

# Rheological and mechanical properties of recycled poly(ethylene terephthalate)/high density polyethylene blends

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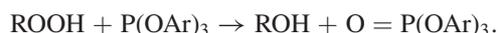
**Abstract.** Triphenylphosphite (TPP) has been used as a chain extender to regenerate polyethylene terephthalate (PET) and high density polyethylene (HDPE) wastes and to improve the properties of PET/HDPE system based on recycled materials. TPP incorporation in PET and HDPE showed a noticeable increase of the torque as a function of the mixing time and proved that the degradation reactions are considerably decreased. In the case of PET/HDPE blends, the increase of the torque was strongly dependent on the composition of the homopolymers and on the time of mixing. TPP incorporation contributed to significant variations of the rheological and mechanical properties of the regenerated PET and HDPE and their blends.

## 1. INTRODUCTION

Nowadays, recycling is the most adapted solution to overcome the inexhaustible amounts of plastic packages thrown every day after being used only once. Also, face to the increased awareness of the environmental protection and the larger consumption of plastic packages, post-consumed plastics recycling is actually a must alternative that is adopted and encouraged by all the governments. Poly(ethylene terephthalate) (PET) and polyethylene (PE) are widely used as packaging materials such as containers, bottles and films. Their annual rates of growth of production and consumption steadily increase. Their recycling can reduce the resources needed for manufacturing, conserve energy and decrease the impact of their wastes on the environment [1, 2].

Compared to the other post-consumed plastics, PET recycling is a complicated process because it undergoes simultaneously several degradation reactions during processing. Indeed, melt reprocessing is difficult and engenders generally a series of degradation mechanisms especially hydrolytic and thermal reactions which cause serious deterioration of PET performances. Thus, blending with recycled PE can yield better properties since it may reduce considerably the susceptibility to hydrolysis.

To reinforce PET/PE blends, chain extenders like phosphites can also be incorporated to overcome the decrease of viscosity noticed during recycling. Phosphites react with hydroxyl and carboxyl end groups of PET to diminish the possibility of their reaction via hydrolysis. They can also reduce the hydroperoxides to alcohol in polyolefins [3–6] according to the following reaction:



The aim of this work is to characterize the rheological and mechanical properties of PET/PE blends based on recycled materials as a function of the composition of the blend and the concentration of triphenylphosphites (TPP) incorporated during melt mixing.

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## 2. EXPERIMENTAL

Recycled HDPE (R-HDPE) was prepared by extruding HDPE **Marlex HHM 5502 BN** of Qatar Chemical Company (Q-Chem) in a Controlab single screw extruder for two cycles. Scraps of recycled PET (R-PET) were obtained after grinding PET water bottles. Recycled PET was melt mixed in an internal mixer alone and with HDPE without TPP and in the presence of 1% of TPP at 30 rpm and at a temperature of 270 °C for a mixing time of 15 min. R-PET/R-HDPE ratios were 30/70, 50/50 and 70/30. R-PET/R-HDPE (0/100) was mixed at 190 °C and at the same conditions as the previous formulations.

During mixing, the torque was recorded as a function of the mixing time. After granulating, the melt flow index (MFI) of the blends was measured on a Melt-Indexer using a load of 1.2 Kg. Films were realized to perform Fourier transform infrared spectra (FTIR) with a Perkin Elmer 1000 spectrophotometer. Izod impact test was realized on a Ceast apparatus on unnotched samples prepared by compression molding according to the standard ISO 180. Tension tests were performed on dumbbell compression molded samples using a Zwick Roell apparatus and at a tension rate of 10 mm/min.

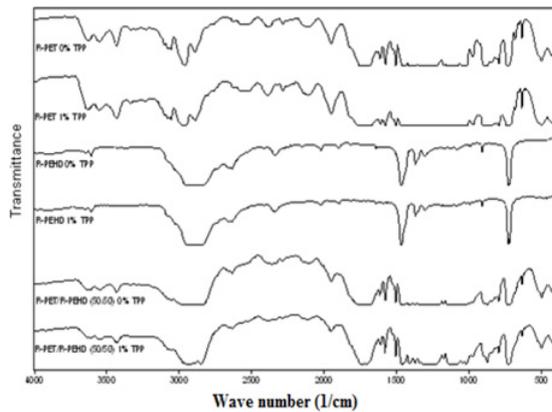
## 3. RESULTS AND DISCUSSIONS

### 3.1. Infrared analysis

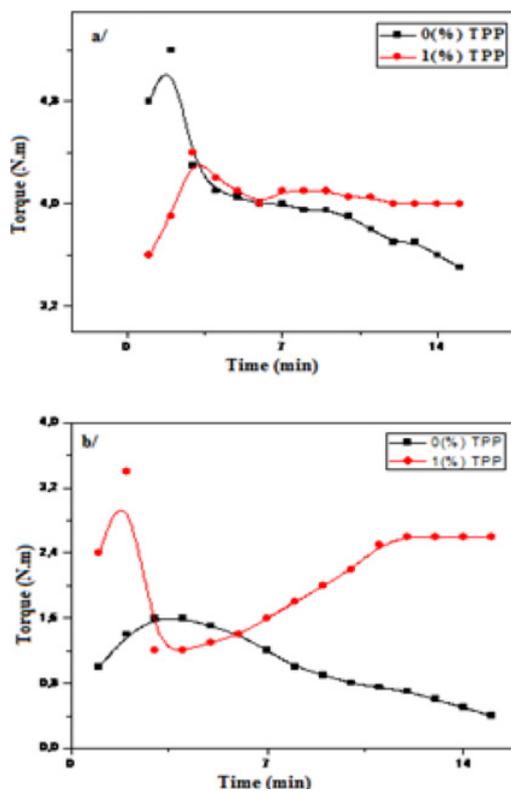
Infrared spectra of R-PET, R-HDPE and (50/50) (R-PET/R-HDPE) melt blended without TPP and with 1% of TPP gave no evidence of the occurrence of reactions between R-PET and TPP and R-HDPE and TPP (Figure 1). The phosphorous compounds that may be formed after the reaction of R-PET with TPP appear in the region where the R-PET spectrum is rich in bands, which do not allow the observation of new characteristic bands.

### 3.2. Torque and MFI variations study

The melt mixing of R-PET, R-HDPE and R-PET/R-HDPE without TPP showed a sharp decrease of the torque as a



**Figure 1.** FTIR spectra of R-PET, R-HDPE and (50/50) (R-PET/R-HDPE) melt blended with and without TPP.

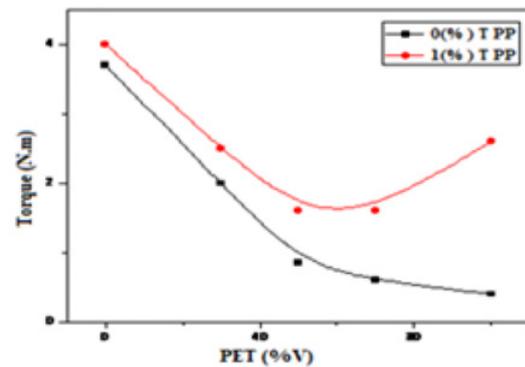


**Figure 2.** Torque variations versus time for: a/R HDPE, b/ R-PET.

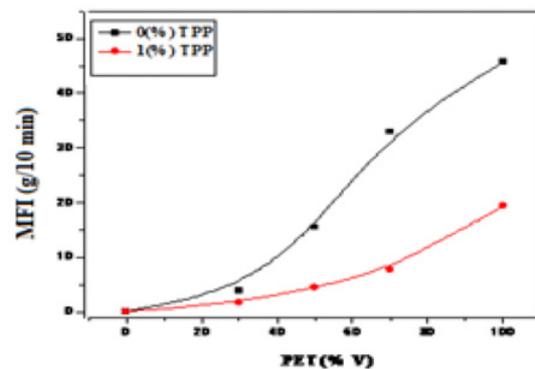
function of mixing time which means that the degradation processes are very favored (Figures 2–3).

The reduction of the intrinsic viscosity or the molar mass is especially pointed out for R-PET which undergoes hydrolytic and thermal degradation at a higher extent than HDPE which torque decrease is lower. This result is supported by the MFI variations (Figure 4) which prove that the higher the content of R-PET, the higher is the MFI of the blends. When TPP is introduced during mixing, a noticeable increase of the torque is displayed for all the formulations. This result proves that the degradation reactions responsible of the viscosity reduction are considerably avoided.

It is also noticed that the torque increase for R-PET and for the formulations with a high concentration of



**Figure 3.** Variations of the torque after 15 minutes versus the composition and the concentration of TPP.



**Figure 4.** MFI variations as a function of R-PET concentration in (R-PET/R-HDPE) blends.

R-PET is much more important than that showed by HDPE and the formulations containing less R-PET. This result is essentially due to the fact that TPP acts as an antioxidant for HDPE but as a chain extender for PET. So, more there is R-PET in the blend, the higher is the torque (Figure 3). The increase of the torque is also evidenced by the decrease of the MFI of the regenerated homopolymers and blends (Figure 4).

### 3.3. Mechanical properties

The Melt mixing of R-PET, R-HDPE and their blends without TPP produced materials with a low impact strength due the reduction of the viscosity, and the incompatibility of the blend (Figure 5).

The same trend is observed when studying the strain at break variations versus the blend composition (Figure 6). This brittleness is still observed when 1% of TPP was added and the degradation processes diminished, because these behaviors are practically governed by the situation at the interface which weakness produce materials with poor performances.

The stress at break and Young modulus values depend strongly on R-PET concentration. After blending in presence of TPP, the increase of the viscosity increases the stress at break for the formulations with higher rates of R-PET but do not affect the values of the modulus of the materials.

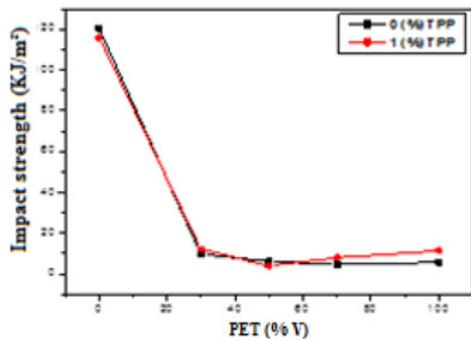


Figure 5. Impact strength variations as a function of R-PET rate and TPP concentration.

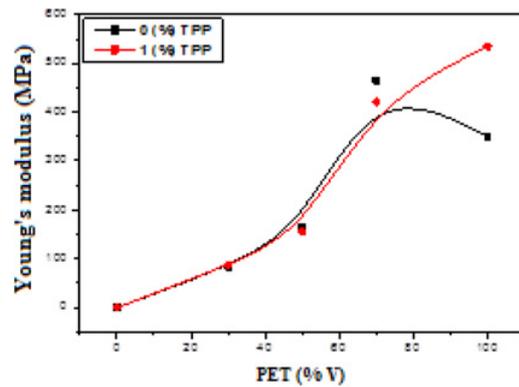


Figure 7. Young's modulus variations versus R-PET and TPP concentrations.

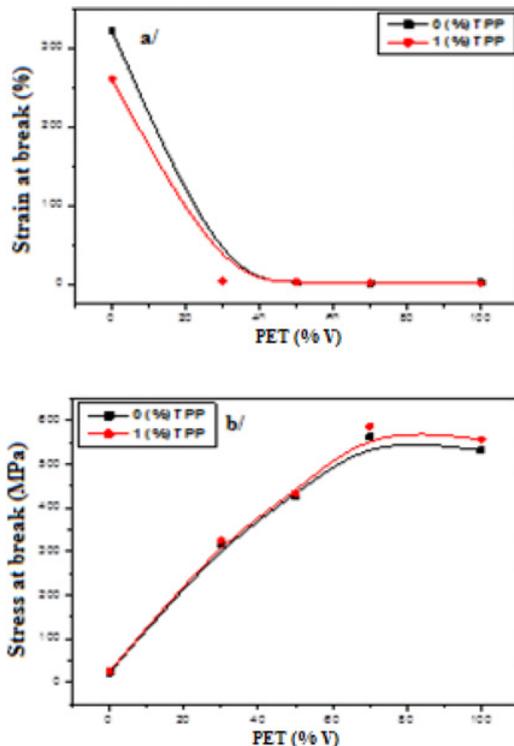


Figure 6. Variations of a/ Strain and b/ stress at break as a function of R-PET rate and TPP concentration.

#### 4. CONCLUSIONS

The effectiveness of triphenylphosphite in upgrading R-PET, R-HDPE and their blends properties has been

revealed by the torque and the MFI increase as a function of the composition. An improvement of the impact strength was also pointed out after adding TPP which permitted to limit the degradation reactions and provide a safe processing of these formulations based on recycled materials.

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