



Multi-Layer Film Recycling Trial



Multi-Layer Film Recycling Trial

Plastics Forming Enterprises (PFE) conducted a material analysis of post-consumer multilayer flexible film on behalf of the Flexible Film Recycling Alliance (FFRA) and Ridwell. The study evaluated the recyclability and performance of flexible film packaging collected through a consumer-facing collection system and assessed its potential for circular economy applications in both food-contact and non-food-contact end markets.

Multilayer flexible films were collected through [Ridwell's subscription-based residential collection program](#), which provides an alternative recovery pathway for materials that are often excluded from traditional curbside recycling systems. The project examined the full recycling value chain, including collection, sorting, reprocessing, and end-use performance evaluation.

A bale of collected multilayer film products was supplied to PFE and manually sorted into two primary categories: food-contact and non-food-contact materials. For this study, "food-contact" materials were defined as packaging that had, or was suspected to have had, direct contact with food. This distinction is important because performance requirements and regulatory considerations differ between food-contact and non-food-contact applications. Separating these streams supports future evaluation of recycled materials for potential FDA-regulated food-contact uses as well as non-food-contact applications.

During sortation, PFE removed three material categories expected to negatively impact reprocessing performance or complicate interpretation of the datasets:

- Flexible films with paper labels, causing further contamination during extrusion.
- "Clear crinkle" materials believed to be primarily polypropylene-based films.
- Flexible films containing visible metalized materials.

Additional screening and sortation was conducted on metalized film materials to identify packaging structures that could potentially damage processing equipment. Acceptable materials were then returned to their respective food-contact or non-food-contact streams.

Following sortation, each material stream was divided into two processing categories. One stream was processed without washing, while the second underwent a washing procedure modeled after the RecyClass film washing methodology. The washing process used no added chemicals or heat and relied solely on gentle agitation.

Evaluating washed and unwashed material streams provided insight into contamination management, the presence of food organics, and the importance of collection quality. Unlike store drop-off programs, which often require films to be clean and dry, curbside-collected materials may contain higher and more variable

contamination levels. Understanding wash performance is vital to lab studies when evaluating commercial recycling pathways for post-consumer flexible films.

This approach resulted in four recycled material streams:

- Non-Food Contact – Washed
- Non-Food Contact – Unwashed
- Food Contact – Washed
- Food Contact – Unwashed

Each recycling stream was extruded, injection molded and evaluated for rigid-part mechanical performance. In addition, blend-down studies were conducted to determine the maximum practical incorporation levels of the post-consumer recycled (PCR) material in film-to-film applications.

The results detailed in this report demonstrate that recycling pathways for post-consumer multilayer flexible films are technically feasible and that viable end-market opportunities exist for film-derived recycled materials. By evaluating collection, sorting, washing, reprocessing, and end-use performance, the study provides valuable insight into how multilayer flexible film packaging can be integrated into circular economy systems. The findings also highlight key considerations for both food-contact and non-food-contact applications and support continued development of flexible film recycling infrastructure and end markets.

Multi-Layer Bale Sortation

The incoming bale was first evaluated to verify that the material consisted primarily of polyethylene (PE) film. Materials identified as non-PE were classified as contaminants and removed from the study. Examples of contaminants included wood, fiber, metal, polyethylene terephthalate (PET), polypropylene (PP), and heavily soiled film. The initial screening ensured that only PE films suitable for mechanical recycling advanced through the evaluation process.

Following confirmation of PE composition, each item was visually inspected for the presence of visible metal and categorized according to food-contact parameters.

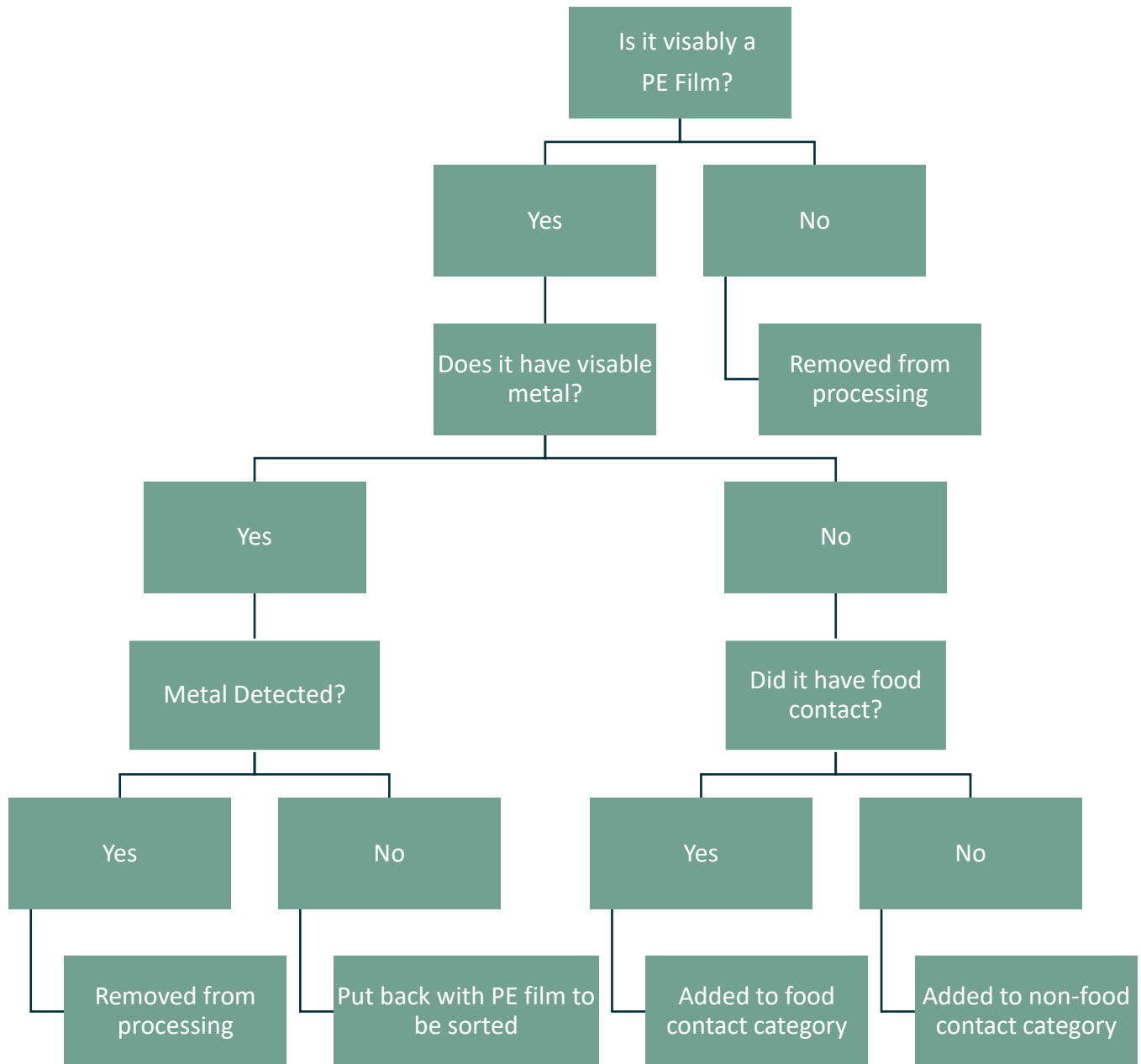
Materials containing visible metal and metalized layers underwent additional screening using a metal detection system calibrated to reject material containing metal equivalent to or greater than a 12 mm sphere. This quality-control measure was implemented to prevent excessive metal contamination from entering the recycling process and potentially damaging processing equipment. Material that passed metal detection was returned to the appropriate recycling stream, while material that failed was removed from further evaluation.

Following contamination removal and metal screening, acceptable PE films were separated into food-contact and non-food-contact categories. Material that had direct contact with food products, including pet food packaging, was classified as food-contact material. Material that had not been used in direct food-contact applications was classified as non-food-contact material. This classification was intended to support evaluation of recycled resin performance for potential circularity applications and to better understand considerations associated with food-contact and non-food-contact end markets.

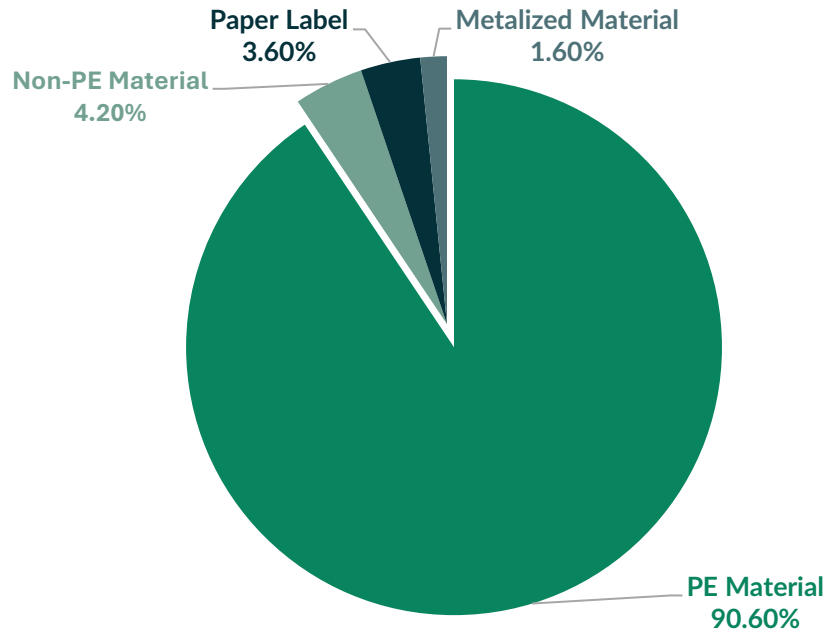
After sortation, food-contact materials represented approximately 23% of the recovered PE film stream and achieved a yield of 80%. Non-food-contact materials represented approximately 77% of the recovered PE film stream and achieved a yield of 90%.

In addition to evaluating these streams independently, PFE developed an "industry blend" designed to represent the overall composition of the incoming bale after contaminant removal. The blend was formulated using unwashed pelletized material and consisted of 77% non-food-contact resin and 23% food-contact resin, reflecting the proportions observed during sortation. This blend was intended to simulate a commercially realistic mixed-film recycling stream, where food-contact and non-food-contact PE films are recycled together, contaminants are removed, and the remaining material is processed as a single feedstock.

The industry blend was evaluated alongside the segregated food-contact and non-food-contact streams to assess material performance and better understand the end-market potential of recycled resin representative of the overall bale composition.

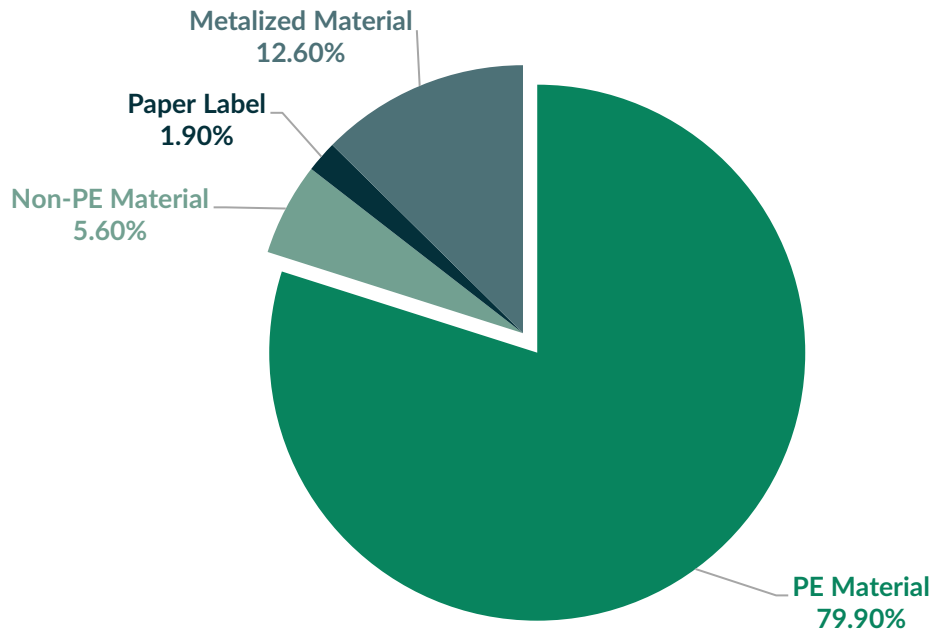


NON-FOOD CONTACT SORTATION



CLEAR CRINKLE (POLYPROPYLENE)	PAPER LABEL	METALIZED
		

FOOD CONTACT SORTATION



CLEAR CRINKLE (POLYPROPYLENE)	PAPER LABEL	METALIZED
		

Film Processing Summary

The sorted PE film streams were subsequently prepared for processing and evaluation. Prior to size reduction, representative samples from each stream were visually inspected to confirm that the materials remained consistent with their assigned classifications and that no significant contamination had been introduced during handling. The food-contact, non-food-contact, and industry blend streams were then processed independently to maintain traceability throughout the study and enable direct comparison of the resulting recycled materials.

Each material stream was granulated under controlled conditions to produce a uniform flake suitable for washing and downstream processing. Following granulation, the materials underwent washing operations designed to remove residual dirt, product residues, labels, inks, adhesives, and other surface contaminants commonly associated with post-consumer PE film. The washed flakes were subsequently rinsed and dried prior to further characterization. Throughout processing, observations were recorded regarding contamination levels, material behavior, and overall processability to identify any notable differences among the food-contact, non-food-contact, and industry blend streams.

Following washing and drying, the recovered flake was subjected to a series of laboratory evaluations to characterize material quality and assess suitability for recycling applications. Testing included visual inspections, contamination analysis, color measurements, and processing assessments. The objective of these evaluations was to determine whether the segregated streams or the representative industry blend exhibited meaningful differences in recycled resin quality that could influence potential end-market applications. Particular attention was given to characteristics affecting recyclability, aesthetic properties, and material performance during subsequent converting and manufacturing operations.



During the extrusion process, PFE utilized the standard polyethylene film screen pack configuration consisting of 20/40/150/40/20 mesh screens. Each of the four material categories, including washed food-contact, unwashed food-contact, washed non-food-contact, and unwashed non-food-contact film, was processed at a 100% concentration rate using this standard filtration arrangement. Under these conditions, only the washed and

unwashed non-food-contact materials were successfully pelletized. Both food-contact streams triggered the extruder's high-pressure shutdown system early in processing, preventing pellet production. This safety mechanism activates when melt pressure exceeds 3,000 psi.

To enable pellet production of the food-contact material stream, the screen pack configuration was progressively modified to reduce filtration resistance. An intermediate 40/60/40 screen pack was initially evaluated; however, both washed and unwashed food-contact materials again exceeded the pressure limit and triggered a high-pressure shutdown. A subsequent configuration consisting of 20/40/20 mesh screens was successfully processed and produced pellets from both food-contact streams.

While the reduced filtration configuration enabled pellet production, it also increased the likelihood that contaminants such as food residues, particulate matter, gels, and higher-melting multilayer materials would pass through the extrusion process and remain in the recycled pellets. The presence of these contaminants has the potential to negatively affect downstream conversion operations, particularly processes requiring consistent melt quality and homogeneity, such as blown film extrusion and injection molding.

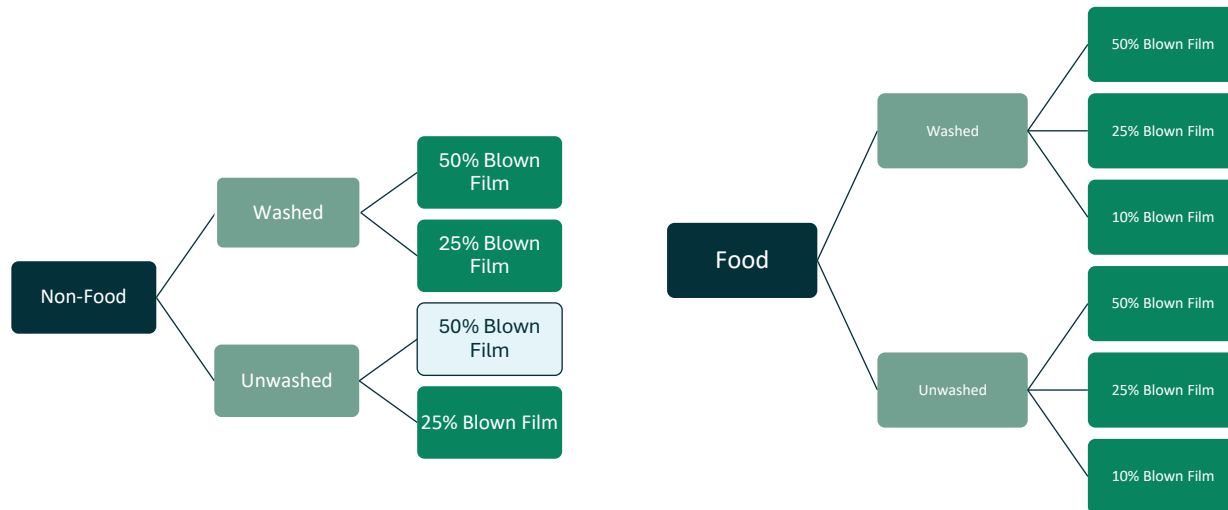
Following pelletization, all four material categories were molded into test specimens and evaluated for key mechanical properties, including tensile strength, flexural performance, and Izod impact resistance. In addition, a representative industry blend was prepared using 77% unwashed non-food-contact material and 23% unwashed food-contact material, reflecting the composition identified during bale characterization and sortation activities.

Blown Film Evaluation

Blown film trials were conducted to assess the maximum post-consumer recycled (PCR) content that could be processed while maintaining stable bubble formation. A virgin polyethylene control resin was used to dilute each PCR pellet type to progressively lower concentrations.

Initial trials were conducted at 50% PCR content. Under these conditions, only the washed non-food-contact material produced a stable bubble and acceptable film. All other material streams failed during processing. Subsequent trials were performed at 25% PCR content for each recycling category. Both washed and unwashed non-food-contact materials successfully produced film, while neither of the food

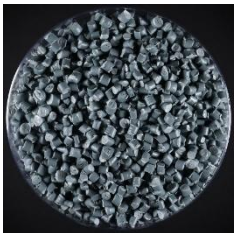
contact materials could maintain a stable bubble. Overall results from both recycling categories are listed below:

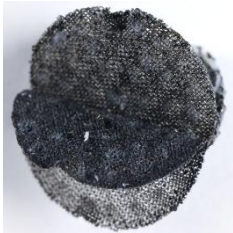
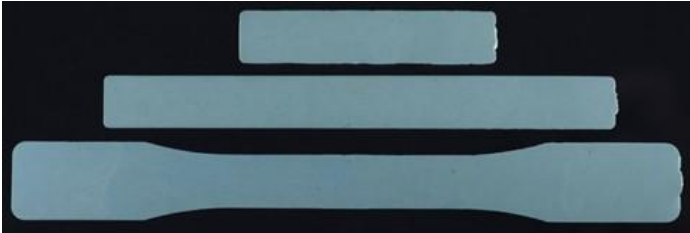
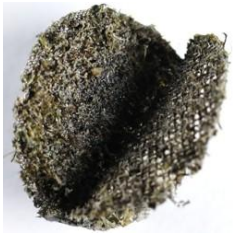


Additional testing was conducted at 10% PCR content for the washed and unwashed food-contact materials; however, both continued to exhibit unstable processing and failed to maintain blown film bubble integrity. It is likely that the reduced filtration required during pelletization contributed to elevated contamination levels within the food-contact PCR pellets, resulting in defects that adversely affected film formation and bubble stability.

Finally, a representative industry blend was prepared using the relative proportions of food-contact and non-food-contact film identified during the original bale sortation study. Pellets produced from the unwashed food-contact and non-food-contact streams were blended accordingly and evaluated in both injection molding and blown film applications. The industry blend was successfully processed into injection-molded test specimens at 100% PCR content. However, the material was unable to maintain a stable bubble during blown film processing, even at 10% PCR content, indicating significant limitations for film applications under the conditions evaluated.

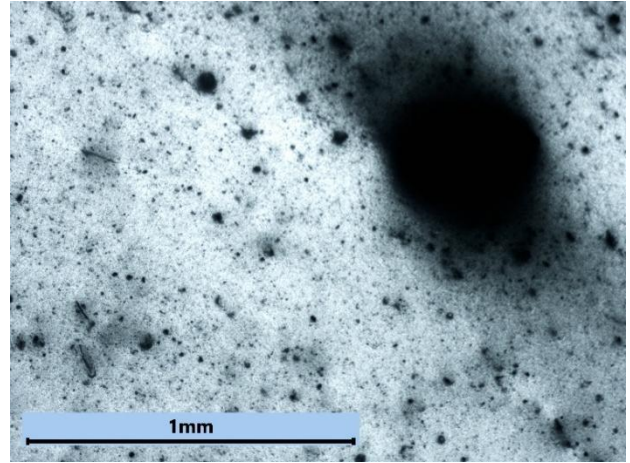
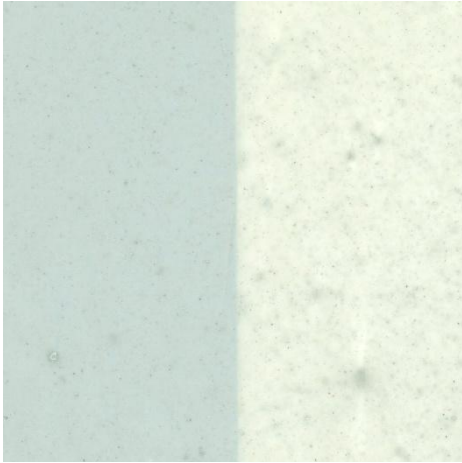
Industry Blend		
		

Non-Food Contact (Washed)		
Pellet	Screen	Parts
		
Non-Food Contact (Unwashed)		
Pellet	Screen	Parts

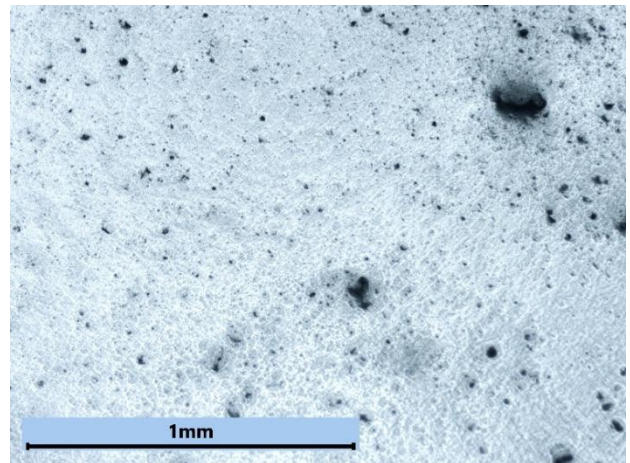
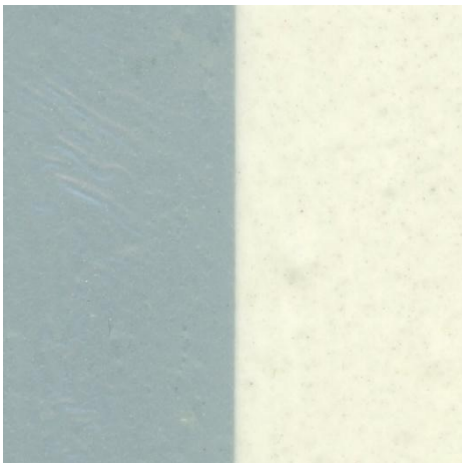
		
Food Contact (Washed)		
Pellet	Screen	Parts
		
Food Contact (Unwashed)		
Pellet	Screen	Parts
		

SUCCESSFUL BLOWN FILM PRODUCTION PICTURES

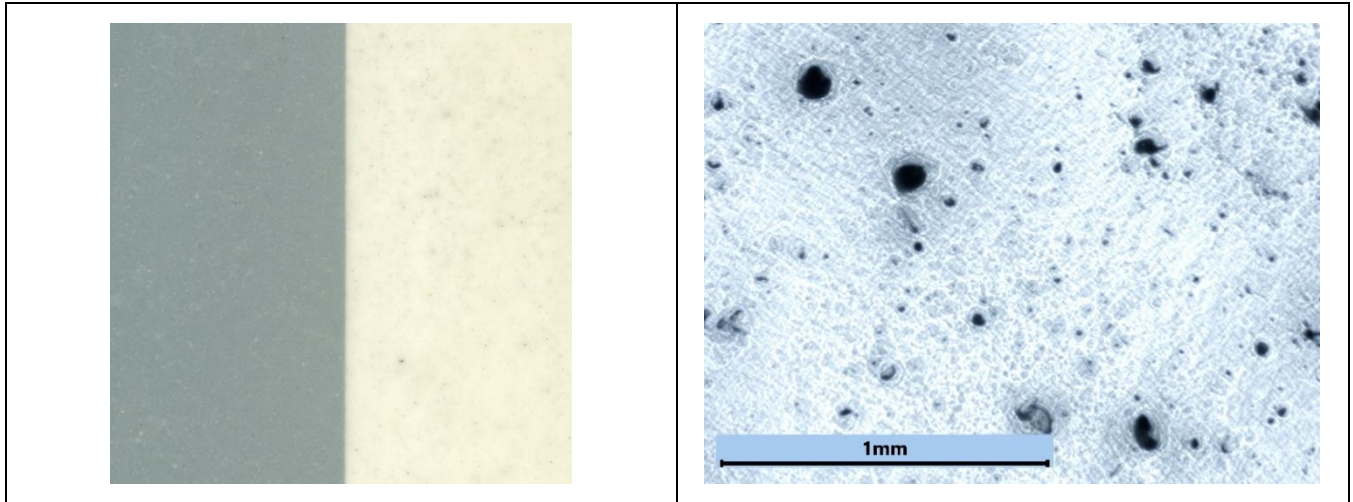
Non-Food Contact (Washed) 50%



Non-Food Contact (Washed) 25%



Non-Food Contact (Unwashed) 25%



PELLET SUMMARY

Property	Non-Food Contact		Food Contact	
	Washed	Un-Washed	Washed	Un-Washed
Screen Size	20/40/150/40/20	20/40/150/40/20	20/40/20	20/40/20
Screen Pack Pressure Build (%)	11.08%	12.73%	21.85%	11.30%
Average Pressure (psi)	2002	2327	1962	1891
Density (g/cc)	0.849	0.828	0.835	0.844
Melt Index (g/10min)	0.601	0.591	0.308	0.361
Moisture Content (%)	0.3454	0.0240	0.2912	0.7051
DSC Primary Peak (°C)	124.48	123.16	124.38	121.30
Ash (%)	3.59	3.39	2.74	3.83
Pellet Colors L*	57.35	55.20	54.22	53.75
Pellet Colors a*	-4.01	-3.78	-0.80	-0.82
Pellet Colors b*	0.98	0.75	7.40	7.67

FILM SUMMARY

Property	Non-Food Contact					
	Washed				Unwashed	
	50%		25%		25%	
	MD	TD	MD	TD	MD	TD
Film Thickness	2.0		1.9		1.9	
Gauge Variation	5%		4%		4%	
Tensile Strength (psi)	2162	1860	2420	2503	2184	2223
Elongation at Break (%)	751.94	823.72	803.78	905.09	784.08	858.51
Tear Strength (gf)	376.8	724.0	382.1	672.3	324.8	594.1
Impact Failure Weight (g)	89		147		96	

The food contact material did not produce film, and the unwashed non-food contact material was only able to produce film at a 25% concentration.

PART SUMMARY

Property	Non-Food Contact		Food Contact		Industry Blend
	Washed	Un-Washed	Washed	Washed	
Flexural Modulus (psi)	58803	59934	85935	75113	67226
Tensile Strength (psi)	2523	2493	2350	1863	2485
Elongation at Yield (%)	31.17	34.11	14.31	15.59	49.88
Elongation at Break (%)	NA	NA	411.36	258.11	370.56
Notch Izod Impact Break Type	Partial	Partial	Partial	Partial	No Break
Part Colors L*	58.53	52.24	51.87	48.22	51.60
Part Colors a*	-6.51	-6.16	-2.86	-2.08	-5.58
Part Colors b*	1.17	2.88	11.47	8.89	4.22

Key Findings

Based on the testing results, the strongest opportunity for mechanically recycled multilayer film is in non-food-contact polyethylene (PE) applications, particularly where the material can be washed prior to reprocessing. The non-food-contact stream achieved a 90.6% yield during sortation and was successfully pelletized using standard film recycling filtration systems. In blown film trials, washed non-food-contact material successfully produced stable film at up to 50% PCR content, while both washed and unwashed material produced acceptable film at 25% PCR content. These results demonstrate that well-sorted, predominantly PE-based multilayer film can serve as a viable feedstock for secondary film applications such as shipping sacks, industrial liners, construction film, agricultural film, and other non-regulated packaging applications.

By contrast, the food-contact film stream presents significantly greater processing challenges. While food-contact film represented approximately 23% of the recovered material, higher contamination levels and metalized structures required reduced filtration during extrusion to avoid excessive pressure buildup. Even after pelletization, neither the washed nor unwashed food-contact materials were able to produce stable blown film at PCR concentrations as low as 10%. These findings suggest that food-contact-derived multilayer films are not

currently well-suited for film-to-film recycling pathways without additional cleaning, sorting, or advanced recycling technologies. Instead, this material appears better suited for more contamination-tolerant applications where film quality and melt homogeneity are less critical.

Injection molding proved to be the most promising end-market for all recycled material streams. Both food-contact and non-food-contact materials, as well as the industry blend, were successfully processed into molded parts at 100% recycled content. Mechanical property testing showed that the recycled resins maintained tensile and flexural performance, while the industry blend exhibited particularly strong impact performance with no break observed during Izod testing. These results indicate that mixed multilayer film could be effectively utilized in durable molded products such as pallets, totes, storage containers, landscaping products, automotive dunnage, protective packaging components, and other non-food-contact industrial applications.

From a market development perspective, the data support prioritizing recycling systems that maximize recovery of the non-food-contact PE fraction while continuing to remove polypropylene films, paper labels, and excessive metalized materials before processing. Investments in enhanced sorting and contamination control are likely to produce the greatest results in film-to-film circularity. For the broader mixed-film stream, the study suggests that a practical near-term strategy is to direct material into injection-molded applications where the recycled resin demonstrated processability and performance. As collection programs expand, improving identification and separation of food-contact multilayer films will be critical to increasing the overall value and recyclability of these materials

Overall, the study demonstrates that post-consumer multilayer flexible films can be successfully recycled through mechanical processes, but end-market selection should be based on material composition and contamination requirements. Washed non-food-contact films offer the best opportunity for incorporation into new film products, while mixed and food-contact streams are currently better aligned with molded-product applications. These findings support a tiered strategy that maximizes value by reserving the cleanest recycled streams for higher-performance film applications and directing more challenging streams toward durable goods and industrial products.

Acknowledgments

Plastics Industry Association

The [Plastics Industry Association \(PLASTICS\)](https://www.plasticsindustry.org/) supports the entire plastics supply chain, including Equipment Suppliers, Material Suppliers, Processors, and Recyclers, representing over one million workers in our \$551 billion U.S. industry. PLASTICS advances the priorities of our members who are dedicated to investing in technologies that improve capabilities and advances in recycling and sustainability and providing essential

products that allow for the protection and safety of our lives. Since 1937, PLASTICS has been working to make its members, and the eighth largest U.S. manufacturing industry, more globally competitive while supporting circularity through educational initiatives, industry-leading insights and events, convening opportunities and policy advocacy, including the largest plastics trade show in the Americas, [NPE: The Plastics Show](#).

Plastic Forming Enterprises

Plastics Forming Enterprises, LLC. is an independent full-service testing and R&D company serving the plastics, packaging, recycling, and consumer products industries worldwide with a range of services. This range of services was founded in 1984 with experience in these diverse but connected industries. We clarify the confusion for clients concerning the technical and often political issues surrounding recycling. PFE delivers practical answers and arms its clients with the knowledge, tools and technologies they need to make sound business-focused decisions as guided by trade association and brand owners, which PFE works with daily.

Ridwell

is a service that inspires people to create a future without waste. Today, the company makes it easy to reuse and recycle more by identifying reusable and hard-to-recycle items that standard city curbside programs don't collect, picking them up directly from customers' doorsteps, and matching them with local partners that can use them sustainably. Originally started as a local father-and-son project called Owen's List, Ridwell helps individuals and communities close the loop by offering transparent, traceable recycling and reuse services that make responsible disposal accessible to everyone. Its programs have already helped divert tens of millions of pounds of hard-to-recycle materials from landfills, proving that small actions, done collectively, can lead to lasting environmental change. To learn more, visit [Ridwell.com](#).