systems.

“All stakeholders in the food packaging value and supply chain are increasingly under pressure to assess and improve the sustainability of products and services to meet the future demands of a circular economy,” explained Brecht Van der Hoeven (**Pack4Food, Belgium**) about the reason for the investigation. “To meet these challenges for (food) packaging, life cycle assessment (LCA) calculations and tools are often used today. The results of such LCA tools are used in an effort to optimize packaging configurations and the associated value and supply chain.”



Brecht Van der Hoeven of Pack4Food in Belgium. Photo: IAPRI/ITENE

A total of 27 were analyzed in the TACTIC project. Of these, one related solely to food, 17 to packaging materials, eight to the combination of food and packaging materials, and five to reuse.

A comparative study in the context of the TACTIC project into the effectiveness of LCAs revealed several important discoveries, according to Van der Hoeven: “The results show that the majority of available LCA instruments do not offer an option to include the impact of food in the assessment. Furthermore, the comparison between a reuse and single-use model requires the calculation of the

minimum number of cycles where both scenarios are equal. Something that does not yet exist in the current LCAs examined."

To fill the gap, Van der Hoeven formulated the following challenges: LCA knowledge at individual company level, certification, and a solution for reusable packaging. "There should also be a harmonization of LCA methods, reproducibility of the results and attention in the LCAs for the functionality of packaging."

[SIDEBAR] Packaging & Packaging Waste Regulation (PPWR)

The fact that the importance of packaging scientists will only increase in the coming years was evident from the keynote presentation by Mattia Pellegrini, head of the From Waste to Resource department of the European Commission's DG Environment.

Mattia Pellegrini, Head of Unit From Waste to Resource of the European Commission's DG Environment. Photo: IAPRI/ITENE

The measures include national targets for reducing packaging waste, minimizing unnecessary packaging, and imposing reuse/refill targets on economic operators by sector and packaging type. The requirements apply to all packaging marketed in Europe, whether produced in or outside Europe.

The **PPWR** was adopted by a majority of the European Commission at the end of April. The concrete implementation at detailed level is expected in 2026, but a number of important guidelines are already known.

All packaging items must first undergo a recyclability assessment process to ensure they meet the Design for Recycling (DfR) criteria set out in a delegated act. Packaging is graded from A to E based on its score of compliance with the DfR criteria. Packaging that scores in class (E) will be banned from the market from 2030. Performance classes A-D correspond to the amount of the compensation in the context of extended producer responsibility. The better the recyclability, the lower the compensation the producer has to pay.

Secondly, packaging must be suitable for sorting into specific waste streams without affecting the recyclability of other waste streams, and recycled on a large scale (from 2035). "At scale" refers to an annual amount of recycled material equal to or greater than 55% (30% for wood). Producers will therefore have to ensure an efficient infrastructure for recyclability, which they only control to a limited extent.

To facilitate consumer sorting, logos inspired by the Scandinavian pictogram system will be mandatory. Reusable packaging must also carry a mandatory label, including a quick-response (QR) code. In addition, a label for recycled content is proposed on a voluntary basis. Deposit return systems (DRS) for plastic bottles and metal cans will become mandatory.

The PPWR percentages are also recorded for the mandatory amount of recyclate in a packaging material. That is 10% for contact-sensitive packaging made of plastics other than PET and not used as single-use plastic beverage bottles; for contact-sensitive PET packaging this is 30%, as well as for single-use plastic beverage bottles made of PET or another plastic material.

From 2040, the minimum percentages will increase significantly, for example to 25%, 50%, and 65% respectively for the above packaging types.