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BIODEGRADABLE FOIL EXTRUDED FROM THERMOPLASTIC STARCH

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Summary. The work was designed to determine the influence of a screw kind, emulsifier used and moisture on the tensile strength parameters of biodegradable foil obtained from starch and glycerol. The results imply a direction of further development of studies on the biodegradable foil production technology.

Key words: biodegradable foil, extrusion, film blowing, emulsifier

INTRODUCTION

An increasing demand on disposable packaging has contributed to a substantial development of the packaging market, yet it caused another problem, i.e. waste management. The major drawback, however, is synthetic packaging which in vast amounts pollute the man environment. Recycling is a way to help out but it requires high costs and appropriate waste segregation.

Regarding ecology, the most favourable way to reduce the used packages is to produce biodegradable package materials [Roper and Koch 1990, Czerniawski 2001]. The first stage of the biodegradation process of traditional synthetic polymers can concentrate on plastics modification or introduction of supplements capable of solar radiation absorption [Korzeniowski *et al.* 1998]. In recent years there have been introduced materials obtained from polyolefine polymers supplemented with modified starch, termed thermoplastic, on the commercial scale of production. They belong to biodegradable materials based on resources of natural origin. Starch is a relatively inexpensive fully biodegradable material. Unfortunately, the materials manufactured from a starch alone tend to brittle, are not water-resistant and loose their mechanical properties due to the recrystallization process. Starch can get plasticized through the barothermal treatment as long as proper plasticizers are added [Leszczyński 1998, 1999].

MATERIALS AND METHODS

The investigations on foil extrusion process from the thermoplastic starch granulate (TPS) and physical properties measurements are performed in the laboratory of the Department of Food Process Engineering, Agricultural University in Lublin (Biopack project EU CRAFT 5 FP).

The TPS granulate was obtained by the extrusion cooking process, commonly known in the agricultural-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). The material composition of mixtures applied in the investigations are presented in Table 1.

Table 1. Material composition of biodegradable granulates

Sample	Potato starch	Glicerol	Emulsifier	Water
I N	Potato starch	22%	BRIJ35 2 %	-
II N	Potato starch	22%	BRIJ 35 1 %	-
III N	Potato starch	22%	-	5%
IV N	Potato starch	22%	-	10%
V N	Potato starch	22%	TWIN 20 2 %	10%
AB3/4	Potato starch	20%	-	-

The process of film extrusion with film blowing method was conducted on a line specially designed in K.I.P. for film manufacture for laboratory use (Phot. 1).The line was produced by SAVO, Wiązowna.

During the film blowing process, an obtained film sleeve was of varying diameter and thickness subject to granulate composition, the treatment temperatures from 90-140°C, screw rotational speed from 70-90 rpm and two screws of differentiated geometry (compression grade: 1.4 and 2.0).

The obtained film was subjected to the tensile strength tests using a materials testing machine Zwick BDO-FBO 0,5 TH type. The film resistance to stress and elongation was evaluated. The measurement of destructive force values consisted in the measure belt tensile at the crosshead shift speed of 100 mm/min. At the testing time the following were investigated: εM – tensile strength at max stress, σM – max stress, εB – tensile at break, σB – stress at break. The measure belts cut from foil were of 100 mm length and 20 mm width. The investigations were performed in six replications [PN – 68/C – 89034, Instr. obsł. testXpert, Soest *et al.* 1996].

Phot.1. Stand for film extrusion processing

The final research stage included the microscopic analysis of film on Studar G1 microscope type under polarized light with magnification from 50x to 400x to observe the presence of unprocessed starch in the produced material.

RESULTS

During the film extrusion and blowing, the film sleeves of different parameters were obtained. Depending on the processed granulate composition they were more or less flexible. In the first research stage there were applied mixtures composed only of starch and glycerol. The initial investigations confirmed a possibility of the TPS application in foil manufacture and at the same time they directed the further studies. The film obtained from pure mixtures with differing glycerol content got a little flexible and broke after cooling, despite good flexibility parameters showed throughout the blowing time. Therefore, our work aimed at film flexibility improvement after cooling as well as keeping proper mechanical properties for a long time.

Some new mixtures with 22% glycerol were used. Moreover, the mixtures I N and II N were supplemented with 2 and 1% emulsifier BRIJ 35, respectively. Whereas, the mixtures III N and IV N had only water additive in the amount of 5 and 10% dry mass. The mixture V N, apart from 10% water, contained a different emulsifier Twin 20 at amount 2%.

Although quite satisfactory effects were recorded at the mixture II N application, better results were obtained with a screw of higher compression ratio equipped with mixing elements (2.0 c.r.). The obtained film showed very high flexibility at blowing, while after cooling it maintained substantial flexibility and did not break. Yet, the film required the use of higher blowing temperatures (145°C).

The film originating from III N, IV N granulate were fairly flexible and transparent despite their great thickness but could not be blown sufficiently. Owing to a considerable water content, the extrusion process needs higher temperature to be employed.

The film produced from the mixture I + AB3/4 at 1:1 ratio demonstrated unexpectedly good effects – a sleeve was flexible and easily blown. Being cooled the film did not break and was flexible. More advantageous results, however, were observed when a screw of 2.0 ratio compression was used.

The film obtained from granulate V N could not be blown to appropriate degree due to a high water content, it remained very thick.

Employment of different screws not always had a significant influence on the final product. It is manifested by the film extruded from granulate I N. In both cases, irrespective of screw rotation and its geometry, it was impossible to get a film of satisfactory parameters. Under the influence of temperature the TPS granulate fed into became sticky and difficult for further treatment (Tab. 2).

Material	Screw speed rpm	Motor load A	Temperature °C							Screw compression ratio
			Barrel				Die			
			I	II	III	IV	d	m	u	
II N	80	8.4	101	102	136	116	122	123	117	2.0
II N	80	7.9	100	100	136	119	115	116	116	1.4
III N	80	12.5	112	101	136	117	124	131	121	2.0
III N	80	8.6	103	101	137	115	126	122	118	1.4
IV N	80	8.4	100	102	136	115	124	123	118	2.0
IV N	80	7.8	97	97	133	125	114	110	106	1.4
V N	80	8.4	98	90	138	114	142	139	135	2.0
V N	80	8.1	99	92	139	114	146	142	137	1.4
I N + AB3/4	80	7.8	91	90	137	123	124	125	124	2.0
I N + AB3/4	80	7.2	91	90	136	123	123	123	121	1.4

d – down thermocouple m – middle thermocouple u – up thermocouple

The obtained film was tested for stress and elongation. Some results of the investigations are given in Figures 1–6.

The effects obtained from the strength tests have confirmed good parameters of film from mixture II N despite the screws used. Percentage of the tested film elongation ranged from 40 to 130% relative to film thickness oscillating from 0.15 to 0.42 mm. This film demonstrated good breaking strength and max force that reached 3.12 MPa – 6.11 MPa, the max tensile strain ε M at measurements was at average 40.88 – 114.6%, while tensile at break εB 42.69 – 116.01%.

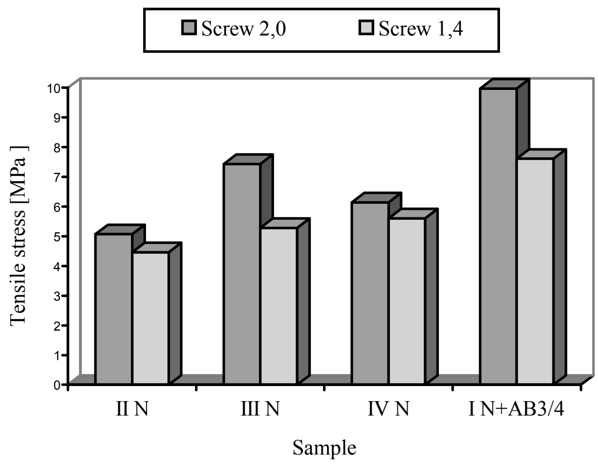

Fig. 1. Mechanical strength comparison of film specimens (screw rotational speed 80 rpm)

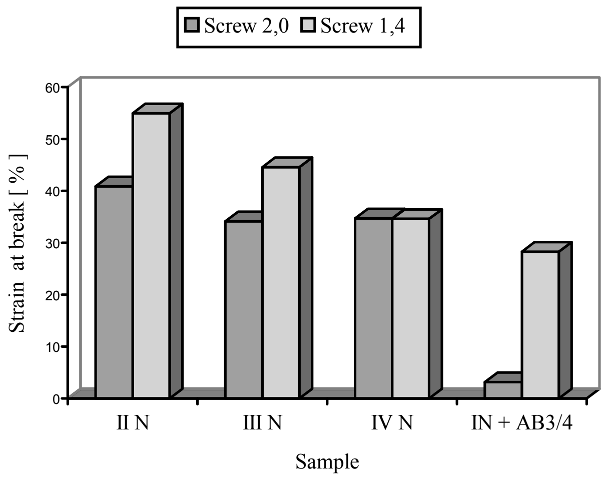

Fig. 2. Elongation comparison of film specimens (screw rotational speed 80 rpm)

The films produced from mixture III N and IV N, despite good transparency at 0.39 mm – 0.52 mm thickness turned out to be little flexible and its elongation was 38%-98%. Their tensile strength was from 4.06 to 7.43 MPa, respectively, while the max stress σM varied from 3.33 to 6.61 MPa.

The film obtained from I N + AB3/4 mixture showed that in spite of its slight elongation (up to 40%) it demonstrated very good strength parameters. The max tensile stress σM was from 7.61 to 9.97 MPa, whereas the max tensile at break varied from 6.16 to 8.77 MPa.

The microscopic analysis of the film sampled in the polarized light have confirmed the appropriate material processing at most cases and only in few samples very fine single grains of unprocessed starch were recorded. Their presence did not affect substantially the produced film quality.

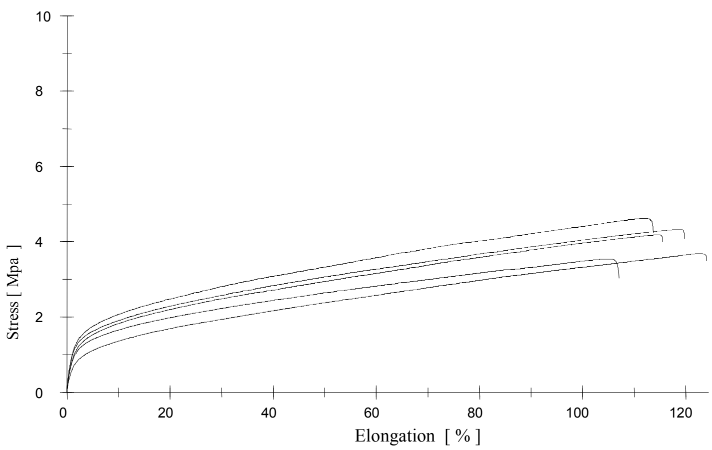

Fig. 3. Dependence strength of elongation on of film from mixture II N

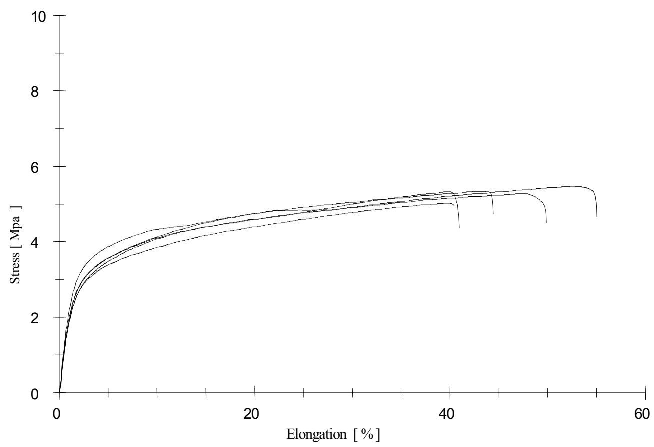

Fig. 4. Dependence strength of elongation on of film from mixture III N

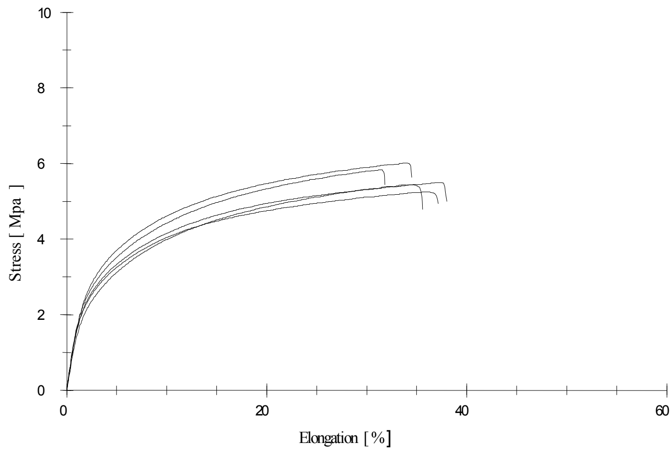

Fig. 5. Dependence of elongation on strength of film from mixture IV N

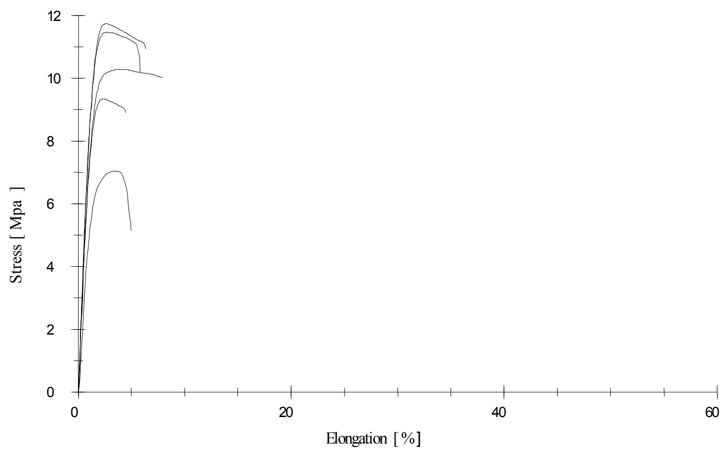

Fig. 6. Dependence of elongation on strength of film from mixture I N + AB3/4

CONCLUSION

The analysis of mechanical properties measurements of film extruded from TPS proved that the extrusion processing parameters, emulsifier presence and water content in material exert a vital impact on film strength and elongation. The use of screw of 2.0 compression ratio equipped with extra mixing section affected film strength more, while a screw of 1.4 compression ratio influenced film elongation in a greater measure. The best effects were reported when film was extruded from the mixtures II N with 22% glycerol and BRIJ 35 emulsifier.

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