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# SELECTED MECHANICAL PROPERTIES OF TPS FILMS STORED IN THE SOIL ENVIRONMENT.

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**Summary.** The results of measurements of susceptibility to biodegradation and the effect of storage in soil on the mechanical properties of thermoplastic starch films obtained from blends of starch, glycerol and emulsifiers. Studies have shown a varied influence of the blend compositions, extrusion conditions and storage on the scope and efficiency of biodegradation of the products.

**Key words:** biodegradation, mechanical properties, blends, storage.

## INTRODUCTION

Biodegradable plastics, which are a mixture of natural polymers, mainly starch (so-called thermoplastic starch - TPS) and cellulose are produced so far on a small scale. Nowadays products present on the market are *de facto quasi*-biodegradable, is still underway to obtain material fully biodegradable in the environment, which may be used in the manufacture of disposable utensils, gardening and packaging film and/or for the manufacture of garbage bags. The use of biodegradable plastics packaging industry is limited mainly because of financial reasons, due to higher production cost compared to traditional materials and because of the still numerous technical imperfections [4, 5, 6, 7, 8].

## MATERIALS AND METHODS

Research on the process of TPS film extrusion with the addition of emulsifiers with an assessment of basic physical properties of the products obtained was carried out in laboratories of the Department of Food Process Engineering (KIP) of the Lublin University of Life Sciences in 2009-2010.

The film was extruded from TPS pellets on a specially designed laboratory line using blowing technique. That line was performed by SAVO Ltd. Co. from Warsaw (Fig. 1).

TPS pellets were made by extrusion-cooking (baro-thermal treatment commonly used in food sector) in a modified single screw extrusion-cooker TS-45 (ZMCh Metalchem Gliwice, PL). Compound consisted of potato starch (ZPZ Łomża), glycerol (Odczynniki Chemiczne Lublin) and polymers: I - Octene-1 Plastomer EXACT TM 8201, and II - EVA Copolymer (Exxomobil Chemical LTD, UK) having excellent strength parameters and water resistance (Tab. 1).

The extrusion-cooking process was conducted in the temperature range 90-130oC, with a screw rotation from 60 to 120 rpm.

Strength and mechanical properties tests were conducted in accordance with the current methodology of research [2].

Fig. 1. TPS film blowing in KIP laboratory [8]

Table 1. Composition of compound

| **Pellets/specification** | **Composition [%]** |
|---|---|
| Probe SP | Potato starch - 77 |
| | Emulsifier I - 1 |
| | Glycerol - 22 |
| **Probe 2SP** | Potato starch - 68 |
| | Emulsifier I. - 12 |
| | Glycerol - 20 |
| **Probe 3SP** | Potato starch - 72 |
| | Emulsifier II. - 8 |
| | Glycerol - 20 |
| **Probe 4SP** | Potato starch Skrobia - 68 |
| | Emulsifier II.- 12 |
| | Glycerol - 20 |

During film extrusion the film tubes with a diameter of 150 to 700 mm and thickness from 0.15 to 0.6 mm were obtained, depending on the composition of the pellets. Film extrusion process parameters are given in Table 2.

Table 2. Terms of TPS film extrusion

| **Probe** | **Screw rpm** | **Motor load [A]** | **Temperature in an extruder's zones [$^o$C]** | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | **Barrel** | | | | **Die** | | |
| | | | *1* | *2* | *3* | *4* | *I* | *II* | *III* |
| SP | 70 | 8 | 110 | 84 | 130 | 122 | 130 | 140 | 120 |
| 2SP | 70 | 12 | 117 | 88 | 135 | 122 | 130 | 149 | 125 |
| 3SP | 70 | 11,8 | 116 | 89 | 138 | 124 | 134 | 145 | 121 |
| 4SP | 70 | 6,6 | 114 | 91 | 177 | 130 | 139 | 142 | 122 |

The resultant film samples were evaluated for biodegradability in soil by using a simplified methodology based on our experiences and described in many works. Film samples before storage as well as during it were periodically tested for mechanical properties in universal testing machine Zwick BDO-FB 0.5TH ; the moisture content of films was also determined in individual stages during storage.

## RESULTS

One of the main factor of the biodegradation of film is its susceptibility to moisture absorption during storage in the soil at the landfill or in natural conditions and loss of strength characteristics . Table 3 presents the results of measurements of moisture content changes during the film stored in the soil; the measurement results of basic mechanical characteristics are presented in graphic form (Figure 1-8).

Table 3. Humidity films in various stages of storage

| **Moisture content [%] /probe** | **SP** | **2SP** | **3SP** | **4SP** |
|---|---|---|---|---|
| Moisture after extrusion | 9,5 | 6,5 | 6,31 | 6,87 |
| Moisture priori storage | 10,6 | 8,7 | 8,9 | 9,8 |
| Moisture after 20 days | 60,3 | 52,5 | 54,1 | 56,3 |
| Moisture after 40 days | 64,4 | 52,9 | 61,1 | 59,8 |
| Moisture after 60 days | spread | 65,8 | 64,8 | 69,6 |

The resistance to puncture foil was carried out in four stages. In the first stage, measurements were made immediately after manufacture, the second stage, after 20 days at the film in the ground, the third after 40 days at the film in the land, while in the fourth stage after 60 days of burying the film. Examination of these samples allowed us to determine the force required to rupture, maximum stress and elongation at the puncture from the destruction of the sample as well as the degree of biodegradability.

Based on the results of research can be said that, the film received from SP, 2SP, 3SP, 4SP pellets, despite the tensile strength is relatively resistant to puncture. Maximum puncture force ranged from 7.73 N to 16.82 N, whereas the elongation at destruction ranged from 4.51% to 4.71%.

After 20 days of stay in the ground, the film moisture content ranged from 54.1% to 60.3% was the most durable 2SP film, where the maximum puncture force was 2.59 N and 5.93% elongation, and proved to be the weakest SP film, where the maximum penetration force was 0.94 N and 4.53% elongation. It was found that humidity had a decisive influence on films (Table 3).

After 40 days of storage, the maximum force of penetration ranged from 0.79N to 0,49 N, while the elongation at destruction ranged from 6.66% to 7.04%.

2 months storage resulted in total destruction of the sample films of SP and 4SP, they were not suitable for testing (see Fig. 9 and 11). Samples of 2SP (Fig. 10) and 3SP films showed maximum force of penetration: respectively 0.33 N and 0.23 N and extending from the destruction amounted to 6.68% and 6.6%.

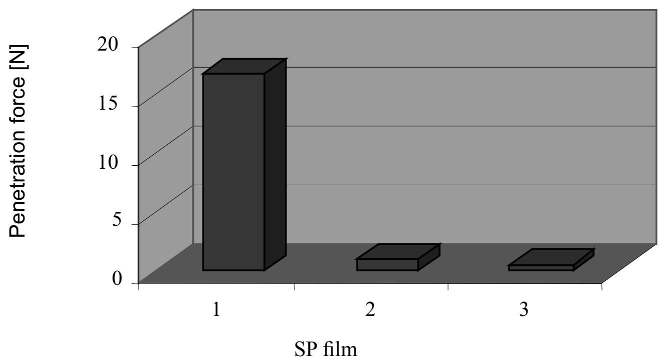


Fig. 1. Comparison of penetration forces of SP film. 1 - test results after production, 2 - after 20 days, 3 - after 40 days of storage

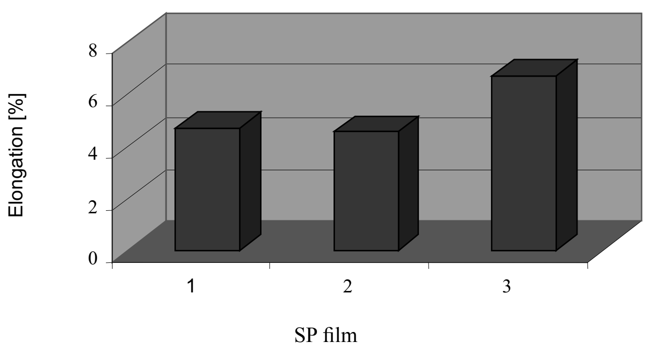


Fig. 2. Comparison of susceptibility for elongation of SP film. 1 - test results after production, 2 - after 20 days, 3 - after 40 days of storage

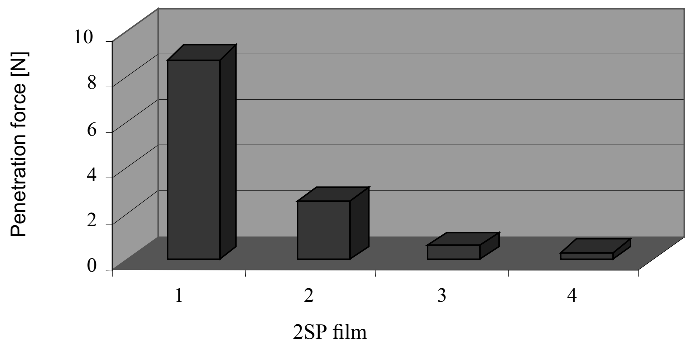


Fig. 3. Comparison of penetration forces of 2SP film. 1 - test results after production, 2 - after 20 days, 3 - after 40 days, 4 - after 60 days of storage

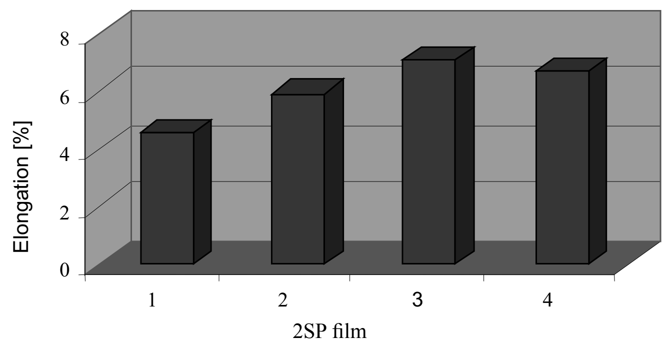


Fig. 4. Comparison of susceptibility for elongation of 2SP film. 1 - test results after production, 2 - after 20 days, 3 - after 40 days, 4 - after 60 days of storage

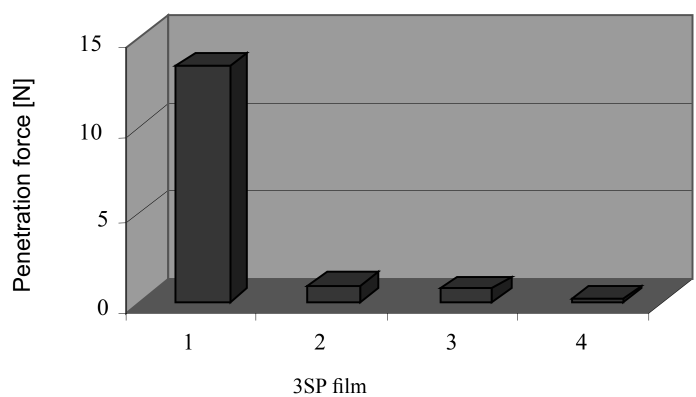


Fig. 5. Comparison of penetration forces of 3SP film. 1 - test results after production, 2 - after 20 days, 3 - after 40 days, 4 - after 60 days of storage

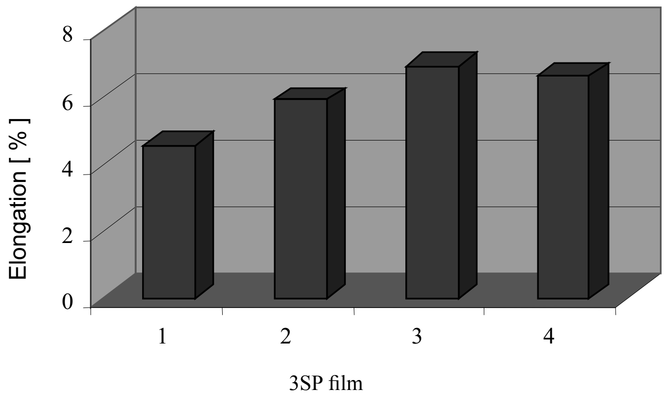


Fig. 6. Comparison of susceptibility for elongation of 3SP film. 1 - test results after production, 2 - after 20 days, 3 - after 40 days, 4 - after 60 days of storage

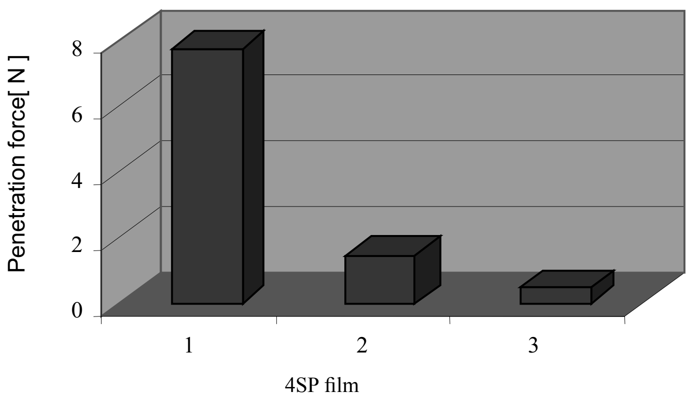


Fig. 7. Comparison of penetration forces of 4SP film. 1 - test results after production, 2 – after 20 days, 3 -, after 40 days of storage

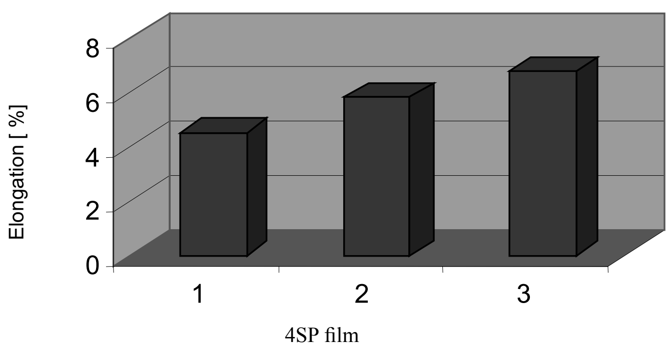


Fig. 8. Comparison of susceptibility for elongation of 4SP film. 1 - test results after production, 2 - after 20 days, 3 - after 40 days of storage

Fig. 9. Film SP after 60 days of storage [8]

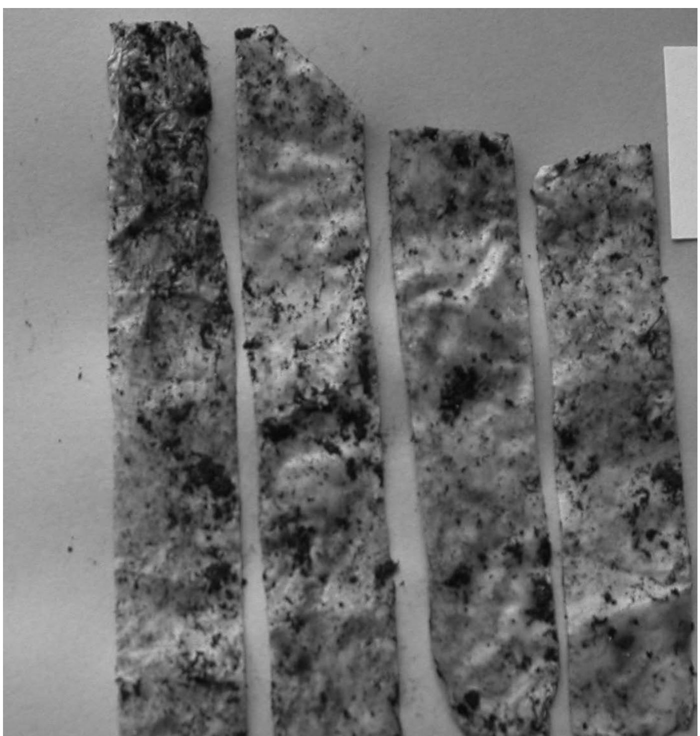

Fig. 10. Film 2SP after 60 days of storage [8]

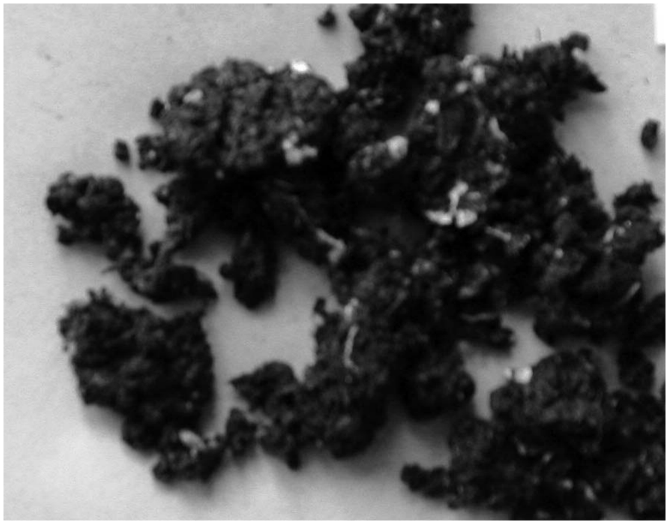

Fig. 11. Film 4SP after 60 days of storage[8]

## CONCLUSIONS

The analysis of the obtained results of mechanical properties of extruded TPS films stored in the soil showed that:

- Susceptibility of film on the biodegradation depended on the composition of raw mixes (including the participation of emulsifier) and extrusion conditions.
- In addition to the storage time was also important the moisture content of soil where samples were stored.
- The best characteristics in terms of mechanical properties had film samples obtained from a mixture of 2SP containing 20% glycerol and 12% emulsifier.
- The most biodegradable were films produced from a mixture of SP - emulsifier free and 4SP processed at the highest baro-thermal conditions. In both cases, the decisive factor was the nature of changes occurring in starch during the manufacturing process and storage time.

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## WYBRANE WŁAŚCIWOŚCI MECHANICZNE FOLII SKROBIOWYCH SKŁADOWANYCH W GLEBIE

**Streszczenie.** W pracy przedstawiono wyniki pomiarów podatności na biodegradowalność oraz wpływu przechowywania w glebie na wybrane właściwości mechaniczne folii otrzymywanej z mieszanek skrobi termoplastycznej z udziałem gliceryny i emulgatorów. Badania wykazały zróżnicowany wpływ kompozycji mieszanek, warunków wytłaczania oraz przechowywania na zakres i efektywność biodegradacji badanych produktów.

**Słowa kluczowe:** biodegradowalność, właściwości mechaniczne, mieszanki, przechowywanie.