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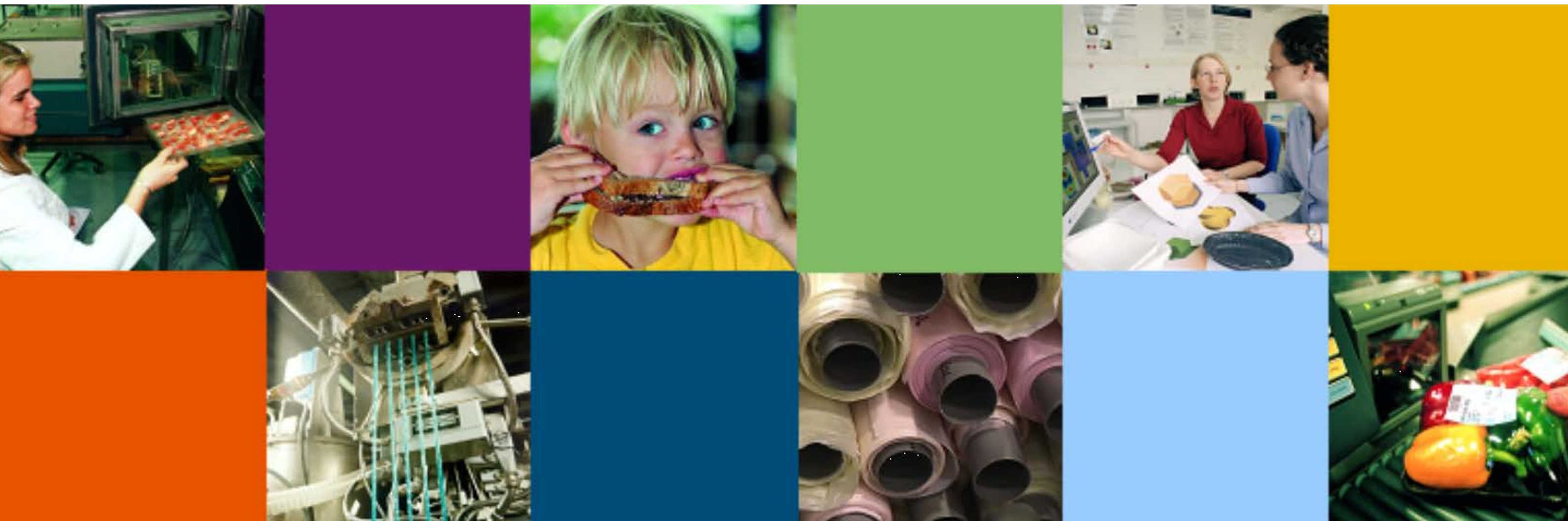

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Author(s)	Karin Molenveld, Ralf Koenhen, Ulphard Thoden van Velzen, Marieke Brouwer
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Wageningen UR Food & Biobased Research
P.O. Box 17
NL-6700 AA Wageningen
Tel: +31 (0)317 480 084
E-mail: info.fbr@wur.nl
Internet: www.wur.nl

Content

1 Introduction

Although Bio-PE (produced by Braskem in Brazil) and conventional PE are chemically identical, there is still a need to convince recycling companies and political stakeholders that Bio-PE does not negatively influence current recycling schemes. Although bio refers to the bio-based origin and the production of bio-PE from sugarcane, the plastic industry confuses bio-PE with biodegradable or even oxo-degradable plastics.

This topic was discussed by Mr. Marco Jansen of Braskem and Christiaan Bolck of Wageningen UR, Food & Biobased Research (FBR) on May 15th 2014. Since FBR has facilities to simulate mechanical recycling processes, FBR was asked to measure the influence of Bio-PE in film recyclates. The study focused on the recycling of bio-PE shopping bags (supplied by Braskem) and an additional experiment was performed using bio-PE flasks (supplied by Ecover).

Bio-PE is increasingly used in film applications like for example shopping bags. These shopping bags can be found in several Dutch supermarkets and stores. After use these bags are discarded and end up in the separate collection system for plastic packaging waste (Plastic Heroes) or in the municipal solid refuse waste (MSW). Similarly, bio-HDPE flasks (like Ecover) will end up in both systems.

Like in other European countries the post-consumer plastic waste is sorted using techniques like wind-sifting, ballistic separation, sieving and NIR classification. In most sorting facilities, films are separated off the mixture with either wind sifters or ballistic separators. The remaining mostly rigid plastic packages are sorted with a cascade of NIR machines to several products, including PET, PE and PP. The residual plastics (PS, PMMA, PC, bio-plastics) and plastics that cannot be sorted in single categories are added to the mixed plastic product (MKS). Finally a sorting rest remains which is composed of residual waste, unwanted plastics (PVC) and dark colored plastics that cannot be detected with NIR.

The sorted plastic products should meet DKR standards. The film product has to comply with DKR specification 310, which states that it should contain at least 92% plastic film. The sorted film product can contain up to 4% other plastic packaging and up to 4% other materials like paper, textile and glass. There is no requirement with respect to the plastic type.

The sorted product PE should comply with DKR specification 329, which states that it should contain at least 94% rigid PE bottles, flasks, trays, etc. Allowed impurities include:

- less than 3% rigid PP articles
- less than 5% plastic film
- less than 0.5% foamed plastics like EPS
- less than 3% other residual waste (cardboard, paper, textile, sand, stones, etc.).

Mechanical recycling facilities for sorted rigid plastic products tend to have a similar base process scheme which include: milling, metal removing, washing, flotation separation, drying and storing. There are many variations on this process scheme; an additional sieving step between the mill and the washing vessel, types of washing equipment (friction washing), use of cold or warm water, use of detergents or caustic agents, and potentially an additional flake sorting step for the washed milled goods. The washed milled goods can be traded to plastic converters or are used within the company to make re-granulates. In this process the washed milled goods are fed into an extruder, degased and melt-filtered.
Next to the wet mechanical processing facilities, as discussed above, mechanical recycling of plastics films can be done by a dry mechanical processing route. As it is relatively expensive to dry plastic film flakes after washing, most recycling companies prefer the dry route, in which the material is loosened, de-metallized, milled, fed in a cyclone separator to remove small heavy particles like sand and glass and subsequently an agglomerator. The agglomerates are extruded, degased and melt-filtered.

2 Methods

2.1 Introduction

The influence of bio-PE shopping bags on the quality of post-consumer plastic recyclates was tested by simulating the entire recycling process and measuring the mechanical properties of recyclates of which the PE-film in the sorted product contained 0%, 25% and 50% bio-PE. Addition of post-consumer bio-PE is not possible, since the concentration in separately collected plastic waste is very low and since bio-PE cannot be distinguished from regular PE. Instead new printed bio-PE shopping bags were added to the film product and bio-HDPE flacons were added to the PE sorted product.

2.2 Materials

Printed bio-PE shopping bags were supplied by Braskem.
Bio-PE flacons (HDPE) were supplied by Ecover.
Film recyclate (one bale, ca 75 kg) was obtained from SITA (sorting facility Rotterdam)
PE recyclate (one bale) was obtained from SITA (sorting facility Rotterdam).

2.3 Sorting, analyses and sample preparation

The sorted products (film and PE) were sorted manually on object type (tray, bottle, film, etc.) and analysed on material type using NIR (PE, PP, PS, PVC, PET, etc.). All objects were weighted determining the exact composition of the bales, according the sorting protocol of Wageningen UR Food & Biobased Research[1]

Based on the exact composition of the bales similar samples were prepared (sample size 2.5 kg). To study the influence of bio-PE on the properties of film recyclate PE film material was replaced by bio-PE film material resulting in the following samples:

1) Reference sample representative for a SITA film recyclate
2) Recyclate sample based on washed milled goods, of which 25% of the PE film in the sorted product was replaced by bio-PE
3) Recyclate sample based on washed milled goods, of which 50% of the PE film in the sorted product was replaced by bio-PE

Additionally HDPE samples were prepared:

4) Reference sample representative for a SITA PE recyclate
5) Recyclate sample which 50% bio-PE was added to the sorted product

In a next step the samples were subjected to our standard mechanical recycling process; milling, washing with hot water and NaOH, flotation separation with water and drying to produce washed milled goods.. The wet mechanical recycling processing route is used, as it is best practice compared to the dry mechanical recycling route.

The samples were dried and compacted in an oven to allow further processing in to test samples. An additional reference sample was produced based on 100% bio-PE bags (compacted in the same way, but not milled and washed). The film recyclates were mixed (in the melt) using a batch kneader, grinded in course granules and processed in to samples for mechanical testing using injection moulding. Prior to batch kneading and injection moulding the granulates were dried. The (dried) rigid PE recyclates were mixed using a compounding extruder. The granulates originating from extrusion were dried and injection moulded into test specimen for mechanical testing.

2.4 Mechanical testing

Prior to testing all samples were stored (conditioned) one week at 20 °C and 50%RV.
Samples were analysed using tensile testing according to ISO 527-1 using a Zwick Z010.universal testing machine equipped with Multisens extensometers.
Notched Charpy impact was measured according to ISO 179/1eU using a Ceast Resil 50 pendulum impact tester.
All mechanical testing was performed in 5-fold and averages and standard deviations were determined.

3 Results

3.1 Analysing sorted film products

A bale of sorted film products obtained from SITA was analysed on packaging type and packaging material determining the exact composition of this input material. The bale weighted in total 75 kg.

The sorted film material contained very little non plastic impurities. Impurities found were about 1% (coated) paper and 0.1% metal and textile. The bale contained about 10% non-film materials including 4% PET trays, 3%PP trays and 1% PS trays. During washing and flotation separation most of the PET and PS is removed in the sink fraction. The amount of non-film material appears to be rather high, which is in agreement with previous analyses of sorted film fractions. And although this might appear to contradict to the DKR 310 specification, this is widely accepted by the film recyclers, as this is still well recyclable material. From experience we know that most of these rigid plastic trays are compressed and flattened trays, which are also removed by air classification or ballistic separation.

Using NIR the material composition of the bales was determined. The film recyclate contained about 75% PE (very low in HDPE) including about 6% PE laminate, 7% Plastic Heroes collection bags and 11% shopping bags. About 6% of the plastics could not be analysed with NIR because of their dark colour, but this is mainly PE film. The material composition is shown in Figure 1.

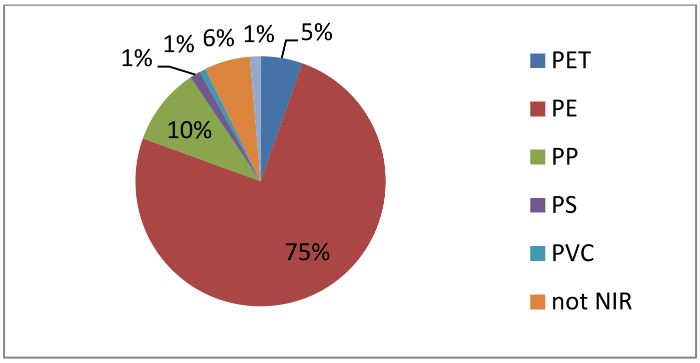

Figure 1 Composition of the sorted film sample obtained from SITA

3.2 Sample preparation

Based on the composition found during sorting 2.5 kg samples were prepared for further processing and analysis. To study the influence of bio-PE film, the PE film in the sorted film product was replaced (25 and 50%) by bio-PE shopping bags. This to keep the other impurities constant. The film product was milled to allow washing with 0.01 M NaOH solution and heavy impurities were removed using flotation separation. Sample size before milling was 2.5 kg and after milling, washing and flotation about 2 kg sample was collected (80%). During the procedure both dirt and heavy plastics (like PET) were removed. All samples showed a highly similar weight loss.

The film material is very fluffy and needs to be compacted before further processing. Industrial methods are not available on a lab scale size, so film material was compacted in an oven to allow some fusion of the film material. This could then be milled and added to processing equipment. At this stage a reference sample was added containing 100% bio-PE shopping bags. Because of the sample size it was decided to mix the sample using a batch kneader. Injection moulding was used to produce uniform samples. After milling and mixing the plastic recyclate becomes grey and no obvious impurities or colour variations can be seen in the samples.

3.3 Mechanical properties

Samples were analysed using tensile testing and notched impact testing. The best indicators of plastic quality are the strain at break (tensile testing) and the notched impact.

3.3.1 E-modulus

In Figure 2 it can be seen that the E-modulus of the film recyclate is a higher than that of LLDPE. This is caused by the presence of impurities like HDPE. The E-modulus of the 100% Bio-PE is in correspondence with expectations. It can be seen that the modulus of the recyclate slightly drops by addition of bio-PE although the amount of non PE materials is kept at the same level. However, this effect is small.

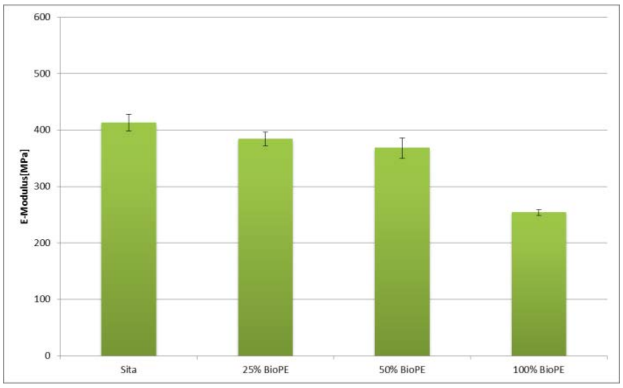

Figure 2 E modulus of recyclates (references and samples containing bio-PE)

3.3.2 *Strength*

The strength of the samples is shown in Figure 3. According to tensile testing bio-PE does not influence the strength of the samples. All differences seen are within error margins.

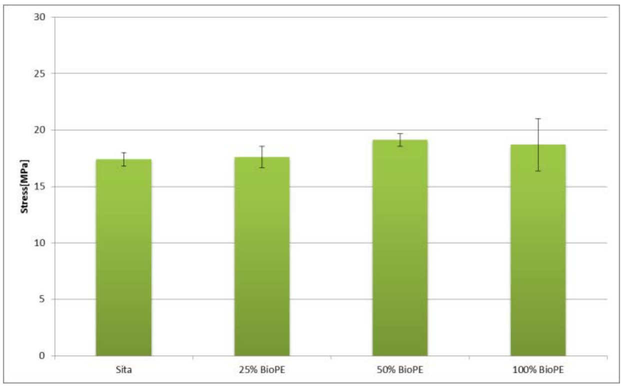

Figure 3 Strength of recyclates (references and samples containing bio-PE)

Strain at Break

As indicated before the strain at break is a good indicator of the quality of a plastic (recyclate). Analyses shows (Figure 4) that addition of bio-PE shopping bags has a positive effect on the quality of the film recyclate. This can be explained by the fact that the bio-PE shopping bags have not been used (not post-consumer like the other packaging) and addition of this bio-PE results in samples containing a more uniform PE fraction. The strain at break found is in accordance with expectations.

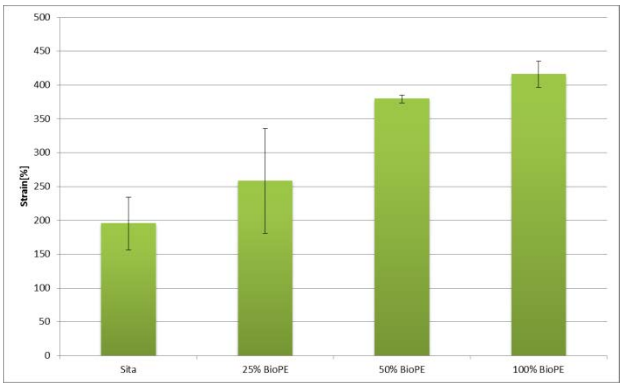

Figure 4 Strain at break of recyclates (references and samples containing bio-PE)

3.3.3 Impact properties

Another good indicator of the properties of a film recyclate is (notched) impact. All recyclate samples need to be notched, otherwise they do not break. After notching the 100% bio-PE sample still does not break and this corresponds with an impact strength > 40kJ/mm^2. It indicates that the quality of this sample is good. Like seen from the results of the strain at break, also measuring impact properties it can be concluded that the quality of the film recyclate improves by adding bio-PE shopping bags.

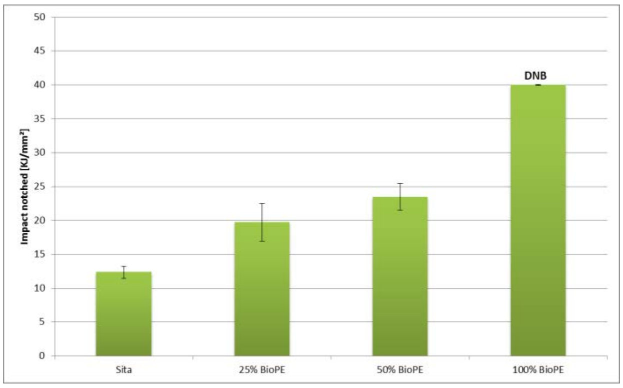

Figure 5 Charpy notched impact of recyclates (references and samples containing bio-PE)

3.4 PE recyclates

Some additional experiments were performed testing the influence of bio-HDPE (Ecover flasks) in a sorted PE product of SITA. The composition of the PE sorted fraction in terms of type of packaging objects is shown in Figure 6. Roughly 92% (gross weights) of the objects present are PE based packaging objects, of which the PE bottles (25.9%) and flasks (61.7%) dominate. This composition is similar to previously analysed samples in 2013 and 2012.

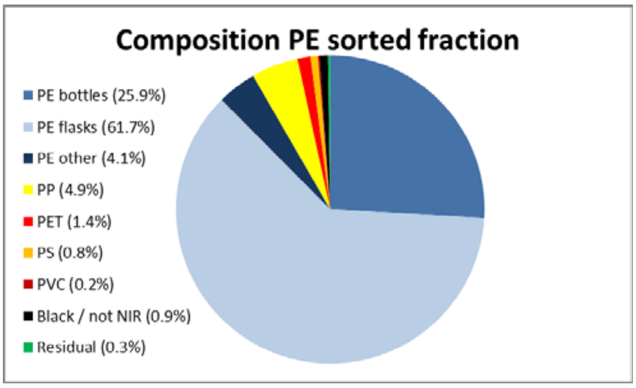

Figure 6 Composition of the sorted PE product obtained from SITA.

Since the PE bottles and flasks contain labels and caps the amount of polymeric impurity (non-PE) is higher than just the detected PP, PET and PS packages. When all the PE based packages are decomposed (caps, closures and labels separated) and all elements are separately NIR-analysed on polymers the actual polymeric impurity levels was found to be >15%. .

The effect of bio-PE flacons was tested by replacing 50% of the PE bottles and flasks by bio-PE flasks in the sorted product. As a preparation to extrusion, the sorted PE fraction was milled, washed, flotation separated and dried.
The HDPE recyclate can be fed to a compounding extruder after further milling (and drying). The material is not fluffy and a larger sample size was used (7 kg). After compounding extrusion and injection moulding the material becomes evenly grey and is clearly more rigid than the film recyclate. No obvious impurities are visible. Mechanical testing indicated that the strain at break does not change when adding Bio-PE flasks (remains 75%). The impact properties slightly improve from 15 to 18 kJ/mm^2.

4 Conclusions

Adding bio-PE to a representative bale of sorted film product obtained from SITA improves the properties of the recyclate. This result is expected because of the addition of not previously used and uniform material. The best mechanical properties were found in a sample containing 100% bio-PE shopping bags.

It is expected that results are similar when adding new PE shopping bags and FBR will verify this hypothesis.

Nevertheless, these experiments have proven that the adding of bio-PE to post-consumer sorted film, does not lower the quality of the film recyclate.

An additional experiment with bio-HDPE also verifies that bio-PE does not have a negative effect on current recycling schemes. Only slight improvements were found in the impact properties.

The quality of both film and PE recyclates is mainly determined by the quality of the sorting process which influences the polymeric purity of the recyclate mixture.

5 References

[1]Annex 1 Sorteerprotocol kunststofverpakkingsafval from: Scenarios study on post-consumer plastic packaging waste recycling, 2013, U. Thoden van Velzen, H. Bos-Brouwers, J. Groot, X. Bing, M. Jansen, B. Luijsterburg, Wageningen UR Food & Biobased Research.

