WHITE PAPER

INCREASING RECYCLED CONTENT IN MILK BOTTLES

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Find out how much mechanically recycled HDPE (rHDPE) could be incorporated into milk bottles
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Circular economy targets have been established to improve the sustainability of plastic packaging and avoid environmental damage. While countries such as the United Kingdom have incorporated up to 31% recycled content in their milk bottles for many years[1], lack of supply has prevented the understanding of the technical limitations on recycled content. A study was conducted to assess the effect of repeated mechanical recycling loops on 50% and 70% rHDPE in milk bottles. Processability, aesthetics and mechanical performance was maintained for milk bottles at both levels of recycled content throughout the experimental program.

AUSTRALIA'S 2025 NATIONAL PACKAGING TARGETS SPECIFY A SET OF GOALS FOR IMPROVING PACKAGING SUSTAINABILITY. AMONG THESE IS A TARGET FOR 50% AVERAGE RECYCLED CONTENT ACROSS ALL PACKAGING MATERIALS. FOR HIGH DENSITY POLYETHYLENE (HDPE), THE 2025 TARGET IS 20%[2]. IN THE 2018-2019 FINANCIAL YEAR, THE AUSTRALIAN PACKAGING COVENANT ORGANISATION (APCO) REPORTED AN AVERAGE OF JUST 3% POST-CONSUMER RECYCLED (PCR) CONTENT FOR HDPE PACKAGING[3].

The gap to the 2025 target that needs to be closed is significant and requires a thorough understanding of the opportunities and limitations of incorporating mechanically recycled plastics in packaging.

The aim of this white paper is to provide insights into the maximum percentage of mechanically recycled HDPE that can be incorporated into milk bottles while maintaining performance and aesthetic requrements.

PLASTICS CIRCULAR ECONOMY

Plastic packaging is durable, lightweight, efficient, safe and very effective in many applications. However, leakage of packaging materials into the environment after use is harmful and wasteful. Post-consumer polymers are a valuable resource, and there has been considerable focus from industry in recent years to move towards a more sustainable model. The circular economy describes an alternative to the historically linear take-make-waste model for polymer products. In a circular economy, end-of-life materials become the feedstock for production of new materials.

Beginning with the New Plastics Economy reports from the Ellen MacArthur Foundation[4], in 2018 businesses around the world committed to some 2025 targets for reduced plastic waste. APCO have published Australia's 2025 National Packaging Targets[5] which align with the commitments from other countries:

- 100% of packaging to be reusable, recyclable or compostable
- 70% of plastic packaging recycled or composted
- 50% average recycled content across all packaging
- Phase out problematic and unnecessary single-use plastic packaging

Much of the recycling today is termed "down-cycling," meaning that the recycled resin is lower quality and cannot be used in the original application. The Australian Dairy Sustainable Packaging Roadmap to 2025 outlines a range of actions required to move the dairy industry towards Australia's circular economy targets[6]. Milk bottles are particularly suited to closed-loop recycling, where PCR material is returned to the original application, due to the ease of sorting and the use of unpigmented resin. As many brand owners and manufacturers of food packaging have committed to sustainability goals, it is important to understand the mechanical recycling process and limiting factors for mechanically recycled content.

UK experience

The UK provides an excellent case study for milk bottle recycling as the packaging formats are very similar to Australia. In 2008, the Milk Roadmap was published, a document which later became the Dairy Roadmap. This document outlines a range of targets and initiatives for environmental improvements throughout the dairy supply chain. The 2018 report states that milk bottles are among the consumer products with the highest rate of recycling and reuse in the UK, with 85% recycled. The recycled HDPE (rHDPE) content in milk bottles reached 31% in 2014, but later reduced to about 25% in 2018 due to reductions in supply of food grade rHDPE[1].

The UK experience shows that in the current environment, supply of high quality rHDPE is often the bottleneck for increasing recycled content. It does not appear that technical difficulties have yet limited the increase in mechanically recycled content in industry, so the maximum level of rHDPE that can be used successfully is not known.

MECHANICAL RECYCLING OF POLYETHYLENE

After a consumer places an empty milk bottle in their recycling bin, numerous steps are required to produce food grade rHDPE suitable for use in new milk bottles. The order and location of steps can vary depending on the infrastructure and processes available, but the general process for mechanical recycling for food grade rHDPE are[7]:

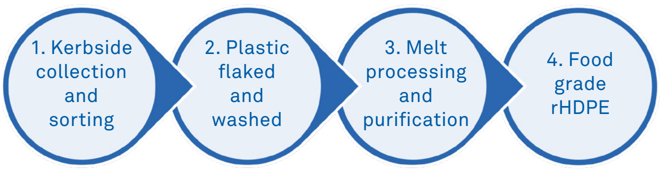

Figure 1. Steps required to product food grade recycled high density polyethylene (rHDPE)

1. Materials Recycling Facilities (MRFs) take in the mixed recycling streams from kerbside collection and other sources. Major contaminants are removed, and the material is sorted by container type and by material. Bales are created for plastic waste.
2. Plastics Recycling Facilities (PRFs) take in the bale materials. The plastic containers are (further) sorted and shredded before washing the flake to remove contaminants such as food, ink, labels and glue. The material is then sorted for polymer type and colour.
3. The purified flake material is processed through a specially designed extruder with degassing and melt filtration. A solid state degassing process is often used before or after the extrusion to further reduce the amount of volatile organic compounds that cause odour.
4. Provided the appropriate food contact requirements are met, the granules produced from the melt processing step are suitable to be incorporated into new milk bottles.

Food contact requirements for mechanically recycled HDPE

In Australia, the requirements for materials in contact with food are taken from either the EU or US FDA regulations. APCO provide a useful summary of the legal and other restrictions for recycled content in food packaging in Australia[8].

While the US FDA does not set out additional requirements for rHDPE compared to virgin resin, they do provide guidance to industry[9] as well as offering assessments of recycling systems upon request. Once a process has been assessed favourably, the FDA will issue a Letter of No Objection stating the input material requirements, and limits on rHDPE content and end use applications based on the data submitted. Processes for food grade rHDPE production are now available for up to 100% rHDPE content in dairy applications.

WHAT IS THE MAXIMUM rHDPE CONTENT THAT CAN BE USED IN MILK BOTTLES?

With technologies now able to produce rHDPE suitable for food contact applications at high recycled content levels to support the circular economy, it is increasingly of interest to understand any technical barriers to mechanically recycled content in packaging.

A study was initiated by Bega and Qenos, and co-funded by Food Innovation Australia Limited and Dairy Australia. The objective of this study was to investigate the effect of mechanically recycled HDPE on polymer processability and performance. The effect of thermal processing was the primary objective of this analysis as it is often hypothesized that the number of successful recycling loops for polymers will be limited by thermal degradation. The effect of contamination that would be present in PCR material due to pigments or other foreign materials was a secondary objective.

Mathematical Model

The US FDA describes different types of recycling, two of which are relevant to this study. Primary recycling describes the reprocessing of internal scrap (regrind), while secondary recycling describes the most common process for post-consumer material recovery, i.e. mechanical recycling[9]. Figure 2 provides a schematic of the recycling processes that are currently available to the dairy market.

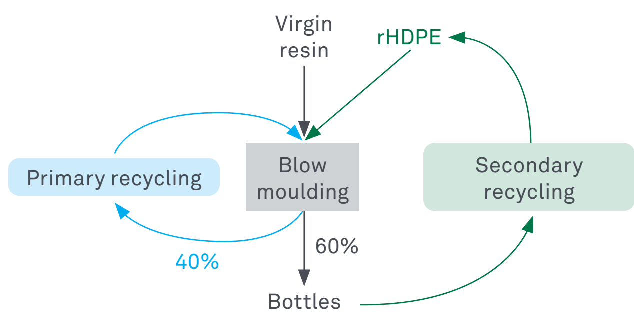

Figure 2. Schematic of recycling processes currently utilised by the dairy market

A mathematical model was created to simulate a closed-loop recycling processes at varying levels of rHDPE. Regrind was held constant at 40%. As the PCR level increases, the quantity of material exposed to high counts (loops) of reprocessing steps dramatically increases (Figure 3). The mathematical model was utilised to determine the number of experimental loops required until the process approaches a steady state, i.e. the material's heat exposure ceases to change significantly with further loops.

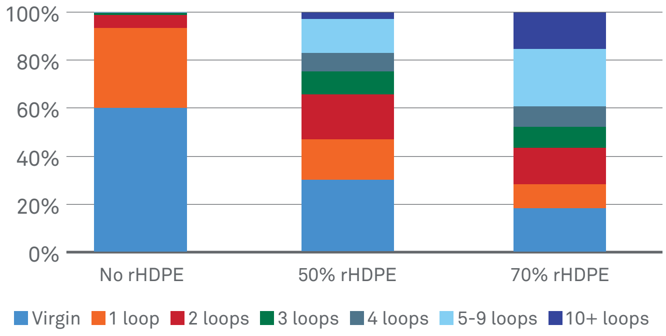

Figure 3. Steady state heat exposure for different PCR levels, assuming 40% regrind (primary recycling). One loop defined as the equivalent of modelled recycling extrusion process.

Laboratory Model

Two litre milk bottles of standard weight were moulded on a single head reciprocating blow moulder at the Qenos Technical Centre using dry blends of virgin Alkatane® HD6400 dairy resin and post-consumer rHDPE. A portion of bottles was granulated and returned to the blow moulder feed mix to emulate the primary recycling (regrind) stream. After the regrind process reached a steady state, the bottles were collected and ground before being re-pelletised through a twin screw extruder to simulate the secondary (mechanical) recycling process. This re-pelletised material was then used as the rHDPE input for the subsequent loop (Figure 4). This process was used to assess the effect of reprocessing at 50% and 70% rHDPE content as it progresses towards steady state.

An ideal model will replicate the process of interest as closely as possible. Analysis using the mathematical model showed that it would be difficult to accurately assess the effect of thermal processing while also including post-consumer rHDPE at every loop. As thermal processing was the primary objective of the study, post-consumer rHDPE was only used for the first loop. This resulted in a decreasing level of contaminants, as the lab simulated rHDPE used in subsequent loops does not collect the contaminants that are present in a PCR stream.

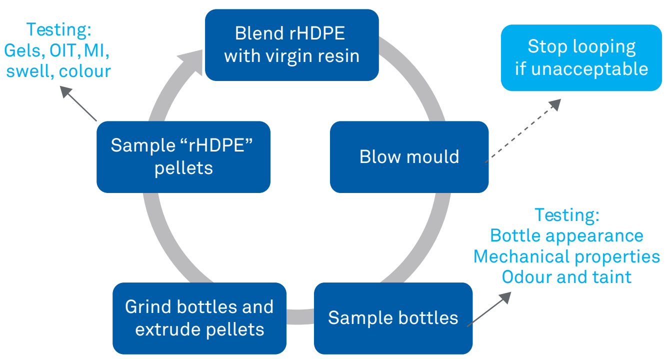

Figure 4. Laboratory model schematic. Regrind was also used during at each loop to emulate the commercial scale process.

> MILK BOTTLES ARE PARTICULARLY SUITED TO CLOSED-LOOP RECYCLING, WHERE PCR MATERIAL IS RETURNED TO THE ORIGINAL APPLICATION, DUE TO THE EASE OF SORTING AND THE USE OF UNPIGMENTED RESIN.

Product Testing

As the material was looped through the simulated primary and secondary recycling steps, samples were collected for aesthetic and mechanical testing by Qenos and Bega. The ease of manufacturing bottles was assessed via observations during the blow moulding process, as well as polymer characteristics such as melt index (MI) and swell. Bottle performance measurements focussed on properties critical for commercial milk filling and transport processes. Bottle aesthetic testing considered visual and other sensory testing related to product appeal as well as food contact suitability. Table 1 provides a list of tests performed during the study.

TABLE 1. PROPERTIES ASSESSED AT DIFFERENT STAGES IN THE LOOPING.

Characteristic	Properties Assessed
Ease of Manufacturing Bottles	Cycle time Die lines Gel levels Parison swing Missing handles Tab width Polymer swell Bottle weight variation Thermal stability (OIT) Melt Index (MI)
Bottle Aesthetics	Odour and taint Bottle appearance Colour Migration testing (food contact)
Bottle Performance	Drop Impact Test Top Load Neck diameter Wall thickness Leak test Brimful capacity

Test Results

Throughout the repeated loops, the ease of manufacturing bottles remained consistent for both 50% and 70% rHDPE content. No issues were found with blow moulding defects such as die lines, holes from gels, or missing handles. The tab width, or polymer swell, decreased slightly with each loop (Figure 5), but bottle weights and wall thickness were easily maintained within tight tolerances using simple die gap adjustments. Cycle time was not affected by the increased recycled content or thermal reprocessing. The polymer stability, assessed by Oxidation Induction Time (OIT), was reduced after repeated loops through the laboratory model. However, the addition of at least 30% virgin HDPE at each stage was sufficient to maintain adequate stability to avoid material degradation which affects aesthetics or processability.

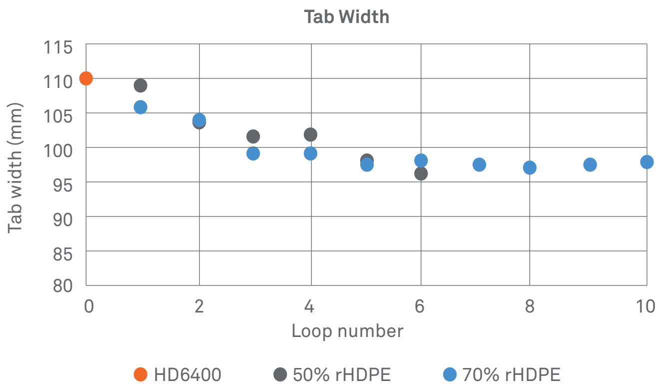

Figure 5. Tab width as a function of thermal processing

Bottle aesthetics were affected slightly when using PCR material, but the results were not considered problematic. The level of gels and other defects were highest in the first loop when PCR material was used. As the material was reprocessed without extra contaminants, the number of defects decreased to a similar level to the virgin HDPE (Figure 6). A similar trend was observed for the colour, which took on a green tint from the PCR material (Figure 7). The colour is largely a result of contamination from blue and yellow caps in the mechanical recycling process. Odour and taint results for the bottles were favourable at all stages. Migration testing on selected samples for food contact suitability did not reveal any issues.

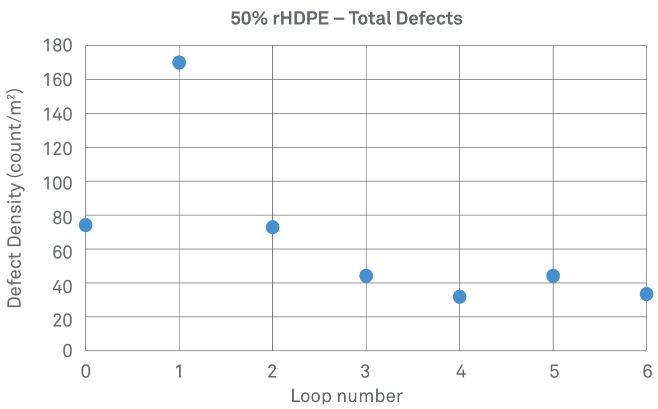

Figure 6. Defect levels measured (50% rHDPE)

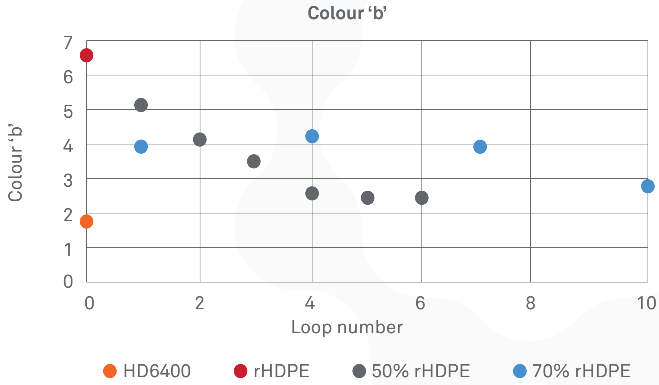

Figure 7. Colour results for the pelletised product

Bottle performance characteristics such as top load and drop impact are critical to ensure the container can withstand the filling, transport and use requirements. Bottle top load is a measure of stiffness, which is affected by the resin, wall thickness and the bottle design. An optimal bottle will maintain the required top load strength with minimal wall thickness, to reduce resin usage. The inclusion of rHDPE did not reduce the top load strength in this study (Figure 8). The drop impact test is used to assess the toughness of the bottle, and it was consistent throughout the loops at both 50% and 70% rHDPE levels. Neck diameter and leak tests showed that the reprocessing did not impact the integrity of the cap's seal. Finally, the brimful capacity measurements showed that the shrinkage, and therefore bottle volume, was consistent when rHDPE was included.

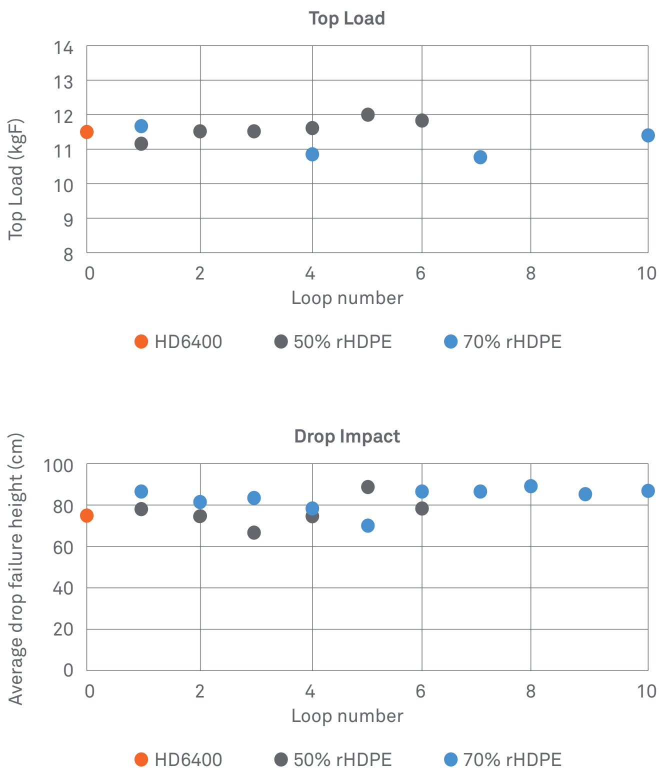

Figure 8. Top Load and Drop Impact, two important bottle properties, were maintained throughout the loops

CONCLUSIONS

The laboratory model and testing have shown that HDPE can withstand the thermal effects of repeated loops through a recycling process at up to 70% rHDPE content without compromising processability, performance or aesthetics, based on the methodology used. One area of interest was the effect of repeated loops on colour and contamination. These results decreased after the first round which incorporated PCR material. This strongly suggests that the main source of colour and contamination is due to outside sources such as pigments, dyes, labels and foreign materials, rather than polymer degradation as a result of thermal processing. These results indicate that polyethylene is a robust material which can readily support increased levels of post-consumer recycled material in dairy applications if used containers are sorted and decontaminated to high purity.

HOW THE RESIN MANUFACTURER CAN HELP

Resin manufacturers can support their customers in trials to increase the recycled content in their products. The Qenos Technical Centre in Melbourne is well equipped with a wide variety of plastics processing lines, most of which are commercial or semi-commercial scale. These are supported by extensive physical and chemical analysis techniques to evaluate the effect of the recycled content on product performance and stability.

REFERENCES

1. Dairy UK, “The Dairy Roadmap,” 2018. [Online]. Available: https://www.dairyuk.org/publications/the-dairy-roadmap/. [Accessed 12 October 2021].
2. Australian Packaging Covenant Organisation, “2025 Recycled Content Targets,” 31 March 2020. [Online]. Available: https://documents.packagingcovenant.org.au/public-documents/2025%20Recycled%20Content%20Target. [Accessed 8 November 2021].
3. Envisage Works, IndustryEdge, Randell Environmental Consulting and Sustainable Resource Use, “Australian Packaging Consumption & Recycling Data 2018-2019,” Australian Packaging Covenant Organisation, 2021.
4. Ellen MacArthur Foundation and McKinsey & Company, “The New Plastics Economy - Rethinking the future of plastics,” World Economic Forum, 2016.
5. Australian National Packaging Covenant Organisation, “Australia’s 2025 National Packaging Targets,” [Online]. Available: https://apco.org.au/national-packaging-targets. [Accessed 12 October 2021].
6. Australian Packaging Covenant Organisation, “Australian Dairy Sustainable Packaging Roadmap to 2025,” 1 October 2021. [Online].
7. Sustainability Victoria, “Where your recycling goes,” 30 June 2021. [Online]. Available: https://www.sustainability.vic.gov.au/recycling-and-reducing-waste/at-home/where-your-recycling-goes. [Accessed 12 October 2021].
8. “Recycled Materials in Food Contact Applications,” Australian Packaging Covenant Organisation, 2014.
9. Food and Drug Administration, “Use of Recycled Plastics in Food Packaging (Chemistry Considerations): Guidance for Industry,” 2006. [Online]. Available: https://www.fda.gov/media/150792/download. [Accessed 3 August 2021].

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