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Plastic flexible films waste management – A state of art review

O. Horodytska [a,*], F.J. Valdés [b], A. Fullana [a]

[a] Chemical Engineering Department, University of Alicante, San Vicente del Raspeig Road, s/n, 03690 San Vicente del Raspeig, Alicante, Spain
[b] Olax22 SL, Artesanos Street, 4A, 03690 San Vicente del Raspeig, Alicante, Spain

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ABSTRACT

Plastic flexible films are increasingly used in many applications due to their lightness and versatility. In 2014, the amount of plastic films represented 34% of total plastic packaging produced in UK. The flexible film waste generation rises according to the increase in number of applications. Currently, in developed countries, about 50% of plastics in domestic waste are films. Moreover, about 615,000 tonnes of agricultural flexible waste are generated in the EU every year. A review of plastic films recycling has been conducted in order to detect the shortcomings and establish guidelines for future research.

This paper reviews plastic films waste management technologies from two different sources: post-industrial and post-consumer. Clean and homogeneous post-industrial waste is recycled through closed-loop or open-loop mechanical processes. The main differences between these methods are the quality and the application of the recycled materials. Further research should be focused on closing the loops to obtain the highest environmental benefits of recycling. This could be accomplished through minimizing the material degradation during mechanical processes. Regarding post-consumer waste, flexible films from agricultural and packaging sectors have been assessed. The agricultural films and commercial and industrial flexible packaging are recycled through open-loop mechanical recycling due to existing selective waste collection routes. Nevertheless, the contamination from the use phase adversely affects the quality of recycled plastics. Therefore, upgrading of current washing lines is required. On the other hand, household flexible packaging shows the lowest recycling rates mainly because of inefficient sorting technologies. Delamination and compatibilization methods should be further developed to ensure the recycling of multilayer films. Finally, Life Cycle Assessment (LCA) studies on waste management have been reviewed. A lack of thorough LCA on plastic films waste management systems was identified.

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* Corresponding author.
E-mail address: oksana.hka@ua.es (O. Horodytska).

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1. Introduction

Plastics, since the discovery of polyethylene (PE) and propylene (PP) in the fifties, have reached almost all areas of our lives. Global production of plastic materials in 2015 was about 322 million tonnes, which represents 40% increase over a decade. In Europe, plastic production oscillates at around 60 million tonnes (Plastic Europe, 2016). This success is largely attributed to low cost, low density and numerous mechanical and thermal properties that make plastics suitable for a broad range of applications. The biggest end-use markets for plastics are packaging (39.9%) and building and construction (19.7%) sectors. The agricultural sector remains in a lower position but still represents 3.3% of the total plastic demand (Plastic Europe, 2016).

Some plastics, such as PE and PP, change from rigid to flexible form when the thickness of the material decreases. Among all the plastic materials, flexible films are becoming increasingly popular mainly due to their versatility, lightness, resistance and printability, among other properties. A current trend, for example, is to substitute rigid beverage packaging by flexible materials with the aim to reduce virgin plastic consumption and the negative effects on the environment during its life cycle. Hence, the market is continually growing. In Western and Central Europe there are already more than 1200 flexible plastic extrusion companies (AMI, 2017).

Plastic film applications are diverse, but they can usually be grouped into two categories: packaging and non-packaging. Packaging products, in turn, are divided into consumer and non-consumer (commercial and industrial) packaging. Consumer packaging is also called primary packaging and its main function is to protect the product. Commercial and industrial packages are in the next level of the packaging system. Other widely used terms are secondary and tertiary packaging. Their main purpose is to group together several primary packages for easy and safe transportation (Hellström and Saghir, 2007). The non-packaging sector includes films from agriculture, construction, trash bags, labels, etc. Regarding the plastic material, PE is primarily used for both packaging and non-packaging applications. Within the consumer packaging sector, the low density polyethylene (LDPE) and the high density polyethylene (HDPE) are most commonly used, followed by PP and polyethylene terephthalate (PET). For agricultural applications and non-consumer packaging, LDPE is the most used material (WRAP, 2016). It accounts for approximately 60% of the production of all agricultural plastic, approximately 502,000 tonnes (Briassoulis et al., 2013a).

Within the total packaging market, plastic films like shrink and stretch films (10.8%), shopping bags (3.3%) and other flexible packages (26.1%) can be found (Pilz et al., 2010). A study from the UK (WRAP, 2016) indicates that plastic films have accounted for about 34% of total plastic packaging in 2014. This amounts to 414,000 tonnes of plastic-based flexible packaging placed in the market every year. In North America, 630,000 tonnes of carrier bags were generated in 2011 (RSE, 2013). The global volume of consumer flexible packaging is predicted to increase from 27.4 million tonnes in 2017 to 33.5 million tonnes in 2022 (Smithers Pira, 2017). On the other side, flexible plastics cover almost the totality of non-packaging sector, especially for agricultural applications. In Europe, the agricultural sector is led by Spain and Italy, where 235,000 and 383,000 tonnes of plastic film were consumed in 2004, respectively (Scarascia-Mugnozza et al., 2012).

Upon observation of the final structure of the film, it is possible to find two main groups: monolayer and multilayer films. Monolayer film consists of a thermoplastic polymer sheet made of PE, PP or PET whose thickness normally lies within the range from 20 to 200 μm. These films are commonly used for tertiary and secondary packaging production (e.g., stretch film) and for agricultural and building application to a lesser extent. Regarding multilayer films, their structure is made of a different number of sheets that can be polymeric (thermoplastics) and non-polymeric materials (paper or aluminium foils). It is possible to make from 2 to 17-layer films using modern technologies and the most important application is primary packaging production (Wagner, 2016). Around 17% of world film production is currently multilayer films (Tartakowski, 2010). The purpose of the converting process is to transform raw materials in the form of polymer pellets or film substrates into the final structure of the product. All of them have a common component: the extrusion. This is the first step where the solid plastic is converted into a melt that can be shaped into a film or coating by means of a die (Morris, 2017). Different converting processes are shown in Table 1.

The general issue associated with the plastic sector is the increasing generation and accumulation of non-biodegradable waste. Plastic materials, owing to the ease of production and low costs, have become a product that is easily discarded by the consumers. A vast number of plastic products are currently designed for a single use or have a short service life. In Eu-27, 25 million tonnes of post-consumer plastic waste is generated every year (Plastic Europe, 2016) while globally the total amounts to 150 million tonnes of plastic solid waste (Singh et al., 2017). Plastic waste represents about 13% of the municipal solid waste stream in the United States (EPA, 2014) and in EU-27 the percentage varies among countries from 5% in Germany and Finland to 15% in Switzerland (Hannequart, 2004). In 2017, it has been estimated that more than 50% of plastics in household waste in Norway and Sweden are films, mainly PE films (Mepex Consult AS, 2017). Regarding agricultural plastic waste, 615,000 tonnes are generated in the EU every year (Bos et al., 2008).

Table 1
Plastic film converting processes and applications.

Monolayer	Extrusion	Blown film	Bags, agricultural and construction film, stretch film, can liners
		Cast film	Textile packaging, flower wrapping, coating substrates
Multilayer	Co-extrusion	Blown film	Food and chemical packaging
		Cast film	Packaging
		Coating	Candy wrappers, snack food bags
		Lamination	Medical packaging, condiment packages, soup sachets, cable wrap
	Lamination	Adhesive	Food packaging, lidding foil, chemical storage, outdoor exposure film

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