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TESTS AND ASSESSMENT OF QUALITY OF THE PACKAGINGS IN THE ASPECT OF THEIR APPLICATION IN TRANSPORT PROCESSES

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Abstract – Packagings play an important role in economy. In transport, they are used to secure all kinds of products from sender to consumer. Due to growing and changing needs of the market, packagings must have appropriate aesthetic qualities and resistance to external factors that may occur during transport. Therefore, it is important to constantly adapt packagings in the context of complying with standards of transport of products. The goal of the article was to analyse and assess selected properties of packagings of cosmetic products in the aspect of transport processes. Strength tests (compression test, tensile test), test of resistance of the packagings to high temperature and test of changes of properties of the packagings using an immersion method were conducted. An analysis of conducted tests gave an answer for the question whether packaging properly protect products in a transport process.

Key words – transport process, quality of packaging and deliveries, safety

JEL Classification – L91, R41, R42

INTRODUCTION

Condition of cargos during transport is an important issue for transport enterprises because for the contractors, it is often the only form of direct contact with the consumers [19]. Therefore, the most significant criterion of evaluation of the carriers is duration of transport process and percentage of damages to cargos [16]. Therefore, the most important goal of a carrier is to deliver the goods in pristine condition, often in Just-in-Time system [5, 14]. This aspect is an inherent element of quality of deliveries because percentage of cargos damaged during the process of transport has considerable impact on the quality of transport services and image of suppliers [6-8]. Safety of cargos during transport process is the most significant issue for the customers while selecting specific service provider [13, 20].

Packagings must have appropriate resistance to various factors occurring in transport because their basic role is protection of products [9-10, 12, 17]. In order to fully use the potential of a packaging, it is necessary to determine values and properties that specific product is characterized by [11, 15]. Strength tests were conducted to determine the moment when packaging materials cease to fulfil their function and when they are deformed. An analysis of conducted tests is supposed to give an answer to a question whether packagings properly protect the products in a transport process.

1. THE IMPORTANCE OF PACKAGINGS IN A TRANSPORT PROCESS

In recent years, growing role of the packagings in transport processes has been observed. It is an effect of the needs of the market, development of new products, machines, progress of technological processes and environmental protection requirements [2].

At present, about 99% of products require specific packagings. Average annual use of packagings per one inhabitant was presented on Figure 1. It can be observed that packaging materials are used most frequently in highly developed countries such as United States, where average annual use of plastic packagings per one inhabitant within a year is about 250 kilograms. Whereas, in the underdeveloped countries of Africa, Asia (Bhutan, Nepal, Afghanistan) or Latin America, it is about 5 kilograms. In Japan, it is about 150 kilograms, and in Europe - 120 kilograms.

Due to growing importance of the packagings, their efficient and cheap moving during transport from manufacturer to consumer is becoming increasingly significant. The importance of the packagings is clearly seen during handling works, in transport systems and securing products. Packaging support distribution processes of goods**,** therefore, packing and logistics of the packagings are very significant. There are many factors that efficient and prompt delivery of the products in pristine condition depend on. They include proper selection of a packaging material, packing method, securing and flow of manipulation works.

Packagings make it possible to deliver products to the buyers on schedule and in a good quality. The factors that affect duration of transport include labelling method, quality of the packagings, and their functions [1]. The quality of applied packagings largely affects safety and costs of transport. The main and the most important factor affecting the quality of the packagings is to design them in a proper way. It is based on proper adjustment of materials, shape, structure and parameters of a packaging with reference to packed products and probable circumstances of use. An important aspect is to minimize damages of goods during transport. It is possible through:

- improvement of technical condition of means of transport and trans-shipment devices,
- improvement of transport infrastructure,
- quality of packing of products,
- proper deployment and securing cargos in the means of transport,
- technique of loading works,
- the method of placing goods.

In addition, large impact have the following factors:

- properly selected and designed packagings,
- conducting tests of applied packagings,
- correct forming of loading pallet units,
- the method of packing of products and control of their quality.

Properly selected and designed packaging allows to avoid huge losses resulting from damages or complete destruction of products during a transport process. Therefore, packaging has large impact on wear of materials, as well as costs of packing and transport. In order to design a transport packaging, the first step is to determine its conditions of use. Therefore, it is necessary to conduct an analysis of the following factors:

- shape, size and weight of the products,
- duration of transport, planned method of transport and trans-shipment,
- value of a product and type of its distribution,
- properties of packed products such as resistance to factors affecting products during transport.

In the event of designing unit packagings, proper selection of a packaging material, shape and method of opening, determining capacity and preparing graphic layout play a fundamental role.

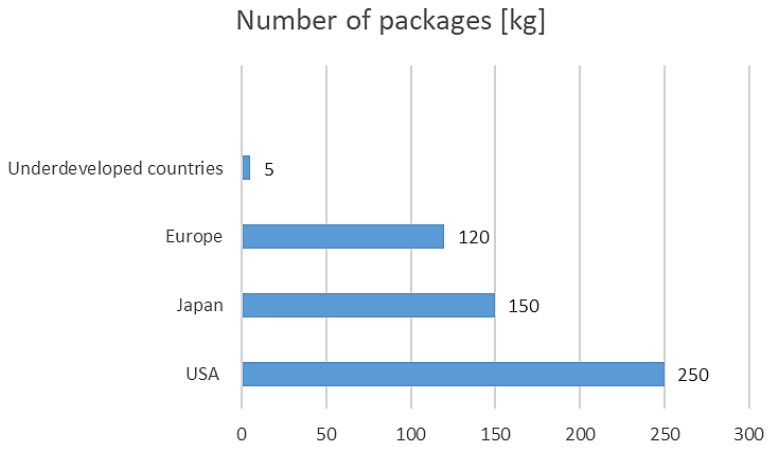

Fig. 1. Average use of the packagings in kilograms per one inhabitant in 2020

The quality and utility values are also significant. They largely affect the damages of goods such as, for example, spilling out or damage to the products placed inside.

Tests of applied packagings in order to improve them should be constantly conducted. It is important for their sustainable development. Research and development units make it possible to create packagings adjusted to transport. Therefore, specialist tests are conducted. Their goal is to check strength under various conditions that occur in a process of transport or manipulation works. They enable to determine the degree of resistance before damaging as a result of such factors as too high or low temperature, pressure, vibrations during transport or humidity. The value of a product must be taken into consideration. It affects the level of protection that specific manufacturer of the packagings may choose [4].

The basic condition and the first point while forming of loading pallet units is proper placing of products on the pallet. It is necessary to comply with specific principles [3]:

- aiming at the best possible use of loading area of a pallet, that is, when it is possible to apply – the use of the packagings in accordance with a dimensional system,
- adjustment of appropriate height of a loading unit by taking various limitations into account, such as, for example, type of the packagings, permitted piling up due to the means of transport**,**
- putting the goods on the pallet so as to make pallet unit stable,
- placing goods on the pallet so as not to cross its outline, only in some cases, it is allowed to cross it maximum 20 mm from each side,
- cargo on the pallet should be homogeneous, that is, it should have an equal form, weight, sizes and content. When it is not possible, each layer of the same packagings should be placed gradually according to weight of layers – those of the highest mass should be placed at the bottom of a pallet.

The goal of forming loading pallet units is to enable handling of products using handling devices such as fork lift trucks or jacks. Therefore, it is necessary to apply appropriate methods in order to attach cargo to the pallet. The most popular methods of securing products on the pallet is the use of tapes along with hoods made of shrink film, or wrapping cargos with stretch film.

Packing of products, and then quality control are the last stages of preparing products for transport. There are many methods of packing of goods. To make packing effective, special machines and devices were created for this purpose. The next stage is to check the quality of products and method of packing. It should be done by manufacturing enterprise and product users. It is also important to check correctness of labels and whether packaging is not damaged in any way.

2. AN ANALYSIS AND ASSESSMENT OF STRENGTH OF PLASTIC PACKAGINGS IN A TRANSPORT PROCESS

In order to conduct the tests, specific category of plastic packagings was selected for cosmetic industry where their use is common because, among others, it enables to properly secure products during transport. Common use of such packagings results, among others, from making various shapes, implementation of new, innovative methods of packing, using polymers.

Cosmetic industry is a unique industry in the aspect of transport of products because substances in the packagings are of various consistency, therefore, they must be properly secured, taking into account the process of storing and transport. These substances can change its properties due to the impact of temperature or pressure force, compression or tensile force. It all causes that the product packagings must meet specific requirements and be characterized by suitable resistance to above factors.

Analysed selected packagings differ in size and capacity, however, in the presented form, they are to the highest extent exposed to external factors because like samples or smaller equivalents (e.g. 50 ml) of cosmetics applied every day, they are used while travelling.

The following packagings were tested:

- sachet for a sample of, for example, shower gel, shampoo,
- cream jar,
- soap/gel bottle.

Tested packagings were presented in Table 1.

Table 1. Tested packagings [18]

Packaging	Height	Length	Width	Capacity	Type materials
	[mm]	[mm]	[mm]	[ml]	
Sachet	120	70	0,5	7	PP
Jar	50	55	55	50	PP
Bottle	100	40	25	50	PP

Table 2. Tests of samples

TESTS				
PACKAGE	Squeezing	Stretching	Property change	Resilience
Sachet		ν	ν	ν
Jar	ν		ν	
Bottle	ν		ν	

Fig. 2. QC-505M1 test machine 505M1 [21]

Packagings considered in the tests differ not only in shape, but also in size and capacity, as well as usefulness or possibility of reuse.

2.1. TEST

The goal of the test was to analyse selected properties of plastic packagings in transport processes. For the purposes of the test, various types of the packagings were analysed. Tests of strength character were conducted on selected samples (packagings). Packagings were subjected to:

- pressure force,
- compression,
- tensile force,
- temperature.

Moreover, resistance of prepared samples was verified in global migration test through application of the method of complete immersion or filling.

In order to conduct the test, that is, assessment of resistance of plastic packagings to mentioned factors, selected packagings were tested. An assumption was to present the impact on these packagings of maximum negative conditions and assess such impact in order to determine strength and properties. These tests included:

1. Strength test – compression test, tensile test.
2. Test of changes of properties through application of immersion method.
3. Test of resistance of the packagings to high temperature.

Not all of tested packaging materials were subjected to three tests. Table 2 presents the packagings that were subjected to specific types of tests [18].

Strength test was conducted with the use of QC-505M1 machine (Fig. 2).

Test with the use of the machine was conducted in order to determine maximum pressure force that would destroy the packaging. Two out of three samples were subjected to strength test, that is, cream jar and soap/gel bottle. Empty packagings were placed in the machine.

Static tensile test was conducted in order to determine how packaging is affected by tensile force, what force is required to tear the packaging. As a result of impact of mentioned force, test sample was not damaged. It has no elements that would be easily separated from remaining part of the packaging. Before the test, the sachet was not emptied because it is for single-use only, and results would not be credible after emptying it.

Global migration conducted using a method of complete immersion is a test that is conducted in order to determine the level of safety of application of selected packagings. This test provided information showing whether analysed packaging after immersion tests are still suitable for use. This test was conducted on all selected packagings. Before the test, packagings were emptied, photographed and then weighed. Then, they were subjected to contact with model substances, which imitate presence of the cosmetics, that is:

- rapeseed oil,
- 3% CH_3COOH (acetic acid),
- 10% ethyl alcohol.

These substances were applied inside and outside of the packagings because it is the only way to verify reaction of a specific packaging on placing a specific cosmetic. In order to conduct this test, sachet was completely immersed in all substances mentioned above, whereas, jar and bottle were filled with acetic acid and ethyl alcohol. The packagings were in contact with substances incessantly for 48 hours in temperature of 29°C. The results of this experiment were presented on Figure 7.

Method of checking and verifying resistance of the packagings to high temperature was applied using foil contractility tester 2010 (Fig. 3).

The goal of such test was to determine and assess the degree that packaging material was modified to as a result of impact of temperature, and to determine whether it affected its external condition. The subject of this test was a sachet, in order to obtain results, 4 fragments in the shape of a circle were cut out. These fragments were exposed to high temperature, that is, 150°C for 30 seconds, 60 seconds, 90 seconds and 120 seconds.

2.2. Results and discussion

As a result of conducted tests, test material was collected and its analysis allowed to determine and assess the impact of specific conditions on the packaging material used in the transport processes.

The first test that was conducted was a compression test. Two out of three selected packagings, that is, jar and bottle were tested. Both these packagings are made of polypropylene material and have hard structure. Cream jar can't be bent manually, whereas, bottle is affected by pressure force. Test, in accordance with assumptions, was conducted with the use of a test machine QC-505M1.

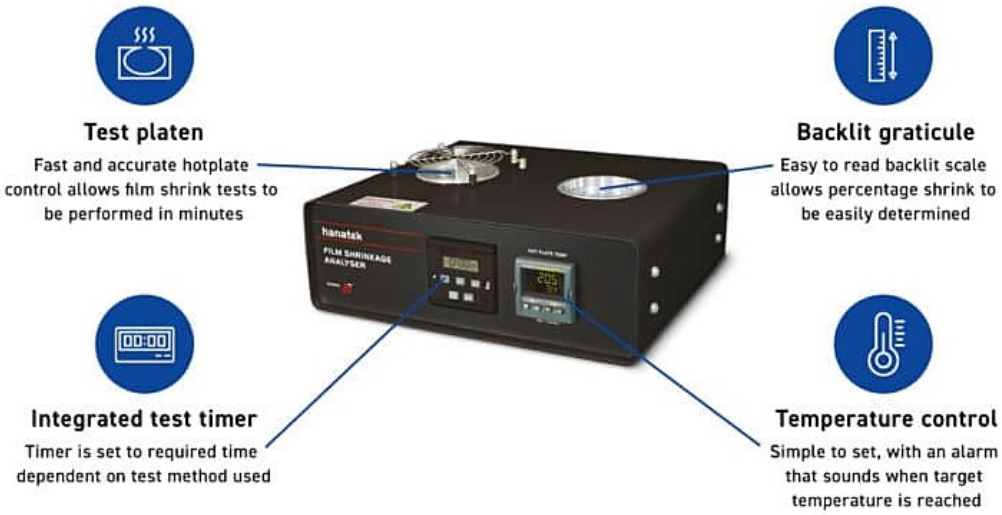

Fig. 3. Foil contractility tester 2010 [22]

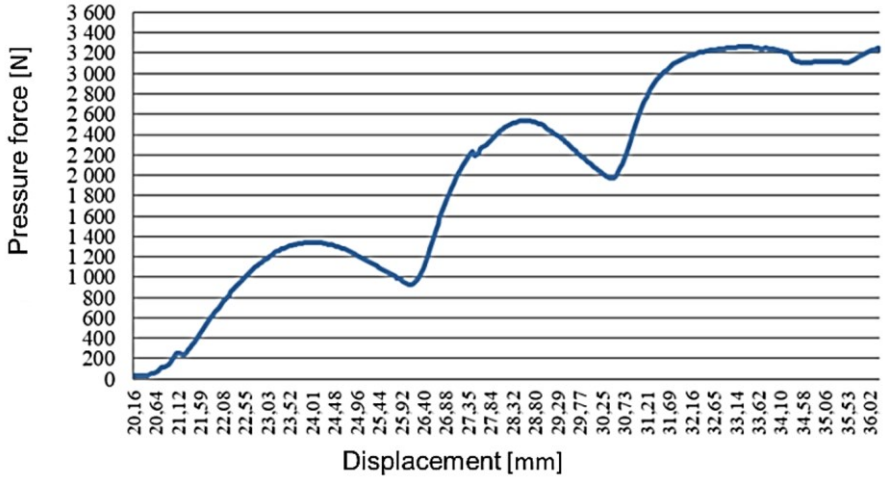

Fig. 4. Pressure force in a punch displacement function during static pressure test for the jar

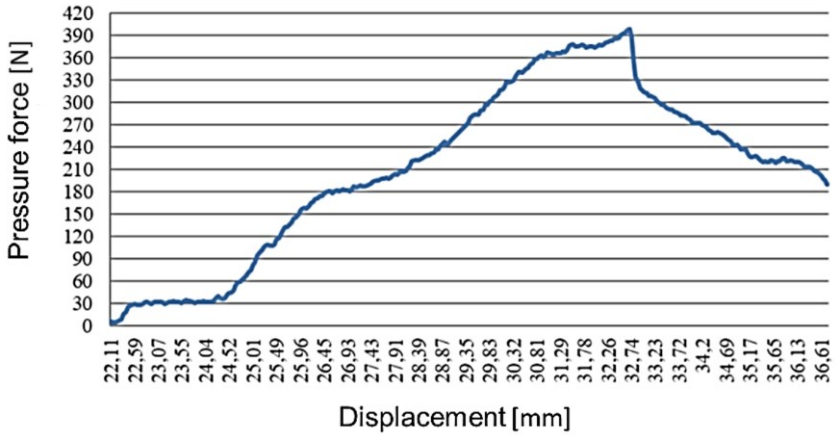

Fig. 5. Pressure force in a punch displacement function during static pressure test for the bottle

Appearance of the packagings before and after the test clearly showed that both analysed materials were deformed and such deformations were of irremediable character. The changes are visible, among others, in the bottom batches of the packagings in the form of dents. As a result of permanent changes, there was a problem with opening and closing them again. Affected by pressure force, substances inside the packaging would be contaminated or permanently damaged resulting in products not suitable for use.

During compression test, movement of punch and values of pressure force were recorded. The course of this process was presented on Figure 4 and 5 [18]. Jar, which was the subject of the test, has been broken already at an initial stage of the test, it was accompanied by typical sound showing breaking of plastic. The packaging was exposed to 1342,26 N and it was a maximum pressure force.

Whereas, the results of the test of analysed bottle show that packaging is less resistant to pressure force than the jar. This property was observed earlier when packagings were attempted to be modified manually. It is confirmed by maximum value of impact force, that is, 398,03 N.

Comparing results obtained in this test, it was found that the jar is made of harder material than the bottle, and it is more resistant to pressure force that the packagings may be affected by during transport process. Pressure force that the jar was exposed to was higher by 237,23% than force that the bottle

was exposed to (Fig. 6.) [18].

Then, tensile strength test was conducted on the sachet. Force has considerably damaged the sachet, which excludes its market trade. Such damages of the packaging would contaminate substances inside the packaging and as a result, it was no longer a product of full value. Whereas, Figure 7 presents relation between tensile force and movement of punch [18].

Conducted analysis showed that the sachet was exposed to maximum force of 209,03N. The packaging was destroyed (Fig. 7.).

Then, global migration test was conducted on the samples of packaging materials. The weight of the samples before and after the test was presented on Table 3 [18].

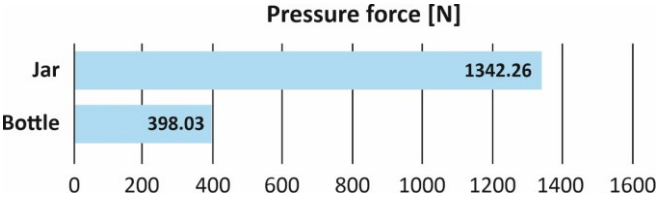

Fig. 6. Relation between pressure force and type of a packaging

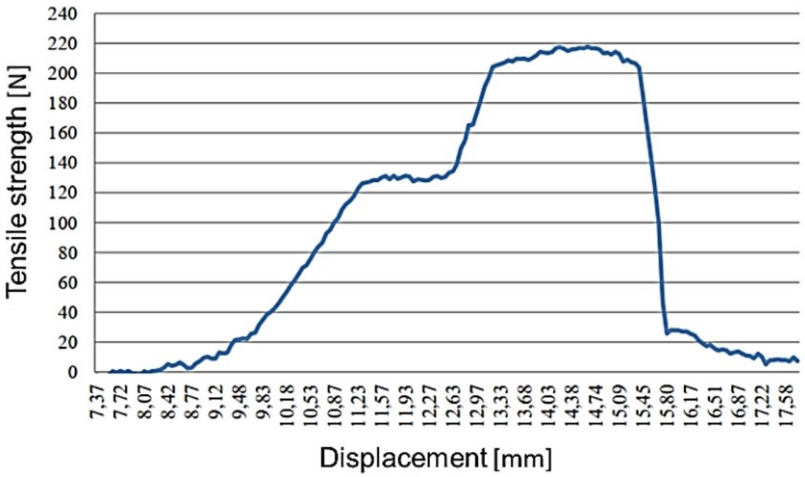

Fig. 7. Tensile force in a punch displacement function for the sachet

Table 3. The samples of the packagings before and after global migration

SACHET			
	Sample 1	**Sample 2**	**Sample 3**
Weight before [g]	9,3957	9,4009	9,4118
Weight after [g]	9,4114	9,5602	9,4119
Symulant	3% CH_3COOH	Rapeseed oil	10% ethanol
JAR			
	Sample 1	**Sample 2**	
Weight before [g]	15,7201	15,9212	
Weight after [g]	15,6877	15,9037	
Symulant	3% CH_3COOH	10% ethanol	
BOTTLE			
	Sample 1	**Sample 2**	
Weight before [g]	10,4940	10,7927	
Weight after [g]	9,9996	10,0343	
Symulant	3% CH_3COOH	10% ethanol	

Sachet, as the first test object, was immersed in all three substances, that is, 3% CH_3COOH, rapeseed oil and 10% ethyl alcohol in temperature of 29°C for 48 hours. After a lapse of this period of time, appearance of the packagings was checked.

Inspection of the sachets showed that the packagings have not significantly changed in visual terms, however, weight of sample no. 1 and no. 2 has changed as a result of conducted experiment. It may show negative impact of acetic acid and rapeseed oil on the quality of examined packaging.

Another subject of the test was a jar that two out of three available tests were conducted on. Emptied packagings were filled with 3% CH_3COOH and ethyl alcohol. The test lasted 48 hours, and samples were filled with 29°C solution.

Comparative analysis showed that jar has not changed as a result of conducted migration test, and differences in weight before and after the test were not significant.

Another type of a test was conducted on the bottle upon immersion in 3% CH_3COOH and rapeseed oil.

Just like in the case of the jar, packaging material has not changed, however, differences in weight were higher. The weight of the first sample was lower by about 0,5 g, whereas, of the second sample by nearly 0,8g. These results show that both acetic acid and ethyl alcohol have negative impact on quality of the bottle, which may cause adverse effects.

As a result of conducted test, it was found that in the event of the first analysed packaging material, that is, sachet, it reacts with acetic acid and rapeseed oil. The jar is resistant both to rapeseed oil and 10% ethyl alcohol. Whereas, the bottle reacted both with oil and ethyl alcohol. The results of this test show that packagings lose their weight after immersion in specific solutions.

The last test, that is, strength test shows how the packagings behave after exposure to high temperature, that is, 150°C. The goal of this test, as it was mentioned before, was to determine the changes in appearance and properties of analysed packagings.

Test was conducted with the use of a test machine, which was heated up to temperature of 150°C, and then packaging material was placed in it (cut out from the sachet) and tested in four various time periods, that is, between 30 seconds and 120 seconds. It was aimed at verification of temperature that packaging is resistant to and under what external conditions their protective functions will be fulfilled for the substance inside.

Conducted analysis showed that the sachet was deformed after 30 seconds, and the longer it was exposed to high temperature, the more visible and larger were deformations. It was be observed that directly after the test, deformations are larger, whereas, they are reduced after a lapse of next 10 seconds. The results obtained from conducted tests show that temperature significantly affects quality and shrinkability of a sachet. Packaging material exposed to high temperature has considerably shrinked and also changed its shape.

As a result of conducted tests, it was found that additional protection of the packagings is required to conduct transport processes. The following methods can be applied for this purpose: wrapping the packagings up using a shrink film, cargo tapes or the use of a bubble wrap. The application of additional protection of the packagings is significant because tests showed that the packagings are deformed under the influence of high pressure. Bubble wrap is used for filling packagings and absorption against mechanical damages occurring in transport. The use of a shrink film secures packaging materials against harmful impact of atmospheric factors, pollutants and humidity. The application of additional protection will minimize the risk of damages and losses of products during transport processes.

CONCLUSIONS

Conducted analysis determined the moment that packaging materials ceased to fulfil their function and when deformations occurred. Tests were of strength character. Packaging material was subjected to the tests of pressure force, compression force, tensile force and exposure to high temperature. In addition, global migration test was conducted on the packagings, that is, complete immersion or filling of samples.

The goal of conducted tests was to analyse the impact of selected factors occurring in transport processes on the packagings. Three various types of plastic packagings were selected to conduct tests: sachet, empty cream jar and bottle. The sachet was subjected to tensile strength test, global migration test and exposure to high temperature. Whereas, two types of tests, that is, compression test and global migration were conducted on empty cream jar and bottle.

Firstly, strength test was conducted under the influence of pressure force. Both materials were deformed after the test. However, pressure force affecting the jar was higher by 237,23% than those affecting the bottle. Therefore, it can be clearly stated that the jar is made of harder material than the bottle and it is more resistant to pressure force during a process of transport. However, due to susceptibility of both packaging materials to pressure, it is important to apply additional protection in the

form of fastening tapes that would prevent mechanical damages resulted from moving of the packagings during transport processes.

Then, test was conducted on the sachet, that is, tensile strength test. Packaging material was exposed to maximum force of 209,03N. The sachet has been considerably damaged. Due to the fact that tested material has no appropriate tensile strength, one of the methods to secure it during transport is the use of a bubble wrap, which sufficiently protects against exposure to unfavourable factors.

All three examined packagings were subjected to global migration. All samples were weighed. Then, each of them was immersed in three substances, that is, 3% CH_3COOH, rapeseed oil and 10% ethyl alcohol in temperature of 29°C for 48 hours. In the event of the sachet, visual appearance has not changed, however, weight of sample no. 1 and 2 has changed. No visual changes were found during test on the jar, and differences in weight before and after the test were not high. Test of the last packaging has also not shown visual changes. Whereas, differences in basis weight of a packaging have been observed. The weight of the first sample was lower by about 0,5 g, whereas, of the second sample by nearly 0,8g. These results show that both acetic acid and ethyl alcohol have negative impact on the quality of the bottle and sachet. The jar is resistant both to rapeseed oil and 10% ethyl alcohol. In order to fully protect them against liquid substances, additional protection in the form of a shrink film should be used.

The last test checked resistance of the packaging to high temperatures. It was conducted on the sachet in temperature of 150°C. Test showed that sachet was deformed after 30 s, and the longer exposed to high temperature, the more visible were deformations. The results obtained from conducted tests show that temperature significantly affects the quality and shrinkability of a sachet. Therefore, transport of such packagings should take place in controlled temperature.

An analysis of conducted tests showed that packaging material that is the most resistant to pressure was the jar, which also during global migration test, as opposed to the sachet and bottle, has not changed. Negative results of the test were obtained for the sachet. It is the least resistant to stretching. Therefore, during transport processes, bubble wrap should be secured. It was also tested also in terms resistance to high temperature. Packaging material has not withstood the test lasting 120s, so it requires transport under specific conditions.

BADANIA I OCENA JAKOŚCI OPAKOWAŃ W ASPEKCIE ICH ZASTOSOWANIA W PROCESACH TRANSPORTOWYCH

Opakowania pełnią istotną funkcję w gospodarce. Umożliwiają transport wszelkiego rodzaju produktów od nadawcy do odbiorcy. Ze względu na rosnące i zmieniające się potrzeby rynku opakowania muszą posiadać odpowiednią wytrzymałość na czynniki zewnętrzne, które mogą wystąpić podczas transportu. Dlatego ważne jest nieustanne dostosowywanie opakowań w kontekście spełnienia standardów dotyczących transportowania produktów. Celem artykułu jest analiza i ocena wybranych właściwości opakowań przeznaczonych na produkty kosmetyczne w aspekcie procesów transportowych. Przeprowadzono badania wytrzymałościowe (próba ściskania, próba rozciągania), badanie odporności opakowań na wysoką temperaturę oraz badanie zmian właściwości opakowań metodą zanurzenia. Analiza przeprowadzonych badań dała odpowiedź, czy opakowania chronią wystarczająco produkty w procesie transportowym..

Słowa kluczowe: proces transportowy, jakość opakowań i dostaw, bezpieczeństwo

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