INFLUENCE OF GLYCEROL CONTENT ON THE RHEOLOGY AND MICROSTRUCTURE OF STARCH BASED LOOSE-FILL PACKAGING MADE BY THERMOPLASTIC EXTRUSION

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Abstract

Foam products of plastics are extensively used as cushioning materials to protect fragile products during handling and transportation them in order to sell. Environmental problems created by the synthetic plastics have made in recent years to strive to replace petroleum-based foams with biodegradable polymers foams. Biodegradable polymers decompose in the environment under the action of microorganisms in the presence of water. One of the most used biopolymers is starch, a cheap material and present in abundance in cereals. In addition, starch lends itself particularly well to expansion by thermoplastic extrusion.
Making a product with appropriate characteristics for the intended purpose requires the use of formula that includes besides starch a series of plasticizers. This paper presents some results obtained during researches conducted in order to obtain a biodegradable corn starch-based loose-fill by thermoplastic extrusion, when using in different reports between starch and plasticizers in the formula. Increasing the levels of glycerol in the formula leads to lower viscosity value of the mixture and changing structure of the finished product.

Key words: packaging, starch, loose fill, biodegradable

Romanian`s integration in European Union involves performing of some issues regarding respecting the environment protection norms. The increasing of the volume of non-degradable wastes, made by plastic, the high expenses for their recovery and limiting the available places for their disposal, lead to necessity of development in our country,too, of biodegradable and recyclabe packaging and protective materials.

Bioplastics, which are biodegradable materials obtained from natural polymers derived from agricultural resources, are also a viable solution for solving the problems created by synthetic plastics materials due to the high consuption of petroleum, a more deficitary and more expensive resource, needed for their producing, and due to their negative impact on the environment, as they are not biodegradable.

A large quantity of plastic materials is used as loose fill material to protect fragile products during handling and transportation them for sale. This made that in recent years to strive to replace petroleum-based loose fill packaging with loose fill packaging made of biodegradable polymers.

The development of these materials involves the implementation of appropriate technologies adapted to the quality of local raw materials to achive in this field, too, of some quality organic products as requested by internal and external market. It thus ensures high recovery of biodegradable materials in the country in a direction of greater perspective.

Cheap and abundantly present in cereals, starch is one of the most used biopolymers in manufacturing biodegradable loose fill packaging. (Fang, J., Fowler, P., 2003). In addition, starch lends itself particularly well to expansion by thermoplastic extrusion. (Marcin M, 2006). Making a product with appropriate characteristics for the intended purpose requires the use of formulas which comprised besides starch, a series of plasticizers. This paper presents some results obtained during researches conducted in order to obtain a biodegradable corn starch-based loose-fill by thermoplastic extrusion, when used in different reports between starch and plasticizers in the formula.

MATERIAL AND METHOD

The materials used in experiments were starch, glycerol and water.

The starch used was corn starch manufactured by SC Amylon Sibiu, having a moisture on dry wet of 10.76%, particle sizes between 2.3 and 37.3 μm and a density of 0.561 g/cm^3.

The glycerol used in formula had a concentration of 99.5% and a density of 1.262 g/cm^3.

The water used was from the water supply system.

The technical equipment used (*fig.1*), has as main components: the dosing pump (A), the extruder (B) and the feeder (C).

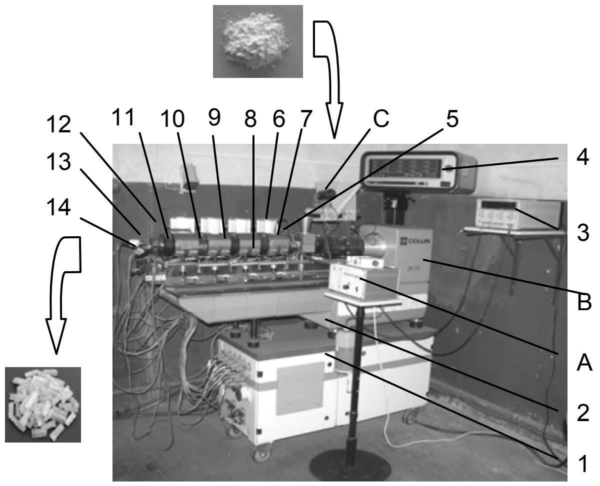


Figure 1 **Extruding installation – general view**
A – Peristaltic pump; B - Extruder; C – Feeder.
1-Plasticizer tank; 2–Plasticizers feeding pipeline; 3- Power source; 4 – Control panel; 5- Supply hopper for starch; 6-Plasticizer pipe connection; 7-11 Area 01-05; 12-Cooling fan; 13-Area 06-Die; 14-Heater.

The dosing pump used to feed with plasticizers was a peristaltic pump PERIPUMP ‚D' 5187 type, of low capacity and high dosing precision, with a power flow between 1 and 42 ml/min.

The equipment used in experiments was a Collin ZK 25 extruder with two co-rotating screw, with a maximum productivity of 15 kg / h, screw diameter D = 25 mm, screw length L = 30 D, screw speed: max. 400 rpm and having six independent heating and cooling areas.

The feeder used in experiments was a volumetric feeder with one screw.

Area 01 of the extruder, which is the supply area, is not heated, but can be cooled with water. The areas 02-05 are provided with electric heaters *(fig.1, pos.14)* and cooling fans *(fig.1, pos.11)*. Each of this five areas is equipped with one temperature sensor that measures temperatures and control starting or stopping of the heaters or fans to maintain temperatures set in each area. Area 06 is the die area - it has its own heater,and no cooling. Its temperature is measured and maintained at the value initially established by the temperature sensor *(fig.1, pos.5)*. Also in the die area there are two sensors that are in direct contact with the material that is processed and measuring its temperature and pressure. These two parameters are very important, for them relying largely the quality and cross size of the extruded product.

Temperature values in this six areas of the extruder are initially set, achieved and maintained during extrusion plant operation with a program whose interface is the control panel of the extruder.

The starch was introduced into the extruder with the feeder, and for supply plasticisers a peristaltic pump was used. In order to use a single dosing pump, both plasticizers, glycerol and water, being miscible, were mixed in the proportion of the formula and placed in the plasticizers tank (*fig. 1, pos. 1*).

The plasticizers were added into the working area through a pipe connection located at 170 mm from axis of the supply hooper. Both supplying, with starch and plasticizers, were made continuously, any interruption to supply are leading to changes in flow and in the properties of the finished product.

The ratio of the three components in the formula, based on which have been established the flows of supplying of the starch and of the plasticisers, was that in the *tab. 1*.

Table 1
The ratio of components in the formula

Formula abbreviation	Starch [g]	Water [g / % dry base]	Glycerol [g / % dry base]
AmAG 411	66.67	16.66/25	16.66/25
AmAG 412	57.14	14.29/25	28.57/50

Meanwhile, along the extruder were provided conditions for thermal processing of the material through the existing temperatures in the six areas of the extruder, shown in *tab.2.* Screw speed was 220 rpm.

Table 2
Temperature on the 6 areas of the extruder

Temperature [^{0}C]					
Area 01	Area 02	Area 03	Area 04	Area 05	Area 06
30	50	100	130	150	150

Temperature values were chosen taking into account of the important points from the DSC termograma of the mixture. For the mixture of starch-water-glycerol, in the ratio from the formula, the glass transition temperature is 73 ºC to AmAG411 formula and 71 ºC to AmAG412.

RESULTS AND DISCUSSIONS

It was done study "falling index", a parameter that it is determinate in the case of flours and starches of different provenience and which gives clues about their quality in terms of resistance to a force applied at a given temperature.

The device used for this analysis was Falling Time System- manufactured by Sadkiewicz Instruments in Poland.

The principle of determining consists in gelatinisation suspension of starch in a test pipe located in a water bath at 100^{o} C and estimating the gelling degree of a suspension by measuring and recording, by the device of the falling time of the agitator in the gel formed.

The falling time is both an index of deformability and of baking properties of starch.

Table 3

The falling time and the macroscopic appearance of the sample

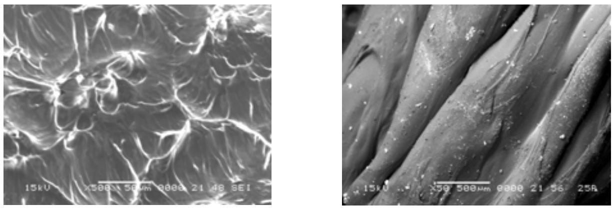
Abbreviation	Falling time [sec]	The macroscopic appearance of the sample after gelatinisation
AmAG 411	250	The gel has many air bubbles embedded
AmAG 412	362	The gel has aspect hollow

As seen, increasing the amount of glycerole in the mixture leads to decrease of falling time. The mixture with a lower glycerole content will have better baking properties, but a higher viscosity, having a higher falling time.

The microstructures of the finished products obtained by thermoplastic extrusion, for the two formulas used, are shown in *fig.2.*

From the SEM images of the finished product made from composite material AmAG411 (*fig. 2a*) we observe a fibrous structure, while the SEM images of the finished product made from composite material AmAG412 (*fig.2b*) we observe a deformed rods structure, which are in contact (compact packed).

These differences are explained by different temperatures at which the glass transition take place, deformability and different baking properties and the different macroscopic appearance of the samples after gelatinisation.



a b

Figure 2 **SEM images**

a – Sample AmAG411; b - Sample AmAG412

CONCLUSIONS

Applied technology allows to obtained expandable products using as raw materials starch, glycerol and water, used in well established proportions and defined by specific physico-chemical and organoleptic qualities.

A lower glass transition temperature, a lower deformability and a greater heterogeneity of the AmAG412 sample after gelatinisation, leads to achieving, in the case of this formula, of a suitable structure for use the final product as a loose fill packaging.

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