PEEL PROPERTIES OF MODIFIED PE-PP BLENDS

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Abstract: *Interest in the peel properties of thin polymer films for sealed packaging has increased dramatically over the past year due to increasing demand, particularly in food preservation and medical applications. For customer convenience in all packaging applications and to ensure sterility in medical device packaging, seals should be as easy to peel as possible without compromising functionality. To achieve the desired peel effect, 6 modified blends of PE and PP were prepared using 3 different commercially available modifiers at 2 different concentrations. The first modifier was an ethylene-based α-olefin copolymer, the other two were ethylene-based octene-1 plastomers and were added at 10% and 20%. The percentage of PE was set at 30 %, and the percentage of PP was 50% or 60%, depending on the modifier content. The prepared blends were extruded and granulated using a twin screw extruder. The granules were pressed into thin films, which were analyzed for their tensile properties by standard tensile tests and dynamic mechanical analysis (DMA), heat sealing and peeled on an universal testing machine, for their chemical structure by Fourier transformation infrared spectroscopy (FT-IR), and for their thermal properties by differential scanning calorimetry (DSC) and thermogravimetric analysis (TGA).*

Keywords: sealing, peel properties, easy-peel, PE-PP blends, packaging

1 INTRODUCTION

In most packaging applications, packaged goods are sealed to prevent contamination and spoilage from light, moisture, temperature, and oxygen in the environment. On the one hand, the seal must protect the contents as it directly affects the quality of the product and its shelf life, on the other hand,

it should be easy to open in order to satisfy customers and provide them with a positive experience, as well as fulfill its original purpose, which is to prevent contamination (SP Group, 2021). Probably everyone has seen a seal that was difficult to peel off without tearing or damaging the container. Most of these packages are coextruded blown films made of multiple layers and different materials, usually having a peelable seal layer and a core layer of polyethylene (PE) (Falla, 2015).

Poor packaging that is difficult to open and tears when opened, regardless of the value of the packaged goods, can cause the product to become unusable - it becomes damaged, difficult to store and handle, and can negatively impact the reputation of the supplier. Experimental characterization of packaging is becoming increasingly important to avoid such inconveniences, save costs and ensure functionality of the packaging (Stable Micro Systems Ltd., 2021).

In view of the above, three commercially available peel effect modifiers were selected and added to the PE -PP blends in an amount of 10 wt.% and 20 wt.%. The prepared granular blends were extruded and granulated. The granules were pressed into films on laboratory press. The mechanical and thermal properties of the films were evaluated as well as their peel properties.

2 MATERIAL AND METHODS

2. 1 Materials

Six blends based on PE and PP were prepared using LabTech LTE 20-44 twin screw extruder. The extrusion temperature profile (from hopper to die) was: 165 °C, 170 °C, 175 °C, 180 °C, 185 °C, 190 °C, 190 °C, 195 °C, 195 °C, 200 °C and 200 °C. The screw speed was set at 600 rpm to achieve good mixing of the components. After cooling in the water bath, granulation was carried out. The granules were then pressed into thin films on the Baopin BP -8170-B laboratory press. Pressing was done at 200 °C and 0.3 MPa for 1 min followed by 7 MPa for 0.3 min. Each blend was based on 30 % PE, the granules used were LDPE 515E from Dow, 50 % or 60 % PP DR155 from Braskem, depending on the percentage of modifier in the blend, and 10 % or 20 % of one of the three selected modifiers. The first modifier was commercially available ethylene-based α-olefin copolymer Tafmer A from Mitsui Chemicals. The other two were ethylene-based octene-1 plastomers produced by Borealis and commercially available as Queo 0201 and Queo 8201.

Table 1: Samples and compositions

Sample	LDPE (%)	Modification	PP (%)
1	30	10 % Tafmer A	60
2	30	20 % Tafmer A	50
3	30	10 % Queo 0201	60
4	30	20 % Queo 0201	50
5	30	10 % Queo 8201	60
6	30	20 % Queo 8201	50

2. 2 Tensile tests

The tensile tests were carried out using Shimadzu Ag - X Plus universal testing machine equipped with a 10 kN load cell. The specimens were cut from pressed films and were 10 mm wide and about 0.3 mm thick. They were tested with parameters according to ISO 527. The gauge length was 50 mm. The test speed was 1 mm/min until elongation of 0.25 %, which was determined with the Shimadzu TRViewX Exstensometer, and then 50 mm/min until breakage.

2. 3 Dynamic mechanical analysis

The DMA was performed with the dynamic mechanical analyzer Perkin Elmer DMA 8000 using tensile testing clapms. The amplitude was set to 0.005 mm and the frequency to 1 Hz. The samples were heated at 2 °C/min from 25 °C to 80 °C.

2. 4 Peel test

The films were heat sealed onto PP fleece at 164 °C for 5 s and clamped in the clamps for tensile test on Shimadzu AG - X Plus universal testing machine equipped with a 10 kN load cell. The entire test was carried out at a crosshead speed of 600 mm/min. The distance between the clamps was 30 mm. 10 measurements were taken for each specimen.

2. 5 Fourier Transformation Infrared spectroscopy

FT-IR spectra of the samples were recorded with Perkin Elmer Spectrum 65 using the Attenuated Total Reflectance (ATR) technique. For each sample, 10 measurements were made in the range between 4000 cm^{-1} and 600 cm^{-1} with a resolution of 4 cm^{-1}.

2. 6 Differential scanning calorimetry

DSC measurements were made using Mettler Toledo DSC 2. Approximately 10 mg of sample was prepared in 40 µL aluminum crucibles. The method consisted of a 5 min isothermal step at -40 °C, followed by heating at 10 °C/min to 210 °C, another 5 min isothermal step at 210 °C, and then cooling from 210 °C to -40 °C. All steps were then repeated again. The entire measurement was performed in a nitrogen atmosphere with a gas flow of 20 ml/min.

2. 7 Thermogravimetric analysis

TGA was performed using Mettler Toledo TGA/DSC 3+. About 5 mg of the sample was heated from 40 °C to 600 °C in an alumina crucible in a nitrogen atmosphere with a gas flow of 20 ml/min at 10 °C/min, followed by heating from 600 °C to 900 °C at 10 °C/min in an oxygen atmosphere with a gas flow of 20 ml/min.

3 RESULTS AND DISSCUSION

3. 1 Tensile test

The tensile properties of the prepared modified PE -PP films were evaluated and are shown in Table 2. The highest tensile modulus was determined for sample 3 modified with 10% Queo 0201. Increasing the amount of modifier in the blend resulted in lower moduli, except for the sample modified with Tafmer A (samples 1 and 2), which were comparable. The samples modified with 20% modifier did not show any differences in tensile modulus. Tensile strength showed a similar trend, with the increase in modifier resulting in lower tensile strength, while the strains at tensile strength increased. Again, sample 3 exhibited the highest tensile strength. From the above, it can be concluded that increasing the amount of modifier at the expense of PP in PE - PP blends increases the toughness of the blends.

Table 2: Gathered results of tensile tests

Sample	***Tensile modulus (GPa)***	***Tensile strength (MPa)***	***Strain at tensile strength (%)***
1	*0.60 ± 0.08*	*15.91 ± 0.46*	*12.73 ± 0.75*
2	*0.63 ± 0.06*	*13.98 ± 0.22*	*17.45 ± 0.24*
3	*0.94 ± 0.05*	*17.33 ± 0.75*	*14.03 ± 0.91*
4	*0.61 ± 0.05*	*15.05 ± 0.19*	*15.91 ± 1.41*
5	*0.72 ± 0.15*	*15.35 ± 0.56*	*11.74 ± 0.79*
6	*0.64 ± 0.07*	*14.45 ± 0.48*	*16.76 ± 1.34*

3. 2 Dynamic mechanical analysis

Figure 1 shows the dependence of the storage modulus from the temperature. Similar to the results of the tensile test, the highest storage modulus was measured for sample 3, and a higher content of modifier resulted in a more tough PE -PP blend due to the lower PP content in the blend. Samples 2 and 6 have the lowest storage modulus over the whole range of measured temperatures, and above 80 °C there is a significant drop in modulus, probably indicating the onset of melting.

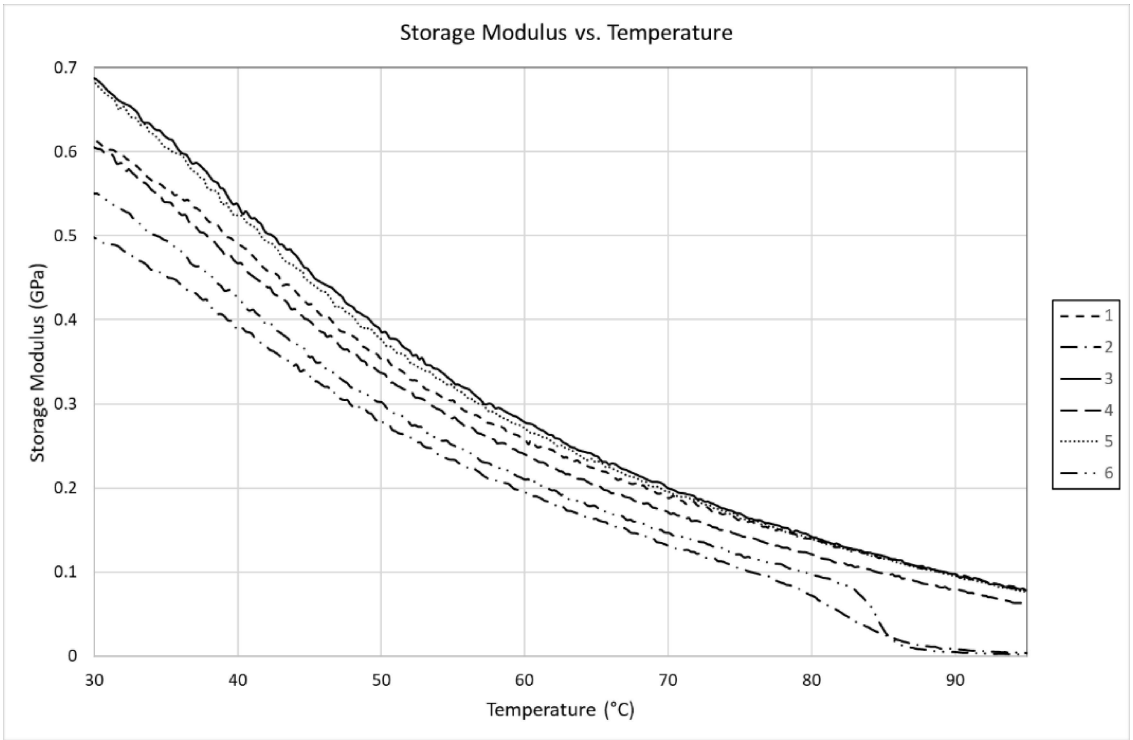

Figure 1: Storage modulus versus Temperature

3. 3 Peel test

Table 3 shows the average maximum peeling forces of the prepared films sealed with the nonwoven PP. The measurement of the peel forces did not prove to be the best possible criterion for the application because, taking into account the standard deviations, all the samples were in the same range. However, the samples differed in their peel properties as can be seen in Figure 2 with the peeled films. Samples 3 and 4 proved to be the most promising, as they were the only samples that detached from the fleece without tearing or damaging it, while all the other films did not detach from the fleece but stuck to it and tore it when pulled apart.

Table 3: Average maximum peel forces

Sample	***Maximal peel force (N)***
1	*8.3 ± 1.6*
2	*7.9 ± 2.1*
3	*7.4 ± 1.3*
4	*7.6 ± 1.2*
5	*7.4 ± 1.3*
6	*6.6 ± 1.8*

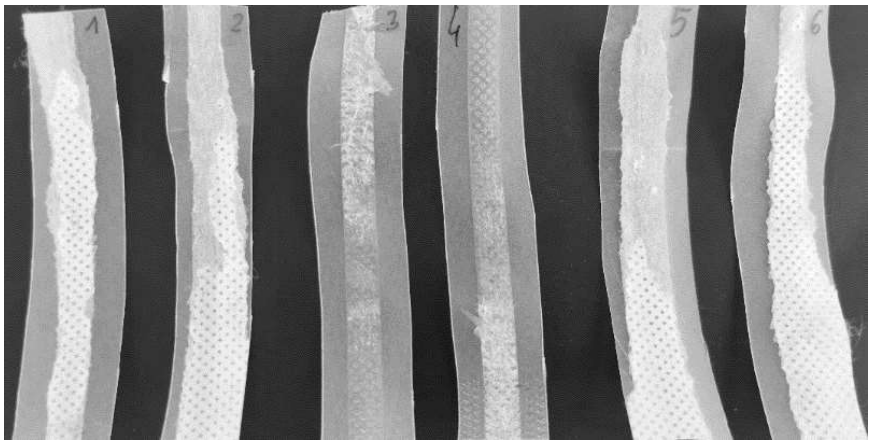

Figure 2: Peeled films

3. 4 Fourier Transformation Infrared spectroscopy

The FT-IR spectra of the samples are shown in Figure 3. The spectra are almost identical, so no significant differences in the chemical structure of the films were found.

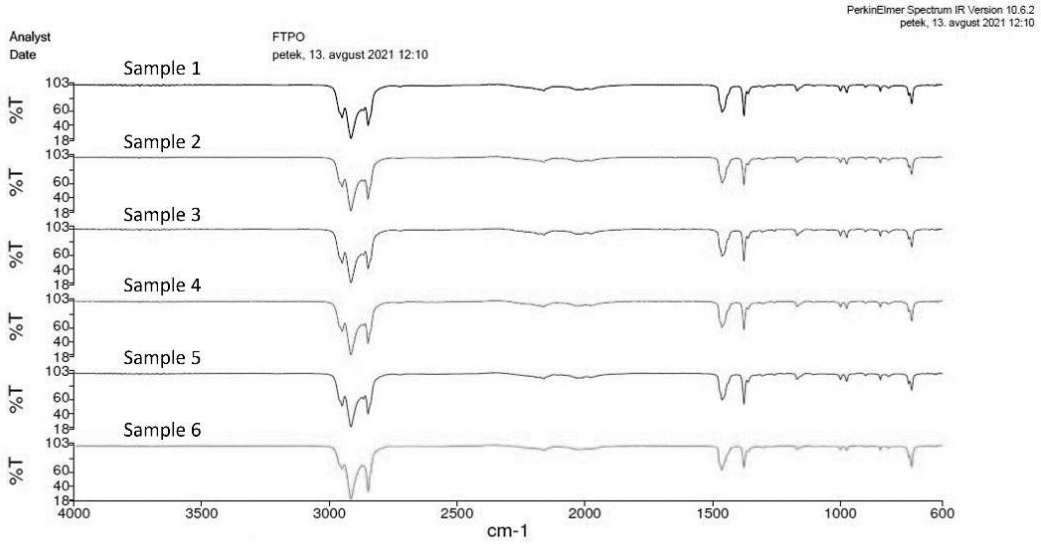

Figure 3: FT-IR spectra of samples

3. 5 Differential scanning calorimetry

Figure 4 shows DSC thermograms of the first cooling of the samples, evaluating the crystallization behaviour of the samples. All samples crystallize in two steps as two peaks can be seen. The peaks at about 110 °C represent the crystallization of the component PP and the following peaks between 100 °C and 105 °C represent the crystallization of the PE component. The peaks of PP are narrower than those of PE, except for sample 2, where the peak of PP collides with the peak of PE, probably due to the compatibilizing effect of Tafmer A at higher concentration, which corresponds to the shift of the melting point of PP (Figure 5) to a lower temperature (141.4 °C). Otherwise, the glass transition temperatures of all samples ranged between -10 °C and -15 °C and do not appear to be dependent on the concentration of the modifier. The melting points of the PE component of the samples were even closer to each other in the range between 115 °C and 118 °C.

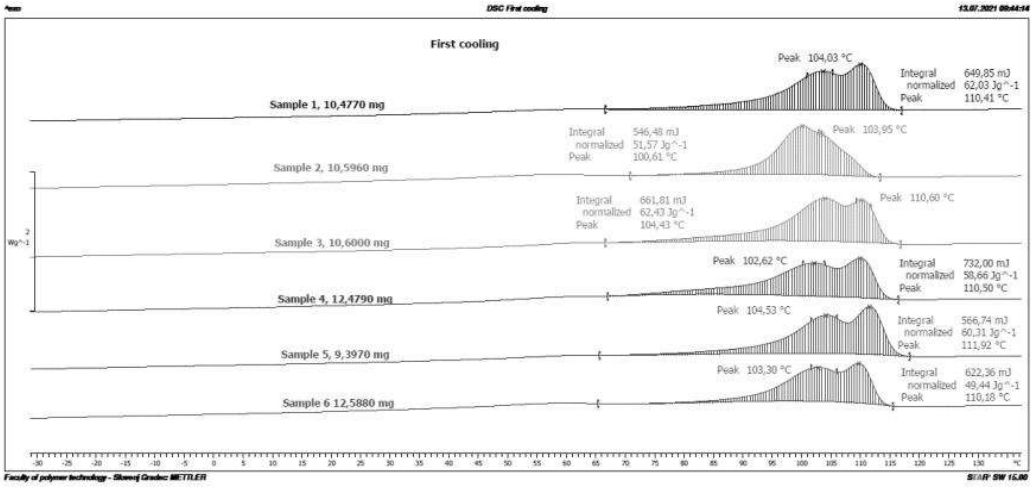

Figure 4: DSC thermograms of first cooling

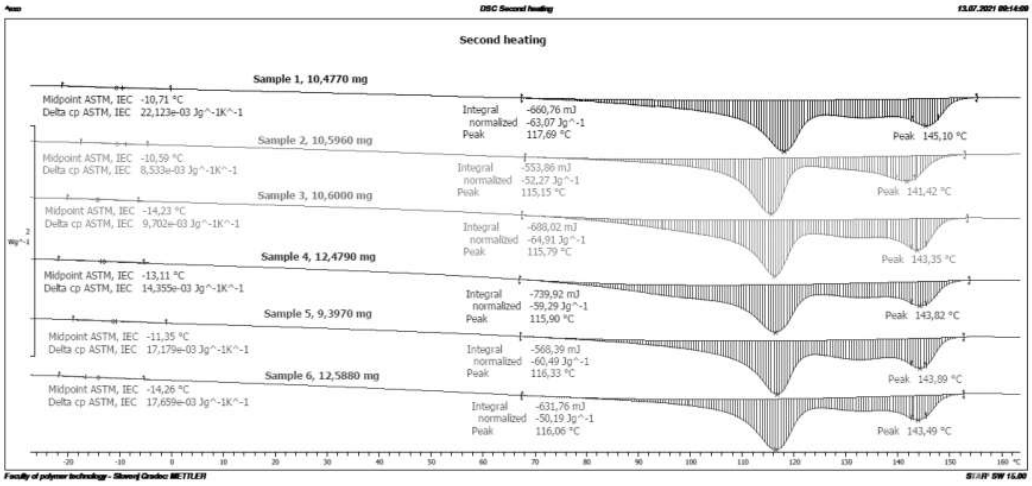

Figure 5: DSC termograms of second heating

3. 6 Thermogravimetric analysis

Thermogravimetric analysis was used to determine the degradation temperatures and decompositions of the samples. Neither different degrees of modifiers nor the modifiers used had a significant effect on the degradation temperature. The lowest degradation temperature and the highest residue were determined for sample 1, which, however, is comparable to the other samples, which showed such small deviations from each other that it cannot be claimed that the samples differ significantly from each other.

Table 4: Gathered results of thermogravimetric analysis

Sample	***Degradation temperature (°C)***	***Decomposition (%)***	***The residue (%)***
1	*463.5*	*99.3*	*0.7*
2	*467.8*	*99.9*	*0.1*
3	*466.3*	*99.7*	*0.3*
4	*464.7*	*99.9*	*0.1*
5	*464.4*	*99.8*	*0.2*
6	*465.9*	*99.9*	*0.1*

4 CONCLUSION

The present study dealt with the preparation of six PE-PP blends modified with three different modifiers. The blends were pressed into films which were tested for their chemical structure, mechanical, peel and thermal properties. As the amount of modifier increased, the toughness of the samples decreased. The highest stiffness of the films was observed in the sample containing 10 wt% Queo 0201 (sample 3). As for the peel properties, the average peel forces do not reflect the actual condition since no differences were found between the films in this respect. However, the samples modified with Queo 0201 (sample 3 and sample 4) showed desirable peel effects, as the films did not damage the PP nonwoven during peeling. Based on the infrared spectra of the samples, no differences were observed between the films in terms of chemical structure. The use of DSC and TGA to determine thermal properties, including thermal transitions, decomposition temperature, and decompositions, resulted in determination of only minimal differences between the samples. Considering the above aspects, especially stiffness and peel properties, samples 3 and 4 modified with Queo 0201 performed the best. It can be concluded that Queo 0201 is the most suitable of the modifiers tested for PE -PP blends for packaging applications where peel properties are important.

5 REFERENCES

Falla, D. (2015). New study helps improve Peelable Seal in Film Packaging, Plastics Engineering. [online] Available at: <http://read.nxtbook.com/wiley/plasticsengineering/novemberdecember2015/technicalpaper_newstudyhelps.html> [Accessed 2 August 2021].

SP Group (2021). How Often have You Struggled to Peel Back the Film on a Tray, or Found It Tears and Breaks on Opening? Available at: <https://www.spg-pack.com/blog/en/packaging-seals-a-key-factor-for-long-shelf-life-and-product-preservation/> [Accessed 29 July 2021].

Stable Micro Systems Ltd. (2021). Packaging : How to Measure the Physical Properties, pp. 1–10. Available at: <https://www.azom.com/article.aspx?ArticleID=20072 P> [Accessed 31 July 2021].