# COMPOSITES OF PET AND PBT/PP WITH BENTONITE

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## 1 Introduction

The need for solid-waste management has pushed the development of alternative systems for recycling and revalue the used plastic containers. Poly(ethylene terephthalate) (PET) is being widely used as raw material for beverage bottles. However, after its processing and use, it shows a large decrease in its molecular weight, and hence, in its tensile properties and viscosity [1]. On the other hand, poly(butylene terephthalate) (PBT) is another thermoplastic polyester with easy processability but high brittleness and cost. Hence, it has been blended with other polymers such as polyolefins to overcome its disadvantages [2].

In this study, the incorporation of a natural clay such as bentonite into PET and PBT/polypropylene blends is carried out. PBT was blended with polypropylene to produce the composite because neat PBT is a very brittle material. Commercial bentonites are generally rich in a nanoclay known as montmorillonite ($Al_2(OH)_2[Si_4O_{10}]$). Nonetheless, in this case, the percentage of montmorillonite in bentonite is very low, as it is its specific area. Hence, it was not used for the purpose of preparing nanocomposites but as inexpensive and natural conventional filler. This study focuses in the determination of rheological and tensile properties and processability of the composites thus prepared.

## 2 Experimental

Three different polymers were employed: a recycled poly(ethylene terephthalate) with a MFI value of 94 dg/min from beverage bottles (in flakes), a poly(butylene terephthalate) with a MFI value of 62 dg/min, and a commercial polypropylene (PP) (MFI value of 7.0 dg/min).

A bentonite (Bnt) was incorporated into the polymeric matrices. Its chemical composition is reported in Table 1. It has a sand index of 3 wt. % (after being sifted through 200 mesh without any drying) in a 37 μm mesh, a free silicon index of 23.1 wt. %, an approximate of 20 wt. % of $SiO_2$ (quartz) and a specific area of 15.6 $m^2$/g. Irganox B215 was also used as stabilizer in PET composites (0.5 wt.%) (Ciba).

**Table 1.** Chemical composition of bentonite.

| Element | Oxide (wt. %) | (wt. %) |
|---------|---------------|---------|
| Na | 3.03 | 2.47 |
| K | 1.41 | 1.17 |
| Ca | 0.10 | 0.07 |
| Fe | 4.65 | 3.25 |

The bentonite was dried in a convection oven for 24 hours at 80ºC and sifted afterwards through 100, 200 and 400 mesh. Then, the resultant powder and PET were dried in a vacuum oven at 80 °C for 24 hours before preparing the composites. They were made in a co-rotating twin-screw extruder at 265 °C and 80 rpm. The polymer and Irganox B215 were previously mixed and fed into the extruder. The bentonite was then added in the first feed port of the extruder. Three different composites with 5, 10 and 15 wt.% of bentonite were prepared.

On the other hand, composites of PBT/PP/PP-f-AM/Bnt were also prepared using the same extruder and 5, 10 and 15 wt.% of bentonite. A PP grafted with maleic anhydride (PP-f-AM) in the melt was prepared in the laboratory and used as compatibilizing agent. As before, the PBT and PP-f-AM were vacuum-dried at the same conditions mentioned above. The composites were extruded in one step at 235 °C and 150 rpm, adding the polymers in the extruder through the hopper and the bentonite in the first following feed port. The extruded material was cooled in a water bath and pelletized afterwards. The polymer matrix had a fixed composition of PBT/PP/PP-f-AM in 80/10/10 proportions.

Melt Flow Index values were determined at 265 °C and 240 °C for PET and its composites and and PBT, PBT/PP/PP-f-AM and its composites, respectively using a load of 2.16 kg. Rheological curves were also obtained using a capillary rheometer.

Samples for mechanical testing were injection-molded at 245 and 225 °C for PET and PBT based composites, respectively. All the materials were also previously vacuum-dried at 80 °C for 48 hours. Tensile tests were carried out at 1 mm/s.

## 3 Results and Discussion

It has been widely reported that PET undergoes degradation and hydrolysis when reprocessed, which produce chain scissions and consequently, a large decrease in its molecular weight and melt viscosity [1]. In this study, after being extruded, a strong newtonean character is ascertained (Table 2). The same table shows that higher viscosities and a more pseudoplastic behavior are obtained when bentonite is added to PET. The highest viscosity is achieved when the largest amount of filler is used. Thus, the addition of bentonite to PET makes obtaining extrusion products as continuous strands possible improving the reprocessability of the polymeric material, otherwise impossible because of its very low viscosity. Furthermore, the inclusion of the filler increases the initial degradation temperature, as observed during the rheological testing. This behavior was also reported by DiLorenzo et al. [3].

**Table 2.** Viscosity Power-law indices and MFI values of PET, PBT and PBT/PP/PP-f-AM composites.

| Composite | Power law index, $n$ | Consistency index K (Pa.s$^n$) | MFI (dg/min) |
|---|---|---|---|
| PET(recycled) | 0.89 | 187 | 93 |
| PET(recycled) and extruded | 0.93 | 142 | 103 |
| 5% PET/Bnt | 0.78 | 78 | 84 |
| 10% PET/Bnt | 0.72 | 83 | 79 |
| 15% PET/Bnt | 0.71 | 97 | 68 |
| PBT neat | 0.76 | 398 | 62 |
| 0% PBT/PP/PP-f-AM/Bnt | 0.71 | 556 | 52 |
| 5% PBT/PP/PP-f-AM/Bnt | 0.70 | 616 | 44 |
| 10% PBT/PP/PP-f-AM/Bnt | 0.68 | 731 | 40 |
| 15% PBT/PP/PP-f-AM/Bnt | 0.66 | 886 | 34 |

Table 2 also displays the viscosity power-law indices and MFI values of PBT and PBT/PP/PP-f-AM composites. Adding PP and PP-f-AM to PBT, and specially, adding bentonite, increases their pseudoplasticity and reprocessability.

The mechanical properties of PET composites are reported in Table 3. All the materials displayed a brittle behavior. When recycled PET is extruded and injection molded with bentonite, it is clearly seen in Table3 that the tensile properties are not strongly deteriorated. On the contrary, there is a slight increase in the Young's modulus values and in the tensile strength, with no noticeable effects on the elongation at break. On the other hand, the blend of PBT/PP/PP-f-AM behave as expected, that is, adding a PP phase to PBT decreased its Young's modulus and tensile strength because of the lower stiffness of PP. Nonetheless, PBT/bentonite composites were not studied because of the brittleness of neat PBT. The Young's modulus values of PBT composites were not significantly affected because of the counteracting effects of PP and bentonite.

**Table 3.** Tensile strength ($\sigma_r$), elongation at break ($\varepsilon_r$,) and Young's modulus (E) of PET, PBT and PBT/PP/PP-f-AM composites.

| Sample | $\varepsilon_r$ [%] | $\sigma_r$ [MPa] | E [MPa] |
|---|---|---|---|
| PET(recycled) | 1.5 ± 0.2 | 28 ± 3 | 2028 ± 46 |
| PET(recycled)and extruded | 1.4 ± 0.3 | 28 ± 6 | 2071 ± 15 |
| 5% PET/Bnt | 1.9 ± 0.4 | 38 ± 5 | 2224 ± 74 |
| 10% PET/Bnt | 1.7 ± 0.4 | 37 ± 4 | 2428 ± 19 |
| 15% PET/Bnt | 1.7 ± 0.6 | 34 ± 5 | 2363 ± 19 |
| PBT neat | 2.7 ± 0.5 | 43 ± 8 | 2114 ± 50 |
| 0% PBT/PP/PP-f-AM/Bnt | 2.5 ± 0.6 | 34 ± 5 | 1899 ± 50 |
| 5% PBT/PP/PP-f-AM/Bnt | 2.4 ± 0.6 | 36 ± 5 | 1930 ± 55 |
| 10% PBT/PP/PP-f-AM/Bnt | 2.4 ± 0.3 | 36 ± 2 | 2107 ± 40 |
| 15% PBT/PP/PP-f-AM/Bnt | 2.0 ± 0.2 | 35 ± 2 | 2115 ± 50 |

## 5 References

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