EVALUATION OF THE BIODEGRADABILITY OF BLENDS OF POLYETHYLENE AND ALIPHATIC POLYESTERS

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The biodegradability of blends of high density polyethylene and aliphatic polyesters were investigated. The morphology of the materials was studied by scanning electron microscopy. Blends with PLA showed reduce elongation at break, but increased Young's modulus when compared with the blends that have PCL, in agreement with the SEM results. These findings indicate that PLC, PLA are incompatible with HDPE, however the adhesion increases with the addition of PE-g-MA. The microscopy data suggest that the microorganisms tend to adhere to the polymer surface along time, nevertheless this fact is more pronounced for sample 4, which has PLA.

Keywords: biodegradable; natural polymers; fluorescence microscopy; morphology; blends

Introduction

The management of solid waste is a growing concern in many countries. Municipal solid waste is a major component of the total solid waste generated by society, and the composting of municipal solid waste has gained some attention even though a composting treatment for it is not yet widespread. One reason for this is that composts made from municipal solid waste tend to contain significant quantities of plastics.

It may not be realistic to replace large portions of these plastics with biodegradable materials, and it may be more important to separate plastics unsuitable for the composting process at the generating spots. However, for food packaging, there is still a great deal of interest in using biodegradable plastics that are difficult to sort at the generation spots. Under these circumstances, many kinds of biodegradable plastic materials that can be degraded along with organic wastes during composting have been developed. A biodegradable polymer may therefore be derived from either natural or synthetic sources. The biodegradation process predominantely takes place as a result of the enzymatic action of microorganisms, its rate being dependent on the materials environment. To be called biodegradable, the rate of degradation must take place in a specified time period comparable with existing natural biodegradable materials [1,2].

The objective of this work is to study the biodegradability of polymeric materials based on blends of a synthetic and biodegradable polymer.

Experimental

Materials

High density polyethylene (HDPE), polyethylene modified with maleic anhydride (PE-g-MA) polycaprolactone (PCL), polylactic acid (PLA) were used. The composition is shown in Table 1.

Table 1 - Composition of the samples

Sample	HDPE (wt %)	PCL (wt%)	PLA (wt%)	PE-g-MA (wt%)
1	70	0	30	-
2	70	30	0	-
3	100	0	0	-
4	50	0	30	20
5	50	30	0	20

Compounding

All blends were tumble mixed and processed in a Leistritz LSM 30.34 laboratory modular co-rotating twin screw extruder using barrel set temperature of 190 °C, a screw speed of 100 rpm and a throughput of 3 kg/h. The screw contains a series of transport elements separated by three mixing zones, consisting of staggered kneading disks and a left-hand element, respectively (Figure1).

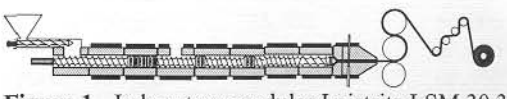


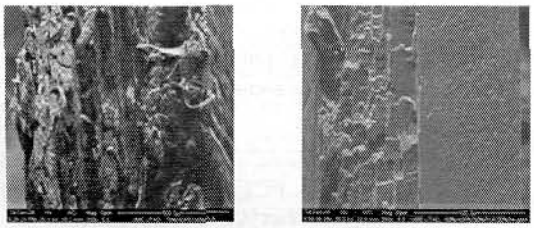
Figure 1 - Laboratory modular Leistritz LSM 30.34 with a coupled flat sheet line.

Material characterization

After fracture of the samples in liquid nitrogen and gold plating, the morphology of the blends was studied using a FEI Quanta 400 Scanning Electron Microscope
The uniaxial tensile properties of the materials (tensile specimens) were determined using an Instron 4505 Tensile Machine at crosshead speed 50 mm/min, relative humidity of 50 % and temperature 23 °C. An average of 10 tests was performed to calculate the elongation at break and modulus values.
Biodegradability of the materials was evaluated using bacteria (*pseudomonas fluorescens).*. Since the only available carbon source for bacteria in the prepared middle is present in the polymeric material, the microorganisms adhere to the polymer surface. The bacteria were observed by fluorescence microscopy using a colouring designed DAPI (Di Aminido Phenyl Indol).

Results and discussion

Figure 2 shows an example of the morphology of the blends. In Figure 2a it is possible to observe that the adhesion between PLA and HDPE is not prevailing, thus low miscibility would be expected. However, when PE-g-MA is added (Figure 2b), the interfacial adhesion increases due the chemical interaction between the hydroxyl group of PLA and anhydride group of PE-g-MA.



a) b)

Figure 2 - (a) 70 % HDPE + 30 % PLA (b) 50 % HDPE + 30 % PLA+ 20 % PE-g-MA.

As shown in Figure 3, elongation at break and modulus of the blends depend on the composition. The addition of PLA to the mixture promotes an increase of rigidity of the material, however the addition of PCL promotes an increase in the elongation at break. Addition of PE-g-MA promotes better adhesion between the components of the blend, and as a consequence, an increase of elongation at break. As seen in microscopy results, the increase in the internal forces was promoted by the addition of maleic anhydride.

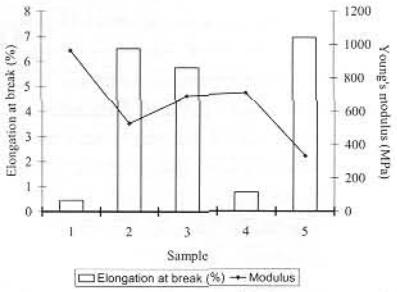
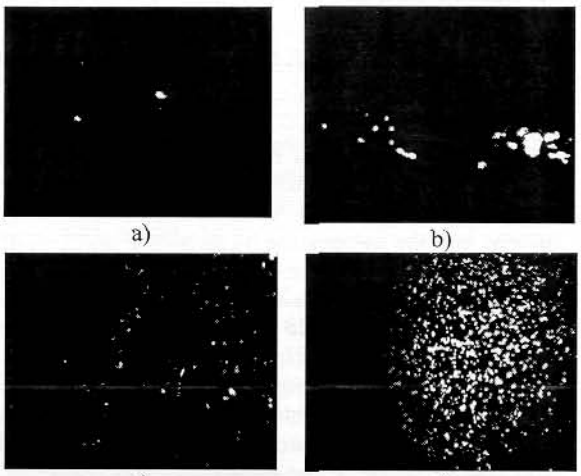


Figure 3 - Elongation at break and Young's modulus of different materials.

Micrographs of sample 4 collected weekly and analysed by fluorescence microscopy are depicted in Figure 4. An increase of microorganisms on the polymer surface along the time can be observed. In the first week the microorganisms tend to form agglomerates on the polymer surface, which tend to disperse along the time.



a) b)

c) d)

Figure 4 - Microscopy of sample 4 after (a) one, (b) four, (c) five and (d) six weeks of incubation

Conclusions

The results obtained show that biodegradability of the various materials depends on the composition and on the combination of the synthetic/biodegradable system. The microscopic results indicate that increasing the incubation time increases the microorganisms on the polymer surface. Among the various materials studied, sample 4 shows a higher amount of microorganisms, and consequently is the most biodegradable.

References

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