

# EXTRUSION FOAMING OF PET/PP BLENDS

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## Abstract

In order to develop new applications for recyclable commingled resin streams, blends containing PET and PP resins with different rheological characteristics were dry blended or compounded at different ratios and subsequently foamed by using PBAs and CBAs. Properties of the foamed blends were compared with those of similar products obtained by foaming the individual PET and PP components in the absence of compatibilizers/rheology modifiers. Foamed polymer blends with fine cell size and low density could be produced in the presence of suitable compatibilizer systems consisting of functionalized polyolefins or their combinations with reactive coagents

## Introduction

By contrast to the commonly used PS and LDPE resins, extrusion foaming of PET to low densities, (<0.2 g/cc), by injection of physical blowing agents (PBA) is a relatively new and increasingly active area presenting several challenges. Difficulties are mostly related to the required high processing temperatures and the particular rheological characteristics, rate of crystallization and process stability of the resin. Similarly, foaming of conventional polypropylene grades to low densities, also present difficulties due to the resin low melt strength that prevents uniform gas expansion and formation of stable cells. Significant developmental work has been conducted over the past fifteen years by resin producers and converters to develop reactor or post-reactor modified resins with high melt strength for low density foaming in single or tandem lines.

Both PET and PP can be foamed to higher than >0.5 g/cc densities by selecting suitable chemical blowing agents. In our earlier work with PET (1) we have shown that resin rheology is not as important for CBA foaming

as for PBA foaming and stable foams can be produced with commodity PET or PP grades as long as they meet certain minimum melt viscosity and melt elasticity requirements. For example, standard thermoforming grades of PET with IV's ranging from 0.83 and 0.96 could not, in general, be foamed to densities lower than 0.7 g/cc in flat sheet dies when carbon dioxide was used as a blowing agent. (2). Such density values are not that different from the lowest density values attainable with certain CBAs used with the same resins. However, lower density foams, (0.2 g/cc density), could be produced with carbon dioxide blowing agent in the same equipment, only when the PET was modified with reactive multifunctional compounds containing for example, acid, anhydride, epoxy or hydroxyl functionality (2,3).

In this article, an attempt is made to produce extrusion foamed PET/PP blends at different resin weight ratios with either PBAs or CBAs. Virgin resins were used to prepare compositions mimicking mixtures of post-industrial, post-consumer materials. The ultimate objective is to assess the possibility of using recyclable mixed waste streams containing resins with different rheological characteristics in order to produce novel low-density items. The inherent lack of miscibility of the PET/PP pair that would lead to technologically incompatible systems is addressed through the use of reactive additives that are expected to affect, not only morphology but, also rheology of these complex, multiphase, multicomponent systems (4).

## Experimental

### Foaming with Carbon Dioxide

Resins used in these foaming experiments were predried PET (Shell Traytuf 9506, 0.96 IV) and Polypropylene PP (EXXON Escorene PD 9374 MED). A commercially available polyolefin based copolymer containing acrylic acid (Primacor 3460) was used as potential compatibilizer, in some cases in the presence of

a multifunctional coagent that was expected to react with the compatibilizer and the PET end groups, thus, acting as a bridging agent. A 34 mm diameter 40 L/D long co-rotating intermeshing twin-screw extruder was used. Dry blended material with no additional nucleating agent was meter fed into the hopper. The screw of the extruder was designed to achieve melting within 10 L/D length with the gaseous blowing agent injection section immediately after. The rest of the length of the screw was used for mixing the blowing agent with the melt, pressurizing and cooling the gas laden melt to an optimum level of pressure and temperature. The melt was extruded through a 3 mm diameter rod die, expansion taking place thereafter. Density and cell size, and thermal properties of the foamed extrudates were measured.

### Foaming with Chemical Blowing Agents

Resins used in these foaming experiments, combined with vendors' information, are listed in Table 2. Prior to extrusion foaming, material combinations were evaluated in a Brabender batch mixer at 270 °C and 60 rpm under nitrogen. PET/PP blends were compounded in a Werner&Pfleiderer co-rotating twin-screw extruder with or without compatibilizers. Extrusion foaming was carried out in a Brabender 19 mm single screw extruder equipped with 1 inch slit die in the presence of 1% CBA (Expandex 5PT, Uniroyal Chem.). Conditions are listed in Table 4. Samples approx. 1-1.5 mm in thickness were extruded at screw speeds ranging from 30 to 80 rpm, and die temperatures ranging from 200 to 250 °C; die pressure was monitored throughout the experiments (Table 4). The extrudates were characterized for density, processability such as melt sagging, appearance and thermal properties.

## Results and Discussion

### Foaming with Carbon Dioxide

The PET homopolymer did not produce good quality foam (Table 1). The average density of the foamed rod was 0.41 g/cc with uneven diameter, rough skin and non-uniform cell size. The die pressure was also found to fluctuate widely. In preliminary experiments with binary blends of PP and PET, it was observed that the density of foams went through a minimum at 20% by wt. PP to a value of about 0.26 g/cc. For this composition, operating conditions were stable and extrudate surface was relatively smooth. However, cells were coarse and the average cell size of the foam increased from about 0.95 mm for PET to about 1.5 mm at 20 wt% PP.

In subsequent runs, a dry blend of 80% PET, 15% PP and 5% compatibilizer was used and a foam of

density of 0.25 g/cc was obtained (Fig. 1). The extrusion process was also found to be very stable (Table 1). Though the decrease in density was marginal, the average cell size of the compatibilized foamed blend was found to be about 900  $\mu\text{m}$  versus about 1500  $\mu\text{m}$  for the uncompatibilized foamed blend (Fig. 2). The use of the reactive coagent to enhance compatibility had a great effect on both density (0.17 g/cc) and cell size (180  $\mu\text{m}$ ) as shown in Figs. 1 and 2. The peak melting temperatures of PET and PP and the % crystallinity of PET were not significantly affected by the addition of compatibilizer as shown in Table 2. However, when the compatibilizer or compatibilizer/coagent combination was used, the crystallization peak temperatures of PET and PP were shifted to much lower values. This is presumably the result of enhanced interactions between the blend components delaying their ability to crystallize. These results are in agreement with DSC data reported earlier on PET/PP and PET/PP-g-AA unfoamed blends (5).

### Foaming with Chemical Blowing Agents

The viscosity and elasticity/melt strength of the PET used in this study could be upgraded through the addition of the reactive copolymers promoting chain extension/branching reactions (Table 3). The effects are more pronounced for the E-GMA copolymer; torque, in this case, kept increasing even at 9 min. after addition of the modifier. By contrast, following an initial increase upon the addition of Primacor 3460, torque tended to decrease thereafter. The PP used in these experiments had much lower viscosity than the PET at process conditions and appeared to degrade rapidly at these high melt temperatures. For example, the torque ratio of PET/PP (25/75) was 5.5 after three minutes and increased to a value of 9 after mixing for nine minutes. Comparison of the Brabender torque values, (data not shown), for combinations of PET/PP/compatibilizer (25/70/5) and PET/PP (25/75) suggest that certain viscosity/elasticity changes resulting from the addition of the modifier are translated into higher torque values. The high concentration of the low viscosity PP appears, however, to dilute these effects.

Data shown in Table 5 suggest that although no significant changes in foam density were observed in the case of compatibilizer containing blends, melt strength as related to sagging tendency improved. Similarly, appearance and dimensional stability were judged to be superior to those of the uncompatibilized PET/PP blends.

Table 5 shows thermal property data for the foamed homopolymers and blends. As shown earlier in

the case of PBA foaming, the presence of the reactive copolymers suppresses and/or delay crystallization of the PET. In fact, at 5% Primacor, no crystallization peak temperature is observed. This is significant information in designing extrusion foaming processes, since in addition to the viscoelastic properties of the resins, their ability to crystallize, the rate of crystallization and the interference of crystal nucleation with the bubble nucleation process are known to be of importance.

## Conclusions

The preliminary results presented in this article show that a low density foam with fine cell size can be obtained by blending PET, PP, compatibilizer and a suitable coagent followed by foaming with carbon dioxide in a twin screw extruder. The use of PP or polyolefinic based compatibilizer did not affect the melting peak temperature of PET or the PET crystallinity in the foam, although it decreased its crystallization temperature. As expected, densities of PET/PP blends produced with CBA's were higher. For such blends containing 25% PET in a polyolefin matrix, the use of reactive compatibilizer was shown to improve overall process stability and product characteristics.

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**Keywords:** Extrusion foaming, PET, PP, polymer blends, compatibilizer

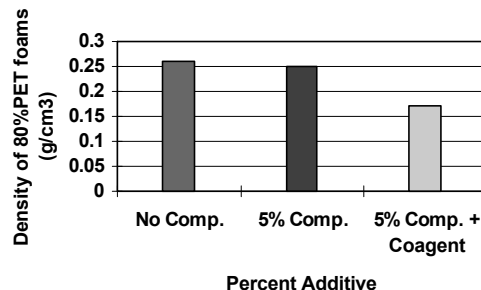


Figure 1. Blend Foam Density vs. % and type of Additive

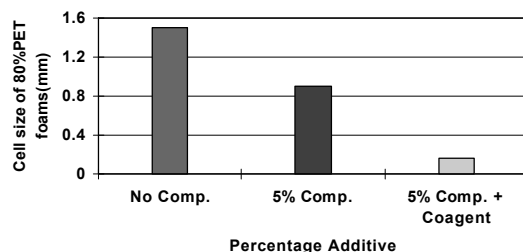


Figure 2. Blend Foam Cell size vs. % and type of Additive

Table 1. Properties of carbon dioxide foamed PET/PP (80/20) blends with/without compatibilizer (PP – Escorene PD 9374 MED, PET – Traytuf 9506)

Composition	Melting Peak (°C)		Crystallization Peak (°C)		Crystallinity Of PET(%)	Surface appearance	Process stability
	PP	PET	PET	PP			
PET	N/A	250.2	196.9	N/A	30.1	Unacceptable	Unstable
80%PET + 20%PP	145.3	248.8	199.2	109.0	30.3	Smooth	Stable
80%PET + 15%PP + 5%comp.	146.1	250.9	179.3	91.2	31.7	Smooth	Stable
80%PET+ 15%PP + 5% (comp.+ coagent)	145.3	246.3	161.5	102.2	26.4	Very smooth	Stable

Table 2 Properties of materials used in CBA Foaming

Materials	Supplier	Description
PET (recycled) PP Achieve 3825	Wellman ExxonMobil	IV=0.7 MFR=32g/min @230°C/2.16kg,
Primacor 3460 (ethylene- acrylic acid copolymer)	Dow	MFR=20g/min @ 190 °C/2.16kg, M.P.=95 °C by DSC
Lotader AX8840 (E-GMA, copolymer)	Atochem	MFR=5g/10min @ 190 °C/2.16kg, M.P.=108 °C by DSC

Table 3 Batch mixer results of PET with reactive copolymers

Composition	Additive added after PET torque stabilized (3~4min)	Torque ( $\Gamma$ , Nm) , Temperature (T, °C)		
		Before addition	After addition, 3min	After addition, 9min
PET+ additive (25:5 by wt.)	Primacor 3460	$\Gamma$ =2.5 T=270	$\Gamma$ =3.1 T=270	$\Gamma$ =2.9 T=273
	Lotader AX8840	$\Gamma$ =2.5 T=268	$\Gamma$ =7.2 T=273	$\Gamma$ =9.3 T=275

Table 4. Processing conditions of PET/PP foams using 1% CBA

Materials	Processing Conditions						
	Die pressure (psi)	Temperature profile (°C)				Feed rate (lb/hr)	Screw rpm
		T <sub>1</sub>	T <sub>2</sub>	T <sub>3</sub>	T <sub>die</sub>		
PET	1000	270	284	270	242	3.83	50
PP	800	220	224	220	200	2.40	30
25PET/75PP	500	222	250	226	212	1.82	32
25PET/70PP/ 5Primacor	600	239	255	246	238	2.37	40
25PET/70PP/ 5Lotader	600	251	269	255	244	2.24	40

Table 5 Properties of CBA foamed PET/PP (25:75)blends with/without compatibilizer

Composition	Melting Peak (°C)		Crystallization. Peak (°C)		Cryst. of PET(%)	Density of the foam (g/cm <sup>3</sup> )	Comments
	PP	PET	PET	PP			
PET Pellet	-	246	174	-	40	0.63	Satisfactory melt strength
PP Pellet	152	-	-	97.9	-	0.62	Poor melt strength, large cells, poor processability
25%PET+75%PP	149.6	245.3	195.1	110.4	33.28	0.68	Poor melt strength, corrugation; Poor dimensional stability
25%PET+70%PP+ 5%Primacor	148.8	245.1	No peak	97.4	26.87	0.68	Satisfactory melt strength and appearance
25%PET + 70%PP + 5%Lotader	147.5	243.3	180.7 (weak )	98.6	32.09	0.63	Satisfactory melt strength and appearance