Material change for a better environment

**Final Report**

# Research & development to improve the recyclability of plastic milk bottles

The amount of recycled HDPE plastic (rHDPE) that can be used to make new plastic milk bottles is limited because the recycled material currently has a green hue to it. This research and development project investigated the causes and developed solutions to reduce the green hue in rHDPE and enable a higher recycled content to be used.

**Project code:** MDP025-003
**Research date:** January 2009 to April 2010 **Date:** January 2011

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**Front cover photography:** HDPE Milk Bottle

# Executive summary

The Dairy Supply Chain Forum's Sustainable Consumption and Production Taskforce produced the Milk Roadmap[1] in May 2008.

Through the Milk Roadmap, the UK dairy industry has set targets for recycled content in new HDPE plastic milk bottles sold in the UK as follows:

- 10% addition rates to be achieved by 2010 or sooner;
- 30% addition rates to be achieved by 2015 or sooner; and
- 50% addition rates to be achieved by 2020 or sooner.

Increasing the recycled content in plastic milk bottle packaging realises environmental benefits by reducing the use of virgin plastic. This uses resources more efficiently, reduces waste to landfill, saves energy and reduces greenhouse gas emissions.

The methodology for assessing the climate change impacts of packaging optimisation under the Courtauld Commitment Phase 2[2] states that for HDPE bottles the $CO_2$ (equivalent) impact of the overall pack can be reduced by 10% by increasing the recycled content of the overall pack by 22%.

The current proportion of recycled HDPE (rHDPE) content in plastic milk bottles sold in the UK is 10%. However achieving future targets will become increasingly difficult due to the green hue visible in current rHDPE pellets.

This project directly supports the achievement of the Milk Roadmap targets. It set out to find ways of reducing the green hue in rHDPE to enable a higher proportion of rHDPE to be used, replacing virgin HDPE in new milk bottles.

The objectives of the project were to:

- Identify the root cause of colour contamination in rHDPE pellets;
- Develop solutions and;
- Define a specification for the recommended solutions.

The consortium, led by Robert Wiseman Dairies and consisting of Systems Labelling and Alpla engaged the leading HDPE reprocessing plants in the UK, recycling equipment manufacturers and chemical suppliers in Europe and associated specialists to conduct a series of laboratory and medium scale trials. This led to the development of a range of solutions.

The first phase analysis found that the following elements contribute in different amounts to the colour of the final recycled HDPE pellet:

- Coloured caps;
- The recycling process;
- Labels, inks and adhesives.

Subsequent trials identified the indicative level of contamination caused by each element and tested prototype solutions to reduce the amount of colour that finds its way into the final rHDPE pellet. Masterbatch from the bottle caps caused the majority of colour contamination with only a small amount of cap material required to spread concentrated pigment during the extrusion stage of the recycling process.

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[1] *http://www.defra.gov.uk/environment/business/products/roadmaps/documents/milk-roadmap.pdf*

[2] *Courtauld Carbon Methodology Dec 10*

The solutions are as follows:

## Caps

Tinted Caps

The most significant quick win for caps is the use of "tinted caps" with a range of lighter colour tones. This can be achieved by reducing the level of pigment and in some cases using a different colour (pantone) within the masterbatch used to colour the caps. A broad range of colours is achievable whilst maintaining clear identification of the milk variant (skimmed, semi-skimmed, whole) by colour. Trials have demonstrated that tinted caps would significantly reduce the impact on the colour of the final rHDPE pellet and could enable bottles with more than 30% rHDPE to be acceptable from a colour perspective.

Comparison of current caps (on left) and light tinted caps (on right)

Tests at reprocessors and in a dairy have confirmed that the tinted caps can be recognised by colour recognition/sorting equipment as effectively as the current coloured caps.

This solution is cost neutral to implement and consumer research has indicated that the lighter cap is generally not a barrier to consumers recognising the type of milk. The majority of respondents (86%) said they would be likely to buy their current milk with the new (tinted) cap.

In conjunction with this, reprocessors should optimise their colour sorting process to minimise the amount of cap material entering the extrusion stage. However, there will always be a small percentage that gets through, so these two changes are complimentary and implementing them together would minimise colour contamination from caps.

Natural/clear caps

Removing colour completely from the cap would eliminate the potential for the cap to affect the rHDPE pellet colour. However it became clear from discussions with dairies that this is not feasible in the short term.

The key concerns are that:

- The colour in the cap is a key mechanism to identify the product variant (skimmed, semi skimmed, whole milk) throughout the dairy and retail supply chain. The project team explored the use of a coloured pull tab insert (liner) to maintain the colour identifier, but it was felt that underneath the natural HDPE cap recognition was still impaired.
- Currently, colour sorting removes most of the cap material from the bottle HDPE flake prior to the extrusion step at the reprocessor. However, with natural HDPE caps, cap material would no longer be separated from the HDPE bottle flake because the colour differentiation between the two materials would no longer exist. Most caps are made of compression moulded grade HDPE and bottles are made of extrusion blow mould grade. The two materials would need to be compatible in order to successfully manufacture new bottles using rHDPE to the required quality level. Further tests are required to demonstrate whether the two materials are compatible and do not adversely affect the quality of the rHDPE pellets and bottles. If the compatibility of the HDPE cap and bottle material is proven to be acceptable, then the need to sort natural cap material from the HDPE prior to extrusion is removed. However if the two materials still need to be separated, alternative ways of sorting the natural cap material from the bottle HDPE would need to be developed.

rHDPE in caps

Another complementary option would be to use rHDPE in caps. This doesn't affect the colour of the final rHDPE pellet and would deliver additional environmental benefit, through increased recycled content in the overall pack.

Trials have demonstrated that rHPDE content in the current coloured caps is acceptable at 30%. This could also be an option for tinted caps and clear/natural caps. Recycled content in caps would be lost from the closed loop food grade system however if used in coloured/tinted caps as these would be largely filtered out on reprocessing.

## Labels

Of the label types widely used on UK HDPE milk bottles, wraparound, stretch sleeves and synthetic (PP) self adhesive labels were found not to contribute significantly to the colour hue problem because trials have shown that over 90% of this material is removed from the HDPE in the air separation and wash processes at the reprocessor.

For self adhesive labels, paper labels of the specification we tested were found to contribute to the problem and could be replaced. Mini wash trials showed that PP labels, of the specification tested, demonstrated superior label removal, and lower colour contamination than the paper adhesive labels. For the paper labels tested, the laminate and ink was broken down and removed in the hot wash which contaminated the water and cross contaminated clean HDPE flakes. In addition, one reprocessor reported that the build up of paper pulp causes damage to reprocessing equipment. In mini wash trials, PP labels of the specification tested,[3] remained intact and peeled away from the HDPE flakes forming cylinders. The encapsulated labels did not release ink into the wash water and the detergent was found to nullify the tack of the adhesive which was removed and formed a residue in the wash water. Trials also demonstrated that PP labels of the construction tested were removed from the HDPE flake without getting stuck in the air separation equipment.

A switch from paper to PP self adhesive labels would incur around a 3-5% increase in label material costs but the same equipment can be used to apply the label, so no additional capital costs would need to be incurred.

Further improvements to the level of inks on the labels were considered and investigated. Using less ink on the label would reduce the risk of contamination. Different label design options were explored which looked at colouring less of the surface area of the label and reducing the hue of colours used. Initial consumer research indicated positive consumer responses to some of these alternative label designs. However, provided problematic labels are replaced, the remaining label types are mostly removed from the recycling process early and/or don't allow the inks to leach out, so development in this area is likely to deliver smaller benefits and is not essential for the short term.

## The Recycling Process

Reprocessors carry out optical sorting to filter out coloured material from the natural HDPE bottle material prior to extrusion of the material to create a food grade rHDPE pellet. As discussed, coloured cap material can contribute significantly to the colour contamination of rHDPE if it gets into the extrusion process. Reprocessors must keep this contamination to a minimum.

Reprocessors should evaluate their process and measure the colour of the rHDPE pellets produced. Suggested improvements are:

- Increasing the number of optical sorters would improve the removal of coloured flakes going into the extruder, but this equipment is very expensive and may require reconfiguring the process. Optimising the colour sorting process to maximise the number of sorts that are done with the same equipment, whilst maintaining commercially viable throughput volumes and speeds, can dramatically improve the removal of coloured material.
- In addition, ensuring colour contamination monitoring systems are in place to flag and resolve any deterioration in colour sorting performance is essential. Systematic colour contamination monitoring and analysis should be incorporated into the standard quality control procedures for HDPE reprocessors.

[3] *See Figure 10 in section 3.2 for details of the specification*

- Mini wash trials demonstrated how critical correct temperature and cleaning agents are in the successful removal of labels and contaminants. Maintaining the optimum temperature of the wash process at 85°C throughout the 10 minute hot wash cycle is key to achieving successful label removal and cleaner flakes.
- Trials demonstrated that a detergent only solution performs best when considering flake cleaning, wash water quality and label removal. Detergents dosed at 2% enabled the most effective label removal. It is recommended that reprocessors implement tight systems of dosage control to ensure that the effect of the wash plant is optimal. Also it is advised that reprocessors carry out large scale trials prior to implementation of any changes.
- Mini wash trials demonstrated that caustic soda causes cross colour contamination to clean HDPE flakes. Some food grade reprocessors however require the use of caustic soda as it is integral to their food grade recycling process, but where possible, from a colour perspective, it is recommended that caustic soda is not used. It is advised that reprocessors carry out large scale trials prior to implementation of any changes.

## Conclusions and short term quick wins

Small and medium scale trials have demonstrated that the following quick wins would enable the production of a bottle that contains at least a 30% rHDPE and is aesthetically acceptable from a colour perspective. The results in this project indicate that this has the potential for around 50% rHDPE. This would support the achievement of the milk roadmap targets for 2015 (30%) and 2020 (50%).

1. Introduction of tinted caps (suggest an industry standard hue for skimmed, semi and whole milk products is agreed).
2. Switch from self adhesive paper and paper laminate labels to 50 or 60 micron PP of the construction type tested in this work (existing label applicators can be used).
3. Reprocessors implement all suggested improvements.

The next steps for the industry would be to carry out large scale trials of these quick wins prior to implementation.

# Contents

# Glossary

| | |
|---|---|
| HDPE | High Density Polyethylene |
| COD | Chemical Oxygen Demand |
| LDPE | Low Density Polyethylene |
| rHDPE | Recycled High Density Polyethylene |
| Hue | Colour or tint - a variety or shade of colour caused by the admixture (addition of a minor ingredient) of another colour or tint |
| LDPE | Low Density Polyethylene |
| Delta-E | Delta E is the overall measure of how far the colour (in this case of HDPE) is from the standard. This is explained further in Appendix 1. |
| PP | Polypropylene |
| OPP | Orientated Polypropylene |
| UV | Ultra Violet |
| Masterbatch | Pigmented polymer used to colour plastic components |
| Blow-moulding | Process used to manufacture HDPE bottles |
| PSL | Pressure Sensitive Labels - commonly referred to as self adhesive labels |
| MFI | Melt Flow Index |

# Acknowledgements

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**HDPE Recyclers**: Greenstar WES and Closed Loop Recycling
**Recycling Equipment Manufacturers**: Erema (Austria) and Sorema (Italy)
**Bottle Manufacturer:** Alpla (Droitwich)
**Chemical Supplier:** McDermid

## 1.0 Introduction

### 1.1 Dairy Industry Milk Road Map

The Milk Roadmap produced by the Dairy Supply Chain Forum's Sustainable Consumption and Production Taskforce in 2008 is one of ten pilot roadmaps to be published by Defra and sets short, medium and long term targets to reduce the environmental impact of producing, processing and consuming liquid milk. The aim is to build on the significant steps taken so far to reduce the environmental impact of the dairy supply chain and accelerate the process.

The UK dairy industry produces between 13 and 14 billion litres of milk each year with around 6 billion litres of this being processed into liquid milk (The Milk Road Map, May 2008[4]).

The Road Map also estimates that around 80% of the milk sold by retailers in the UK (around 3 billion bottles each year) utilises plastic HDPE milk bottles which requires 120,000 tonnes of HDPE.

Increasing the recycled content in plastic milk bottle packaging realises environmental benefits by reducing the use of virgin plastic. This uses resources more efficiently, reduces waste to landfill, saves energy and reduces greenhouse gas emissions.

The methodology for assessing the climate change impacts of packaging optimisation under the Courtauld Commitment Phase 2[5] states that for HDPE bottles the $CO_2$ (equivalent) impact can be reduced by 10% by increasing the recycled content by 22%.

The Milk Roadmap sets targets for recycled content in new HDPE milk bottles as follows:

**Figure 1:** The Milk Roadmap targets for including rHDPE in milk bottles (Source: Defra)

| Year | Target rHDPE content (%) | rHDPE (tonnes) |
|---|---|---|
| 2010 | 10 | 12,000 |
| 2015 | 30 | 36,000 |
| 2020 | 50 | 60,000 |

### 1.2 Project Objectives

The current proportion of recycled HDPE plastic (rHDPE) in plastic milk bottles sold in the UK is 10%. However the amount of rHDPE that can be used to make new plastic milk bottles is limited because the recycled material currently has a green hue, which can be seen in the pellets in Figure 2. As the recycled content increases so does the green appearance of the bottle and a green tint is not regarded as attractive to the consumer and therefore is not accepted by retailers.

**Figure 2:** The colour of current rHDPE (left) vs virgin HDPE (right)

[4] ttp://www.defra.gov.uk/environment/business/products/roadmaps/documents/milk-roadmap.pdf

[5] Courtauld Carbon Methodology Dec 10

In order to achieve future Milk Roadmap targets for recycled content in new bottles, it will be increasingly important to reduce the green hue of rHDPE pellets.

This project set out to:

- Identify the root cause of colour contamination in rHDPE pellets;
- Develop solutions to make rHDPE less green and as close to natural colour (un-pigmented) as possible; and
- Define a specification for the recommended solutions.

The results from this can be used to support the achievement of the Milk Roadmap targets by providing ways of reducing the green hue in rHDPE which will in turn enable a higher proportion of rHDPE to be used to substitute for virgin HDPE in new milk bottles.

### 1.3 Project Management

The project was managed by a consortium group covering the dairy, bottle-blowing and label printing industries, namely: Robert Wiseman Dairies, Alpla and Systems Labelling. The consortium completed the project in two phases conducted between January 2009 and April 2010. This comprised of site visits, desk research and a series of controlled trials.

## 2.0 Phase One

### 2.1 Phase One Objective

The overall objective of Phase One was to identify the root cause(s) of the green colour contamination in rHDPE. The project team worked with the UK food grade rHDPE reprocessors to review current milk bottle recycling processes in the UK and also engaged with bottle, cap, ink, adhesive and raw material manufacturers to understand the varying challenges in bottle, label and cap design.

As a result of the initial site visits the project team identified that there are a number of elements in the recycling process that could contribute to the colour contamination. Three trials were conducted at the Greenstar WES plant in Redcar to identify the potential contribution of contamination from:

- The recycling process;
- Labels/inks/adhesives; and
- Caps.

### 2.2 Trials

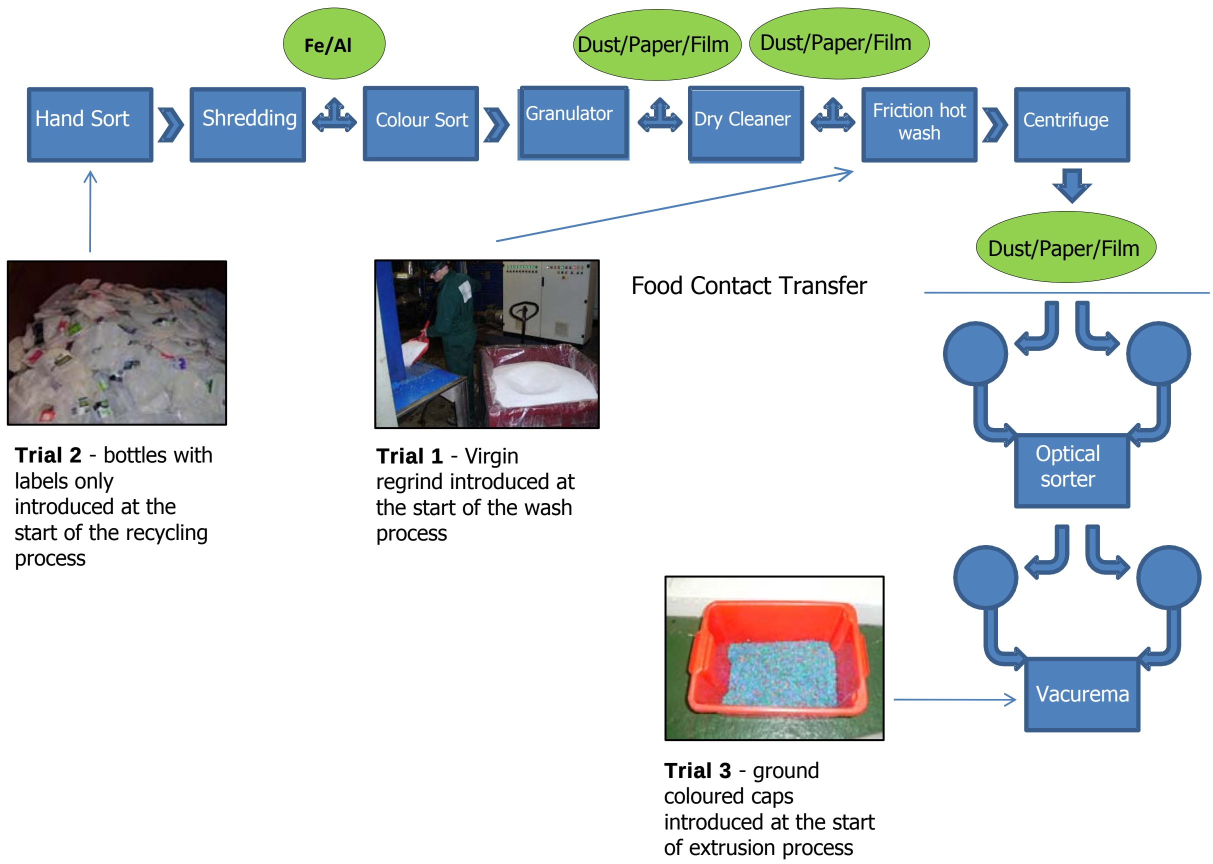
**Trial 1**: Involved running approximately two tonnes of clean virgin regrind HDPE through the recycling process to determine the level of colour contamination generated by the process itself. This included the wash process and the Vacurema/extruder. The use of virgin HDPE removed any influence from caps and labels/inks/adhesives.

**Trial 2**: Reprocessing of post consumer milk bottles with labels but no caps to determine the levels of contamination caused by labels. The bales used were typical stock and therefore of mixed colour and label types.

**Trial 3**: Loading virgin regrind directly into the Vacurema extrusion system with varying levels of ground caps to determine the level of contamination caused by caps.

Figure 3 (on the next page) shows at which stages in the process, trial material was added.

**Figure 3:** Phase One trial process flow




## 2.3 Results

The pellets produced from all three trials were assessed using a colour system (Delta-E) and compared to a virgin white HDPE flake. Delta E is the overall measure of how far the colour, (in this case, of HDPE) deviates from the standard. More details can be found in Appendix 1**.**

**Trial 1: Virgin HDPE**

- Processing virgin HDPE flake through the Greenstar WES hot wash and Sorticanter darkened the material by a Delta E of 10. Note that the virgin material prior to the trials was the standard by which the samples were measured (thus it effectively had a Delta E of 0)**.** The majority of the colour that is picked up is yellow.
- Further processing and compounding of the material through the Vacurema added yet more colour to the HDPE. A Delta E increase to 18 was observed. Again, the majority of colour seen was yellow.

**Trial 2: Labeled bottles (no caps)**

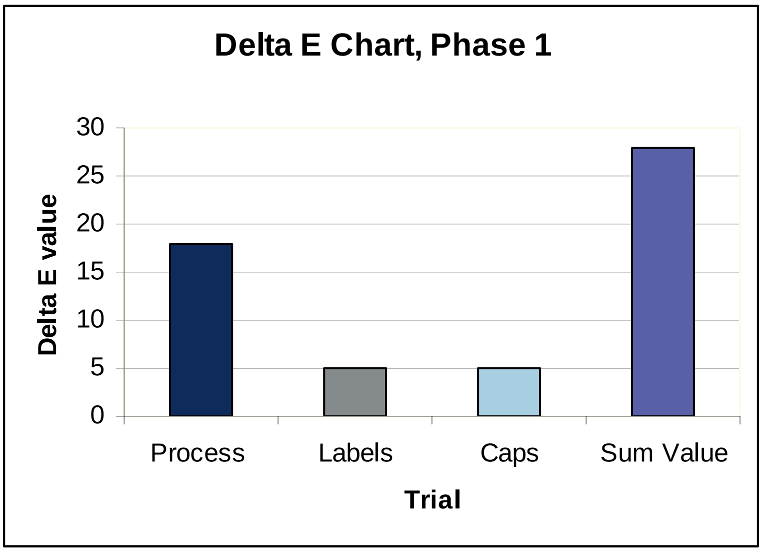
- From the results it can be concluded that the difference between Sorticanter and hot wash waters remain generally unaffected by the washing process.
- However it was calculated that the average individual contribution of the labels to the shift in colour is equivalent to a Delta E of 5.
- Paper labels represent around 25% of overall ink consumption of milk labels. These cause the following issues. i) clogging up the wash tank, ii) sticking to flake and then carrying colour into the Vacurema, iii) residual material is sent to landfill whereas plastic labels that are removed are recycled.

**Trial 3: Virgin HDPE + Caps**

- Trials were conducted with 0.1%, 0.2%, 0.3%, 0.5% and 1% of the material extruded being cap material.
- At 0.1% of the material extruded being cap material (mixed at the typical colour proportions of 60% green, 30% blue and 10% red), although barely discernable to the human eye, it caused a distinct colour shift when added to virgin HDPE.
- At 1% of the material extruded being cap material, the colour change is obvious, even to the human eye. It is clear that contamination at this level has the potential to seriously affect the colour of the final product.

The overall contribution is indicated by column 4 in Figure 4. At the time of the trials and based on the perceived colour contamination levels the control trials provided adequate data to confirm three elements were responsible for colour contamination of the final rHDPE pellet.

**Figure 4:** Delta E- results from Phase One trials (Source: Greenstar-WES)




Note: The level of coloured cap material getting into the extrusion process is critical. The level of cap contamination in this analysis was 0.2% of the material extruded being cap material.

Further investigation was necessary to establish exact proportions during normal recycling operations. Subsequent evidence indicated this percentage was averaging 1.2% in June 2009. A repeat test in April 2010 reported this figure to now be averaging 0.11%. This is as a direct result of improving the configuration and performance of the final optical sort in the process prior to extrusion.

The impact on the wash process is thought to be largely due to residual ink, adhesive and paper mash water which builds up over time and taints the flake.

The discolouration caused by the process itself was thought to be a combination of dirt built up in the system and the potential impact of cleaning agents and the impact of temperature in the hot wash, friction wash and extrusion process. Further investigation during Phase 2 broke down each stage to identify the key areas for improvement.

## 2.4 Phase One Conclusions

The results from this initial control trial provided Delta E values which in turn were converted to percentages to illustrate the level of colour contamination from each trial. From the Phase One Delta E results, the project team concluded that:

- Coloured caps, the recycling wash process and label inks and adhesives all contribute to the overall colour contamination of the final recycled HDPE pellet.
- The colour difference in virgin HDPE post and pre recycling, (with no labels or caps) indicated that the recycling process contributed 64% to the cause of overall discolouration. At this stage the project team and recycling partner perceived it to be a combination of dirt built up in the system, the potential impact of cleaning agents and the impact of temperature in the hot wash, friction wash and extrusion process. Further investigation during Phase 2 broke down each stage to identify the key areas for improvement. After carrying out a subsequent extrusion trial (see section 5) the project team found that the extrusion process itself does not actually contribute significantly to the colour contamination.
- The inks from labels contributed a maximum of 18% to the cause of discolouration; and
- The caps contributed a minimum of 18% to the cause of discolouration (Based on 0.2% caps contamination).

## 2.5 Phase Two Objectives

The objective of Phase Two was to investigate each element in turn to establish the cause of green colour tinting in more detail. From this the aim was to identify where changes could be made to reduce the colour contamination of the final rHDPE pellet, to develop solutions within the package design itself (caps and labels), and within the recycling process. Each factor was investigated and solutions and suggestions for each are discussed.

# 3.0 Labels

The five label types currently used in the dairy industry to decorate HDPE milk bottles were assessed for their impact on the green hue of rHDPE during the recycling process.

**Figure 5**: Share of UK HDPE dairy market split by label type (April 2009)

| Material Type | Market Share |
|---|---|
| Self adhesive polypropylene laminate | 45% |
| Self adhesive paper | 27% |
| Stretch sleeve LLDPE | 19% |
| Wraparound OPP | 9% |

## 3.1 Mini Wash Trials

A series of mini washing trials were conducted on the five existing label types (wraparound, stretch sleeves, self-adhesive paper, self-adhesive PP – 60 micron and self-adhesive PP – 50 micron). The aim was to understand how each label type performs in isolation during washing under the current process conditions. Time, temperature and cleaning agents were set to mirror the hot wash processes at both rHDPE UK plants. In addition the trials investigated the variables in dosage rates of cleaning agents typically used in the industry including caustic solution and detergent products.

**Figure 6**: Examples of the five existing types of label on HDPE milk bottles in the UK

**Figure 7**: Specifications of the label types investigated

| Label Description | Substrate | Print Technique | Ink/Coating System |
|---|---|---|---|
| Wraparound | 30 micron OPP (Matt appearance) | Gravure (reverse printed) | Solvent based inks and opaque white overprint to act as a sealing agent. |
| Stretch Sleeves | 45-50 micron clear LDPE with added slip and no sealer. | Solvent based flexographic printing (reverse printed) | Solvent based nitrocellulose inks. No sealer. |
| Synthetic Self Adhesive Labels (50 micron) | 50 micron Polypropylene core with 12 micron Polypropylene overlaminate. | UV Flexographic Printed on face then encapsulated with overlaminate. | UV cured in line. Adhesive applied to back is chiller permanent with an initial high tack for damp conditions. |
| Synthetic Self Adhesive Labels (60 micron) | 60 micron Polypropylene core with 12 micron Polypropylene overlaminate. | UV Flexographic | UV cured in line. Adhesive applied to back is chiller permanent with an initial high tack for damp conditions. |
| Paper Labels | 80gsm or 60gsm paper with a 12 micron overlaminate. | UV Flexographic | Water based inks UV cured in line. Adhesive applied to back is chiller permanent with an initial high tack for damp conditions. |

There may be labels in use that are of a different specification, (for example using different inks or adhesives) to those mentioned above. These were not tested in this project.

A purpose built mini wash device was commissioned in order to replicate a large scale industrial hot wash, based on the design of a Sorema 'hot-wash' system. This incorporated an agitator consisting of four axial flow impellors and a digital temperature control, and provided a convenient experimental unit that reduced the times and volumes of material required for comparative tests. This approach ensured specific experimental variables (such as temperature and detergent levels) were controlled and either kept constant or varied by known amounts between experiments.

### *3.1.1 Mini wash trial methodology*

The following analysis was conducted for each trial:

- **Colorimetric analysis** of the wash water to determine the amount of ink leaching, plus visual inspection of cross contamination of the HDPE flakes.
- **Adhesive and substrate analysis** by filtration of the label flakes from the wash medium (analysis of number detached from plastic for adhesion trials).
- **Residue Analysis** to determine the mass of any dissolved/dispersed components in the wash water.
- **Label Removal** – the labels and HDPE flakes were 'pre cut' from new and unused 4 pint bottles; the number of removed labels was individually counted for all trials and a label removal percentage was calculated for each type. (Not relevant in the case of stretch sleeves and wraparound labels as the labels are not "fixed" to the bottle.)

The results showed that individual label types perform differently in terms of label removed and colour contamination.

### *3.1.2 Mini wash trail results*

**<u>Paper Labels</u>**

During mini wash trials paper labels were shown to leach ink and the construction broke down with overlaminate, ink and pulp showing in the wash water. This contaminated the wash water and cross contaminated clean HDPE flakes. This was experienced in water only, and became worse as agents were added, particularly caustic. One re-processor reported that this also causes damage to reprocessing equipment in the plant.

At the wash conditions of 85$^{o}$C for 20 minutes with a 2.5% detergent dosage, removal of self adhesive paper labels was found to be 47% in the mini wash (Please refer to Appendices 2 and 3 for detail). This is lower than at the reprocessors, possibly due to differences in scale, the level of friction and the size of flakes between the mini wash and full scale wash plants. Nevertheless the results of the mini wash trials do provide a consistent baseline from which to make comparisons between the wash performance of different label types. Figure 8 below shows paper label residue remaining on HDPE flake after mini wash trials.

**Figure 8:** Paper label residue on HDPE flake after the mini wash

**PP Self Adhesive Labels**

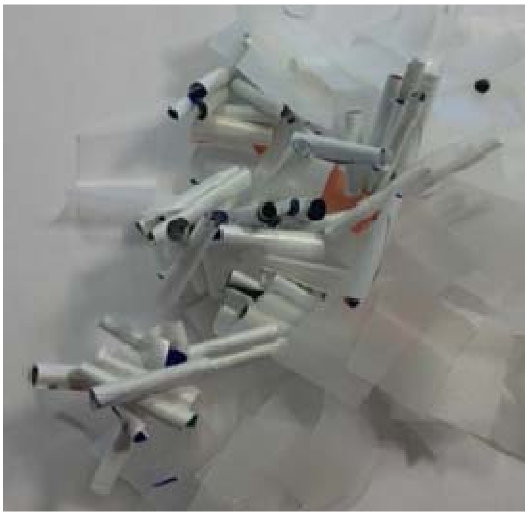
PP labels remained intact and peeled away from the HDPE flakes forming cylinders. The encapsulated labels did not release ink into the wash water.

Label removal exceeded 90%, with the best result achieving 98% label removal at conditions of 85°C for 20 minutes with a 2.5% detergent dosage. No cross colour contamination was evident.

The detergent appeared to nullify the tack of the labels as the adhesive was removed and formed a residue in the wash water.

Figure 9 below shows a high degree of PP label removal during the mini wash trials.

**Figure 9:** PP labels forming cylinders and separating from HDPE in the mini wash



**Wraparound and Stretch Sleeves**

Wraparound and stretch sleeves leached ink and left deposits in the mini wash tank with and without the use of cleaning agents. However subsequent research showed that over 90% of these label types were extracted at the initial granulation and air separation stage of the recycling process prior to the hot wash.

**Caustic Solution**

All labels were found to break down and cause colour contamination when caustic solution was used.

### *3.1.3 Mini wash trial conclusions*

- Self-adhesive over laminated paper labels were broken down easily even without the use of cleaning agents and created a pulp. They released ink into the wash cycle which tainted washed flake. The level of label removal was comparatively low (47% label removal in detergent dosed at 2.5%).
- Synthetic (PP) self-adhesive labels performed well during the trials with minimal ink leaching and excellent label removal, in excess of 90%.
- Wraparound and stretch sleeves leached ink into the wash cycle due to lack of sealant or encapsulation in the product design however the majority of these label types were extracted at granulation and air filtration stage (in excess of 90%).

For further details and results of the mini wash trials please refer to Appendices 2 and 3.

## 3.2 Label Solutions (Current Label types)

**Labels:** The following conclusions have been reached on how the construction and specification of the current label types can be improved to reduce the level of colour contamination in rHDPE pellets.

**Figure 10:** Label solutions (current label types)

| Label Description | Problem | Solution | Technical Specification | Economic Evaluation | Environmental Evaluation |
|---|---|---|---|---|---|
| **Wraparound** | No Issue. >90% removed during pre-wash air separation. | Acceptable to use | 30 to 40 micron OPP printed with UV inks for improved adhesion. | No change | No change |
| **Stretch Sleeves** | No Issue. >90% removed during pre-wash air separation.. | Acceptable to use | 45 to 50 micron transparent LDPE with added slip. Reverse printed with UV inks for improved adhesion. | No change | No change |
| **Synthetic Self Adhesive Labels** | No Issue. >98% removed via air separation, post-wash. | Acceptable to use | 50 to 60 micron PP printed with UV inks and encapsulated with 12 micron PP overlaminate to be a minimum of 24% of the thickness of the label. This encourages the label to curl and peel away from the HDPE flake during recycling process due to the natural tensions that occur. Adhesive to be chiller permanent and applied in damp conditions. However water releasable between 65 to 85 degrees centigrade during wash cycle. | No change | No change |
| **Paper Labels** | Paper labels cause issues during the recycling process and leach colour and sediment into the wash process which cross-contaminates the HDPE flake. | Transfer to synthetic self-adhesive labels. | As above. Synthetic labels can be applied using existing equipment therefore no barrier to switching over. | Approx 3-5% increase in material costs.<br><br>No additional capital costs. Existing equipment can be used. | Small increase in $CO_2$ impact of label manufacture, but reduction in landfill. |

## 3.3 Alternative Label Designs

The project team also investigated the merits of designing out the volume and density of colour typically used as a means of product identification within the dairy industry. From desk research into the North American market and industry expertise, a variety of designs were explored which could reduce ink coverage on labels in excess of 50%.

### *3.3.1 Reducing the surface area coloured*

The use of less ink on labels would mean that less ink would contaminate the HDPE or wash water if not removed from the system. Labels with lower levels of ink coverage are in use in USA (see Figure 11 below):

**Figure 11:** Examples from US market. Source: www.walmart.com

Some concepts were developed for UK milk (as shown in figures 12-14 below):

**Figure 12:** Typical label design (Source: Systems Labelling)


**Figure 13:** Concept one - single stripe (Source: Systems Labelling)


**Figure 14:** Concept 2 - double stripe (Source: Systems Labelling)

Some further examples of how colour coverage could be reduced are shown in figure 15 below.

**Figure 15:** Prototype labels showing opportunities to reduce colour coverage (Source: Systems Labelling)


The effect of reduced colour on labels on the identification of the milk variant within the supply chain will also need to be investigated, and brand owners and marketeers will need to input into label development. Therefore modified label designs are seen as potential medium to long term improvements.

### *3.3.2 Overlamination of wraparound labels*

The potential cause of colour leaching released from wraparound labels is believed to be due to the minimal sealant used to trap the inks. Wraparound labels are currently reverse printed onto clear film then overprinted with an opaque white ink for mainly aesthetic reasons. The following wash trials were conducted to compare the benefit of using an alternative print and finishing technique.

The potential solution was to print the image on the face of the film and then encapsulate the ink with a 12 micron overlaminate. The following results highlight the benefits of this method in comparison to the existing technique.

**Figure 16:** Results of overlamination of wraparound labels

| Trial | Method/Description | Result Summary |
|---|---|---|
| Trial 1 | Current wraparound labels (semi skimmed only) plus HDPE flakes for agitation/ friction. 2% cognis detergent for 10 minutes at 85ºC. | Wash drum was clean and water cloudy with green hue and minimal sediment. Printed side of label flakes were lightly scuffed/scratched. |
| Trial 2 | Laminated wraparound (semi skimmed only) plus HDPE flakes for agitation/friction. 2% cognis detergent for 10 minutes at 85ºC. | Wash drum was clean and water cloudy with white hue and minimal sediment. Label flakes intact including overlaminate. No ink leaching. |
| Trial 3 | Current wraparound (semi skimmed only) plus HDPE flakes for agitation/friction. 2.5% caustic solution plus 0.15% RP16 detergent for 10 minutes at 85ºC. | Wash drum dirty – green ink leached badly and attached to the sides of drum. Wash water was initially cloudy and green with large amount of green sediment. Water then cleared. Virtually all the ink was removed from the label flakes. |
| Trial 4 | Laminated wraparound (semi skimmed only) plus HDPE flakes for agitation/friction. 2.5% caustic solution plus 0.15% RP16 detergent for 10 minutes at 85ºC. | Wash drum was clean and water clear with slight green hue and some green and white sediment. Majority of label flakes intact however some are scuffed/scratched leaching small amount of ink. Overlaminate separating on some flakes. |

Once the issue of paper labels is resolved, then the remaining labels are mostly removed from the recycling process early and/or don't allow the inks to leach out, so development in this area is likely to deliver smaller benefits. This is subject to the implementation of the process suggestions.

# 4.0 Caps

From the initial control trials during Phase One it was concluded that cap material finds it way into the extrusion process and causes significant discoloration of the pellet. Some work has been done to increase the colour sortation performance and one recycler is now achieving circa 0.11% cap contamination at pre-extrusion stage. However there will always be a small element of cap material that inadvertently gets in the extrusion stage.

The project team engaged with a leading UK cap manufacturer to explore alternative ways of reducing the colour contamination from HDPE caps and explore the use of rHDPE in caps.

## 4.1 Natural Caps

The obvious solution to eliminating the colour contamination caused by caps is to remove the pigment from the caps completely. However it became clear from discussions with dairies that the challenges in introducing such a step change across the industry would be too great to implement in the short term. The key concerns are that:

- The colour in the cap is a key mechanism to identify the product variant (skimmed, semi skimmed, whole milk) throughout the dairy and retail supply chain. The use of a coloured pull tab insert to maintain the colour identifier was explored, but it was felt that underneath the natural HDPE cap recognition was still impaired, this option is shown in Figure 17.

**Figure 17:** Natural caps with coloured liners/inserts

- Currently, colour sorting removes most of the cap material from the bottle HDPE flake prior to the extrusion step at the reprocessor. However, with natural HDPE caps, all the cap material would get into the extruder because it could no longer be separated from the HDPE bottle flake on the basis of colour prior to the extrusion step. Most caps are made using compression grade of HDPE and bottles are made from extrusion blow mould grade. The two materials would need to be compatible in order to successfully manufacture new bottles using rHDPE to the required quality level. Further tests are required to demonstrate whether the two materials are compatible and do not adversely affect the quality of the rHDPE pellets and bottles. If the compatibility of the HDPE cap and bottle material is proven to be acceptable, then the need to sort cap material from the HDPE prior to extrusion is removed. However if the two materials still need to be separated, alternative ways of sorting the cap material from the bottle HDPE would need to be developed.

Before implementation of natural caps, further work would be required to test both identification of milk variants with natural caps throughout the supply chain and the quality of food grade rHDPE consisting of cap and bottle material.

## 4.2 Tinted Caps

Tinted caps (see Figure 18 on next page) were produced successfully by reducing the level of pigment and in some cases in conjunction with use of a different colour (pantone) within the masterbatch. In each case the masterbatch dosage remains at 1% of the total cap material. A significant reduction in the "strength" of colour lead to positive results in the medium scale trials, as the bottles produced from samples using tinted caps were visually acceptable at 50% even with 0.6% tinted cap contamination.

**Figure 18:** Comparison of current caps (on left) and light tinted caps (on right)

Optical sorting trials conducted at Greenstar-WES and Closed Loop Recycling have confirmed that tinted caps can be identified and sorted with existing optical sorting equipment. Tests at Robert Wiseman Dairies have confirmed that tinted caps can be recognised by colour recognition systems with the dairies. It is recommended that further trials are done at specific dairies prior to implementing this to ensure that the particular equipment in operation can identify tinted caps.

This solution is cost neutral to implement and consumer research has indicated that the lighter cap does not appear to be a barrier to consumers recognising the type of milk. The majority of respondents (86%) said they would be likely to buy their current milk with the new (tinted) cap.

Complementary to this, reprocessors should optimise their colour sorting process to minimise the amount of cap material entering the extrusion stage. There will always be a small percentage that gets through, so these two changes together will minimise colour contamination from caps.

Following consultation with a key masterbatch manufacturer, it was decided to focus on decreasing the concentration of colour pigmentation whilst trying to avoid any adverse impact on consumer purchasing behaviour. It was found that the following pigment concentrations (see figure 19 below) provide a good balance of colour and would limit the density of colour entering the extrusion process.

**Figure 19:** Pigment concentrations for original (light) tinted caps

**Existing standard dairy cap**

| Colour | Ref | % of masterbatch being pigment | % of cap being pigment (masterbatch at 1%) |
|---|---|---|---|
| Blue | 6380RCE | 55.0% | 0.55% |
| Green | 6983RCE | 23.8% | 0.24% |
| Red | 6378RCE | 20.0% | 0.20% |

**Tinted caps used in consumer research**

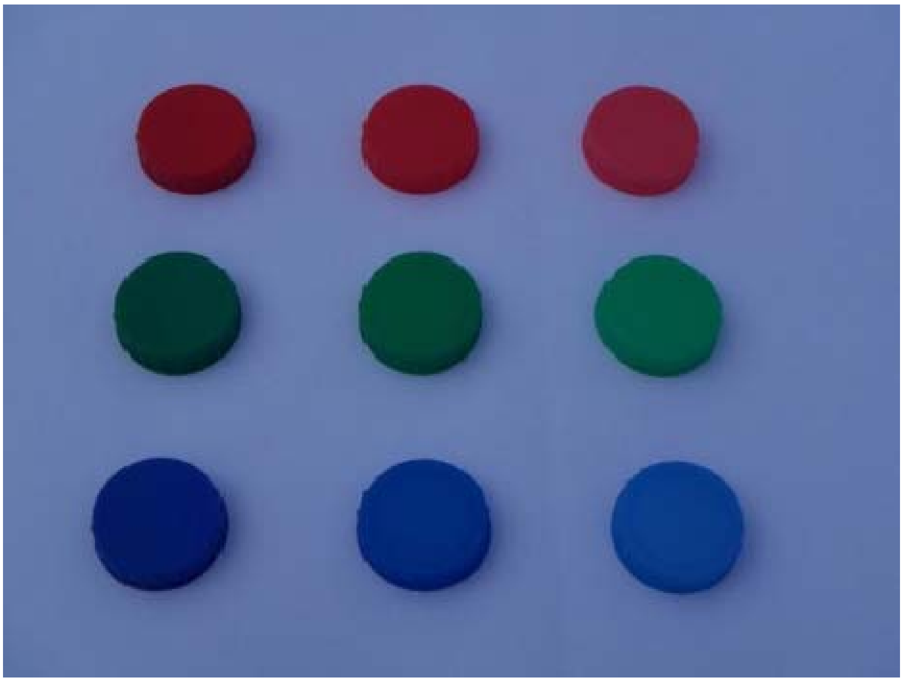
| Ref | % of masterbatch being pigment | % of cap being pigment (masterbatch at 1%) | Quantity of tinted caps per same amount of pigment as existing standard dairy closure |
|---|---|---|---|
| 839AA | 2.5% | 0.03% | 22.0 |
| 840AA | 6.8% | 0.07% | 3.5 |
| 838AA | 4.6% | 0.05% | 4.3 |

The pigment concentrations in the table above applied to the tinted caps that were used in the consumer research (see Section 7 and Appendix 4). However the pigment concentrations and pantone colours can be modified or optimised to suit specific requirements. A range of alternative blends were formulated to provide further examples.

**Figure 20:** Comparison of some alternative pigment concentrations for light and mid tinted caps with standard caps

| Standard cap | | Mid tint cap | | | Light tint cap | | |
|---|---|---|---|---|---|---|---|
| Colour | Pantone | % of pigment used in standard closure | Quantity of tinted caps per same amount of pigment as existing standard closure | Pantone | % of pigment used in standard closure | Quantity of tinted caps per same amount of pigment as existing standard closure | Pantone |
| Blue | 2728C | 14% | 7.3 | 660C | 7% | 14.6 | 2925C |
| Green | 340C | 29% | 3.5 | 340C | 14% | 7.0 | 3395C |
| Red | 200C | 25% | 4.0 | 186C | 13% | 8.0 | 1787C |
| Orange | 137C | 31% | 3.2 | 1575C | 16% | 6.4 | 156C |
| Purple | 258C | 10% | 10.0 | 2573C | 5% | 20.0 | 2563C |

**Figure 21:** Comparison of different tinted cap examples (corresponding to the table above). Left: Standard caps, Middle: "Mid tint", Right: "Light tint"



## 4.3 rHDPE Caps

The use of rHDPE in caps would not affect the colour of rHDPE pellets per se, however because it would increase the recycled content of the overall pack it was worthy of investigation. Three cap types were tested to understand what percentage of rHDPE that would be able to mould into a standard dairy HDPE cap. The selected proportions were 15%, 30% and 50%.

All caps were moulded successfully using the standard colour hue although problems were experienced with the upper limit of 50% rHDPE. These caps showed slight imperfections and resulted in some 'fouling' and minute quantities of debris within the compression toolset. No further investigation was undertaken to ascertain exactly what this fouling was caused by. However caps produced at 30% rHDPE content were successfully produced and would be suitable for mass production.

Recycled content could be incorporated into tinted caps and clear/natural caps. It should be noted though that recycled content in caps would be lost from the closed loop food grade system if used in coloured/tinted caps, as these would be mainly filtered out on reprocessing and go into the non food grade stream.

## 4.4 Alternative cap materials

As part of the investigations the use of alternative polymer types was considered. These included polyethylene tetraphthalate (PET) and polypropylene (PP) as a base material for standard 38mm dairy closures.

Initially, the key benefit that was identified with PET was its ability to be separated from HDPE due to the differential in materials specific gravities. Whilst, on face value this appears to 'favour' further investigation it was concluded that there were several complex forming, cost and operational considerations that would require to be investigated at both the packaging suppliers and the dairy industry end users before alternative polymer types could seriously be considered.

It was also recognised that using alternative materials would introduce polymer contamination into the recyclate waste stream which could have an adverse impact on rHDPE yield.

## 4.5 Cap Solutions

Figure 22 (on the next page) summarises the cap solutions explored.

**Figure 22:** Caps Solutions: Significantly reducing the level of colour contamination caused by caps that reach the extrusion stage is key

| Cap Description | Solution | Economic Evaluation | Environmental Evaluation |
|---|---|---|---|
| **Tinted caps** | Tinted caps significantly reduce colour contamination due to the reduction in pigment strength in "Masterbatch" used. Performed well in consumer testing with a minimal impact on product identification and buying behaviour. | Tinted Caps: No cost implications as same quantity of masterbatch is being used, it is only lighter in shade. | Medium scale trials resulted in a visually acceptable bottle being produced at 50% rHDPE content (0.6% cap contamination). Increasing recycled content by 22% achieves a 10% reduction in $CO_2$. |
| **Clear caps with coloured liner** | A coloured liner and natural/clear cap. This is the ideal solution which would allow caps to be recycled with bottles. (Note further research would be required to assess the impact of injection or compression moulded caps that could find their way into the system.) However this would be a significant step change and require full support and buy-in from all stakeholders.<br>Note: There is some concern that this option would result in some identification issues in the supply chain. | Clear Caps: Coloured Liner. No implications for liner, although removal of masterbatch colourant could make the cap 2-3% cheaper. | The transition to a natural (clear) cap could result in a 75% rHDPE bottle. However large scale trials are required to assess the impact on blow moulding production efficiencies. Increasing recycled content by 22% achieves a 10% reduction in $CO_2$. |
| **rHDPE caps** | Use 30% rHDPE cap and maintain existing colourant levels. This would allow us to state 30% rHDPE content, although the cap could not be recycled again within a closed loop cycle. | At current prevailing market prices the cost of rHDPE is equal to that of Virgin Material. This could be effected by supply & demand principles in the future. | Increasing recycled content by 22% achieves a 10% reduction in $CO_2$. |

**Note**: Optical sortation trials conducted at Greenstar WES and Closed Loop Recycling have confirmed that tinted caps can be identified and sorted with existing optical sortation equipment.

## 5.0 Extrusion trial of virgin HDPE

### 5.1 Purpose

Preliminary results from the virgin HDPE trials run on the Vacurema in March 2009 (Phase One) indicated a discolouring effect was brought about by the extrusion process leading to a noticeable yellowing of virgin material during extrusion.

A further trial was conducted to determine the extent of colouration at different barrel and melt temperatures on the extruder due to the extrusion process itself. In addition, any physical changes could be analysed (Melt Flow Index (MFI), density) as well as any organoleptic or chemical changes.

### 5.2 Methodology

Approximately 4.5 tonnes of virgin HDPE flake (supplied by Alpla) was fed into the extruder (Vacurema). The Vacurema throughput was kept as constant as possible through the trial (~700kg/h) as was the screw speed (60rpm). The barrel and melt temperatures were then altered. The temperature ranged from 230°C to 250°C and ran for at least 30 minutes to ensure settled temperatures and uniformity in material composition. Multiple samples were obtained from each temperature setting. Each sample was analysed to check the following parameters:

- MFI – to determine any changes in melt flow characteristics;
- Density – to determine any changes in polymer density;
- Colour – to analyse the temperature effects on polymer colour;
- Headspace Gas Chromatography – to determine any changes in volatile components/chemical or polymeric degradation; and
- Odour – samples were checked using an electronic nose to determine any changes in odour at different temperatures.

### 5.3 Results

The results show that the virgin flake had a relatively low negative 'a' value (see Delta E explanation in Appendix 1), suggesting a slight green tint. Upon extrusion, there was an increase (imperceptible to the naked eye) in the shift towards negative 'a'. So the material became slightly greener upon extrusion. However, once the extrusion process had started, there was little variation from that point on, with a very slight drift towards more negative 'a'. Overall, this suggests that after the initial extrusion colouration, there is little further red/green colouration influenced by increasing temperatures. In contrast to the trials conducted in March (where problematic discolouring of the extruded material was observed), there was less colouration of the virgin material (a drop in L value of 6.48), and in fact the material colour actually appeared to improve as the extrusion temperature increased.

### 5.4 Conclusions

- Very few of the analytical tests performed on the extruded material showed significant deviation from each other;
- Melt Flow, Density, Headspace analysis and E-Nose analysis all showed minor variations between samples, but no trends or otherwise that would suggest negative or detrimental changes to the material at higher temperatures;
- Increases in temperature appeared to improve product colour slightly although not significantly;
- Although the material was not subjected to excessively high temperatures (which in a real life industrial scenario would be unrealistic), an increase in melt temperature of 45°C (from 215°C to 260°C) does not detrimentally affect the material; and
- Overall the extrusion stage of the recycling process was found to have minimal impact on colour contamination.

## 6.0 Process and Medium Scale trials

### 6.1 Background

The potential cap and label solutions developed were tested and validated by carrying out a series of medium scale trials on commercial recycling equipment. During these trials the key process parameters were investigated to identify the optimum recycling operating conditions to minimise colour hue of the final recycled HDPE pellet.

A series of wash trials were carried out on the wash plant at Previero Sorema (Italy). The level of colour contamination was observed and the percentage of label removal was recorded.

The washed material was then extruded at Erema (Austria) and the rHDPE pellets produced were used to manufacture new milk bottles with varying levels of rHDPE at Alpla. rHDPE pellet material and the sample bottles were then analysed in the lab at Greenstar WES to measure the effect of these solutions on colour.

### 6.2 Sorema wash trials

The purpose of this trial was to simulate and observe the benefit of implementing the most promising conditions from the mini wash trials. These were: not using paper labels, washing at a temperature range of 80-85°C, maintaining a 2% detergent level and washing for 10 minutes.

The trials were conducted to establish the removal rate of labels and sleeves from the wash process and establish the effect on colour contamination. While the process at Sorema is different from the UK operations (both of which are different in themselves), it is representative of the general process and therefore can be used to inform a large scale trial.

The trial material consisted of 2 tonnes of factory waste bottles without caps, but decorated with current label designs consisting of PP 50 micron self-adhesive labels (60% of total weight) and stretch sleeves (40% of total weight), but no paper, or paper laminate, labels.

The colour split matched current market sales proportions, i.e. 60% green (semi skimmed), 30% blue (whole) and 10% Red (skimmed).

#### *6.2.1 Stage 1 – Granulation and hot wash*

The first stage was to grind the material and then pass it through an air separator to remove sleeve material (this also removed some of the HDPE flake). After air separation the material was washed at 80°C - 85°C with 2% RP10 detergent for 10 minutes. From there the material was processed through a centrifuge to remove excess water and stored in large sacks prior to stage 2 processing.
During the trial the following weights were taken for the material mass balance calculation:

- Weight of each bale;
- Waste material from air separator;
- Material after washing and centrifuge;
- Waste bottle bags;
- Waste sleeves;
- Banding used to contain bales;
- Bags used to contain washed material; and
- Material not used in trial.

Knowing the weight of each of these components allowed an accurate mass balance to be calculated. The stage one process resulted in approximately 1,750 kg of washed material for stage two.

Samples (50 grams approximately) were taken every 30 minutes from the following stages in the process: grinding, after air separation, waste material from air separation and post wash.

The samples were then combined to give a representative sample from each step. Stage one material had some residual colour flakes evident and was consistent with the levels of contamination evident in the UK operations.

**Figure 23:** Research & Development Equipment

The following equipment was utilised for the medium scale wash trials:

**Granulator**

**Aerodynamic separator**

**Hot Wash**

**Centrifuge**

**Dryer (Hot Air)**

At the UK reprocessors colour sorting removes colour contamination from the HDPE flake prior to the extrusion step. However, during this trial, a colour sorter was not available, so an additional air separator was used to help remove label/cap fragments.

### 6.2.2 Stage 2 – Rinse and hot air drying

1,750 kg of washed flake was fed into the washing unit. The water temperature was 40°C and consisted only of water for rinsing. After rinsing, the material was processed through a centrifuge to separate the solids out of the solution into specific layers, and then a hot air dryer. From there it was put through an air separator to remove any dislodged sleeve/label material (lights).

Samples of the extracted waste label material and of the final washed flake were taken at regular intervals throughout the trial. From these samples four random 200g sample bags were analysed to arrive at a label/sleeve removal average. The labels were not found to be tacky and the result was an average of 0.14% of the total washed flake pre-extrusion was label/sleeve material. This is a marked improvement on the overall colour contamination results of 1.2% taken in June 2009. Given the flakes produced in this trial were not passed through optical sorting equipment the 0.14% figure could be improved on further. This clearly does not account for the colour contamination from caps.

The finished material was then transported to Erema in Austria for extrusion trials.

### 6.2.3 Wash trial results

- Washed flakes were visibly cleaner than standard production;
- High stretch sleeve label removal at granulation and air filtration stage (>90%);
- PP labels were removed from the HDPE during hot wash and rinse cycle confirming the mini wash findings;
- The PP labels did not have an adhesive tack and did not get stuck in the air separators, even after being processed through the air separators twice;
- On average 0.14% of label/sleeve material remained in the washed flake prior to extrusion demonstrating very good label removal. This is a particularly positive result given the absence of optical sorting in the trial; and
- Accurate detergent dosage and temperature control is key to sustained label removal performance.

## 6.3 Stage 3 - Extrusion

Extrusion trials were conducted to establish the effect of clear, tinted and standard caps on the final rHDPE pellet. The process at Erema is representative of the general UK operations and therefore can be used to inform a large scale trial.

The washed flake material processed at Sorema was split into three batches. Each batch was extruded to produce food grade rHDPE pellets. The purpose of each trial is described as follows:

**Trial 1 material**

Trial 1 material consisted of washed flake from stage two with no cap material added. This effectively simulated the use of natural caps or a scenario where 100% of cap material was removed prior to extrusion.

**Trial 2 material**

The second trial material was washed flake from stage two plus 1.2% of ground tinted HDPE prototype caps (the original tinted caps specification as used in the consumer research (see figure 19), with reduced colorant dosage, and split by the following colour proportions: 60% green, 30% blue and 10% red. This was to test the effect of tinted caps on the final product.

**Trial 3 material**

The third trial material was washed flake from stage two plus 1.2% of current specification full coloured HDPE dairy caps ground and split by the following colour proportions: 60% green, 30% blue and 10% red. This was to test the effect of the current coloured caps on the final product and to provide a comparison with natural and tinted cap material from trials 1 and 2.

The extrusion trials utilised the patented Vacurema Advanced extrusion system. It featured an additional, continuously operating upstream vacuum crystallisation dryer. The operating parameters for the Vacurema Advanced extrusion system were:

## Vacuum crystallisation dryer

- Continuous operation temperature at 110ºC;
- Vacuum 0.9 mbar; and
- Holding time: 45 minutes.

## Vacuum reactor

- Continuous operation temp 120ºC;
- Vacuum 3.3 mbar; and
- Holding time 45 minutes.

The Vacurema basic extrusion system operates with a gravimetric doser screw feed into the extruder with an output of 0.5kg per minute. The temperature reached 230ºC in the extruder.

Three equal batches of washed and dried flake material produced in the wash trials at Sorema (stages one and two) were measured for extrusion into pellets. Prior to the extrusion trials the extrusion system was purged with 400kg of the trial material.

The resulting extruded pellets, shown in Figure 24, highlight the visual benefit of reducing cap pigment strength.

**Figure 24**: Comparison of extruded rHDPE pellets from Erema trials with natural, tinted and standard caps (at 1.2% cap contamination level)

| **Trial 1** | **Trial 2** | **Trial 3** |
| --- | --- | --- |
| Natural caps + labels (but no paper) | Tinted caps + labels (but no paper) | Standard caps + labels (but no paper) |

## 6.4 Pellet colour analysis and conclusions

Colourimetric tests were conducted to establish the improvements in the Delta E values (See Appendix 1 for an explanation of Delta E) of the final pellets compared to standard/current production. Figure 25 shows the results obtained.

**Figure 25:** Colour analysis results of pellets produced in the trial

| Absolute colour | | | Difference against virgin HDPE | | | | |
|---|---|---|---|---|---|---|---|
| **L** | **a** | **b** | **DL** | **Da** | **Db** | **DE** | **Sample** |
| 63.57 | -2.96 | 8.10 | -24.36 | -1.79 | 7.73 | 25.62 | Batch 3613 (Greenstar std. pellet) |
| 77.08 | -3.57 | 7.58 | -10.84 | -2.39 | 7.24 | 13.25 | Trial 1 (nat caps) |
| 76.78 | -11.12 | 5.95 | -11.07 | -9.99 | 5.63 | 15.94 | Trial 2 (tinted caps) |
| 66.23 | -17.33 | 6.60 | -21.69 | -16.16 | 6.72 | 27.75 | Trial 3 (std caps) |
| Trial 1 as the benchmark | | | 0.30 | 7.55 | 1.63 | 7.73 | Trial 2 (tinted caps) |
| | | | 10.85 | 13.76 | 0.98 | 17.55 | Trial 3 (std caps) |
| Trial 2 as the benchmark | | | 10.55 | 6.21 | -0.65 | 12.26 | Trial 3 (std caps) |

The main points of interest in the first row of data are the readings from the baseline Greenstar WES samples taken at the time of the tests. The DL value is negative, showing that the sample was darker than virgin. The Da is also negative showing that the sample is greener than the standard. The Db value is positive so the sample is more yellow than standard. The overall DE is 25.62; this could be viewed as a fairly 'standard' result for rHDPE.

Below summaries the results from the colourimetric tests for each trial.

### Trial 1 (Natural caps plus labels)

- For the first trial the 'L' value is higher than that of the Greenstar sample, suggesting that it is lighter.
- The DL value is negative so the material is darker than virgin, but by less than the Greenstar sample.
- The Da value is negative, suggesting that the sample is greener than virgin and greener than the Greenstar sample (-2.39 compared to -1.79).
- The Db values for both the WRAP sample and the Greenstar sample are very close (7.24 and 7.73 respectively) indicating that both samples are equivalently slightly blue compared to virgin.
- The DE is lower than the Greenstar sample (13.25 compared to 25.62), no doubt resulting from the much higher (i.e. less negative) DL of the WRAP sample.
- This material has the 'best' colour of the three trial materials and is a better colour than the average Greenstar sample, with only small variances in the greenness and yellowness.

### Trial 2 (Tinted caps @ 1.2% dose plus labels)

- For the second trial, the DL value is not dissimilar from the first trial (-11.07 compared to -10.84) suggesting a comparable lightness. The 'a' value is greatly different however, at -9.99. This shows that the trial 2 sample is much greener than both the virgin standard and the Greenstar sample.
- The Db value of 5.63 shows the material is yellower compared to virgin, but less so than trial 1 and the Greenstar sample.
- This results in a higher DE than trial 1, but only slightly (15.94 compared to 13.25 for trial 1), derived from the higher Da value) but is still lower than the Greenstar sample.
- This material has the second 'best' colour of the three trials.

### Trial 3 (Standard caps @ 1.2% dose plus labels)

- For the third trial, the DL value is higher (more negative thus darker) at -21.69 and is closer to the Greenstar sample than either of the other two trials.
- The Da value of -16.16 is the highest of all the analyses and suggests a large amount of green influence.
- The Db value is about average when compared to the Greenstar sample and the other two trial values. Unsurprisingly, as a result of the increased DL and Da, the overall DE is much higher and exceeds that seen from the Greenstar sample.
- This material has the "worst" colour of the three trials.

### Trial 2 compared to trial 1

- When compared to trial 1, trial 2 has a comparable DL (lightness) and Db (slightly bluer).
- The material is greener than trial 1 material with a Da of -7.55.
- The DE is 7.73, mainly from the Da.

### Trial 3 compared to trial 1

- When compared to trial 1, trial 3 is darker (has a negative DL), is more green (-13.76 DA value), and has a comparable Db value.
- As a result of the DL and Da values, the DE is correspondingly higher than trial 2 at 17.55.

### Trial 3 compared to trial 2

- When compared to trial 2, trial 3 material is darker (has a negative DL), greener (has a negative Da), and a comparable Db.
- The overall colour difference from trial 2 is 12.26.

The use of tinted caps shows a significant improvement in the delta E colour reading in comparison to material with standard caps (from the trial and Greenstar WES). It should be noted that the material for the trials added caps at 1.2%. This is typical of previous Greenstar WES levels. However Greenstar WES has recently optimised its colour sorting process so that a much lower level of cap material is getting into the extruder.
Two colour sorters were working in parallel (i.e. the material passed through one or the other sorter). A third optical sorter was purchased and the three sorters are now configured in series so that the material passes through all three. As a result the colour contamination into the extrusion process has significantly reduced.

These results clearly show the strong effect of the cap colour on the final rHDPE pellet colour and that tinted caps would significantly reduce the green hue of rHDPE. It is expected that tests with tinted caps and with reduced cap levels (for example 0.6%) would show an even further reduction of colour contamination.

## 6.5 Stage 4 – Bottle manufacturing trials

The culmination of the trials resulted in the production of HDPE bottles at Alpla using rHDPE pellets produced during the EREMA trials in combination with virgin HDPE flake at varying proportions.

Manufacturing took place on a full scale production line at Alpla's Droitwich facility.

### *6.5.1 Bottle manufacturing trials - Samples manufactured*

**Figure 26:** Summary of the different bottle compositions manufactured. The blue number in brackets refers to the bottle in Figure 27 (on next page)

| | 10% rHDPE | 30% rHDPE | 50% rHDPE | 75% rHDPE |
|---|---|---|---|---|
| **Bottle series 1** | N/A | Pellets containing natural caps | Pellets containing natural caps (5) | Pellets containing natural caps (2) |
| **Bottle series 2** | N/A | Pellets containing tinted caps dosed at 0.6% | Pellets containing tinted caps dosed at 0.6% (4) | Pellets containing tinted caps dosed at 0.6% |
| **Bottle series 3** | N/A | Pellets containing tinted caps dosed at 1.2% (3) | Pellets containing tinted caps dosed at 1.2% | Pellets containing tinted caps dosed at 1.2% |
| **Bottle series 4** | N/A | Pellets containing standard caps dosed at 1.2% | Pellets containing standard caps dosed at 1.2% | Pellets containing standard caps dosed at 1.2% |
| **Bottle series 5** | Standard pellets. Baseline sample (1) | N/A Standard pellets. Baseline sample | Standard pellets. Baseline sample | Standard pellets. Baseline sample |

### 6.5.2 *Bottle manufacturing trials - Conclusions*

The photos below compare the four best performing combinations with the current 10% rHDPE bottle, indicating that a step change to a minimum of 50% rHDPE content is achievable with the suggested solutions.

The samples pictured were all deemed to be visually acceptable and passed the standard Alpla quality control tests.

**Figure 27:** Comparison of manufactured bottle samples

N.B. here, "proposed labels" means the labels used in the medium scale trials. That is PP, synthetic wraparounds and sleeves but not paper/paper laminate.

| | | | | |
|---|---|---|---|---|
| (1) Current production @ 10% rHDPE | (2) Natural caps & proposed labels @ 75% rHDPE | (3) 1.2% tinted caps & proposed labels @ 30% rHDPE | (4) 0.6% tinted caps & proposed labels @ 50% rHDPE | (5) Natural caps & proposed labels @ 50% rHDPE |

**Figure 28:** Aggregated analysis

| Proposed Solution | Colour | Bottle Blowing QA | Consumer Testing |
|---|---|---|---|
| 1. **Natural/Clear Cap + coloured insert.**<br>2. PP/Sleeve/Wraparound labels.<br>3. Recycling process improvements. | Pass<br><br>Could increase up to 75% rHDPE content | Pass | Not tested |
| 1. **Tinted Cap.**<br>2. PP/Sleeve/Wraparound labels.<br>3. Recycling process improvements. | Pass<br><br>Could increase up to 50% rHDPE content | Pass | Tinted cap concepts were accepted by the majority of the 557 sample. Standard 10% rHDPE bottles were used. |
| 1. **rHDPE Cap.**<br>2. PP/Sleeve/Wraparound labels.<br>3. Recycling process improvements. | Not tested | Not tested | Not tested |

## 6.6 Process findings from the medium scale trials

The laboratory and medium scale trials (based on 2 tonnes of bottle material) were conducted to isolate specific sections of the recycling process in order to improve the project teams' understanding of where and to what degree the process variables affect colour contamination.

The project team identified that there are a limited number of cleaning agents available to HDPE reprocessors for enhancing the performance of the wash cycle. Cleaning agents are added to the wash water in the wash process to encourage label removal and clean the rHDPE flakes prior to extrusion. Greenstar WES and Closed Loop Recycling use different products and wash techniques.

It was found in both the mini wash and medium scale trials conducted during Phase 2 the following hot wash conditions produce the best results in the context of:

- Good label removal;
- Cleanliness of flake;
- Integrity of label waste – i.e. not broken down; and
- Wash water contamination and sediment.

### Suggested hot wash conditions

A temperature of 85ºC maintained for a 10 minute cycle with a constant 2% dosage of a detergent only based cleaning agent. Positive results have been achieved from the following products:

- Cognis Dehypound LLD 60; and
- McDermid RP10.

*Note:* Not all products available were tested.

### Suggested rinse wash conditions

Water only, maintained at a temperature of 40ºC for a 10 minute cycle.

It was also suggested that an additional hot air drying and separation unit installed post granulation and pre hot wash would:

- Dry the feedstock flakes and labels; and
- Enable the dynamic air separator to remove more 'lights' prior to the hot wash.

It is considered that this suggestion would significantly increase the removal of labels and 'lights' prior to the wash cycle. Further investigation and investment would be required.

**Figure 29:** Recycling Process Solutions

The following measures to improve the current recycling process and therefore reduce colour contamination of rHDPE pellets are summarised in the table below.

| Process Description | Solutions | Economic Evaluation | Environmental Evaluation |
|---|---|---|---|
| **Cleaning agents** | ■ A detergent only solution performs best when considering flake cleaning, wash water quality and label removal. Cognis Dehypound LLD 60 and McDermid RP10 were used during the mini wash and medium scale trials dosed at 2%.<br>■ Improvements in dosage control will be required in order to manage consistency.<br>■ Mini wash trials demonstrated that caustic soda causes cross colour contamination to clean HDPE flakes. Some food grade reprocessors however require the use of caustic soda as it is integral to their food grade recycling process, but where possible, from a colour perspective, it is recommended that caustic soda is not used. It is advised that reprocessors carry out large scale trials prior to implementation of any changes. | Minimal increase in material costs. | Increase in rHDPE yield due to improved label removal. |
| **Temperature** | ■ Maintaining the optimum temperature of 85ºC throughout the 10 minute hot wash cycle is key to achieving successful label removal and cleaner flakes. | Minimal increase in utility costs. | Cleaner flakes and pellets enable higher recycled content. |
| **Colour Sorting** | ■ Additional optical sorters and/or optimising the use of existing sorters to increase sorting efficiency would increase label and cap removal prior to extrusion.<br>■ Hot air filtration pre and post wash cycle would also dry the flakes and labels and enable the dynamic air separator to remove more "lights" prior to the hot wash.<br>■ Systematic colour contamination analysis should be incorporated into the standard Quality Control procedures for HDPE recyclers. | Will require investment in additional equipment or reconfiguration of existing processing line. | Cleaner flakes and pellets enable higher recycled content. |

## 7.0 Consumer Research

A consumer research exercise was commissioned to test the label design and tinted cap concepts with consumers. The full methodology, sample selection and results are in appendix 4.

The purpose was to engage consumers to understand their views, opinions and attitude towards alternative product design and identification and to test whether the tinted cap and alternative label concepts would be positively received in the market.

**Figure 30:** Label design concepts with tinted caps used during consumer research exercise (left is full colour label, middle is two stripe label, right is one stripe label)


### 7.1 Research, Background and Objectives

TNS-BMRB, a market research agency, undertook research to test consumer reaction to the new tinted cap, and to test three versions of labels that could be used alongside the new cap. In particular, the research aimed to:

- Establish whether or not sales of milk would be adversely affected if the tinted cap was introduced, given that at least initially, the current, darker caps could also be available on other brands; and
- Establish whether or not sales of HDPE milk bottles using the new cap would be affected by a change to label colour strength.

Over 550 people were interviewed. Participants were initially shown bottles with a generic label and tinted caps and then they were shown samples of bottles with tinted caps and alternative label designs.

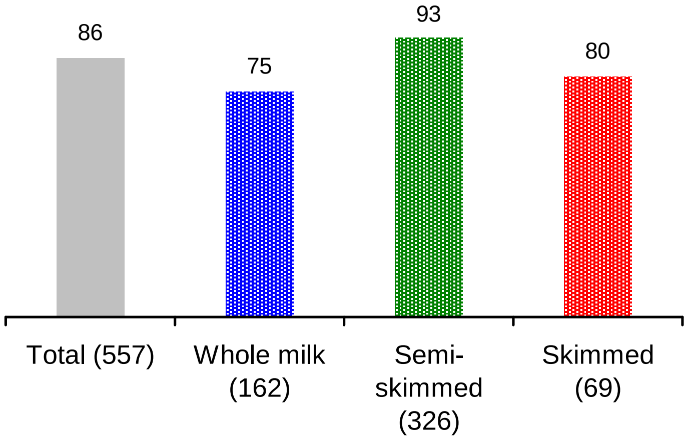
#### *7.1.1 Key Findings*

**Initial reaction to new lighter cap**

The majority (86%) of milk buyers said they would be likely to buy their usual milk if it had the new cap on it.

- Buyers of semi-skimmed milk in particular accepted the new cap; virtually all (93%) said they were likely to buy their usual milk in a bottle with the lighter cap;
- Whole milk buyers were less positive, but even then a clear majority (75%) would be likely to buy.

**Figure 31**: Percentage of consumers who would be likely to buy their usual milk if it had the new cap on it




When the lighter cap was combined with a label of varying amounts of matching colour, the percentage saying they would be likely to buy the milk increased to 94% among all milk buyers from 86% (when the lighter cap was shown with a generic black and white label).

- 83% said it would be easy to recognise bottles with the new cap as the milk type they usually bought (semi-skimmed - 94%);
  - Adding labels of matching colour increases recognition to 96% (whole milk 91% from 75%).
- 71% of semi-skimmed milk buyers have no preference between buying the milk they normally buy with a lighter or a darker cap when forced to choose.
- 97% said they would buy their current milk with a lighter cap once they were told about the environmental benefit - an additional 11%;
  - 94% of whole milk buyers said this - an *additional* 19%.
- 34% said they would switch from their normal milk to buying milk that used the lighter cap if they know about the environmental benefits;
  - Increased to 40% with addition of matching label.
- 37% described the 'one stripe' label and 33% the full colour label as 'standing out' compared with 20% the two stripe label;
  - 27% described the two stripe label as cheap (12% full colour; 18% one stripe);
  - 12% described the two stripe label as 'environmentally friendly' (4% full colour; 7% one stripe).

### *7.1.2 Conclusions*

Milk appears to be a habitual purchase that is not strongly affected by the changes to packaging being tested:

- Most milk buyers, especially those buying semi-skimmed milk, would still be likely to buy their usual milk if the bottle included the new, lighter cap;
- The inclusion of labels with varying amounts of matching colour improved the results further.

The lighter caps did not appear to be a barrier to recognition:

- The addition of the coloured labels made them even more recognisable.

Although, when prompted, milk buyers said they associated a number of negative adjectives with the lighter caps, none of these appeared to be a barrier to purchase:

- The main barrier that would need to be addressed is the association among whole milk buyers of stronger colours with richness and the perception that a lighter colour signifies a less rich milk.

The label with two stripes was seen to stand out less than either the label with a single stripe or the full colour label and was more often described as 'cheap' and 'environmentally friendly' than either of these.
Describing the environmental benefits of the caps with less dye could be used to counter any negative impressions:

- Doing this would encourage milk buyers, especially whole milk buyers, to continue to buy their usual milk if it was sold with the new cap;
- Potentially it could encourage some milk buyers of all milk types to switch to buy milk having a lighter cap;

The matching label might encourage additional switching. However subsequent process trials have resulted in identifying that the alternative label designs would deliver minimal benefit (by reducing ink coverage) given the proportion of labels that are removed following the process changes recommended in this report.

## 8.0 Environmental Assessment

Increasing the recycled content in plastic milk bottle packaging realises environmental benefits by reducing the use of virgin plastic. This uses resources more efficiently, reduces waste to landfill, saves energy and reduces greenhouse gas emissions.

The methodology for assessing the climate change impacts of packaging optimisation under the Courtauld Commitment Phase 2[6] states that for HDPE bottles the $CO_2$ (equiv) impact of the overall pack can be reduced by 10% by increasing the recycled content of the overall pack by 22%.

The solutions and suggestions put forward in this document enable a higher recycled content to be achieved in new milk bottles (around 50%) and therefore will help to deliver additional environmental benefits.

The $CO_2$ savings achieved will depend on the level of recycled content that is used in each case.

For further details and data on this, please refer to the WRAP document: "Life cycle assessment of example packaging systems for milk"[7]

## 9.0 Project Conclusions and next steps

### 9.1 Cap conclusions and next steps

- Natural/clear caps would eliminate colour contamination from caps and increase the supply of rHDPE but there are concerns over identification of milk variants in the supply chain using natural caps, even with a coloured liner. An alternative way of identifying bottle variants may enable this option to be implemented and it is recommended that this is investigated. In addition it is recommended that the compatibility of cap and bottle material in the manufacture of new bottles is demonstrated, as colour sorting could no longer separate cap and bottle material prior to extrusion.

- Tinted caps significantly reduce the level of colour contamination and maintain the ability to identify milk variants in the supply chain. There are no technical or cost barriers to implementing tinted caps. Large scale manufacturing and recycling trials prior to implementation are recommended. The pigment levels can be varied to optimise the balance between reduced contamination and visible colour depth required. This is a quick win and has no adverse effect on costs and we suggest an industry standard hue for skimmed, semi and whole milk products is agreed. We recommend that the dairy supply chain carries out further experimentation with the pigment levels to optimise the balance between reduced contamination and visible colour depth and ensure that each dairy is satisfied that it's equipment can work with the modified cap colours.

- Using up to 30% rHDPE in caps and maintaining existing colourant levels would increase the overall recycled content in the pack, although the cap could not be recycled again within a closed loop cycle unless it was natural/clear.

### 9.2 Label Conclusions and next steps

- Of the label types widely used on UK HDPE milk bottles, wraparound, stretch sleeves and synthetic (PP) self adhesive labels, of the specifications tested in mini wash and medium scale trials, were found not to contribute significantly to the colour hue problem because over 90% of this material is removed from the HDPE at the reprocessor.

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[6] *Courtauld Carbon Methodology Dec 10*

[7] *http://www.wrap.org.uk/downloads/Final_Report_Retail.9cebfada.8405.pdf*

- In the mini wash trials, over laminated paper labels of the specification tested leached colour and sediment into the wash process and cross contaminated the HDPE flake. The level of label removal was found to be comparatively low.
- In the mini wash trials PP labels, of the specification tested remained intact and peeled away from the HDPE flakes. The encapsulated labels did not release ink into the wash water. In the detergent only trials, label removal exceeded 90% with the best result achieving 98%. No cross colour contamination was evident and the PP labels did not have an adhesive tack and were removed by post wash air separation equipment. This was then confirmed during medium scale recycling trials with two tonnes of bottles.
- The results of trials in this project indicate that a significant reduction in the colour hue of rHDPE could be achieved by switching paper labels of the specification we tested to synthetic (PP) labels of the specification tested, because PP label removal was found to be higher and colour was not leached out of the labels. This may incur around a 3% to 5% increase in material costs, but the same equipment can be used to apply the label so no additional capital costs would need to be incurred. Our recommendation is that the industry undertakes to follow up this work with large scale trials prior to implementation. This would include large scale recycling trials of PP labels of the specification we tested and analysing the level of label removal at the hot wash stage at reprocessors.
- Further improvements could be realised by reducing the level of inks and the hue of colours on the labels. Initial consumer research indicated positive consumer responses to some of the alternative label designs developed. Investigations into the effect of any problematic inks and adhesives may also lead to additional improvements.

## 9.3 Process Conclusions and next steps

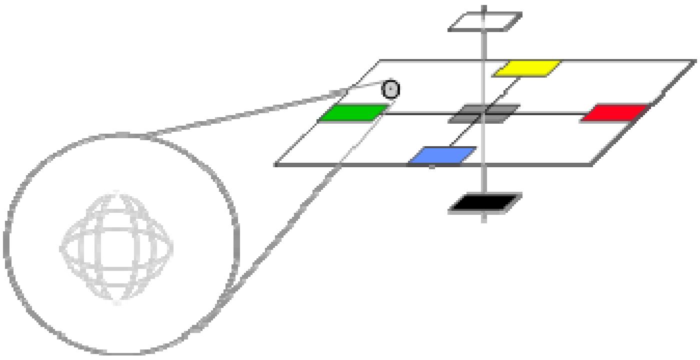
- Reprocessors carry out optical sorting to filter out coloured material from the natural HDPE bottle material prior to extrusion of the material to create a food grade rHDPE pellet. Coloured cap material can contribute significantly to the colour contamination of rHDPE if it gets into the extrusion process. Reprocessors must keep this contamination to a minimum. Increasing the number of optical sorters would improve the removal of coloured flakes going into the extruder, but this equipment is very expensive. Optimisation of the colour sorting process to maximise the number of sorts that are done with the same equipment, whilst maintaining commercially viable throughput volumes and speeds can dramatically improve the removal of coloured material.
- In addition, ensuring colour contamination monitoring systems are in place to flag and resolve any deterioration in colour sorting performance is essential. Systematic colour contamination monitoring and analysis should be incorporated into the standard quality control procedures for HDPE reprocessors.
- Wash trials have demonstrated how critical correct temperature and cleaning agents are in the successful removal of labels and contaminants. Maintaining the optimum temperature of the wash process of 85$^{o}$C throughout the 10 minute hot wash cycle was found to be key to achieving successful label removal and cleaner flakes. Medium scale trials to recycle two tonnes of milk bottles with PP self adhesive labels and sleeves demonstrated a very high level of label removal. The next step for the reprocessors would be to carry out large scale trials prior to implementation of any changes.
- A detergent only solution was found to perform best when considering flake cleaning, wash water quality and label removal. Trials demonstrated that detergents dosed at 2% enabled the most effective label removal. It is recommended that reprocessors implement tight systems of dosage control to ensure that the effect of the wash plant is optimal and to carry out large scale trials prior to implementation of any changes.
- Mini wash trials demonstrated that caustic soda causes cross colour contamination to clean HDPE flakes. Some food grade reprocessors however require the use of caustic soda as it is integral to their food grade recycling process, but where possible, from a colour perspective, it is recommended that caustic soda is not used. It is advised that reprocessors carry out large scale trials prior to implementation of any changes.
- Hot air filtration pre and post wash cycle would also dry the flakes and labels and enable the dynamic air separator to remove more "lights".

## 9.4 Overall Conclusions

Small and medium scale trials have demonstrated that if tinted caps were implemented, paper labels of the specification we tested switched to PP labels of the specification we tested, and the process suggestions identified in this project are implemented, it would enable the production of at least a 30% rHDPE bottle to be aesthetically acceptable from a colour perspective. The results in this project indicate that this could increase to around 50% rHDPE if <0.6% of the extruded rHDPE is tinted cap material. This is subject to large scale dairy production tests and recycling trials at reprocessors which we recommend would be the next steps towards implementation.

# Appendix 1 Delta E- Explanation

### Measuring colour values using Delta-E



### Delta-E methodology was used to identify colour contamination levels scientifically

L= lightness of colour

a = its position on the red and green axis

b = its position on the yellow and blue axis

The Colorimeter has an electronic reference to virgin standard built in. 'Sample' tests are run and compared against this electronic standard. The colour is tested in two ways:

Absolute: this is a measure of the samples actual colour co-ordinates.

*Difference*: these are the colour co-ordinates (and overall colour difference) with reference to a standard (in this instance the electronic virgin standard).

'L' is a measure of the lightness/darkness of a sample. The higher the L value the lighter (closer to pure white) the colour is. The lower the L value, the closer to black the colour is. DL (or ΔL) is a measure of the samples lightness or darkness as compared to the standard. 0 would be equivalent. A positive DL value shows that the sample is lighter than the standard whilst a negative DL shows that the sample is darker than the standard.

'a' is a measure of how green or red the sample is. A negative 'a' indicates a green colour whereas a positive 'a' is an indication of how red the sample is. As with the 'L' value, for the Da, a negative means that the sample is greener than the standard and a positive means that it is redder.

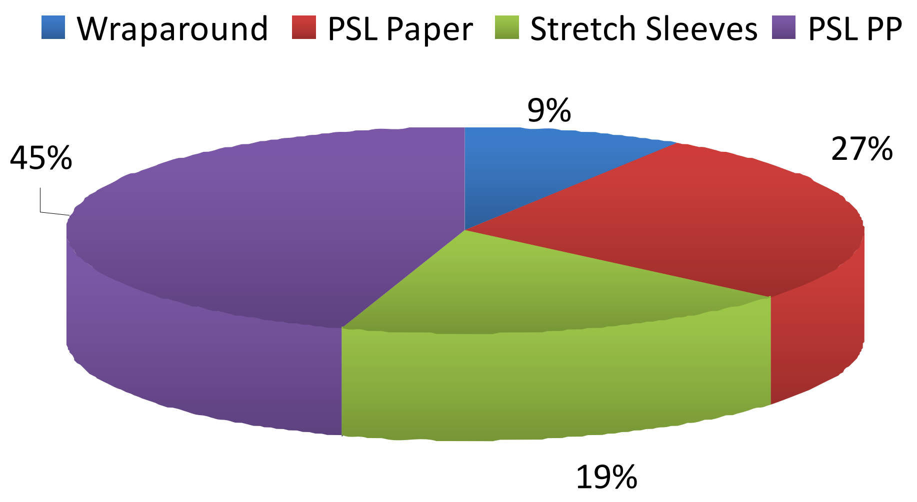
'b' is a measure of how yellow or blue the sample is. A negative 'b' indicates a blue colour whereas a positive 'b' is an indication of how yellow the sample is. As with the 'L' value, for the Db, a negative means that the sample is bluer than the standard and a positive means that it is more yellow.

Delta E (DE) is the overall measure of how far the colour is from the standard (it is a combination of the effects of the L, a, and b readings, but is not simply a sum).

# Appendix 2 Mini Wash Trial Report

The key objectives for the label element within the R&D phase were to investigate the construction and properties of each label type used on HDPE bottles in the UK dairy industry. The project team identified a series of trials would be required to understand the individual contribution of each label type currently used in the UK dairy market. Namely; wraparound labels, stretch sleeve labels, self-adhesive paper labels and self-adhesive synthetic labels. The current market split by label type is illustrated in the graph below.

**Share of UK HDPE dairy market split by label type**




Source: Systems Labelling March 2010

The project team engaged adhesive, ink and substrate suppliers as part of the initial investigation. However following the results from a series of laboratory trials the project team were able to identify the best performing label types through a process of elimination.

The initial experiments were conducted at a micro level given the volume of materials, costs involved and down-time required to conduct the necessary volume of tests with the full operation. To this end a mini wash system was designed and developed to replicate the full scale system used at Greenstar WES. A full description and schematic drawing is included in this section.

In order to clarify the current production methods the table below provides a summary of the materials, printing technique and ink/coating systems used for each of the label types identified.

## Label types and current printing systems (tested in the mini wash trials)

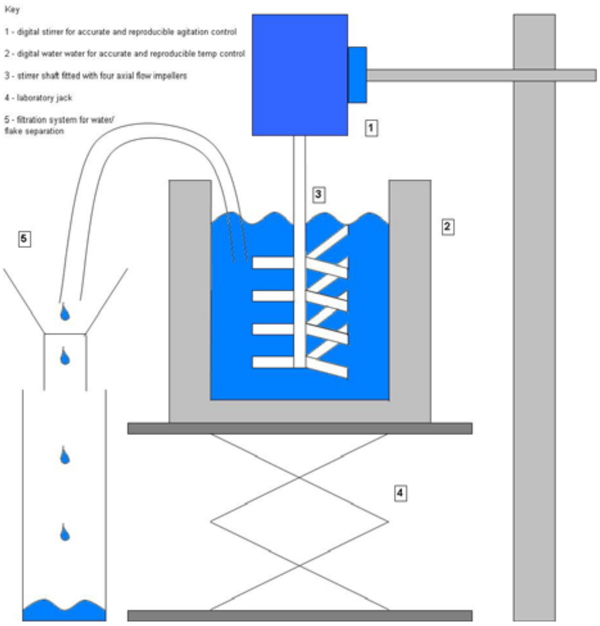
| Label Description | Substrate | Print Technique | Ink/Coating System |
|---|---|---|---|
| Wraparound | 30 micron OPP (Matt appearance) | Gravure (reverse printed) | Solvent based inks and opaque white overprint to act as a sealing agent. |
| Stretch Sleeves | 45-50 micron clear LDPE with added slip and no sealer. | Solvent based flexographic printing (reverse printed) | Solvent based nitrocellulose inks. No sealer. |
| Synthetic Self Adhesive Labels (50 micron) | 50 micron Polypropylene core with 12 micron Polypropylene overlaminate. | UV Flexographic Printed on face then encapsulated with overlaminate. | UV cured in line. Adhesive applied to back is chiller permanent with an initial high tack for damp conditions. |
| Synthetic Self Adhesive Labels (60 micron) | 60 micron Polypropylene core with 12 micron Polypropylene overlaminate. | UV Flexographic | UV cured in line. Adhesive applied to back is chiller permanent with an initial high tack for damp conditions. |
| Paper Labels | 80gsm or 60gsm paper with a 12 micron overlaminate. | UV Flexographic | Water based inks UV cured in line. Adhesive applied to back is chiller permanent with an initial high tack for damp conditions. |

## Mini Wash Label Trials

A 'mini wash system' was designed to perform laboratory trials on bottle labels to determine ink leaching and adhesion of the label to the HDPE. The plant is based on the design of the Greenstar WES recycling line 'hot-wash' system.

The design of the mini wash plant was to ensure that as many experimental variables as possible are controlled or kept constant between experiments. Therefore a digital agitator control was used in addition to a digital temperature control on the water bath. This achieves a level of consistency and reproducibility that could not be achieved using analogue instruments. Agitation is achieved using four axial flow impellers which mimic accurately the agitation design of the hot wash. The equipment provided a suitable small scale system to test label types comparatively. The design has been inserted below;

## 'Mini wash Plant' drawing



## Mini Wash Trials – Series 1

### Methodology

A trial was held at WES Greenstar week commencing 27th July 2009. The aim of the trial was to identify the impact of temperature, cleaning agents and the wash process on the label properties which include adhesive, inks and substrates. The trials focused on the label types predominantly used in the dairy industry today and are typically in the mix of bales reprocessed by WES Greenstar.

A series of label trials were planned to establish:

1. The best performing label type in current conditions.
2. The impact of altering wash cycle time.
3. The impact of adding chemicals at various levels.

### Substrates

The label types to be included in this trial include:

- Paper
- PP (Polypropylene)
- Wraparound
- Stretch Sleeves

### Design

Although reducing ink coverage is a likely element of the proposed solution this trial will test existing designs which include a significant amount of ink. All three of the standard milk products will be used including skimmed (red), semi-skimmed (green) and whole (blue) in order to identify any differences in the results based on the pigment used.

### Quantity

| Label Colour | Paper | PP (Polypropylene) 50 micron | PP (Polypropylene) 60 micron | Wraparound | Stretch Sleeves |
|---|---|---|---|---|---|
| Mix of red (10%), blue (30%), and green (60%) | 12 bottles | 12 bottles | 12 bottles | 12 bottles | 12 bottles |

### Label requirements for colourimetry analysis

| Label Colour | Paper | PP (Polypropylene) 50 micron | PP (Polypropylene) 60 micron | Wraparound | Stretch Sleeves |
|---|---|---|---|---|---|
| Red 1 pint skimmed | 12 labels | 12 labels | 12 labels | 12 labels | 12 labels |
| Green 2 pint skimmed | 12 labels | 12 labels | 12 labels | 12 labels | 12 labels |
| Blue 4 pint whole | 12 labels | 12 labels | 12 labels | 12 labels | 12 labels |

## Method

The trial series is detailed in the tables below outlining the conditions including temperature and time which were kept constant whilst differing concentrations of detergent and caustic were trialled. This method was followed for all five label types and results recorded in a controlled environment.

The labels were removed from the bottles and cut into approximately 1cm square segments. An equivalent amount of HDPE material was used for the wraparound and shrink sleeve trials to provide an element of friction.

| | |
|---|---|
| *Water temperature* | 85°C |
| *Water volume* | 2.4 litres |
| *Agitator speed* | 300 rpm |
| *Washing time* | 20 minutes. |

## Analysis

The following analysis was completed for each trial:-

- **Colourimetric analysis** of the wash water to determine the amount of ink leaching. The wash water was removed from the heating bath and diluted to a defined volume, to ensure that all trials were consistent and that there were no inter- trial errors due to differing levels of water evaporation. A sample was then removed and analysed by colourimetry. If the water samples were too weak in colour to discriminate clearly between label types then the sample will be concentrated by rotary evaporation. This enhanced any ink leaching and enabled better discrimination between trials.

- **Adhesive and substrate analysis** by filtration of the label flakes from the wash medium (analysis of number detached from plastic for adhesion trials).

- **Residue Analysis** determined the mass of any dissolved/ dispersed components in the wash water. A set volume of water was removed (100ml), and placed in an aluminium dish and evaporated to dryness and constant weight on a laboratory hotplate. The mass of any residue was then determined using a laboratory analytical balance. Note: this provided an overall residue mass and did not differentiate between residue obtained from ink or adhesive.

- **Label Removal** – the labels and HDPE were 'pre shredded' and the number of labels removed manually counted.

## Results

The high level findings from the mini wash trials (series 1) have been summarised in the tables below.

| **Label Type** | **Outcome** |
|---|---|
| PP 50 Micron | Minimal contamination, labels removed remained intact and formed cigar shapes. |
| PP 60 Micron | Minimal contamination, labels removed remained intact and formed cigar shapes. |
| Paper | Contaminated wash water, the base of the label did not remove however the top layers broke down and deposited over laminate film and the paper fibres converted to mush/pulp. |
| Wraparound | Minimal contamination and label breakdown. |
| Sleeve | Contaminated wash water and stained the wash drum with ink build up. |

| | Label colour | | | | | |
|---|---|---|---|---|---|---|
| Trial number (Label Type) | Green | Blue | Red | Label removal | Caustic % | Detergent % |
| 1 (PP/50) | 121 | 57 | 18 | 42% | 0 | 0 |
| 2 (PP/60) | 119 | 62 | 21 | 56% | 0 | 0 |
| 3 (Paper) | 113 | 50 | 20 | 0% | 0 | 0 |
| 4 (Paper) | 117 | 52 | 18 | 47% | 0 | 2.5 |
| 5 (PP/50) | 116 | 58 | 24 | 97% | 2.5 | 0 |
| 6 (PP/60) | 118 | 63 | 21 | 94.6 | 2.5 | 0 |
| 7 (stretch) | 46 | 24 | 8 | N/A | 0 | 0 |
| 8 (PP/50) | 96 | 49 | 18 | 95.1 | 0 | 2.5 |
| 9 (PP/60) | 131 | 59 | 23 | 98.6 | 0 | 2.5 |

## Unlisted trials

The initial trials (which are not detailed in the above table were conducted to gauge the most appropriate water volume, washing time, and 'friction agent'. These trials were performed using paper labels on flake. Non-labelled flake was charged (1 litre volume) to the wash vessel to provide a level of friction for the labels to work against. This resulted in poor label removal, however, the large number of flakes present after decanting of the water would have made determining the exact percentage extremely time consuming and potentially unworkable. A second trial was performed, again using paper labels, but this time with an addition of 0.5kg of HDPE virgin pellet added to the wash vessel to aid with friction. Much the same result was obtained as for the first trial, with little label removal noticed, but the flakes mixed in with the pellets to an extent where removal would be very difficult. Based on the results obtained from the first two trials it was decided to conduct the remainder of the trials with no friction agent, but to compensate for the lack of friction the washing time was increased from 8 minutes to 20 minutes. It was observed initially that some labels were beginning to peel from the flakes but were not being completely removed. The increased washing time was suggested to allow for higher label removal and to enable more valid comparisons between the trials. It is recognised that this does not accurately reflect the washing time observed in the WES hot wash process, but as all the mini wash trials would be conducted under the same time frame, they would all be comparable and so the increase in time was valid. A breakdown of each of the trials is given below.

It should be noted that although the trials vary in the number of flakes used, the surface area of label in contact with the water is always constant as the same number of bottles were used for each trial.

## 50 micron Polypropylene labels

Label removal

Only moderate label removal was noted (42%) in water only however this increased to 95 – 97% when using cleaning agents.

Wash water colouration

**Water only** - Only slight lightening of the water was noted with an increase in the 'L' value from 3.65 to 3.90, although this can be attributed to experimental variation. There was a colour increase with a slight shift towards green and blue (representative of the label make up)

## 60 micron Polypropylene labels

Label removal

Higher label removal was noted for 60 micron than for 50 micron. However, 56% removal could best be described as average. This increased to 94 – 98% when agents were added.

Wash water colouration

**Water only** - Slightly higher lightening of the water was observed compared with trial 1. Again, this may be in part due to experimental variation. As with trial 1, there was a slight shift in water colour towards blue and green (less green but more blue than in trial 1).

## Paper labels

Label removal

No (complete) label removal was observed. The top layer of paper turned to pulp in the wash when using water only and moderate removal of 47% when using a 2.5% dose of detergent.

Wash water colouration

**Water only** - A darkening of the water was noted. The 'L' value of the water decreased by 2.22 suggesting a level of water darkening. Only a small portion of this could be attributed to green colouration, however there was a noticeable increase in the blue colouration (from -0.47 to -1.97)

## Stretch Sleeves

Due to the nature of the label (no adhesive) no HDPE flakes were used in the wash.

Label removal

N/A

Wash water colouration

Very little colour change was noticed, with essentially no darkening of the water. A tiny shift towards green was seen, whilst a larger shift (from -0.41 to -1.33) was seen towards blue.

A further observation noted was the deposition of 'sediment' in the wash water, and coloured residue left around the walls of the mini wash heater tank.

## Conclusions

Conclusions from the initial trials:

- Paper labels show the poorest performance, both in terms of ink stability and label removal. It was also observed that the top layer of the paper label turned to pulp in the wash system.
- Stretch sleeve labels, whilst showing no particular tendency to leach ink into the wash water, were observed to leave a 'sediment' in the water. There was also a green residue inside the wash tank.
- Polypropylene labels (both micron sizes) show good ink stability during the wash process, with little water colouration noted.
- Any colouration of the water is largely blue or green.
- Label removal is improved hugely by the addition of 2.5% caustic or detergent for polypropylene labels.
- Inks used on Polypropylene labels do not appear to be particularly affected by the use of caustic.
- Polypropylene label removal is close to 100% (for 60 micron) when using detergent at 2.5%.

## Outcome

Following the initial trials we concluded paper labels were to be excluded from trial series 2 for the following reasons.

1. Label breakdown formed a pulp/residue in wash water which is disposed of by landfill. Greenstar confirmed large scale build up causes significant operational issues on some occasions snapping screws and causing down-time.
2. The label breakdown includes overlaminate removal and ink leakage staining the wash water demonstrated in the Delta E readings.
3. Low removal experienced with paper remaining on flake. In some instances ink was removed however paper remained which could be missed by the sensors of the optical sorter resulting in finding its way to the extruder and final pellet.

At this point no other label type has been eliminated however it was clear that the PP samples performed best in terms of label removal. Samples illustrate "cigar" shapes forming, indicating the ply construction of overlaminate and substrate assist the removal process.

## Paper labels post mini hot wash

## Mini Wash Trials – Series 2

### Methodology

The aim of the second series of trials was to:

1. Measure the impact of adding varying % of caustic and time parameters.
2. Measure the impact of varying % of detergent and time parameters.
3. Measure the impact of varying % of a mix of both caustic & detergent against a variety of time parameters.

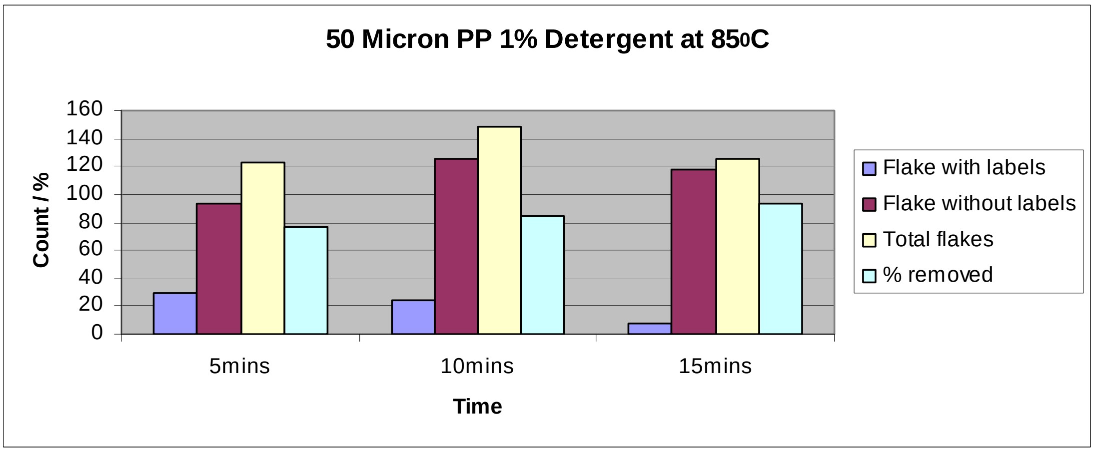
### Synthetic Self Adhesive Labels

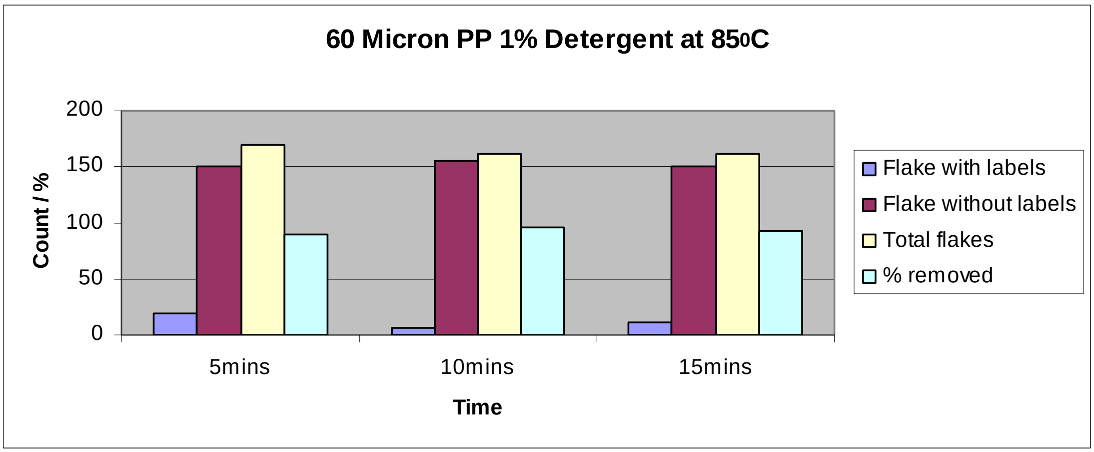
Focus on PP labels due to initial findings and time constraints. 32 trials were conducted over 2 days with the key aim to hone down the mix of additives, substrate against time.

Each sample was assessed by counting flakes with labels removed as a proportion of the total. In addition a qualitative assessment was made of the tack, label curl and evident colour contamination to the naked eye. The best performing approach appeared to be the detergent only combination of:

| Label | Process Conditions |
|---|---|
| 60 micron PP | 2% detergent for 10 minutes resulted in a 98% removal with "clean flakes," no visible label/ ink breakdown. Appeared to neutralise adhesive tack. |
| 50 micron PP | 2% detergent for 15 minutes resulted in a 93% removal with "clean flakes", no visible label/ ink breakdown. Appeared to neutralise adhesive tack. |

It was observed that a similar performance was experienced at 1% and 2% mix at 10mins+ (See the graphs below). Therefore it was concluded the next step would be to identify the minimum % additive required to achieve an acceptable label removal in a micro environment prior to proceeding to full scale trials.




## High level conclusions:

- Caustic causes label breakdown contaminating label free flakes.
- Increased dosage of detergent achieves excellent label removal with minimal water contamination and very clean flakes.
- Caustic/detergent mix has high label removal however caustic element resulted in minor label breakdown and colour contamination of flakes.

Given the minimal difference in performance and for environmental reasons it was decided to progress to the medium scale wash trial using 50 micron PP. The methodology and results from these trials are included in the Sorema and Erema reports in the main document.

## PP labels post mini hot wash

## Shrink Sleeves & Wraparound labels

### Design

Although reducing ink coverage is a likely element of the proposed solution this trial will test existing designs which include a significant amount of ink. All three of the standard milk products will be used including skimmed (red), semi-skimmed (green) and whole (blue) in mixed samples split proportionately by sales volumes.

| Label Colour | Wraparound | Stretch Sleeves |
|---|---|---|
| Mix of red (10%), blue (30%), and green (60%) | 1 red<br>3 blue<br>6 green | 1 red<br>3 blue<br>6 green |

### Method & Findings

The labels were removed from the bottles and chopped into approx. 1cm square segments. An equivalent amount of HDPE material was used to provide an element of friction and therefore match the material volumes used in the previous PP trials. The trials conducted are detailed in the analysis spreadsheet below.

| TRIAL 2.4 | Wraparound | Stretch Sleeves |
|---|---|---|
| Wash Temperature | 85°C | 85°C |
| Caustic | 1% | 2% |
| Time | 5mins | 5mins |
| | 10mins | 10mins |

| TRIAL 2.5 | Wraparound | Stretch Sleeves |
|---|---|---|
| Wash Temperature | 85°C | 85°C |
| Detergent | 1% | 2% |
| Time | 5mins | 5mins |
| | 10mins | 10mins |

| TRIAL 2.6 | Wraparound | Wraparound | Stretch Sleeves | Stretch Sleeves |
|---|---|---|---|---|
| Wash Temperature | 85°C | 85°C | 85°C | 85°C |
| Caustic/Detergent mix | 1% each | 1.5% each | 1% each | 1.5% each |
| Time | 5mins | 5mins | 5mins | 5mins |
| | 10mins | 10mins | 10mins | 10mins |

One of the UK's leading shrink sleeve printers coordinated laboratory tests on wash water samples collected during trials held at WES Greenstar on the 10th September 2009.
Samples were collected from two stretch sleeve mini-wash trials along with baseline wash samples collected prior to the addition of label material and agitation.

- Sample A – 200ml solution of water and 1% Caustic washed for 10mins at 80 0C
- Sample B – 200ml solution of water and 1% Detergent washed for 10mins at 80 0C

The initial results from the laboratory tests were based on samples extracted at a micro level. The project team identified that further trials would be necessary to fully understand the impact of stretch sleeve labels on the wash cycle at an operational scale. The results from the preliminary and medium scale trials held in January and February 2010 are contained in the Process section of this report. In summary when the recycling process was broken down we found that a high proportion (90%+) of stretch sleeves were removed at the granulation and air separation stage.

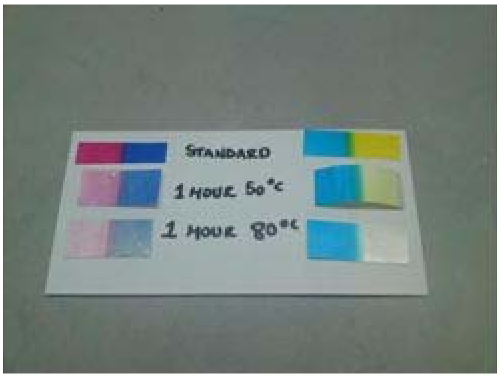
## Inks

### Self adhesive synthetic labels

It has been noted that most of the commercially available organic pigments used in the manufacture of printing inks have a high resistance to caustic solutions and therefore colours persist after the de-inking process. The key ink supplier of Systems Labelling investigated the chemical stability of a range of basic colours with some simple laboratory trials, using a commercial bleaching agent in an attempt to break down the ink pigments.

Laboratory proofs of the inks were prepared using the flexographic printing technique onto a Polypropylene substrate. The proofs were immersed in an undiluted household bleach solution in a constant temperature water bath and allowed to soak without agitation for 1 hour at 50ºC and also for 30 minutes at 80ºC.

Four UV-curing inks were tested; Reflex Blue, Rubine Red, Yellow and Cyan Blue. The Cyan blue pigment was noted to be the most resistant from those tested, with the yellow pigment the least resistant. It was also noted that the bleach solution was not discoloured following the tests, which indicates that the ink itself was not being "washed off" but rather that the pigments were decomposing and losing their colour value.





A follow up test was then made using printed Polypropylene labels from Systems Labelling, made using similar UV-curing inks. The aim was to assess the possible residual colours after bleaching of typical commercial labels, however it should be noted that the prints were un-laminated versions of labels which would normally be laminated.

The test method was similar to the first laboratory trial i.e. the print samples were placed in undiluted household bleach solution in a constant temperature water bath without agitation. The degree of bleaching was assessed after 1 hour at 40ºC and after 30 minutes at 80ºC.

After 1 hour at 40ºC only a slight degree of colour loss was noted, however after 30 minutes at 80ºC the results were very similar to the first tests, with the cyan blue pigment noted as being the most persistent. On this occasion it was also noted that the inks themselves were being removed from the polypropylene film.

## Series 3 Wraparound Labels Mini Wash Trials

The potential cause of colour leaching released from wraparound labels is believed to be due to the minimal sealant used to trap the inks. Wraparound labels are currently reverse printed onto clear film then overprinted with an opaque white ink for mainly aesthetic reasons. The following wash trials were conducted to compare the benefit of using an alternative print and finishing technique.
The potential solution was to print the image on the face of the film and then encapsulate the ink with a 12 micron overlaminate. The following results highlight the benefits of this method in comparison to the existing technique.

| | **Method / Description** | **Result Summary** |
|---|---|---|
| Trial 1 | 10 Current wraparound labels (Semi only) plus HDPE flakes for agitation/friction. 2% Cognis detergent for 10 mins at 85ºC. | Wash drum was clean and water cloudy with green hue and minimal sediment. Printed side of label flakes were lightly scuffed/scratched. |
| Trial 2 | Laminated wraparound (Semi only) plus HDPE flakes for agitation/friction. 2% Cognis detergent for 10 mins at 85ºC. | Wash drum was clean and water cloudy with white hue and minimal sediment. Label flakes intact including overlam. No ink leaching. |
| Trial 3 | Current wraparound (Semi only) plus HDPE flakes for agitation/friction. 2.5% Caustic Solution plus 0.15% RP16 detergent for 10 mins at 85ºC. | Wash drum dirty – green ink leached badly and attached to the sides of drum. Wash water was initially cloudy and green with large amount of green sediment. Water now cleared. Virtually all the ink was removed from the label flakes. |
| Trial 4 | Laminated wraparound (Semi only) plus HDPE flakes for agitation/friction. 2.5% Caustic Solution plus 0.15% RP16 detergent for 10 mins at 85ºC. | Wash drum was clean and water clear with slight green hue and some green and white sediment. Majority of label flakes intact however some are scuffed/scratched leaching small amount of ink. Overlam separating on some flakes. |

## Label design progress

The project team identified in the early stages of Phase 1 that an obvious way of reducing the overall colour used in current packaging was to "design out" the use of block or solid colour. The challenge the team faced was to retain the simple visual identification required for consumers, retailers and manufacturers. The example below gives an initial comparison as to the options available against a current design used by a large grocery retailer. This format, colour coding and design is relatively standard across the industry and has developed into an unwritten industry benchmark. A shift from this format would require an extensive education campaign through an effective marketing communication strategy targeted at all stakeholders.
The project team believes by working with retailers and manufacturers an effective design can be achieved that will strike a balance between the product usage including logistics and presentation and the environmental benefit achieved through significant reduction in colour leaching in the rHDPE recycling process.

**Before** | **After**

Approx 63% coverage


Approx 45% coverage

Approx 27% coverage

Approx 32% coverage

**Existing design, colours and coverage**

**Alternative design reducing coverage**

These concepts were developed for project purposes only; not be used for production.

A comprehensive consumer research survey was conducted at the end of the project. The findings are included in appendix 4.

## Suggested Label Solutions

The recommended solutions and high level rationale for the label element of the project is included in the main body of the project report.

# Appendix 3 Mini Wash Trial Results

**Mini Wash Trial – Series 1 Results**

| Label Type | Total pieces | Total pieces remaining | Additive | Time | % label remaining |
|---|---|---|---|---|---|
| **Paper** | 183 | 183 | N/A | 20 mins | 100 |
| | 187 | 99 | 2.5% D | 20 mins | 53 |
| | | | | | |
| **PP - 50 micron** | 196 | 114 | N/A | 20 mins | 58 |
| | 163 | 8 | 2.5% D | 20 mins | 4.9 |
| | 198 | 6 | 2.5% C | 20 mins | 3 |
| **PP - 60 micron** | 202 | 89 | N/A | 20 mins | 44 |
| | 213 | 3 | 2.5% D | 20 mins | 1.4 |
| | 202 | 11 | 2.5% C | 20 mins | 5.4 |
| **Wraparound** | N/A | | | | |
| | | | | | |
| | | | | | |
| **Sleeve** | N/A | | | | |
| | | | | | |
| | | | | | |

# Mini Wash Trial – Series 2 Results

| TRIAL 2.1 | 50 Micron PP | Flake with labels | Flake without labels | Total flakes | % removed |
|---|---|---|---|---|---|
| Wash Temperature | 85°C | | | | |
| Caustic | 1% | | | | |
| Time | 5mins | 48 | 58 | 106 | 54.72 |
| | 10mins | 37 | 79 | 116 | 68.10 |
| | 15mins | 34 | 63 | 97 | 64.95 |

**Notes & Observations**

| 5mins | | 10 | | 15 | |
|---|---|---|---|---|---|
| Tack | 3 | Tack | 2.5 | Tack | 2.5 |
| Stain/leak | 1 | Stain/leak | 3 | Stain/leak | 5 |
| Curl | 3 | Curl | 4 | Curl | 3 |

**15 mins all flakes had flecks of label**

| 50 Micron PP | Flake with labels | Flake without labels | Total flakes | % removed |
|---|---|---|---|---|
| 85°C | | | | |
| 2% | | | | |
| 5mins | 38 | 69 | 107 | 64.49 |
| 10mins | 26 | 77 | 103 | 74.76 |
| 15mins | 28 | 57 | 85 | 67.06 |

**Notes & Observations**

| 5mins | | 10 | | 15 | |
|---|---|---|---|---|---|
| Tack | 3 | Tack | 3 | Tack | 3.5 |
| Stain/leak | 3 | Stain/leak | 3 | Stain/leak | 3.5 |
| Curl | 2.5 | Curl | 3.5 | Curl | 4 |

**some specks at 10 mins**

| 60 Micron PP | Flake with labels | Flake without labels | Total flakes | % removed |
|---|---|---|---|---|
| 85°C | | | | |
| 1% | | | | |
| 5mins | 26 | 105 | 131 | 80.15 |
| 10mins | 34 | 127 | 161 | 78.88 |
| 15mins | 46 | 140 | 186 | 75.27 |

**Notes & Observations**

| 5mins | | 10 | | 15 | |
|---|---|---|---|---|---|
| Tack | 5 | Tack | 3 | Tack | 4 |
| Stain/leak | 2.5 | Stain/leak | 2.5 | Stain/leak | 3 |
| Curl | 4 | Curl | 3 | Curl | 4 |

**some laminate peel and label scratch/breakdown**

| 60 Micron PP | Flake with labels | Flake without labels | Total flakes | % removed |
|---|---|---|---|---|
| 85°C | | | | |
| 2% | | | | |
| 5mins | 27 | 135 | 162 | 83.33 |
| 10mins | 56 | 117 | 173 | 67.63 |
| 15mins | 46 | 116 | 162 | 71.60 |

**Notes & Observations**

| 5mins | | 10 | | 15 | |
|---|---|---|---|---|---|
| Tack | 4 | Tack | 3 | Tack | 2 |
| Stain/leak | 2 | Stain/leak | 1 | Stain/leak | 2 |
| Curl | 2.5 | Curl | 2 | Curl | 3.5 |

**minimal specks on flakes**

| TRIAL 2.2 | 50 Micron PP | Flake with labels | Flake without labels | Total flakes | % removed |
|---|---|---|---|---|---|
| Wash Temperature | 85°C | | | | |
| Detergent | 1% | | | | |
| Time | 5mins | 29 | 94 | 123 | 76.42 |
| | 10mins | 24 | 125 | 149 | 83.89 |
| | 15mins | 8 | 118 | 126 | 93.65 |

**Notes & Observations**

| 5mins | | 10mins | | 15 | |
|---|---|---|---|---|---|
| Tack | 2 | Tack | 2.5 | Tack | 0.5 |
| Stain/leak | 0 | Stain/leak | 0 | Stain/leak | 0 |
| Curl | 3 | Curl | 2 | Curl | 4 |

| 50 micron PP | Flake with labels | Flake without labels | Total flakes | % removed |
|---|---|---|---|---|
| 85°C | | | | |
| 2% | | | | |
| 5mins | 85 | 45 | 130 | 34.62 |
| 10mins | 21 | 108 | 129 | 83.72 |
| 15mins | 8 | 106 | 114 | 92.98 |

**Notes & Observations**

| 5mins | | 10mins | | 15mins | |
|---|---|---|---|---|---|
| Tack | 3 | Tack | 3 | Tack | 1 |
| Stain/leak | 0 | Stain/leak | 0 | Stain/leak | 0 |
| Curl | 3 | Curl | 4 | Curl | 3 |

**clean flakes on all trials**

| 60 Micron PP | Flake with labels | Flake without labels | Total flakes | % removed |
|---|---|---|---|---|
| 85°C | | | | |
| 1% | | | | |
| 5mins | 19 | 151 | 170 | 88.82 |
| 10mins | 6 | 155 | 161 | 96.27 |
| 15mins | 12 | 150 | 162 | 92.59 |

**Notes & Observations**

| 5mins | | 10mins | | 15mins | |
|---|---|---|---|---|---|
| Tack | 2.5 | Tack | 1 | Tack | 0.5 |
| Stain/leak | 0 | Stain/leak | 0 | Stain/leak | 0 |
| Curl | 3.5 | Curl | 4 | Curl | 5 |

| 60 Micron PP | Flake with labels | Flake without labels | Total flakes | % removed |
|---|---|---|---|---|
| 85°C | | | | |
| 2% | | | | |
| 5mins | 8 | 151 | 159 | 94.97 |
| 10mins | 3 | 153 | 156 | 98.08 |
| 15mins | 17 | 137 | 154 | 88.96 |

**Notes & Observations**

| 5mins | | 10mins | | 15 | |
|---|---|---|---|---|---|
| Tack | 1 | Tack | 0.5 | Tack | 0.5 |
| Stain/leak | 0 | Stain/leak | 0 | Stain/leak | 0 |
| Curl | 5 | Curl | 5 | Curl | 5 |

## Mini Wash Trial – Series 2 Results Continued

| TRIAL 2.3 | 50 Micron PP | Flake with labels | Flake without labels | Total flakes | % removed |
|---|---|---|---|---|---|
| Wash Temperature | 85°C | | | | |
| Caustic/Detergent mix | 1% each | | | | |
| Time | 5mins | 27 | 103 | 130 | 79.23 |
| | 10mins | 6 | 107 | 113 | 94.69 |

**Notes & Observations**

| 5 | | 10 | |
|---|---|---|---|
| Tack | 3 | Tack | 3 |
| Stain/leak | 0.5 | Stain/leak | 0.5 |
| Curl | 2.5 | Curl | 3 |

| 50 micron PP | Flake with labels | Flake without labels | Total flakes | % removed |
|---|---|---|---|---|
| 85°C | | | | |
| 1.5% each | | | | |
| 5mins | 17 | 102 | 119 | 85.71 |
| 10mins | 4 | 108 | 112 | 96.43 |

**Notes & Observations**

| 5mins | | 10 | |
|---|---|---|---|
| Tack | 3.5 | Tack | 1.5 |
| Stain/leak | 0.5 | Stain/leak | 2 |
| Curl | 3.5 | Curl | 4 |

**minor specs on flakes**

| 60 Micron PP | Flake with labels | Flake without labels | Total flakes | % removed |
|---|---|---|---|---|
| 85°C | | | | |
| 1% each | | | | |
| 5mins | 7 | 154 | 161 | 95.65 |
| 10mins | 0 | 163 | 163 | 100.00 |

**Notes & Observations**

| 5mins | | 10 | |
|---|---|---|---|
| Tack | 3 | Tack | 1.5 |
| Stain/leak | 0.5 | Stain/leak | 1.5 |
| Curl | 4 | Curl | 4 |

| 60 micron PP | Flake with labels | Flake without labels | Total flakes | % removed |
|---|---|---|---|---|
| 85°C | | | | |
| 1.5% each | | | | |
| 5mins | 8 | 144 | 152 | 94.74 |
| 10mins | 4 | 147 | 151 | 97.35 |

**Notes & Observations**

| 5 | | 10 | |
|---|---|---|---|
| Tack | 1 | Tack | 1 |
| Stain/leak | 0.5 | Stain/leak | 1 |
| Curl | 5 | Curl | 5 |

# Appendix 4 Consumer Testing Full Results Report

## Robert Wiseman Diaries: New Cap Research Results summary

### Background and Objectives

Working with WRAP, Robert Wiseman Dairies have developed carton tops for plastic poly bottles that can be recycled more efficiently alongside the container as they contain less dye than current caps.

TNS-BMRB undertook research to test consumer reaction to the new cap, and to test three versions of labels to be used alongside the new cap. In particular, the research aimed to:

- Establish whether or not sales of milk would be adversely affected if the cap was introduced, given that at least initially, the current, darker, caps would also be available on other brands;
- Establish whether or not sales of poly milk bottles using the new cap would be affected by a change to label colour strength.

The results of this research will be shared with the wider dairy industry as the ultimate aim would be that the cap would become the industry standard for use on milk poly bottles.

This document reports the summary findings of the research.

### Key Findings

- 86% said they would be likely to buy their current milk with new cap (semi-skimmed - 93%);
  - o Adding labels of matching colour increases likelihood to buy to 94% overall (whole milk 90% from 75%).
- 83% said it would be easy to recognise poly bottles with the new cap as the milk type they usually bought (semi-skimmed - 94%);
  - o Adding labels of matching colour increases recognition to 96% (whole milk 91% from 75%).
- 71% of semi-skimmed milk buyers have no preference between buying the milk they normally buy with a lighter or a darker cap when forced to choose.
- 58% of whole milk buyers would prefer to buy their usual milk with a darker cap when forced to chose;
  - o 25% of this group associate the strength of cap colour with richness of the milk.
- 97% said would buy their current milk with a lighter cap once they were told about the environmental benefit - an *additional* 11%;
  - o 94% of whole milk buyers said this - an *additional* 19%.
- 34% said they would switch from their normal milk to buying milk that used the lighter cap if they know about the environmental benefits;
  - o Increased to 40% with addition of matching label.
- 37% described the 'one stripe' label and 33% the full colour label as 'standing out' compared with 20% the two stripe label;
  - o 27% described the two stripe label as cheap (12% full colour; 18% one stripe);
  - o 12% described the two stripe label as 'environmentally friendly' (4% full colour; 7% one stripe).

## Conclusions

Milk appears to be a habitual purchase that is not strongly affected by the changes to packaging being tested.

- Most milk buyers, especially those buying semi-skimmed milk, would still be likely to buy their usual milk if the bottle included the new, lighter cap;
- The inclusion of labels with varying amounts of matching colour improved the results further.

The lighter caps did not appear to be a barrier to recognition.

- The addition of the coloured labels made them even more recognisable.

Although, when prompted, milk buyers had some reservations concerning lighter caps, none of these appeared to be a barrier to purchase.

- The main barrier that would need to be addressed is the association among whole milk buyers of stronger colours with richness and the perception that a lighter colour signifies a less rich milk.

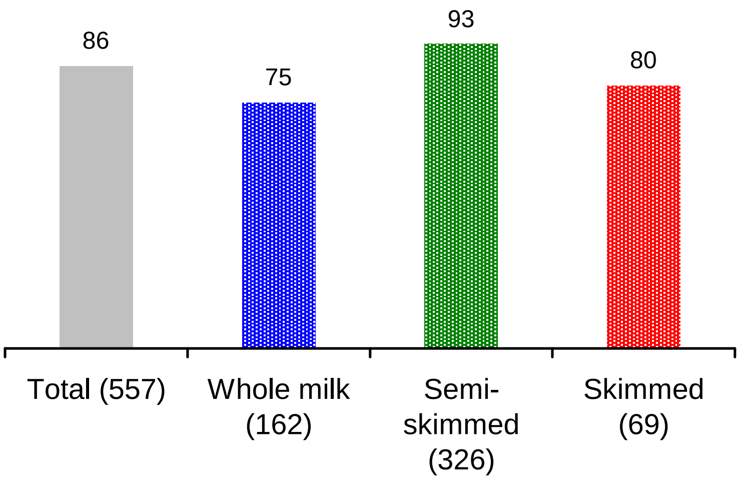
The label redesign with two stripes was seen to stand out less and was more often described as "cheap" and "environmentally friendly" than either the label with a single stripe or the full colour label. Communicating the environmental benefits of the caps with less dye could be used to counter any negative impressions.

- Doing this would encourage milk buyers, especially whole milk buyers, to continue to buy their usual milk if it was sold with the new cap;
- Potentially it could encourage some milk buyers of all milk types to switch to buy milk having a lighter cap; and
- The matching label might encourage additional switching.

## Initial reaction to new lighter cap

The majority (86%) of milk buyers said they would be likely to buy their usual milk if it had the new cap on it.

- Buyers of semi-skimmed milk in particular accepted the new cap; virtually all (93%) said they were likely to buy their usual milk in a bottle with the lighter cap.
- Whole milk buyers were less positive, but even then a clear majority (75%) would be likely to buy.



When the lighter cap was combined with a label of varying amounts of matching colour, the percentage saying they would be likely to buy the milk increased to 94% among all milk buyers from 86% (when the lighter cap was shown with a generic black and white label).

- This effect was strongest among whole milk purchasers where 90% said they would buy the milk with a lighter cap when shown combined with a label of the same colour, compared with 75% when it was shown previously.

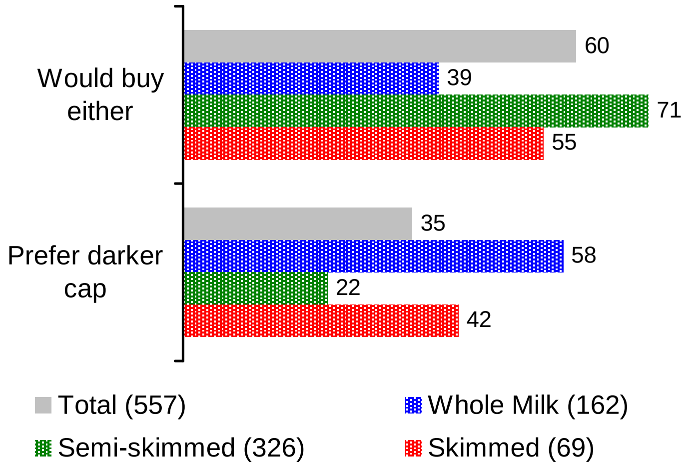
If the lighter cap were to be introduced, it would be sold initially, at least, alongside bottles with darker caps. To explore what would happen in this situation, milk buyers were shown two milk bottles, one with the new lighter cap and the other with a darker cap.

Six in ten (60%) said they had no preference between the two caps and would buy either.

- This rose to 71% of semi-skimmed milk buyers.

Almost all of the remainder said they preferred the darker cap (35% of all milk buyers, falling to 22% of semi-skimmed milk buyers).

- In contrast, a higher percentage of whole milk buyers preferred the darker cap (58%) and a lower percentage had no preference between the two caps (39%).




## Perception of new cap

Perceptions of the cap were explored by asking milk buyers which adjectives they would apply to the cap (prompted).

- Nearly one in five (18%) said the new cap looked 'clean' (24% no preference; 5% prefer darker cap).
- Over one in ten (11%) said it looked 'fresh' (13% no preference; 2% prefer darker cap).
- 7%, when prompted, said they thought the lighter cap looked 'environmentally friendly' and this did not vary according to whether respondents preferred to buy milk with a darker cap or would buy milk with either a lighter or a darker cap.

When shown HDPE milk bottles with lighter caps in combination with labels using varying amounts of the same colour and prompted with a series of adjectives, these were described more positively than the bottles with the caps and a generic black and white label.

Examining the adjectives associated with the different labels used in combination with the lighter cap illustrates the differences between the ways the labels were perceived.

- The poly bottle with the lighter cap and one stripe of colour on the label was described as:
  - Standing out (33%);
  - Clean (33%);
  - Distinctive (25%) and
  - Fresh (20%).
- Similar percentages of milk buyers used these adjectives to describe the poly bottle with the full colour label, describing it as.
  - Standing out (37%);
  - Clean 30%;
  - Distinctive (23%) and
  - Fresh (19%).
- The poly bottle with two stripes of colour was described a little bit differently, as:
  - Clean (41%);
  - Cheap (27%) and
  - Standing out (20%).

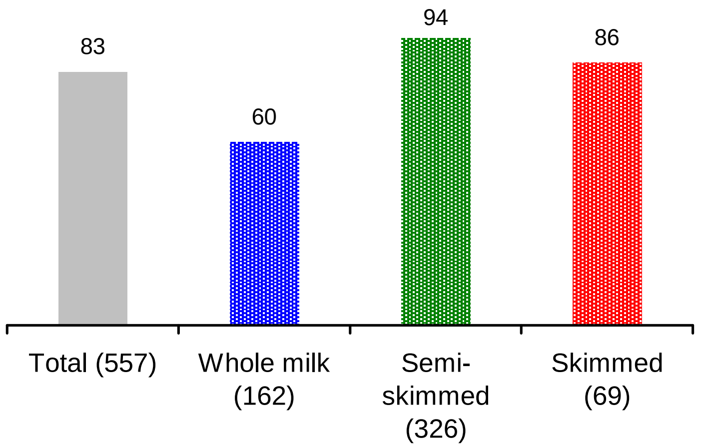
The proportion of milk buyers saying the combination of lighter cap and coloured label (8%) could be described as 'environmentally-friendly' was similar to that found for the lighter cap with the black and white label (7%).

- A higher proportion said this applied to the label with two stripes (12%) than the one-stripe label (7%) or the full colour label (4%).

## Barriers

The lighter cap does not appear to be a barrier to recognising the type of milk normally bought. The majority of respondents (83%) thought the bottle with the lighter cap would be easy to recognise as the type of milk they normally buy.

- Noticeably 94% of semi-skimmed milk buyers said the bottle would be easily recognisable.
- This compared with 60% of whole milk buyers.




The main barriers to purchase were mentioned by whole milk buyers. For them the strength of colour of the cap appears to be associated with the richness of the milk.

- Almost a quarter (24%) of those whole milk buyers who said they would prefer to buy milk with the darker cap made spontaneous comments that related in some way to this issue.
- To overcome this, it would be important to emphasise the richness of the milk if the lighter cap was introduced on the whole milk bottle.

Cross referencing negative descriptions provided a useful indication of other potential barriers to purchase:

- When prompted:
    - One-third (33%) who would buy milk with either cap said the adjective 'faded' applied;
    - Over half (53%) of those who would prefer to buy milk with the darker cap said the adjective 'faded' applied.

Previously, 14% of those who said they would prefer to buy the bottle with the darker cap had said this spontaneously about the lighter cap.

- Almost a quarter (24%) who would buy milk with either cap said the adjective 'washed-out' applied to the lighter cap, compared with 45% of those preferring the dark cap.

Other negative adjectives which are potential barriers include:

- Cheap (20% no preference; 33% prefer dark cap);
- Discoloured (16% no preference; 33% prefer darker cap);
- Off-putting (4% no preference; 26% prefer darker cap) and
- Old (8% no preference; 22% prefer darker cap).

It is important to note that the adjectives applying to the new caps discussed above were prompted and the caps would not ordinarily be put under that level of scrutiny at the point of purchase. As mentioned previously, these more-considered perceptions did not appear to affect recognition or likelihood to buy for the majority, especially semi-skimmed milk buyers.

## Effect of explaining the new cap benefits

Although a habitual purchase, it is important to know whether promotional activity designed to make milk-buyers aware of the reason the cap was lighter in colour would affect their milk purchasing decisions. This would test whether knowledge of the environmental benefits would counter the barriers to purchase, or even persuade milk buyers to make a positive switch.

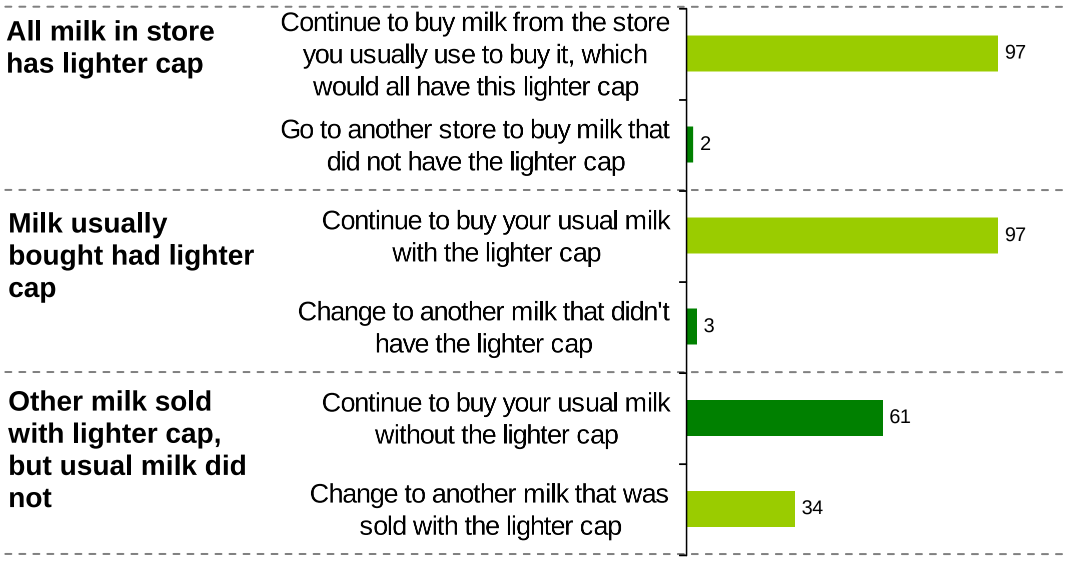
When given the reason behind the new cap, milk buyers were even more receptive to buying milk in bottles using the new cap. They were told that "this cap is a lighter colour because it contains less dye than caps currently used on milk bottles, which makes it easier to recycle along with the bottle" and were presented with a number of milk buying scenarios involving the lighter cap to test how this would affect their buying behaviour.

- The vast majority (97%) of respondents would not change their milk purchasing behaviour to avoid bottles with the lighter cap, either by changing to another store if all the bottles sold there had a lighter cap, or by changing to another milk if their usual milk started being sold with the lighter cap.
- This latter scenario (97% continuing to buy their usual milk if sold with a lighter cap) can be compared with the 86% who, without this knowledge, said they were likely to continue to buy their current milk if it had the new cap earlier in the survey, giving an uplift of 11 percentage points.
- For whole milk buyers, who show the greatest reluctance towards the new cap, the uplift was even larger after being given an explanation (94% compared with 75% - plus 19 percentage points).

As well as reinforcing current purchasing, knowledge that the cap could be recycled along with the bottle could also encourage some milk buyers to change their milk purchasing.

- When given an explanation for the new cap, a third (34%) said they would change their milk buying to one sold with the light cap.

It is possible that this apparent propensity to change is, to some extent, inflated, because recycling is perceived as a 'good thing to do'.




Later in the interview, after milk buyers had answered questions about the new lighter cap in combination with labels that had varying amounts of matching colour, respondents were subsequently told that "using a smaller amount of coloured ink on a label would make it easier to recycle" and were presented with the same milk-buying scenarios, this time involving a label with less colour.

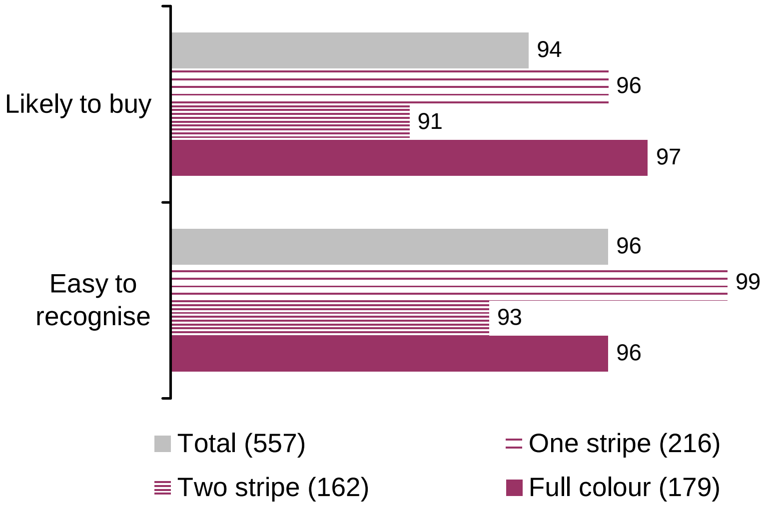
- The main difference between the results for the environmental benefits of the cap and of the label is that the addition of a label of matching colour appears to encourage slightly more milk buyers to change their milk buying to one that had less colour on the label.

- 40% said they would change to a poly bottle that had reduced colour on the label as well as a lighter cap, compared with 34% who said they would change to a milk poly bottle that just had a lighter cap.

## Reaction to the three labels

The second part of the interview examined reactions to the label alongside the new lighter cap. This section looks at the differences between reactions to the three labels that milk buyers were shown.

- More than 90% of milk buyers said they would be likely to buy the milk they usually bought in a bottle with a lighter cap and a matching label regardless of the amount of colour on the label of the bottle they were shown.
- Similarly, almost all milk buyers (96%) said it was easy to recognise the bottle of milk they were shown as the type of milk they usually bought.
- Both of these varied slightly for the two stripe label, which may be linked to the different image of the two stripe label mentioned previously;
- Still more than 9 in 10 said they would be likely to buy (91%) and that the milk was easy recognise (93%) with the two stripe label.




When forced to give a preference between the different labels, milk buyers appeared to have stronger views about the labels in combination with the caps than they did about the caps alone.

- 42% said they would buy their usual milk with any of the labels;
- 57% expressed a preference for which they would buy.

The choice between which label they would prefer to buy was also less clear cut than when considering the lighter cap alone.

- A quarter of all milk buyers (27%) said they would prefer to buy milk with a full colour label;
- 16% said they would prefer to buy milk with the 'one stripe label';
- 15% said they would prefer to buy milk with the 'two stripe label'.

The pattern was similar regardless of milk type usually bought.

## Method

The research was carried out face-to-face in halls with respondents who mainly buy milk from supermarkets. Quotas were set to reflect the broad profile of milk buyers, including the requirement for a minimum of two-thirds to be female.

The type of milk bottles shown to respondents - whole, semi-skimmed or skimmed - depended on the type of milk the respondents bought and so broadly reflected the market share of the three types of milk. Where respondents bought more than one type, they were shown the type they bought most frequently. 7 milk buyers bought more than one type with equal frequency and the supervisor allocated a milk type for them to test.

Following initial screening, respondents were shown two x 2 litre poly bottles of milk, one with the new lighter cap and one with an existing, darker cap. The bottles shown all had the same generic black and white labels. Subsequent questions focussed on the bottle with the new lighter cap

For whole and semi-skimmed milk buyers, the sample was then split into three and each respondent was shown one of the three poly bottles with either one stripe of colour on the label, two stripes of colour or a full colour label and the new lighter cap. Due to the smaller sample size, those who regularly bought skimmed milk were all initially shown the label with one stripe of colour.

After asking about one label individually, the respondents were shown all three bottles and asked additional comparative questions.

In total, 557 milk buyers were interviewed.

| | **Target** | | **Achieved** | |
|---|---|---|---|---|
| | Interviews | % | Interviews | % |
| **Type of milk** | | | | |
| Whole | 150 | 30 | 162 | 29 |
| Semi-skimmed | 300 | 60 | 326 | 59 |
| Skimmed | 50 | 10 | 69 | 12 |
| **Gender** | | | | |
| Male | 150 | 30 | 171 | 31 |
| Female | 350 | 70 | 386 | 69 |
| **SEG** | | | | |
| ABC1 | 250 | 50 | 290 | 52 |
| C2DE | 250 | 50 | 267 | 48 |
| **Age** | | | | |
| 18-34 | 150 | 30 | 179 | 32 |
| 35-64 | 275 | 55 | 290 | 52 |
| 65+ | 75 | 15 | 88 | 16 |
| **Total milk buyers** | **500** | **100** | **557** | **100** |

Interviewing was conducted between 16th April and 24th April 2010 in five locations. In each location interviews were conducted on two consecutive days – Friday and Saturday. The locations and the number of interviews conducted at each one are shown below.

| **Location** | **Target** | | **Achieved** | |
|---|---|---|---|---|
| | Interviews | % | Interviews | % |
| Newcastle | 100 | 20 | 114 | 23 |
| Birmingham | 100 | 20 | 107 | 21 |
| London | 100 | 20 | 112 | 22 |
| Manchester | 100 | 20 | 112 | 22 |
| Bristol | 100 | 20 | 112 | 22 |
| **Total milk buyers** | **500** | **100** | **557** | **100** |

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