Post-consumer recycled resins in film applications

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ABSTRACT: The addition of recycled high-density polyethylene resins to films was studied to determine their effect on film properties as well as to define any limitations to using such blends in flexible packaging. Generally tear strength and optical properties decreased while stiffness increased with addition of increasing levels of the post-consumer resins. Physical properties were affected significantly by the level of contamination in the recycled resins.

KEYWORDS: Film, flexible packaging, high-density polyethylene, impurities, physical properties, postconsumer wastes, recycling, synthetic polymers, utilization.

Major issues in the packaging industry continue to be recycling and the subsequent use of recycled materials in packaging. This is especially true for plastic packaging. While the recycling of rigid containers such as polyethylene terephthalate soda bottles and high-density polyethylene (HDPE) milk and detergent bottles is substantial and growing, recycling of flexible packaging is still in its infancy. This presents a problem for film converters who may wish to use recycled plastics in their film.

It is estimated that recycled resins will supplant 77,000 metric tons (170 million pounds) of virgin resins in garbage bag applications alone by the year 1995.[1] Since a consistent supply of recycled film resins is not yet available, many converters are beginning to examine the use of homopolymer HDPE recycled resins in various film applications because they are readily available in the marketplace. This study was initiated to determine the effects of adding post-consumer milk and water bottle resins to low-density polyethylene (LDPE) and linear low-density polyethylene (LLDPE) films.

[1]Leaversuch, R., Modern Plastics 68(2): 16(1991).

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Experimental work

Post-consumer recycled (PCR) HDPE homopolymer was obtained from domestic sources and blended at percentages of up to 40% with LDPE and LLDPE film resins. The melt indices and densities of the resins used are given in **Table I.** Butene and hexene LLDPE blown films and LDPE cast film were produced from these blends at a gauge of 32 microns (1.25 mils).

The films were tested for tensile strength and elongation, secant modulus, Elmendorf tear strength, impact strength, haze, and gloss. The data were analyzed using analysis of variance and t-testing, where appropriate, to determine the significance of the results at a 95% confidence level.

LLDPE blown film

For the LLDPE blown film trials, PCR HDPE was dry blended at 10%, 25%, and 40% levels in the virgin LLDPE resin. A 100% virgin LLDPE control was also run in each case. All films were produced at a 2:1 blow-up ratio with a gauge of 32 microns (1.25 mils). The results for the butene and hexene copolymer resins were similar in nature and are therefore summarized together.

Tear strength

Machine direction tear strength showed a significant decrease in properties at increasing levels of PCR addition in both LLDPE types. Tear strength in the transverse direction increased. This result can be attributed to the linear nature of the PCR HDPE. The film is oriented during extrusion causing a tendency to split in machine direction and an increase of tear strength in the transverse direction. The hexene trial involved two different PCR suppliers. The resin from supplier A was found to have significantly lower MD tear than that from supplier B. It also exhibited a larger number of gels by visual inspection.

Impact strength

Impact strength decreased significantly with PCR addition due to the addition of the linear HDPE resin and the effects of contamination. At a 10% PCR level, materials from both suppliers showed no differences in impact strength. At higher levels, however, product from supplier B was significantly better than that of the other

supplier. This difference is most likely due to the higher level of gels, contamination, or both in resin from supplier A.

Tensile properties

Tensile strength and elongation exhibited no significant difference between 100% LLDPE and blends of up to 40% PCR in both the machine and transverse directions.

Secant modulus

Secant modulus increased significantly as PCR was added to both LLDPE types. This change is due to the increasing density of the blends as PCR HDPE is added to the LLDPE resins.

Optical properties

The addition of PCR reduced optical properties as measured by haze and gloss in the LLDPE blends. For the butene blends, no significant difference was observed until the PCR content reached 40%. The control film (100% virgin resin) also had poor optics so that the impact of the PCR on optical properties was not evident until the 40% PCR level.

For the hexene LLDPE blend study, a virgin HDPE regrind was also blended with the LLDPE at the same levels as the PCR HDPE. While all samples had reduced optics at the 10% level, the haze and gloss of the samples containing PCR worsened with increasing PCR levels. The regrind blends have optical properties which level off at that point. This difference illustrates how the reduced optics are the effect of contamination rather than resin type in the 25% and 40% PCR samples. There was not a significant difference between the two PCR suppliers in haze and gloss, even though material from supplier A did have more gels by visual observation.

LDPE cast film

Cast film was evaluated at 16%, 26%, and 35% PCR levels in an LDPE resin. The films were produced at a thickness of 32 microns (1.25 mils) on a 55.9 cm (22 in.) coat-hanger die.

Tear strength

Machine direction tear strength exhibited different behavior when compared to results from the LLDPE blown film study. There was an increase in MD tear strength over the LDPE control at up to 26% PCR. Only at a 35% level did the MD tear drop to below the control value. The reasons for this behavior are not yet understood. A similar trial using a different LDPE resin is planned to verify this phenomenon. Transverse direction tear, however, increased with PCR content as in the LLDPE studies.

Impact strength

As PCR HDPE content increased in the blends, impact strength decreased. This result follows the same trend as the LLDPE blends. Although impact strength[2] tends to be related to tear strength, this was not the case for this example. The poor impact most likely results from contamination or gels which are points of failure in an impact test. The virgin control resin as well as the blends exhibited impact values which are low.

Tensile properties

Tensile properties were also affected by the addition of PCR to the LDPE. Tensile strength increased at PCR levels above 16%. Elongation at break was slightly reduced with increasing levels of PCR addition. Modulus increased with PCR content due to a higher film density.

Optical properties

Optical properties of the PCR blends were significantly lower than the 100% virgin LDPE. The increase in haze leveled off after the 16% level, while gloss did not change significantly from the 26% to the 35% PCR level. The poor optics are the result of the PCR contamination, the incompatibility of the HDPE and LDPE resins,[3] and the inherently poor optics of HDPE resins.

I. Description of resins used

Resin type	Melt index (g/10 min)	Density (kg/m³)
Recycled HDPE	~0.6	>960
LDPE	6.0	918
Butene-LLDPE	1.0	918
Hexene-LLDPE	1.0	918

Conclusions and recommendations

From this study the following conclusions can be made:

- The addition of PCR HDPE to LLDPE film resins resulted in a significant loss in machine direction tear strength and impact strength.
- The addition of PCR HDPE to LDPE did not significantly reduce machine direction tear strength until the 35% PCR level.
- The addition of PCR HDPE to LLDPE and LDPE resulted in an increase in stiffness and reduced optical properties.
- The quality of PCR resins had a significant impact on film properties and appearance. Variation between suppliers was evident and substantial for film applications.

Post-consumer homopolymer high-density polyethylene is suitable for use in nonfood film applications. Its use is dependent on the required film properties and the properties of any component added to the blend. Gel levels of PCR resins may vary from supplier to supplier. Thus the suitability of a resin for film applications will ultimately be dependent on the PCR supplier's resin quality. ■

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[2]Yilmanzer, U., J. Appl. Poly. Sci. 42(9): 2383(1991).

[3]Garcia-Rejon, A. and Alvarez, C., Poly. Eng. and Sci. 27(9): 640(1987).