TECHNICAL BULLETIN

TRENDS IN RECYCLING FOR MULTILAYER PACKAGING

POLINTER

1 Introduction

Changing lifestyles and the consequent dependence of consumers on processed, packaged and pre-cooked foods are increasing the sales of flexible packages in order to enhance preservation of products. Rigid Packaging in all its formats (bottles, cans, tins, glass, and plastic containers) is visibly giving way to flexible packaging, mainly, stand-up pouches is the fastest growing application due to its convenient format, light weight, superior barrier properties, prudent use of material resources and high-quality printability. The food and beverage market is flexible packaging's largest end-user segment, although healthcare has become the fastest growing. At this moment, flexible packaging is present in almost every consumer goods section, even for paint and motor oil.

The growing demand for this kind of packaging has been faster than the development of recycling processes based on materials reuse vision. Recycled material is re-used in the same applications as part of the new package: as an additional layer or as an element in the composition or formula used. Delay in creation of new legislation for environmental protection, isolated initiatives to obtain appropriate use of resources to generate energy, and high investment in recycling processes have contributed to a limited extent to take advantage of the available resource.

This bulletin briefly reviews global trends and initiatives in this field designed to overcome the limitations that may arise in the recycling process of this kind of packaging.

2 Challenges in Multilayer Packaging Recycling.

It can be assumed as a premise that multiple-layer packaging is in general not easily recyclable. Consequently, it is not selectively collected and such it ends up in the mainstream of municipal household waste stream (MSW) to be dumped into a landfill.

Plastic-metal packaging and plastic-paper-metal packaging are challenging presentations to be recycled, due to the different raw materials included in those packages. Responding to this challenge, several innovations have been made to fulfill the environmental requisites.

When is talking about *recycling*, as in the above paragraphs, reference is made to recover properly the several components of a multi-layer structure and to convert them individually into a new recyclate resin, which can be used in combination with virgin resin, in a conventional plastic converting process.

In the case of multilayer flexible packaging recycling, it is necessary to take into account the following considerations:

- In principle, it is not the technology which makes difficult to recycle flexible packaging, but the selection and separation processes. In other words, every single flexible packaging component (i.e. layer) has to be analyzed and categorized, separated and recycled individually to recover a maximum of every component for further convert it into a recycled resin.
- Any flexible packaging recycler will hardly accept post-consumer materials, due to the fact that about 80% of the flexible packages are contaminated with food and, as such, they are not suitable to enter in an existing recycle stream because they will contaminate the final product. This contamination makes the recycled unacceptable for first-grade applications or food-related uses.
- Worldwide companies recognize that nowadays, there is as yet no facility in the world that can recycle flexible laminate under the traditional scheme of the use of recycled materials to transform them properly. Therefore, alternatives are being developed to prevent these products go to landfills or garbage dumps (1).

The way of packaging recycling has been evolved, is based upon professional recyclers working with packaging formats which are fairly standardized. Bottles (PET and glass), beverage cans (aluminum or steel), paperboard boxes, and some plastic bags (PE or BOPP) are all easily recycled because the materials used to make the package are easily separated. This recycling activity is able to create a high-value material that can usually be re-used in the same application from where it is originated.

When it comes to flexible packages, the consumer-goods industry has done a very good job on maximizing the value and performance of the package by creating complicated yet very useful structures. Presence of different materials like adhesives, blends and coatings poses new challenges for the traditional classification, separation and recycling. The industry claims that the flexible packaging is 'eco-friendly', because it takes less space in landfills for the same container volume, because a flexible pouch weighs around 9 grams compared to 35 g of a PET bottle, and a 330 ml glass bottle of around 220 grams.

Nevertheless, billions and billions of pouches end up in landfills or incinerators, where valuable materials are wasted.

The most common recovery option is washing and grinding the material for using it in generic recycling applications with low technical and sanitary requirements, such as garbage bags and plant pots. Techniques described below can recover not only the product, but also they add more value to the end-use material.

3 Challenges of the recycling process of post–consumer multi–layer flexible packaging (2).

When a recycling solution is going to be designed for post-consumer multi-layer flexible packaging, several issues have to take into account to overcome:

- The keyword for the recycling process is "post-consumer". Although the aim is to take-in post-consumer packages as clean as possible by organizing selective collection, the fact is that quite some post-consumer residue, i.e. product rests, has to be removed before the packaging effectively can be recycled. Tests have shown that the degree of contamination due to product residues is somewhere between 10 and 20% of the total weight. This means that for a 10 gr average weight of a flexible pack, one or two grams of residues are remaining i.e. processed food (tomato sauce, mayonnaise, soups, oils etc.), cosmetics and detergents (shampoo and others). It has to be considered the possibility that any product residue might interfere in the process.
- Since there are many features on the flexible packaging, such as dosing mechanisms, zippers, drinking spouts or screw caps, it is expected that the consumer will not provide cleaned or rinsed pouches. Due to these caps and spouts, a forcible washing process using hydro-cyclone is neither a solution, since the sticky residues prevent the pouches to open easily.
- There is an absolute lack of consistency in the consumption of post-consumer flexible packs. However, there are studies that have shown that, although there is no such consistency in product residue, there is an almost Gaussian distribution (Gaussian bell curve) in terms of the products and brands used by the consumer.

4 Recycling center: design criteria.

Multilayer packaging recycling process has to set goals in relation to its feasibility, economic factors, technical aspects, and environmental issues.

The recycling center is based upon the following criteria:

1. The set-up is a modular design for a small-scale recycling center, which is designed to be installed in any urban area up to two million habitants/consumers. The reason is that the logistic lines (supply of post-consumer pouches) should be kept as short as possible to encourage the participation of the community for the selective waste collection, and consequently reducing waste volume on the local landfills. These strategies are already implanted in the European Union, where the citizen is responsible for this primary selection.

2. The goal is to create a composite film with excellent chemical and mechanical properties. From this film, a wide variety of high-value durable consumer products can be created.

The set-up of a recycling center, according to the criteria stipulated above, should handle post–consumer flexible packaging, such as multi-layer plastic pouches, wraps for chocolate, cookies and candy, chips bags, biscuits and similar products packages. All these items can have a structure of several types of plastic, aluminum (foil) and metallized film in any combination, which imposes additional challenges.

5 Recycling of Laminated Packaging – Developments and Trends [3].

Laminated films used in packaging manufacture are an increasingly popular option for lightweight product packaging. They comprise a thin foil of aluminum, which is sandwiched or laminated in a matrix of paper and/or plastic layers. They are used in different packaging formats, including pouches, bags and tubes for food, drinks, pet foods, toothpastes, and cosmetic products.

Based on new consumer trends as well as the increase in the logistics needs for the products, a progressive growth in plastic packaging production has become higher and higher, with the consequent rise in plastic waste generation.

European Union has developed new legislation in order to minimize the environmental impact derived from the generation of plastic wastes. Directive 94/62/EC (modified by Directive 2004/12/EC) and Directive 2008/98/EC include a waste management hierarchy where prevention, re-use, recycling and energy recovery are established as criteria for managing plastic waste (in that order of priority). In fact, the those directives establish that 50% in weight of plastic waste coming from the domestic channel has to be recycled by 2020; as of 2013, only 19,7% of plastic are recycled.

Aiming to reduce the gap between the current recycling rate and the European Union's objectives, several scientific approach are being carried out in order to develop new technologies to treat multilayer plastics. Some of these investigations have been focused in the area of chemical recycling. This approach has the potential to treat the combination of different polymers at the same time obtaining energetic products as well as initial monomers which can be used in the manufacture of new polymers.

Concretely, this technology considers three types of thermal depolymerization (pyrolysis, gasification and hydrogenation) and three types of chemical depolymerization (hydrolysis, methanolysis and glycolysis).

5.1 Chemical recycling.

Chemical recycling consists on polymer cracking or decomposition by heat, chemicals and catalysts to produce oil or even the initial monomers, which can be used in the manufacture of new polymers.

5.1.1 Thermal depolymerization

Thermal depolymerization includes several chemical recycling processes that allow the production of monomers as well as other hydrocarbon fractions. This process is done by applying heat without adding any chemical reagents producing polymer chain rupture. These processes are suitable to multilayer packaging materials.

The most widely accepted methods are:

- *Pyrolysis*: it involves the heating of plastic residues at temperatures between 220 and 900ºC (428-1652°F), under oxygen-free conditions, and various residence times. This process generates different solid, liquid and gaseous products which can be used as fuel or raw materials for new polymers production. This technology is being employed by the companies RCP Bremerhaven (Germany) and Enval (England).
- *Gasification*: it involves the heating of plastic waste under low-oxygen atmosphere at temperatures slightly higher than those used in pyrolysis. This process allows the obtaining of "syngas" (synthetic gas) that is produced through the partial oxidation of the plastic

waste. This method has been being improved by the company Thermoselect.

Hydrogenation: it is based on the thermal treatment of plastic waste in presence of hydrogen, at moderated temperatures (400-500ºC or 752-932 °F) and pressures between 10 and 100 kPa (1.45 – 14.5 psi). Hydrogen allows the formation of highly saturated products that can be used as combustibles or as raw material in the refinery industry. The major advantage of hydrogenation is the possibility of obtaining liquid hydrocarbons with yields close to 85%. Nonetheless, dealing with hydrogen at such temperatures has a significant impact on costs, since the security measures needed are special and strict. This process has been developed by BP Chemicals.

5.1.2 Chemical Depolymerization: Solvolysis

The chemical depolymerization or solvolysis uses certain solvents that act as chemical reagents in the reaction. Within these processes are:

- *Hydrolysis*: Uses water as chemical agent in the presence of acids or alkalis. This process can be applied to PET waste. Final products obtained have to be filtered and treated to minimize impurities.
- *Methanolysis*: it is a depolymerization process that uses methanol as chemical agent. This process occurs at high temperature and pressure conditions: 160ºC-300ºC (320-572°F), and 7 MPa (1015 psi), allowing decomposition of the polymer into basic molecules. The main advantage of this process is the higher potential to deal with highly polluted plastic waste.

  Glycolysis: it is the depolymerization process where glycol is used as chemical agent. This process is mainly used for polyesters and polyurethanes. Usually, chemical reaction of glycolysis occurs at medium temperatures (190-200ºC or 374-392°F) to obtain new products for new polymer synthesis.

Among the options of multilayer packaging suitable for recycling with these technologies are the long-term packaging for drinks based on cardboard (manufactured by Tetra Pak, SIG, Combiloc, Elopak, etc.). This kind of packaging can have up to six different layers (3) four of polyethylene, one of aluminum, and the other of cardboard virgin fiber.

In late 2011, Spaniard company Stora Enso put into operation a new plant with pyrolysis-based technology that allows full recovery of plastic and aluminum used in these packages (4).

5.1.3 Other options

The Renewable Energy Solutions *(RES)* technology, developed by Polyflow, converts plastics waste blends into several monomers. These monomers could enter the petrochemical streams of polymers manufactures. The raw materials used could come from plastic waste mixed with rubbers, metalized film and dirt, without any separation.

CYNAR technology is based on the principle of progressive degradation of plastic by applying heat in the absence of oxygen. This process is known as Thermal Anaerobic Conversion (TAC). To do this, plastic waste is pre-processed to reduce its size, removing any contamination and non-plastic materials. This "clean plastic" is fed in molten state into a chamber with stirring devices to transform them into vapor steam (5).

REFLEX Technology (Recycling of Flexible Packaging) is a research and development project conducted by Axion Consulting, Dow Chemical, Amcor, Interflex Group, Sita, Tomra Sorting, Nestle and Unilever. This project aims to create a circular economy for flexible packaging in the UK. It started in 2014, and it focuses on the exploration and evaluation of alternatives to flexible substrates that are difficult to recycle, especially multilayer substrates (6).

6 Trends in sustainability

Many organizations focus their policies on promoting a culture of ecological sustainability of packaging in both converters and consumers. Also, focus is made on sustainable design of packages that will usable at the end of their life.

Modern package design must pursuit the model "cradle to cradle". With this model, the ideal multilayer packaging will be transformed into biological nutrients and/or technical nutrients (metals / petroleum-based polymers, etc.) at the end of it useful life, leaving no residues. Product information should include the way package is collected and processed into bio-nutrients for growing plants for food and farms; or into techno-nutrients to make new raw materials. Finally and most important, it has to include the way companies will finance all the required steps: deployment for the collection, processing, outreach strategies, and technologies to ensure that over 90% of package will be re-used (13).

Some examples are:

- **Fully Recyclable Stand Up Pouch from DOW**

Dow Chemical Company introduced to the US market, in October 2013, a 100% recyclable pouch made of a single material that can be used to pack candy and non-barrier products. The package was tested with frozen foods in Latin America and was introduced to the US market at Pack Expo exhibition. (4)

- **AMPAC Pouches**

AMPAC introduced in 2011 the "No. 2 Pouch® " a non-laminated film made with HDPE and the labeled with the number 2 SPI (Society of Plastic Industries), characterized by being more compatible with existing post-consumer recycling waste streams. The package allows a high barrier to moisture and high resistance to penetration at a lower cost than the equivalent laminated package. (5).

- **Pouch recycling in India**

In India, various brands of cooking oil and milk are packed in flexible pouches multilayer. Structures of LDPE / LLDPE / Nylon 6 and LDPE / LLDPE / PET are used for packaging oil, and 50:50 blends of LDPE / LLDPE are used for milk packaging. These post-consumer pouches, which used to be disposed to municipal landfills, are now recycled. They are used in blends (up to 60% by weight) with virgin material LDPE / LLDPE for manufacturing other products (6).

- **TerraCycle recycling program**

TerraCycle has spread its packaging collection and post-consumer difficult-to-recycling product program up to 26 countries. In this method the recyclable products are turned into new materials and innovative products (concept of "upcycling"). In this method, the waste is transformed into new products, taking advantage of all its parts without destroying its shape or the materials used to make the package (7).

7 Conclusions

Multilayer high-barrier packages, specifically aluminum/foil-paper/polyethylene laminations, are a challenge to conventional recycling processes. This is due to the complexity of its structure, which provides great benefits compared to other options in their end-use applications. To reduce their environmental impact, it has been introduced new technologies for recycling and reuse of this kind of packaging.

Technologies developed based on thermal and chemical depolymerization provide a source of energy. Once the material as a recycled one is exhausted, and provides resultant products greater added value than with other processes.

"Cradle to cradle" is another initiative that has been adopted by several organizations to maintain their packaging products within the packaging reuse system without degrading or converting them into 100% waste (8).

8 Referencias

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