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Biodegradability of thermoplastic starch (TPS)

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Summary. Thermoplastic starch (TPS) can play an important role in the processing of packaging materials. For years the Department of Food Processing has been carrying out investigations in this field. Biodegradability test results of TPS moulding enriched with functional additives are presented in the paper.

Key words: biodegradability, thermoplastic starch, TPS, extrusion, mouldings.

INTRODUCTION

Packaging wastes are now one of the greatest threats to civilization. A big hope for a reduction and perhaps the solution to this problem can be seen in the use of thermoplastic starch (in short TPS).

TPS can be used as a stand-alone packaging material or as an additive which improves the degradation of plastics [1, 3, 4, 5, 7, 9, 10, 11]. Starch is biodegradable in a short time to CO_2 and water. It is a polymer of 6-carbon sugar D-glucose, regardless of the botanical origin. Packaging materials made from thermoplastic starch can be produced by many different methods.

The single-stage method consists in applying low temperature synthetic polymers and starch mixture directly to the machine producing packaging material, e.g. to the plastic extruder. In the second stage the granules, as a half product, are processed with conventional equipment using film blowing or high pressure injecting moulding techniques [9, 10].

In order to obtain thermoplastic starch, the crystalline nature of starch granules must be destroyed, which can be done by thermal and mechanical processing [5, 9, 16]. Because the melting point of pure starch is much higher than its decomposition, during processing a plasticizer, like water, is added. Under the influence of temperature and shear forces natural crystalline structure of starch granules is crushed. In this way polysaccharides make a continuous polymer phase. To increase the flexibility of the material and improve the processing other plasticisers are used, for example: glycerol, propylene glycol, glucose or sorbitol [1, 9, 18, 19, 20]. Glycerol is the best and most common plasticizer. To improve the mechanical properties of rigid TPS packaging forms, different functional additives such as emulsifiers, cellulose, plant fibers, bark, kaolin and pectin are used [12, 13, 14, 15, 17, 21].

For years researches on TPS application in the production of fully biodegradable packaging materials based on potato starch and cereal starch have been conducted at the Department of Food Process Engineering (DFPE), University of Life Sciences in Lublin [3, 5, 12, 13, 14, 15]. The physical properties of the obtained TPS films are very promising (Fig. 1), as well as the mouldings produced in cooperation with Dutch colleagues from the

Fig. 1. The blowing of biodegradable TPS film in DFPE laboratory [5]

Royal University of Groningen. The biodegradability of these products is also analyzed during investigation [11].

BIODEGRADABILITY TESTS OF TPS MOULDINGS

Samples of mouldings (moisture content 4%) were placed in special baskets with the soil of following parameters: moisture content 70%, pH 6.5, and kept for 2, 4, 8 and 12 weeks in an unheated room at the temperature 10 – 15 °C (Fig. 2). Twice in a week water was supplemented to provide constant conditions. In order to widen scope of observation a number of samples were stored individually in the cooling room at the temperature of +3 °C and -36 °C [11].

The mouldings were produced from potato TPS granules containing different amount of glycerol and functional substances (flax and cellulose). After two weeks of storage the mouldings were taken out, weighed and dried to 4% m.c. then again weighed to determine weight loss. The last part of the test was the texture measurement, which was done using Zwick apparatus type BDO-FB0.5TH to determine range of changes in mechanical properties of the samples during the storage [12].

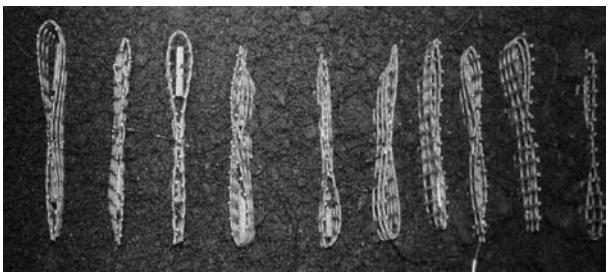

Fig. 2. Mouldings placed in the baskets with soil [11]

Fig. 3. A sample of moulding after 2 weeks of storage [11]

MEASUREMENT RESULTS

During measurements a substantial but varied weight loss of mouldings was observed during storage time. After the first two weeks of storage all samples lost weight rapidly (from 13% - samples containing 20% glycerol to about 23% - samples containing 25% glycerol). The highest change in weight was observed after 12 weeks. The inner moulding's layers (the core) decomposed slower on contact with soil than moulding's topcoat. It was observed that with increasing content of glycerol in the moulding's recipe, changes in weight (loss) were increased.

Increase in flax fiber content of flax limited the rate of destruction of the samples stored during 2 weeks [11]. In subsequent periods of storage (4 to 12 weeks) the weight loss was slower (2 - 6% for all samples). In the initial period of storage many changes on the surface of moulded parts were created because of the biodegradation process (cracks & fissures seen in Fig. 3). Samples produced without the addition of fibers and mouldings containing cellulose fiber crumbled and cracked easily during endurance tests (Fig. 4). After 12 weeks only samples containing added flax fibers had enough consistency to be able to undergo measurements of strength.

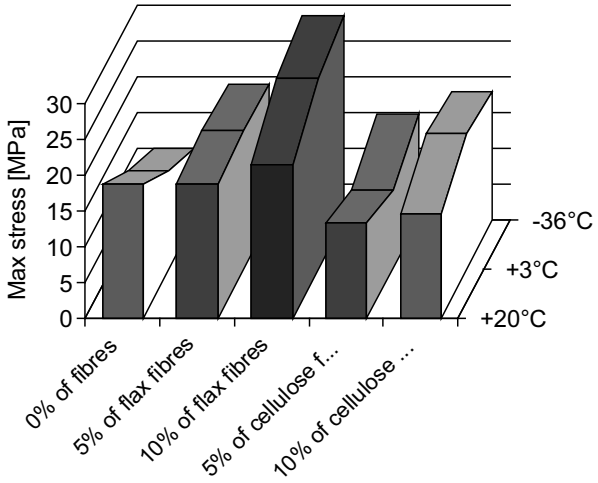

Fig. 4. Influence of storage temperature and the quantity and type of natural fibers in mouldings on the magnitude of maximum stress of mouldings during tension test (glycerol 22%, storage time 24h) [11]

CONCLUSIONS

1. Enrichment of TPS mouldings with functional components gives a very positive effect on their mechanical properties without lowering biodegradability suppleness, which has a practical value for the producers.
2. Results obtained by DFPE researchers confirm the possibility of the production of fully biodegradable packaging material based on TPS.
3. The present study demonstrates the usefulness of further work to improve the application of TPS in the production of packaging materials.
4. At the present time, we are looking for the best use of natural materials; starch seems to be a good alternative in this case. What is important – packaging material made from TPS can be produced using conventional machinery and equipment, typical for synthetic polymers sector.

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Streszczenie. Skrobia termoplastyczna (TPS) może odgrywać istotną rolę w produkcji opakowań. Katedra Technologii Żywności od lat prowadzi badania na ten temat. W niniejszym artykule przedstawiono wyniki testów biodegradowalności form z TPS wzbogaconych dodatkami funkcjonalnymi.

Słowa kluczowe: biodegradowalność, skrobia termoplastyczna, TPS, ekstruzja, formy.