Introduction

Goods moved and stored in logistics processes require proper packaging. Packaging has variety of functions, such as: a protective function, or marketing. In this publication we focus strictly on the logistics function. The aim of the paper was to analyze packaging commonly used in plastics from the point of view of implementation in the logistic function. The paper focused on the plastics used for packaging of consumer goods to be sold as a mass product, apart from the issue of special plastic packaging used in the case of more expensive products.

PACKAGING LOGISTICS FUNCTION

The role of packaging in logistics processes is the result of the function that these packages meet. The most important function of packaging functions include: safety, logistics, information, marketing, environmental, economic and functional [1, 3]. This publication focuses on the logistic function packages.

The packaging is a very important component is an integral part of the product. In accordance with the Act of 11 May 2001 on packaging and packaging waste, packaging placed on the market can be produced from any material, designed for the containment, protection, handling, delivery or presentation of any product, from raw materials to processed goods, as well as part of the packaging and auxiliary elements combined with packaging and for made for the same purpose as the pack [1, 2].

In this case, the implementation of any logistics processes is only possible for the product together with the packaging. The norm PN-0 79000 defines the package as a product which should maintain a specified quality packaged products, adapting to their transport and storage and presentation, as well as protecting the environment from the harmful impacts in certain products.

Logistic function of the package is linked to the movement of goods in the economy. The packaging and its contents participate in the physical movement of the warehouse and transport chains, and therefore must meet the requirements of standardization and coordination of all links of the chain. Information about the nature of the information published on the packaging should facilitate the move of goods, and even determine the content protection and allow efficient storage, manipulation and control in the process of the goods’ flow [4, 8].

Packaging should be designed in such a way that in the process of receiving the product can be possible to use various types of logistic technology to facilitate this process. Implementation of the logistic function by packaging must comply with the rules 7W [5, 6]:

- right product
- right quantity
- right condition
- right place
- right time
- right customer
- right price.

From the logistic point of view of the most important functions of packaging are those that the packaging process can facilitate the flow of materials and goods. Logistics processes can coordinate material flows and innovation throughout their journey from suppliers, through production, distribution, to the end user, and even further, because in some cases up to the disposal of waste and residues useless cassation [9].

The basic requirements related to the implementation of the logistic function for the package include [7]:

- stability of form
- resistance to impact
- static pressure resistance
- resistance to tearing
- susceptibility to impoundment
- resistance to shock
- standardized dimensions
- ease of handling
- susceptibility to automated operations
- the ability to recognize the fork lift trucks
- sensitivity to loading units
- space savings
- space saving.

With more and more complex distribution processes of various kinds of goods and products, especially consumer goods, the role of packaging in a fast, efficient and cost-effective movement of goods on the way from the manufacturer to the customer is very important [7]. This role is particularly high...
CHARACTERISTICS OF PLASTIC MATERIALS USED IN
MASS PACKAGING OF CONSUMPTION GOODS

In the case of plastic materials, packaging business is the largest segment of their use, constituting over 35% of such materials’ application globally, whereas approximately 60% of all packaging is used by the food industry, including food wrap films. The demand for packaging of plastics in the annual scale worldwide is estimated at about 14 kg/person, in the Western Europe at 42 kg/person, while in the Eastern Europe at about 11 kg/person. In Poland, the demand for such products totals about 18 kg/person per year. Forecasts envisage continuous increase in demand for plastic packaging of about 0.7 kg/person per year [11-12]. High share of polymer materials in the packaging industry is due to their properties that make them competitive to other materials. Major advantages of such materials include: small specific weight, lightness of the material, high resistance to chemical and physical agents, mechanical strength, non-permeability of steam, protection against microbe permeation, easy processing (by injection moulding, extrusion moulding, pressing and vacuum forming, and blowing extrusion in the form) and colouring, as well as aesthetic appearance.

Another important property of plastics used in the packaging industry is their multi-functionality and multiple applications, owing to which packaging made of such materials can be and are generally used for backing foods, utility products, toys, household appliances, cosmetics, medicines and medicinal products, chemical agents, as well as large-size products where high mechanical strength of the packaging material is required. It is worth stressing that plastic packaging constitutes about 1 to 3% of total weight of the product weight. In turn, in the event of applying other packaging materials, the percentage share of the packaging weight is much greater. Moreover, plastic packaging occupies increasingly less space, owing to which it reduces manufacturing cost, and thus also costs of transport. The disadvantage of plastic packaging lies in the possibility of migration of harmful compounds to the product, which is particularly dangerous in the case of foods [11-15].

Polyethylene is one of additive polymers most frequently used in the packaging industry. PE structure depends on the method of its obtaining and the polymerisation method. Polyethylene properties not only depend on the process applied, but also on auxiliary agents used during the manufacturing processes, molecular weight, chemical structure, degree of macro-particles branching, physical properties, contents of crystalline and amorphous phase, as well as polymer density [13,14]. Table 1 presents the types and selected properties of polyethylene.

Polyethylene’s disadvantage is the fact that it does not undergo biological degradation process, and its decomposition time exceeds one hundred years. The process can be accelerated by mixing it with natural polymers, e.g. starch, gelatine, or cellulose, as well as synthetic polymers, such as aliphatic and aromatic polyesters. Works on such materials have been lasting since the 1970’s, when polyethylene film with the addition of starch was received for the first time [16,17].

Another polymer from the polyolefin group generally used in the packaging industry is polypropylene, which, similarly as polyethylene, is included among the group of materials not undergoing biological degradation. Polypropylene features the lowest density among all polymers, while its properties depend on molecular weight, degree of polydispersity, and degree of crystallinity. The polymer is characterised with very high chemical resistance, is resistant to solutions of strong acids, bases and inorganic salts, as well as organic solvents. In turn, it is not resistant to strong oxidants and non-polar liquids. The greatest application of polyethylene and polypropylene, as well as PE and PP mixes in the packaging industry, is the production of food wrapping film and containers, as well as household chemical agents [13,14].

Polyethylene terephthalate is another polymer generally used in the packaging industry, particularly for production of bottles for water and beverages. PET is a representative of polyesters revealing physiological indifference, owing to which it can be used for food packaging. Moreover, polyethylene terephthalate is characterised with high mechanical strength, and shows resistance to acids [11,13].

Table 1. Types and selected properties of polyethylene.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Name</th>
<th>density g/cm³</th>
<th>degree of crystallinity</th>
<th>tear strength MPa</th>
<th>Construction of macromolecules</th>
</tr>
</thead>
<tbody>
<tr>
<td>LDPE</td>
<td>Low-density polyethylene</td>
<td>0.920 - 0.930</td>
<td>60 flexible polymer</td>
<td>10-18</td>
<td>branched</td>
</tr>
<tr>
<td>HDPE</td>
<td>Medium-density polyethylene</td>
<td>0.960 - 0.970</td>
<td>80-90 rigid polymer</td>
<td>19-42</td>
<td>linear</td>
</tr>
<tr>
<td>HDPE</td>
<td>High-density polyethylene</td>
<td>0.945 - 0.955</td>
<td>80-90 rigid polymer</td>
<td>20-37</td>
<td>linear</td>
</tr>
</tbody>
</table>
The packaging industry also makes use of polystyrene, linear polymer from the group of thermoplastic materials. PS is one of the lightest materials (density of approx. 1.05 g/cm³), does not dissolve in water, aliphatic hydrocarbons, lower alcohols, acetic acid and phenol. A very important property of PS is its high heat resistance, owing to which it can be processed several times without deteriorating the material’s physical-chemical properties. Polystyrene is used in the packaging industry principally to obtain packaging for electronic equipment. In turn, due to low chemical resistance, it is not used for production of food packaging, particular on the basis of fats [11,13].

Table 2. Advantages and disadvantages of plastics in the aspect of logistic functions carried out by packaging made of them.

<table>
<thead>
<tr>
<th>Logistic function</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Form stability</td>
<td>Depends on type and thickness of packaging and the polymer used for packaging manufacture; stability of plastic packaging increases with packaging thickness; stability can be improved by addition of a filler into the material, e.g. talc</td>
<td>Polyethylene and polypropylene foil susceptibility to deformation, and thus possibility of product deformation; packaging more susceptible to deformation are ones made of polymers containing large share of amorphous phase</td>
</tr>
<tr>
<td>Resistance to bumping</td>
<td>Depends on type and thickness of packaging and the polymer used for packaging manufacture</td>
<td>Depending on the type, packaging is not resistant to bumping; the least resistant are films; in the case of polystyrene, there is a probability of packaging cracking under impact</td>
</tr>
<tr>
<td>Resistance to static pressure</td>
<td>Identically as in the case of resistance to bumping</td>
<td>Identically as in the case of resistance to bumping</td>
</tr>
<tr>
<td>Resistance to tearing</td>
<td>Plastic packaging is resistant to tearing; tear strength for medium- and high-density polyethylene (HDPE) totals 20-40 MPa, polypropylene (PP): 30-40 MPa, polystyrene (PS): 55 MPa</td>
<td>The lowest tear strength is recorded for low-density polyethylene (LDPE) (10-20 MPa)</td>
</tr>
<tr>
<td>Susceptibility to stacking</td>
<td>Due to the possibility of obtaining packaging with various shapes and dimensions, they can be easily stacked</td>
<td>Stacking susceptibility can be rendered difficult in the case of irregular shape packaging, e.g. household chemical agent packaging, bottles of various sizes, etc.</td>
</tr>
<tr>
<td>Resistance to shocks</td>
<td>Identically as in the case of resistance to bumping</td>
<td>Identically as in the case of resistance to bumping</td>
</tr>
<tr>
<td>Standardised dimensions</td>
<td>The advantage of polymer packaging is that, due to easy processing, it can be used to obtain products with strictly specified dimensions</td>
<td>None</td>
</tr>
<tr>
<td>Easy manipulation</td>
<td>The strength of polymers used in the packaging industry is the fact that their physical-chemical properties allow for obtaining any type and shape of packaging</td>
<td>None</td>
</tr>
<tr>
<td>Susceptibility to automated activities</td>
<td>Packaging made of polymers can be easily transported automatically</td>
<td>Susceptibility to automated activities can be rendered difficult in the case of irregular shapes</td>
</tr>
<tr>
<td>Possibility of holding by fork-lift trucks</td>
<td>Plastic packaging is susceptible to formation of loading units</td>
<td>In the case of irregular shapes, separation of particular layers, e.g. with cardboard, is required.</td>
</tr>
<tr>
<td>Susceptibility to formation of loading units</td>
<td>Identically as in the case of possibility of holding by fork-lift trucks</td>
<td>Identically as in the case of possibility of holding by fork-lift trucks</td>
</tr>
<tr>
<td>Space saving</td>
<td>The weight of a plastic packaging constitutes 1 – 3% of total product weight, which assures significant saving of space, as packaging weight is small as compared to product weight; in the case of packaging made of other materials (glass, metal, wood) the percentage share of packaging weight is much higher</td>
<td>None</td>
</tr>
<tr>
<td>Area saving</td>
<td>Packaging of plastics occupy very little space as compared to packaging made of glass, metal or wood</td>
<td>None</td>
</tr>
</tbody>
</table>

Source: own study.
EXECUTION OF LOGISTIC FUNCTION OF BY PACKAGING OF PLASTIC MATERIALS

Based on the information submitted in the previous chapter of the publication, plastic properties of packaging we conducted the analysis of their applicability in the implementation of various logistics functions.

Table 2 shows the advantages and disadvantages of plastic discussed in relation to these functions.

The analysis shows that the plastic is very good in the implementation of logistics functions process. In many cases for example, space-saving the plastic packaging are also better than others used in the package process from materials such as glass, metal, wood and ceramics. Immediately properties depend on the type of material used, because other materials have other packaging properties. However, taking into account the diversity of materials with polymers and great opportunities to shape their packaging allow them done very well to fulfill most of the logistics functions. Therefore, they are one of the most frequently used materials in the packaging of mass products.

Conclusion

Total share of plastic packaging in the value of all packaging globally totals approximately 35%, and is increasing. Properties of polymer materials, principally their high mechanical strength, chemical resistance and resistance to microbes, low weight, and rather low manufacturing costs make such materials carry out logistic functions required from packaging. Despite their many advantages, however, such packaging, has a fundamental flaw. These are materials included among non-ecological products, which is due to their very low decomposition time, reaching as long as several hundred years.

Recently, a tendency has been observed to obtain plastic packaging that not only meets the requirements for materials to be applied in the packaging industry, but which also meet increasingly higher requirements in the aspect of their usefulness for recycling. From the point of view of environmental protection, the best solution is to obtain such materials that after their period of use, namely after fulfilling their role, would decompose to environment-friendly compounds. Among such group of materials, there are bio-degradable materials, namely materials decomposing under the impact of biological factors. Their application in the packaging industry is currently limited due to high cost of multi-tonne manufacturing costs [16, 17].

Abstract

The package is the outer layer of the goods and its main task is protection against damage and external factors. It also aims to facilitate the storage and transportation of products and by its appearance to raise the aesthetic value of the product, and thus encourage customers to buying. The most commonly used packaging is made of paper or cardboard. Big role is also played by plastic packaging, the use of which is increasing. The article presents the advantages and disadvantages of plastic packaging from the point of view of the implementation of logistics functions.

Realizacja logistycznej funkcji opakowań przez opakowania z tworzyw sztucznych

Streszczenie

Opakowanie stanowi zewnętrzną warstwę danego towaru i jego głównym zadaniem jest jego ochrona przed uszkodzeniem oraz działaniem czynników zewnętrznych. Ma ono również ułatwiać magazynowanie i transport wyrobów oraz poprzez swój wygląd podnosić wartość estetyczną wyrobu, a tym samym zachęcać do kupowania. Najszelej stosowane są opakowania wykonane z papieru lub tektury. Dużą rolę odgrywają również opakowania z tworzyw sztucznych, których wykorzystanie wciąż wzrasta. W artykule przedstawiono zalety i wady opakowań z tworzyw sztucznych pod kątem realizacji funkcji logistycznych.

References

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