Podobnost polimerne ambalaže za reciklažu

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Apstrakt: U odnosu na ambalažu se postavlja niz zahteva, od funkcionalnih, estetskih, ekonomskih, ergonomskih, a u današnje vreme sve se više pažnje poklanja ekološkim zahtevima. Od ukupne proizvodnje plastičnih materijala, najveći udeo ima industrija ambalaže. Pored toga, polimerna ambalaža, zauzima i najveći procenat od ukupne proizvodnje ambalaže. Razlog njene primene leži u nizu dobrih osobina kao što je npr. niska cena, raznovrsnost, mehaničke i barijerne osobine, itd. Međutim, sa ekološkog aspekta, ona predstavlja poseban problem zbog kratkotrajne upotrebe i nagomilavanja nerazgradljivog otpada. Zato ambalaža u današnje vreme treba odgovarati i sve većim zahtevima ekonomične i ekološki podobne prerade nakon njenog korišćenja. Iz navedenih razloga se u ovom radu daju osnovne smernice za izradu i izbor ambalažnih materijala u cilju poboljšanja podobnosti za reciklažu, uzimajući u obzir i kriterijume oznake materijala i konstrukcijske izvedbe.

Keywords: polimerna ambalaža, reciklaža, podobnost

The suitability of polymer packaging for recycling

Abstract: Packaging must fulfill functional, aesthetic, economic, and ergonomic requirements, and nowadays more and more attention is paid to environmental requirements. Of the total production of plastic materials, the largest share is refers to the packaging industry. In addition, polymer packaging occupies the largest percentage of total packaging production. The reason for its application is due to a number of good properties such as low price, variety, mechanical and barrier properties, etc. However, from the ecological aspect, it represents a special problem due to short-term use and accumulation of non-degradable waste. That is why packaging nowadays should meet the growing demands of economical and environmentally friendly processing after its use. For these reasons, the paper provides basic guidelines for the manufacture and selection of packaging materials in order to improve recyclability, taking into account the criteria of material labeling and construction performance.

Keywords: polymer packaging, recyclability, suitability

1. Introduction

Global production of plastic materials in 2018 was about 360 million tons. Total European plastics converters demand was about 51.2 million tons. The biggest end-use markets for plastics are packaging (39.9%), and building & construction industry (19.8%) (Plastic Europe, 2019). The most commonly used polymer types for packaging are given in Table 1.

Table 1: The most commonly used polymer packaging materials

Type of polymer ¹	Usage examples
LDPE	Foils, bags, sacks, hollow plastic containers
HDPE	Foils, bottles, containers, tapes
PP	Foils, cups, closures, strips, food containers
PS	Cups, closures, foils
PET	Bottles, bags, heat-resistant foils, food packaging containers

¹ Abbreviations used: LDPE (low-density polyethylene), PP (polypropene), HDPE (high-density polyethylene), PET (polyethylene terephthalate), PS (polystyrene).

The reason for using plastic for packaging manufacturing is the transparency of materials, various barrier properties, and good mechanical and thermal properties. The largest group of packaging is food packaging, and among, the most important group is flexible packaging (monofilms or multilayer compositions combined with paper and aluminum films) (Izdebska, 2016).

The share of plastic packaging materials in the total amount of packaging is significant and amounts to 43.8% on the market. The share of paper, cardboard and corrugated cardboard is 32.7%, metal 16.5% and glass 7.1% (Neue Verpackung, 2015).

The basic function of packaging is to hold and protect the content beginning from the packaging process, to the distribution and to the end consumer. Besides the economic production and optimal performance of the function in the phase of use, the packaging should meet the growing demands of economically and environmentally friendly processing after its use, among other things, its suitability for recycling.

The main problem with plastics in general is the increased generation of non-degradable and the ever growing amount of waste. According to Horodytska (p. 415), “the EU through the Waste Framework Directive (2008/98/EC) has established the following waste management hierarchy: prevention, preparing for reuse, recycling, recovery and disposal”. According to Foltynowicz (p. 65), “The European Commission (EC) set a target of 2030 to increase recycling of plastic packaging stating that the only long term solution is to reduce plastic waste by recycling and reusing more”.

Improving product recyclability leads to easier recycling. Suitability for recycling is primarily determined at the design stage. In that way, the designer can notice the shortcomings at an early stage, which would eventually contribute to the modification of the design, and thus to energy savings, reduction of emissions, etc. (Zhi Li et al, 2017).

The following part of the paper analyzes the above problems and briefly states the basic guidelines for material selection and production of primary polymer packaging, in order to improve recyclability, based on the most important criteria:

- Choice of materials,
- Material markings, and
- Construction designs.

2. Choice of the materials

The required technical-technological knowledge of a number of different polymer materials used for the production of packaging is the basis for their selection with regard to recyclability. According to their thermal properties, they are divided into thermoplastics, elastomers and duroplasts.

Thermoplastics are most often used for the production of packaging. They can be melted when heated and hardened when cooled, and therefore be recycled and reused several times. Duroplasts and elastomers do not have this property and are used only as auxiliary materials.

To improve the suitability of packaging material for recycling and use, when choosing a material, the designer should pay particular attention to:

- Possibilities of reducing the types of materials,
- Tolerability of individual materials,
- Possibilities to increase strength, and
- Homogeneous packaging material.

When choosing the material, the necessary auxiliary parts of the packaging, such as adhesive tapes, closures and labels, must also be taken into account.

Separation of certain types of packaging material and their reduction has a positive effect on the sorting process and the suitability of materials for recycling.

If the packaging composed of different materials cannot be separated, it is necessary to pay special

attention to the compatibility of polymeric materials - Table 2.

For the assessment of the compatibility of different materials, there is literature as well as available data from the manufacturer (Pahl, G.; Beitz, W., 1996, Scalice Kovacs et al., 2009).

Table 2: Compatibility of polymer materials

	PE	PP	PS	PVC	PET	PC	PA
PE	1	3-4	4	4	4	4	2-4
PP	2-4	1	4	4	4	4	2-4
PS	4	4	1	4	3	2-4	3-4
PVC	4	4	2-4	1	4	3-4	4
PET	4	4	4	4	1	1	3-4
PC	4	4	2-4	4	1	1	3-4
PA	4	4	3-4	4	3	4	1
PBT	4	4	2-4	4	3-4	1	3-4

1-compatible; 2-can be mixed up to 20%; 3-can be mixed up to 5%; 4-not compatible

As a rule, different polymeric materials cannot be mixed on a molecularly homogeneous basis, because the recycled material would have poor properties (Nickel, 1997). If the desired purity of the material type is not achieved, macromolecular auxiliaries can be used.

By increasing the strength of the material by uniformly orienting the molecules (eg monoaxial OPP and biaxial BOPP), better recyclability is achieved because the use of combined materials and additives is reduced (Nickel, 1997).

The best suitability for recycling is achieved by a homogeneous structure of packaging - from one material. However, the avoidance of combined and alloyed materials needed to achieve better required properties of packaging material (e.g. permeability, toughness, transparency, slipperiness), as well as due to the requirements of the packaging content itself (especially for food and pharmaceutical packaging), can hardly be avoided. Replacement of multilayer packaging is possible only if the protection of the product is provided to the same extent (Kaiser et al, 2017.)

Research of the recycling of multilayer films goes in the direction of adding compatibilizers (Horodytska et al., 2018). When choosing different types of materials to be joined by gluing, welding or shape, the difference in their densities should be greater than 0.1g/cm^3 , in order to allow separation (Nickel, 1997). However, even in this case, the separation is problematic because with the usually combined packaging, the individual layers differ greatly in density.

3. Markings (signs) on the packaging material

In addition to consumer and marketing information, labels also serve as a criterion for sorting packaging. Appropriate material labeling should facilitate the sorting of polymer packaging by type and contribute to an economically and environmentally sound packaging cycle. The type of labeling should be closely related to the available collection, sorting, and processing procedures. Image, image-text tags, and markers are most commonly used.

Image and image-text labels also have an informative character. They indicate to the consumer that recycling was taken into account when designing the packaging. The recognizability of the signs is important. In addition to the well known signs, signs for biodegradable materials for compostable packaging have recently become significant.

For polymeric materials where it is not easy to detect the composition or properties by which they differ from other materials, it is possible to use markers. They are important in the recycling process in order to facilitate automatic sorting by type of material and achieve the purity of individual types of material.

The procedure with markers enables even marking of different types of the same type of polymeric materials. If a direct print on the packaging is not used, labels (made of paper or polymer foils) are used, which are glued to the packaging. If water-soluble adhesives are used, then labels from other materials can be accepted. If adhesive residues cannot be removed from the surface of plastic

packaging, small particles in the form of powder, fibers, etc. cause impurities in the recycled material. In addition, adhesive residues can disintegrate in the further melting process, leading to discoloration of the material as well as undesirable changes in mechanical properties.

For suitable recycling, polymer labels should be made of the same material as the packaging. If paper labels are used, it is necessary to stick with water-soluble glue. In addition to the insufficient content of information, in the case of pictorial and additional markings, the practical application is questionable, and their direct connection with the available waste collection systems is also problematic.

Further labeling in order to differentiate individual materials would be possible by standardizing colors for certain types of polymeric materials. For the same purpose, it is also possible to use a variety of surface structures on the packaging, with each structure determining the type of material. Care should be taken not to use imitations of other types of materials (e.g. paper).

4. Construction of the packaging

Due to the importance of suitability for sorting recyclable materials, it is necessary to avoid auxiliary parts for opening /closing packaging with appropriate construction or to be made of the same material as the packaging, and to enable good separation of different materials.

In order to reduce the impurity of the packaging used, such a design of the packaging is required to be suitable for emptying the rest of the packaged product. First of all, the contact surfaces of the product and packaging should be smooth and without the so-called *dead zones*.

Design suitability for recyclability of packaging is characterized by two basic criteria:

- Material joining technique, and
- Separation of different materials.

The technique of joining different parts of the packaging is based on known joining principles. For the evaluation of compounds with respect to the goal of this paper, the criteria were selected and their suitability was evaluated-Table 3.

In the case of joining different materials, the friction and shape joints of the opening/closing elements are more suitable than the joints by gluing and welding. However, welded joints should only be used for the same polymeric materials. Bonding joints are only conditionally separable (Nickel, 1997).

Table 3: Assessment of the joining (Müller, 2000)

Types of joints Eligibility criteria	Gluing	Welding	With friction	Whit shape
Separation without permanent deformation	3	3	1	1
Separation with permanent deformation	3	2	1	2
Joint load	2	1	2	1
Suitability for recycling	3	1	2	2

Assesment of the type of joining: 1-most suitable, 2-suitable, 3-less suitable

Separation of different polymeric materials is expedient if the separation in the recycling process is done by crushing. However, e.g. in the sorting process, the auxiliary elements are not removed, and in principle this cannot be expected from the consumer either.

Trying to open/close the polymer material packaging as easily as possible often leads to an increase in the number of additional parts, which should be kept to a minimum due to their recyclability. If they are made of metal or differ from the packaging material, they should be constructed so that they can be easily separated due to their size and strength.

5. Conclusion

These requirements and guidelines for improving the suitability of polymer packaging for recycling, processed through three main influencing criteria, could be summarized according to their importance in the following order:

- Choice of thermoplastics instead of duroplasts and elastomers;
- Production of packaging from one type of polymeric material;
- Use of labels made of polymeric material instead of paper;
- Application of water-soluble labels;
- Direct printing instead of labels;
- Use of printing inks and additives as little as possible;
- Structural coloring of the material.

Regarding the construction of polymer packaging, there are significant requirements:

- The best possible separation of different materials;
- Avoiding auxiliary parts of the packaging, and
- The best possible discharge from the rest of the product content.

The stated requirements and guidelines for packaging recyclability in this paper can be considered only within other requirements related to the function of packaging (content protection, rationalization, marketing, etc.). Since the technical possibilities of packaging recycling in our country are limited, it is necessary to design the most recyclable packaging, raise the environmental awareness of the population and improve the system of staff education

5. Literature

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