INFLUENCE OF PACKAGING PROCESS ON MECHANICAL CHARACTERISTICS OF THE FLEXIBLE PACKAGING MATERIALS

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Abstract:
The paper aimed to examine if the mechanical characteristics (tensile strength, elongation, and friction) of the selected flexible packaging materials (BOPP and PET/PE) change after the packaging process. Some researchers have shown that mechanical characteristics can change because of the various effects to which foils are exposed (temperature, transport devices, solvents, etc.). The measurement of tensile strength and elongation was carried out according to SRPS G.S2.734, and the measurement of friction according to ASTM D 1894. The results show that there were no significant changes in the examined mechanical characteristics that could affect the functionality of the packaging.

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Printing, packaging, tensile strength, elongation, friction, foils

1. INTRODUCTION

Flexible packaging materials are an important group of packaging materials that are used to manufacture flexible food packaging. In the global flexible packaging market, the food industry has a share of 70 % [1].

Due to their good properties such as economic acceptability [2], good tolerability with foodstuffs, good barrier, mechanical, and optical properties, as well as suitability for processing on printing and packaging machines, these materials have an extremely wide application [3,4].

However, flexible packaging materials, especially metalized packaging films, are exposed to various influences of mechanical, thermal [5,6], or electrostatic nature during production, printing, and the process of packaging, and later during handling and distribution [7].

According to research [8], the packaging process may lead to a loss of barrier properties, due to the possible occurrence of pinholes. In researches [9] and [10] investigated how the packaging process or high-pressure processing affects the characteristics of metalized foils. Recent research in [11] investigated the effect of flexing on the barrier properties of a laminate comprising metalized films and aluminum foil.

The findings in the study [12] showed that mechanical characteristics depend on the type of packaging material.

Tensile strength and elongation of foils are important parameters within their mechanical properties [13]. Those characteristics show the suitability of the material for machinability during the entire technological process (printing, lamination, packaging), as well as resistance to transport [14], handling [15], and storage [16].

The foils are especially exposed to tensile forces on packaging machines, which must be safely withstood [17], to remain stable in dimensions and to avoid interference during operation [12].

Friction is of great importance for machinability in the movement of the film through the printing machine as well as for the behavior of the film during further processing, especially in packaging machines. The value of the coefficient of friction must be within the defined values so that further processing will be problem-free. The variability of

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the dynamic coefficient of friction in flexible packaging was tested in [18].

The goal of the present article is to find out whether there are changes in the mechanical properties of flexible packaging foils after the packaging process. To answer this question, we tested the selected packaging materials before and after the packaging process. Selected packaging materials are BOPP (biaxial oriented polypropylene) and PET/PE (multilayer polymeric packaging material composed of polyethylene terephthalate - PET and polyethylene - PE, obtained by lamination.

2. MATERIALS AND METHODS

Selected packaging materials that are tested are the most often used in the production facilities of domestic printing houses. From a whole range of different materials, two alternative packaging materials that are used for packing products in the form of flakes and other geometric shapes, including powder products, have been evaluated.

For this paper, the following materials were selected for testing:

1) BOPP 40 μm (biaxial oriented polypropylene) is used for packing the corn in grain. The characteristics of this material are given in Table 1. BOPP is generally characterized by good transparency and gloss, low permeability to water vapor, and good mechanical strength [19];
2) PET/PE (multilayer polymeric packaging material composed of polyethylene terephthalate (PET) and polyethylene (PE), obtained by lamination, is used for packaging the coconut flour. The characteristics of PET material are given in Table 2. In this combination of foils, the carrier material is PET, which gives strength, and mechanical and optical properties, while the polyethylene layer serves as a heat-sealable joint [20];
3) Polyethylene (PE) is used for laminating the PET material. The characteristics of this material are given in Table 3.

The samples were printed on a column printing machine, type ZBS 450, with 6 printing aggregates, printing width of 460 mm, printing length of 210 mm – 460 mm. The maximum speed is 50 m/min, and the drying temperature ranges from 60 to 75 degrees Celsius. Raster rollers of 800 l/in and 300 l/in are used. The photopolymer printing plate was 1.14 mm thick, Cyrel Fast type, 58 l/cm. The printing inks used are solvent-based "Termoflex" inks. Pressure adjustment is manual. The viscosity was 20 seconds. The tension was around 26 N (automatic adjustment). The drying temperature was around 70 degrees Celsius.

Table 1. BOPP characteristics

Characteristics	Value (according to standard)
Thickness, μm	40
Weight, g/m^2	36,4
Density, g/cm^3	0,91
Tensile strength lengthwise, N/mm^2	140
Tensile strength crosswise, N/mm^2	250
Relative elongation at break crosswise, %	70
Relative elongation at break lengthwise, %	200
Coefficient of friction	0,3
Surface tension, mN/m	38

Table 2. PET characteristics

Characteristics	Value (according to standard)
Thickness, μm	12
Yield, g/m^2	59,5
Tensile strength, lengthwise, N/mm^2	196
Tensile strength, crosswise, N/mm^2	206
Relative elongation at break lengthwise, %	100
Relative elongation at break crosswise, %	90
Coefficient of friction	54
Surface tension, mN/m	38

Table 3. PE characteristics

Characteristics	Value (according to standard)
Thickness, μm	58
Width, mm	383
Density, g/cm^3	0,925
Surface tension, mN/m	≥ 38

To obtain PET/PE packaging materials, PET material is laminated after printing. For lamination, solvent-free adhesives Novacote SF-724-A and Novacote CA-324, which are mixed in a ratio of 2:1, were used.

Tensile strength and elongation were tested on a Shimadzu EZ-LX machine according to the ISO 527-3 method.

Tensile strength and elongation at break of the tested samples are expressed as the mean value of individual measurements, both longitudinally and transversely to the direction of winding of the foil.

Foil friction testing in this paper was performed on a Slipping Tester Type RK 2 E, according to ASTM D 1894. The test was performed on foil samples measuring 100 x 200 mm, with a normal sliding vapor load weighing 200 g, a metal weight surface (according to ASTM D 1894) of 40 cm^2, and a sliding speed of 100 mm/min.

3. RESULTS AND DISCUSSION

In the present article, we investigated whether the mechanical characteristics of flexible packaging, (tensile strength, elongation, and friction), change after the packaging process.

Figures 1 and 2 show the results of testing the mechanical properties (tensile strength and elongation) of the BOPP foils.

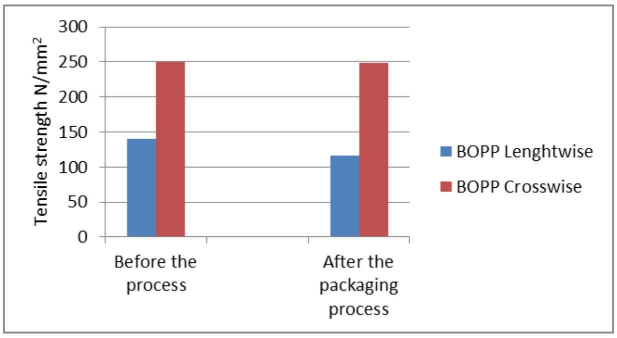

Fig. 1. Tensile strength of BOPP foils before and after the packaging process

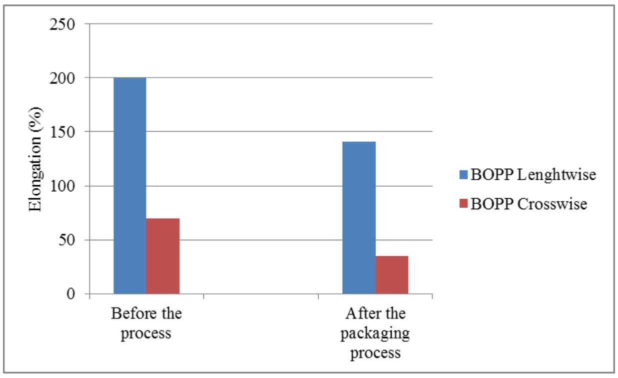

Fig. 2. Elongation of BOPP foils before and after the packaging process

The value of tensile strength of BOPP film, compared to the declared value, decreased, and this change amounted to 16% in the longitudinal direction, while it remained unchanged in the transverse direction.

Elongation in the longitudinal direction decreased by 29%, and in the transverse direction by 50%. The reasons for this behavior of the material may be different. One possible explanation is that the foils during the printing and packaging process are exposed to increased stretching forces, which may be a consequence of the increased speed in the foil movement process, the influence of discontinuous machine operation, and temperature [9,18].

Figures 3 and 4 show the results of testing the mechanical properties (tensile strength and elongation) of the PET/PE foils.

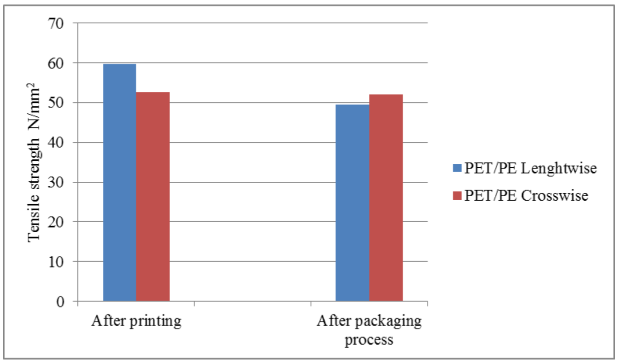

Fig. 3. Tensile strength of PET/PE foils before and after the packaging process

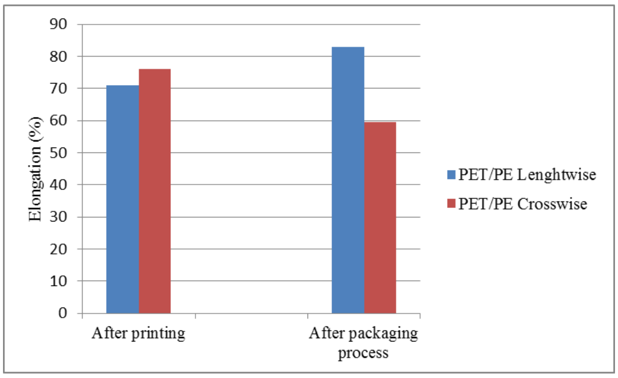

Fig. 4. Elongation of PET/PE foils before and after the packaging process

In the case of PET/PE film, the tensile strength values decreased by 16.9% in the longitudinal direction after the packaging process and remained the same in the transverse direction. After the packaging process, the elongation increased by 16.9% in the longitudinal direction and decreased by 21.57% in the transverse direction.

It should be noted that in the tested multilayer material PET/PE, the PET mono-material has dominant mechanical characteristics. Since the increase in the tensile strength of the laminate compared to the mono-material was noted, it is assumed that the material still retains positive mechanical properties.

It is important to note that the specificity of printing materials is that they are viscoelastic materials with very complex behavior.

In the case of printing materials, with unchanged stretching, the tension of the foil constantly drops. When such a loaded material is unloaded after some time, it does not return to the original length that it had in the unloaded state but remains elongated. Since it is generally printed on stretched foil, the length of repetition, at least in the area of printing devices, is shorter than the length of printing, i.e., the length of the printed format. If the printed film is permanently stretched after passing through the printing device due to excessive stress - e.g., in the winding device - and/or due to excessive heating in the drying device, then in the end the length of the repetition may be greater than the length of the format. The assumption for a constant repeat length is that the film passes through the printing devices with a constant stretch, which means constant stress. If different lengths of repetitions appear on one strip despite constant traction forces, then the reason for the deviation of those lengths must be found in unequal strength parameters in the material of the strip itself. Differences in film thickness and local strength in the cross-section are the reasons for this.

Figures 5 and 6 show the results of testing the coefficient of friction of the BOPP foils.

The coefficient of friction of the BOPP film decreased after the process of printing and forming the packaging. The results are within the allowed limits, so it can be assumed that there will be no problems during further manipulation of the material [9,21].

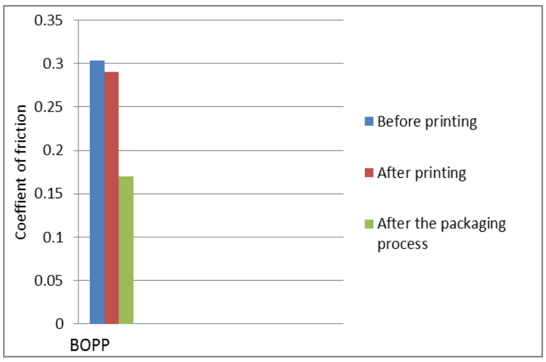

Fig. 5. Coefficient of friction of BOPP foils before and after the packaging process

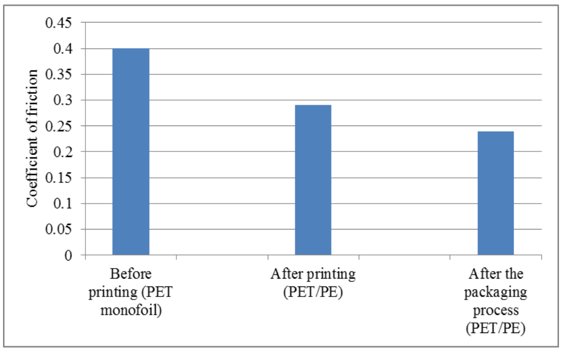

Fig. 6. Coefficient of friction of PET/PE foils before and after the packaging process

With PET mono films, the coefficient of friction is high, but after lamination and printing, it decreases (Figure 6). The coefficient of friction of PET/PE film after the packaging process decreased compared to printed film, but the values lie within the recommended values.

The coefficient of friction can be adjusted according to the requirements by adding sliding agents when extruding the foil. The friction value must be in the recommended range for the inside, between 0.2 and 0.3. The reason for the change in the coefficient of friction in multi-layer foils may be due to the laminating process, which was examined in the work of [18]. The coefficient of friction changes when the materials are combined into a laminate. The results showed that due to the influence of lamination and migration of sliding additives, there is a difference in the value of the friction coefficient, and the reason for these results is the change in the characteristics of the material.

The coefficient of friction in multilayer films containing migrating slip additives can be problematic. Namely, the additives can migrate and be transferred to the back side of the foils that are wound in a roll, and in this way, it is not possible to reduce the coefficient of friction. Layer migration is influenced by the solubility of additives in the layers, e.g., amide fatty acid slip additives are more soluble in polar polymers. Temperature is also one of the factors affecting the solubility of amides. It follows that slip additives in one layer are unlikely to remain in that layer. This should be taken into account when deciding how much additive to add and in which layers.

Overall, with all examined materials, it was established that the packaging process affects the slipperiness, i.e., the foil/metal friction coefficient. However, in addition to friction, important factors in shaping the material are the properties of the material itself, the imprint, the geometry of the molding body, and the upper surface of the material. Therefore, to achieve a reliable result and determine the reason for the unchanged or changed coefficient of friction, it would be necessary to carry out additional tests.

4. CONCLUSION

From the results of measuring the tensile strength and elongation of the selected flexible packaging materials, it can be concluded that their behavior is different. In all tested materials, the tensile strength and elongation decreased to a greater or lesser extent after the packaging process. One of the reasons may be increased tensile forces in the packaging process, as well as increased production of packaging.

However, to confirm these results, tests should be done with other packaging materials and on other packaging machines.

To more accurately determine the values of tensile strength and elongation significant for printing and packaging processes, it would be necessary to measure the tensile strength and elongation of the material in the area of elongation up to 2%, which was not possible in this work.

Although the results of testing the tensile strength and elongation of flexible packaging films after the packaging process for some films show that there are changes, it cannot be said with certainty whether the determined reduction can affect the functional characteristics of the packaging. However, given that printing materials are viscoelastic materials with very complex behavior, changes in the characteristics of foils during the printing process itself (stress and stretching of the foil), primarily due to the effect of temperature and traction forces on the foil, can affect the quality of printing, the appearance of deviations in the passer, the length of the repetition, as well as the creation of folds in the printing foil.

Future research may extend this work with other types of materials, printing, and packaging techniques.

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