

## The anisotropic nature of the strain of biodegradable film produced from TPS starch

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**Summary.** The paper presents results of research aimed at checking the anisotropic nature of the biodegradable film produced from potato starch. On the basis of tension test, Young's modulus as well as breaking force values were determined for material samples cut from the film in directions parallel and perpendicular towards to its production direction. Occurring differences in the longitudinal modulus of elasticity and breaking force values depended on the procedure of sample preparation and indicated the tested material anisotropic nature. Additionally, the influence of granulated raw material composition on the film thickness and strength parameters was examined.

**Key words:** biodegradable film, anisotropy, Young's modulus, breaking force.

### INTRODUCTION

Growing demand for disposable packaging contributed to the significant development of the packaging market. Simultaneously it created a problem with the waste management. The major setback is presented by the synthetic packaging which vast amounts pollute the environment. One of the solutions to this problem is recycling. However, recycling generates high costs and brings difficulties with an appropriate waste segregation. Unquestionable merit of the biodegradable packaging is that it does not spoil the environment and constitute a serious alternative for plastics which composting and degradation requires large amounts of energy.

Regarding ecology, the most favourable way to reduce the used packages is to produce biodegradable package materials [2, 8]. The first stage of the biodegradation process concerning traditional synthetic polymers can concentrate on plastics modification or introduction of supplements capable of solar radiation absorption [11]. In recent years in the industry, materials obtained from polyolefine polymers supplemented with modified starch, also called thermoplastic starch (TPS), have been introduced. They belong to a generation of biodegradable materials based on

natural resources. Starch is relatively cheap and fully biodegradable. It can get plasticized through the barothermal treatment as long as proper plasticizers are added [12, 15]. Unfortunately, the materials manufactured from a starch alone tend to brittle, are not water-resistant and change mechanical properties due to the recrystallization process. Determined strength parameters values also vary according to the way of load [5, 10, 17, 18]. In the case of biological samples, encountered difficulties stem primarily from the specific cellular and structural material building. The literature data shows that the plant material can exhibit both isotropic [6, 7, 13], as well as anisotropic [16, 18] character.

The aim of this study was to examine mechanical anisotropy through



**Fig. 1.** Stand for film extrusion [14]. The line was produced by SAVO, Wiązowna the Young's modulus and breaking force values determination for the biodegradable film produced from potato starch.

## MATERIALS AND METHODS

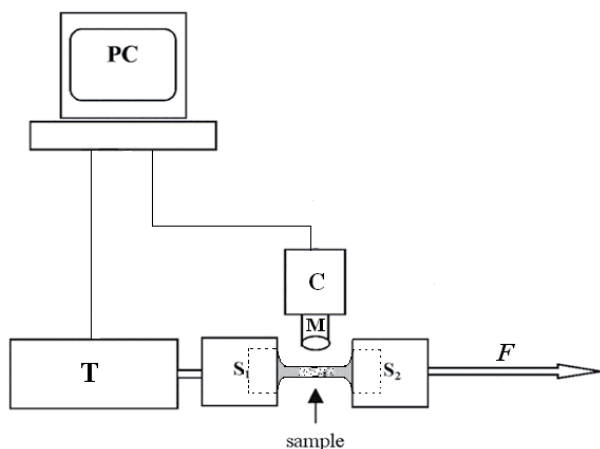
The thermoplastic starch granulate (TPS) was obtained by the extrusion cooking process, commonly known in the farm and food processing. The basic materials were potato starch "Superior" from ZPZ Łomża, technical glycerol purchased at ZPCH Chemical Plants Odczynniki Chemiczne in Lublin, water and emulsifiers: BRIJ 35 and TWIN 20 (alcohol derivatives). Table 1 presents the composition of the mixtures used in the research [14].

The process of film extrusion with the blow moulding method application was conducted in the Department of Food Processing Engineering on a specially designed production line for laboratory film (Fig.1).

The mechanical properties of obtained materials were studied using an original method of random markers [4]. The material for examination was thin-layer sheets of biodegradable film. Young's modulus and breaking force determination was carried out by subjecting the film samples to uniaxial tension test. Figure 2 shows the outline of the measuring system. It should be mentioned that such a test usually requires calculation of the stress occurring near the clamps holding the sample while the main advantage of random markers test is the independence of the results from the boundary effects. The main assumption of the Saint - Venant principle, on which mentioned method is based is the fact that in a sufficiently large distance between the ends of the sample and mounting place, the stress distribution is homogeneous throughout its volume [1, 9].

The computer program „Video” [3] controlled process of collecting the data and the necessary calculations during the measurement.

Two types of samples were cut from the sheet of the film in order to carry the tests in both: the longitudinal and perpendicular axis of the sample regard to the direction of film production. The samples were dumbbell shape with a length of 40 mm and a width equal to 5 mm at its tapered part. Samples were cut



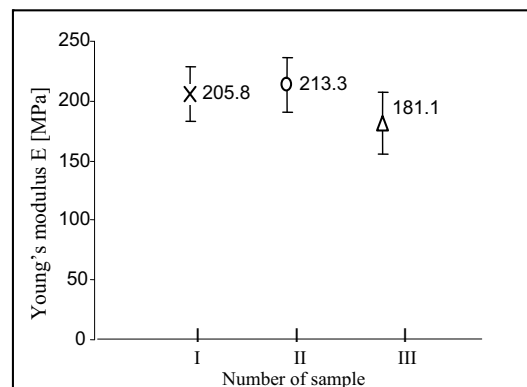
**Fig. 2.** A diagram of measuring station. C – camera, M – microscope object lens,  $S_1$  i  $S_2$  – clamps, T – tensometer,  $F$  – force

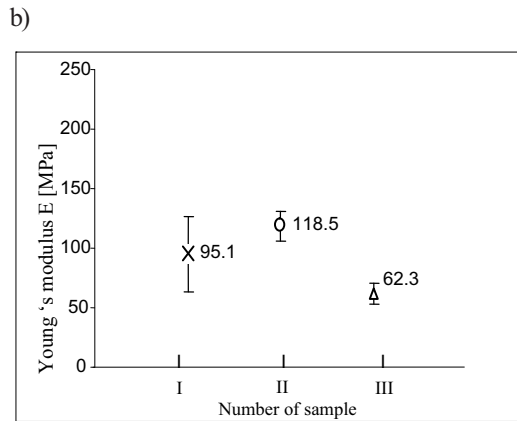
with a special blanking tool that provides dimensional stability. Since the method of random markers requires a third dimension, the thickness of the sample was measured with the micrometer (accuracy  $\pm 0.01$  mm) application. Each measurement series consisted of 15 repetitions. The value of Young's modulus  $E$  for each sample was determined from the tangent of the curve, describing the dependence of  $\epsilon_x = f(\sigma)$ , slope angle, where  $\epsilon_x$  - relative elongation in the direction of the x-axis (stretching direction),  $\sigma$  - stress value (MPa). The arithmetic mean of all 15 individual measurements was the total value of elasticity modulus  $E$ . The study also allowed determining the breaking force value as the maximum value of the force at which destruction of the sample occurred.

## RESULTS AND DISCUSSION

Figure 3 presents the mean values of Young's modulus for the examined film, determined with the random markers method application. The values of longitudinal modulus of elasticity  $E$  differed depending on the choice of direction during sample preparation, which indicates the anisotropic nature of the tested material. In the case of samples that were cut parallel to the direction of film production, the value of Young's modulus was higher than calculated for the perpendicular direction. The highest values of  $E$ , above 200 MPa, were obtained for films I and II (Fig. 3a) and were almost two times higher than for samples that were cut in the perpendicular direction (Fig. 3b). Lower values of Young's modulus with increasing water content in the granules were noted for both ways of cutting the samples. Doubling the water content in the granules from 5 % to 10 % caused the decrease in  $E$  value by more than 15 % for samples cut in the direction of film production and more than 45 % for samples cut perpendicular. Samples of film III with 10 % of water content cut parallel to the direction of production were characterized by Young's modulus value at a level of 181 MPa, while for samples prepared in a perpendicular direction was nearly three times lower and amounted to 62.3 MPa (Fig. 3a and 3b).

a)

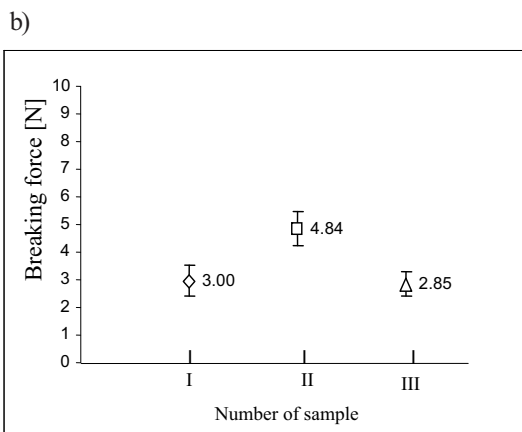
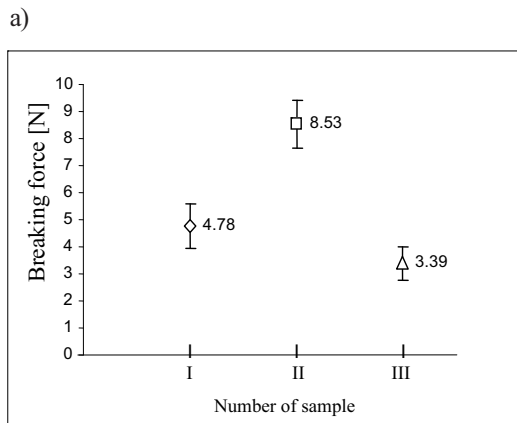




**Fig. 3.** Young's modulus average values with standard deviation for samples I, II III (Tab. 1) cut a) parallel and b) perpendicular to the direction of film production

**Table 1.** Biodegradable granulates material composition

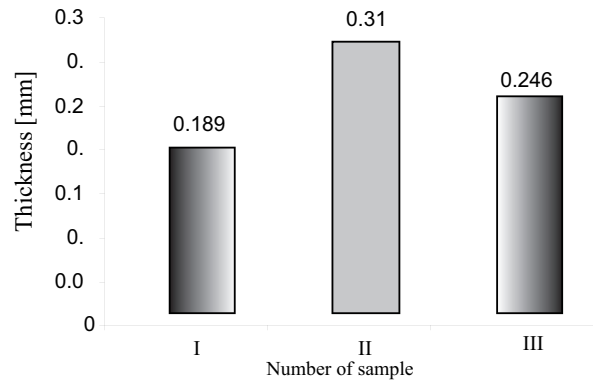
Sample		Glycerol	Emulsifier	Water
I	Potato starch	22 %	BRIJ35 2%	-
II	Potato starch	22 %	-	5 %
III	Potato starch	22 %	-	10 %



**Fig. 4.** Breaking force average values with standard deviation for samples I, II III (Tab. 1) cut a) parallel and b) perpendicular to the direction of film production

Similar relationships were obtained for the tested material when determining the value of breaking force. Film II, without added emulsifier, turned out to have the greatest resistance to rupture, for both methods of cutting the samples (Fig. 4).

The average force value required to destroy the samples from such material prepared parallel to the direction of film



**Fig. 5.** Examined biodegradable film's thickness for samples I, II, III (see Table 1)

production reaching 8.5 N, while for the perpendicular direction was lower by about 43%. The emulsifier presence in the composition of raw material resulted in a lower tensile strength of the produced material. The increase of water content from 5 % to 10 % in the granules without emulsifier resulted in the reduction of the breaking force (Fig. 4).

For such films, reduction in the value of the breaking force by about 60 % for samples cut in a direction parallel to the direction of film production and more than 40 % for film cut in the perpendicular direction has been observed. In the case of film I that contained the emulsifier in the granules, the observed breaking force values in a direction parallel and perpendicular amounted for respectively 4.78 MPa and 3.0 MPa. The smallest differences in the values of breaking strength were noted in the case of material III without emulsifier with 10 % water content in the granules. 3.39 N and 2.85 N respectively for samples cut in a direction parallel and perpendicular to the film production were needed to rupture the foil III (Fig. 4).

Figure 5 shows the differences in the thickness of the obtained biodegradable film sheets. The material made from granules containing 22 % of glycerol and 5 % of water addition (Table 1) turned out to have the greatest thickness measured with an accuracy of  $\pm 0.01$  mm. This film (II) was also over 1.5 times thicker than containing an emulsifier and glycerin foil I, and about 1.3 times thicker than the third film having in its composition glycerol and 10 % of water addition (Fig. 5).

Mechanical properties of the films determined during the examination showed a correlation between Young's modulus and breaking force values and both: the granular raw material composition and a way of preparing samples. The differences in the values of strength parameters in-

dicate that biodegradable films belong to the anisotropic materials group.

### CONCLUSIONS

The highest values of Young's modulus in the case of sampling in a direction parallel to the film production were obtained for films produced from the granules with the addition of an emulsifier (205.8 MPa) and for films with 5 % water content in the granules (213.3 MPa). These values were almost twice as high as in the samples cut perpendicularly to the direction of film production.

Doubling of water content in the granules from 5 % to 10 % resulted in the lower values of Young's modulus and breaking force in both directions.

In the case of material cut in a direction perpendicular to the direction of film production in the presence of the emulsifier composition in granular led to obtaining a rupture force values at the same level as at 10 % water content.

Determined, significant differences in the values of strength parameters of the tested material in two perpendicular directions indicate the anisotropic nature of the examined films.

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*This work was partially supported by Ministry of Science and Higher Education grant no. NN 313 70 47 40.*

#### ANIZOTROPOWOŚĆ ODKSZTAŁCENIA FOLII BIODEGRADOWALNEJ WYTWORZONEJ ZE SKROBI TPS

**Streszczenie.** W pracy przedstawiono wyniki badań mające na celu sprawdzenie anizotropowego charakteru folii biodegradowalnej wytworzonej ze skrobi ziemniaczanej. Na podstawie testu rozciągania wyznaczono wartości modułu Younga i siły zerwania materiału w przypadku próbek z folii wycinanych w kierunku równoległym i prostopadłym do kierunku jej wytwarzania. Występujące różnice wartości modułu sprężystości podłużnej i siły zerwania w zależności od sposobu preparacji próbki wskazywały na anizotropowy charakter badanego materiału. Porównano również wpływ składu surowcowego granulatu użytego do produkcji folii na jej grubość oraz na wartość wyznaczanych parametrów wytrzymałościowych.

**Słowa kluczowe:** folia biodegradowalna, anizotropowość, moduł Younga, siła zerwania.