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**EFFECT OF PLASTIFICATOR AND COMPATIBILIZER ON PROPERTIES  
OF PCL/HEC BLENDS**

Z. JAKUBÍKOVÁ<sup>1</sup>, I. SROKOVÁ<sup>1</sup>, P. BUGAJ<sup>2</sup>, P. SKALKOVÁ<sup>1</sup>, P. KOŠTIAL<sup>1</sup>

<sup>1</sup> *Faculty of Industrial Technologies, Dubček University of Trenčín; Púchov, Slovak Republic, contact author: jakubikova@fpt.tnuni.sk*

<sup>2</sup> *Faculty of Chemical and Food Technology STU; Bratislava, Slovak Republic*

**ABSTRACT:** New type of polymer blends composed of polycaprolactone (PCL), hydroxyl-ethylcellulose (HEC) plasticized with 30 and 50 % of glycerol, and poly(ethylene-co-acrylic) acid (EAA) as a compatibilizer, was prepared. Double-screw extruder tempered on working temperature was used for blends preparation. Achieved product was granulated and films were casted subsequently by using Chill Roll technology.

The morphology of PCL/HEC blends was studied by scanning electron microscopy. The mechanical properties were investigated and the tensile strength and relative elongation at break were evaluated from the stress-strain curve.

The compatibility of HEC with PCL was significantly improved by addition of poly(ethylene-co-acrylic) acid (EAA) and glycerine mixed into master-batch of investigated system. It was found, that the presence of EAA copolymer makes the PCL/HEC blends more homogeneous.

Physico-mechanical properties of prepared blends are comparable with most wide-spread polyolefines and might be exploited in various technical applications.

**KEY WORDS:** Polycaprolactone, hydroxyethyl cellulose, poly(ethylene-co-acrylic) acid, blends, glycerol

## 1. INTRODUCTION

Biodegradable polymers and plastics are materials that completely degrade by microbial attack under appropriate environmental conditions. Generally these materials are more expensive than commodity plastics but they are more environment-friendly and better suited for a number of applications such as shopping bags, food-service packaging, agricultural mulch film, and medical disposables [1] that, once abandoned in terrestrial and marine environments, should break down and ultimately be mineralized by microbial attack.

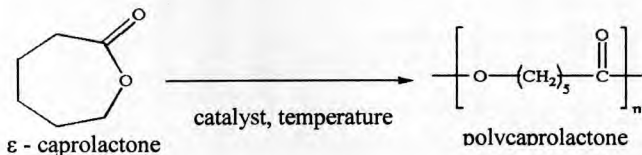
In recent years, increasing concern about environmental issues has renewed great interest in the development of the biodegradable materials. Polysaccharides have been considered as a candidate material in certain thermoplastic applications because of their known biodegradability, availability and low cost.

Physical incorporation of natural polymers such as starch and cellulose in synthetic polymers can be used to improve the biodegradability of the polymer matrix, often being recalcitrant to microbial attack. When disposed of, the poly(saccharide) is biodegraded, leaving the plastic porous and susceptible to further oxidative degradation. However, it is found that 30-50 % of natural biodegradable polymers are required to achieve significant biodegradation [2].

Cellulose esters and ethers, having degree of substitution (DS) between 1.7 and 3.0, can be easily obtained from native cellulose or recycled paper. These materials have mechanical properties

comparable to those of poly(styrene). Moreover, by addition of a suitable plasticizer, they can be melt processed by using the same techniques as adopted for commodity thermoplastic [3].

Polycaprolactone (PCL) is a well-known synthetic, biodegradable, semi-crystalline polyester, characterized by high elongation at break. Its low melting point of around 60°C is often perceived as an impediment for use as a common thermoplastic. However, PCL has complementary strengths and weaknesses same as polymer materials [4].



In polysaccharide-based blend systems, one of important factors affecting mechanical properties is the interfacial affinity with the matrix polymer. Gelatinization of starch-cellulose was a good method to enhance the interfacial affinity [2]. Cellulose is gelatinized in order to disintegrate granules and to overcome the strong crystalline intermolecular forces prior to mixing with other polymers [2,5]. Glycerol was used as plasticizer in this work in order to prevent the reformation of the strong crystalline in cellulose.

Because of the hydrophilic nature of polysaccharide, blends with hydrophobic plastics have poor mechanical properties due to poor interfacial adhesion. One way to increase compatibility in polysaccharide blends is to use a compatibilizer containing groups capable of hydrogen bonding with cellulose hydroxyls. Poly(ethylene-co-acryl acid) (EAA) is such a material [6].

## 2. EXPERIMENT

We prepared polymer blends composed of polycaprolactone (PCL)CAPA 6800 from Solvay Caprolactones, hydroxyethylcellulose (HEC) from SIGMA – Aldrich Chemie plasticized with 30 and 50 % of glycerol, and poly(ethylene-co-acryl) acid (EAA) was supplied from SIGMA – Aldrich Chemie as a compatibilizer.

Double-screw extruder from Labtech, Thailand tempered on working temperature was used for blends preparation. Achieved product was granulated and films were casted subsequently by using Chill Roll technology. Measurements of the mechanical properties such as tensile strength and relative elongation at break were performed according to the Metrotest 5kN under the norm STN ISO 527. Measurements were done by using 1 mm/min in the range deformation of 0-3 % and subsequently by using increase on 50 mm/min.

The morphology of PCL/HEC blends was studied by scanning electron microscopy.

## 3. RESULTS AND DISCUSSION

The PCL/HEC blends plasticized with glycerol and poly(ethylene-co-acrylic) acid (EAA) as a compatibilizer, were prepared at various conditions, that summarizes Tab. 1, in temperature profile of double-screw extruder (Tab. 2).

Subsequently, films were casted using Chill Roll technology.

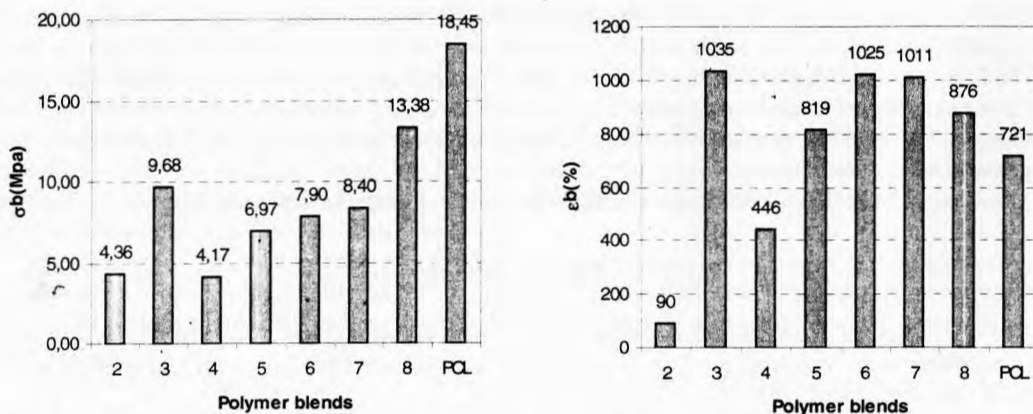
**Tab. 1:** Conditions of preparation of PCL/HEC blends

Sample	PCL (%)	HEC (%)	GL (%)	EAA (%)	PCL (g)	HEC (g)	GL (g)	EAA (g)	Blends PCL/HEC(g)
1	100	-	-	-	200.0	-	-	-	200.0
2	70	30	-	-	105.0	45.0	-	-	150.0
3	90	10	30	-	135.0	15.0	6.43	-	150.0
4	70	30	30	-	105.0	45.0	19.29	-	150.0
5	50	50	30	-	75.0	75.0	32.14	-	150.0
6	70	30	-	25	105.0	45.0	-	15.0	150.0
7	70	39	30	25	105.0	45.0	19.29	15.0	150.0
8	80	20	50	-	120.0	30.0	30.0	-	150.0

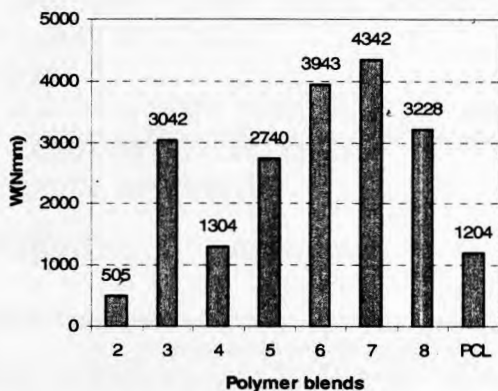
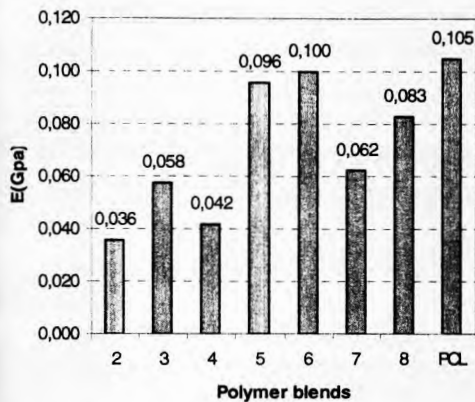
**Tab. 2:** The temperature profile of double-screw extruder

Temperature profile	jet	9	8	7	6	5	4	3	2	1
Temperature [°C]	120	120	120	130	140	150	140	130	120	120

The tensile strength and elongation at break of PCL/HEC blends are shown in Fig. 1. PCL is a ductile polymer with an important elongation at break and medium Young's modulus (Fig. 2). Young's modulus and tensile strength are seen to decrease while glycerol content increases. Depending on the plasticizer content, the elongation at break increases and then it decreases at the highest glycerol concentration. The maximum elongation at break seems to be at a glycerol/HEC close to 30-50 % GL. Mechanical properties were positively influenced by addition of compatibilizer (EAA). The best results show blends 8, 7, 6 and 3. The force necessary for breaking was at highest for blend No. 7. This was presumably caused by presence of 30 % glycerol and 25 % EAA.



**Fig. 1:** Tensile strength and relative elongation at break of PCL and PCL/HEC blends with different amounts of EAA and HEC



**Fig. 2:** Young's modulus and force necessary for breaking PCL and PCL/HEC blends with different amounts of EAA and HEC

#### 4. CONCLUSION

This paper reports on significant improvements in the impact and elongation at break properties of PCL through the addition of HEC. The results demonstrate that binary blend preparation of polycaprolactone, hydroxyethylcellulose plasticized with 30 and 50 % of glycerol and poly(ethylene-co-acrylic) acid as a compatibilizer is a viable technique for expanding the property range of PCL materials.

Prepared blends show excellent mechanical properties depending on amount of glycerol and compatibilizer. It can be concluded, that with increasing amount of plasticizer (up to 50 wt. %), compatibilizer and time of pre-treatment of HEC/GL blends, mechanical properties also increase. Moreover, relative elongation at break and force necessary for breaking show even higher values than at the initial PCL.

Based on the results, it can be established that PCL/HEC blends are well treatable by using standard processing technologies and suitable choice of compounds ratio and they might be exploited in various technical applications.

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