interseroh
zero waste solutions

Evaluating recyclability
according to bifa and Fraunhofer IVV

Evaluating cupsforyou PP-Becher/>50% BIO PE

Background and objectives

Bikapack wishes to evaluate various packaging items used in food retail in terms of their recyclability. After-life scenarios (collection, sorting and recycling) for these materials should also be investigated and evaluated. The packaging analysis is based on product samples submitted. The focus of this evaluation is the packaging cupsforyou PP-Becher/>50% BIO PE.

As an environmental services provider, **Interseroh** provides assistance at almost every stage of the packaging loop. From licensing (dual system) to collection (ALBA), and the sorting of paper and lightweight packaging – and finally to recycling plastics into our regranulate procyclen®. Interseroh also operates a centre of competence for plastics recycling, in which methods for recycling plastics are researched and developed. The centre's services include the evaluation of lightweight packaging in terms of their recyclability.

To comply with the increasingly stringent recycling targets required by law (e.g. German VerpackG) and to ensure waste is processed into high-quality recyclates, materials must be designed for recycling. To be 'recyclable', materials must be capable of proper collection and reliable sorting, and suitable for recycling into a recyclate.

Interseroh is helping companies to design packaging so that it passes smoothly through these *after-life* processes and is therefore truly 'made for recycling'.

List of abbreviations used

PE	Polyethylene
PP	Polypropylene
HDPE	High-density polyethylene
LLDPE	Linear low-density polyethylene
PVA	Polyvinyl alcohol
OPP	Oriented polypropylene
CPP	Cast polypropylene
TP	Tinplate
MP	Mixed plastics
PPC	Paper, paperboard and cardboard
SF	Substitute fuel
LPB	Liquid packaging board
LWP	Lightweight packaging

Contents

1. Our partner institutes

1.1 Bifa environmental institute

As an application-focused research, development and consulting institute, bifa offers a broad-based portfolio of 'technical environmental protection' services, including process engineering (machine/equipment construction), microbiological technology and test methods, integrated corporate environmental protection, sustainable waste management, system/process analysis, strategy development and policy consulting, process technology and chemical analysis.

1.2. Fraunhofer IVV

The work of the Fraunhofer Institute for Process Engineering and Packaging (IVV) promotes high-quality food products and safe packaging that preserves quality while enabling convenient handling. In its developments along the value chain, the IVV is careful to focus on the efficient use of raw materials and minimal environmental impact. Both technology and expertise are also transferred for use in applications outside the food and packaging industries.

The business segments in which Fraunhofer IVV is active include food processes and products, food quality and sensory acceptance, conformity, packaging, and processing and packaging machinery. The work of the Institute also involves functional ingredients for food, as well as for animal feed and cosmetics, and the use of functional materials as food packaging and for technical applications – such as ultra-high barrier films for OLEDs. With an eye on the efficient recycling of secondary and waste streams, the business segments of biogenic raw materials and plastic recyclates round off its portfolio.

2. Motive

Dialogue between the stakeholders within the value chain is essential to promote the recycling-friendly design of packaging. Several platforms and services to promote this dialogue (not all open-access) are now available. Even so, there is a general need for further information about the requirements for recycling-friendly packaging design on the part of developers, fillers and retailers. One key factor likely to exert an effect here is section 21 of the German Packaging Act, which requires licence fees for sales packaging to be determined based on the packaging's recyclability. Essentially, this 'ecological' licence fee model will result in lower system participation fees being charged for recyclable packaging and higher fees being charged for non-recyclable packaging. Section 21 of the Packaging Act directs the question of a formal evaluation of the recyclability of packaging to those stakeholders involved in the packaging lifecycle. The following section presents the general conditions that are applicable to a method for determining the recyclability of packaging. The starting-point for the development of this method is based on several factors, including waste management legislation governing packaging disposal, the German Circular Economy and Packaging acts, and the current German Packaging Ordinance. The discussion also considers the "requirements for packaging to be considered recoverable" formulated in the DIN EN 13430 standard.

Recycling aims to reduce the inputs of raw materials and energy during the production of new goods by utilising recycled material. The term 'recyclability' is basically understood to mean the extent to which the materials used to manufacture the product can be returned to the material loop at the end of the product's useful life, and therefore close this material loop. The degree of recyclability is measured on the basis of

- how the packaging is designed and created;
- the qualitative and quantitative suitability of the packaging in terms of actual treatment using material-specific recycling methods;
- the sorting and recycling techniques that can be used by the waste management sector to separate individual material streams and concentrate these into high-yield target fractions; and
- the quality achieved by the recycled product, which is judged in terms of being able to be reused as a substitute for primary material.

3. Material analysis at the Centre of Competence for Plastics in Maribor

Our Centre of Competence for Plastics in Maribor, Slovenia, consolidates all of our research and development activities in plastics recycling. At the Centre, we develop flexible, product-specific responses to our customers' needs for designing modern recyclable plastics, and to investigate their mechanical and chemical properties.

Figure 1: Centre of Competence for Plastics in Maribor, Slovenia

FTIR

FTIR spectroscopy is a quick, non-destructive testing method for the identification of materials. Typically, FTIR experiments are used to identify specific substances (qualitative testing), although proportions under 3% (by mass) cannot be detected. This means many additives cannot be identified.

DSC

Differential scanning calorimetry (DSC) is a thermoanalytical technique for measuring the amount of heat emitted or absorbed by a sample when subjected to heating, cooling or an isothermal process. Investigating parameters such as the melt/glass transition temperature and the degree of crystallisation can determine the type of material and its individual components. DSC analysis was performed using the DSC3 differential scanning calorimeter from Mettler Toledo.

Heating from 20 °C to 200 °C at 10 °C/min (20 ml/min N2)

Cooling from 20 °C to 200 °C at -10 °C/min (20 ml/min N2)

Heating from 20 °C to 200 °C at 10 °C/min (20 ml/min N2)

Density

The density of a material is determined using an analytical balance and the ISO 1183-1 immersion method. The sample is first weighed in air and then weighed when immersed in water. The difference equals the buoyant force exerted by the sample and simultaneously the weight of the water displaced by the sample, which makes it possible to calculate the sample's density. This measurement enables the material's behaviour during sink-float separation to be predicted.

The density was measured using the XPE205 analytical balance from Mettler Toledo.

TGA

Thermogravimetric analysis (TGA) is used to measure the mass or mass change in a sample either depending on a change in temperature and/or over time. Mass changes occur during evaporation, decomposition or chemical reactions, for example. TGA is used for component analysis: the proportion of inorganic compounds and residues can be determined, as well as the sample's thermal stability.

Thermogravimetric analysis was performed using the TGA2 instrument from Mettler Toledo.

Heating from 30 °C to 900 °C at 20 °C/min in a nitrogen atmosphere and in synthetic air

4. Packaging after-life

4.1. Level 1: Assignment of packaging to collection system. Can consumers match the packaging to its envisaged collection/recycling system?

To ensure packaging recyclability in terms of sorting and preparation, the consumer must be capable of returning the used packaging to the correct collection system. In Germany, consumers have to decide whether the packaging is LWP or PPC, or should be disposed of at a glass bottle bank. Accordingly, packaging that combines LWP materials (e.g. plastics and aluminium) with PPC could therefore cause problems for consumers when making these decisions. This is especially the case for packaging designs that use composite materials or make extensive use of packaging aids (such as paperboard labels wrapped around yoghurt pots). In cases where the packaging design could potentially cause confusion, providing information about disposal can help consumers to make the correct decision.

4.2. Level 2: Sorting mixed collections of packaging (LWP)

4.2.1. Is the packaging large enough?

The minimum size of packaging is a key factor for the success of sorting mixed collections of LWP. If the packaging is smaller than a specific minimum size, it is very likely that the packaging will exit the sorting process early on, i.e. the packaging will not pass through the specialised sorting that guarantees high-quality recycling. One exception here involves ferrous metal packaging or parts of packaging (e.g. bottle caps), which can typically be easily sorted out of material streams – even those including smaller-scale parts.

- Drum sieves are used to classify the starting material into two or three size classes[1]. Limiting the spectrum of particle sizes to a specific minimum or maximum is necessary in order to ensure that the downstream sorting plant can work efficiently. If packaging is smaller than the minimum size, it cannot always be assigned to the correct target fraction.
- In an NIR sorting unit, the discharge (air) nozzles are spaced regularly along the air nozzle bar (see figure 2). Typically, these nozzles are spaced at a distance of 12.5 mm to 37.5 mm. Packaging items smaller than this distance are unlikely to be discharged. Conversely, packaging that exceeds the minimum size is very likely to be discharged.

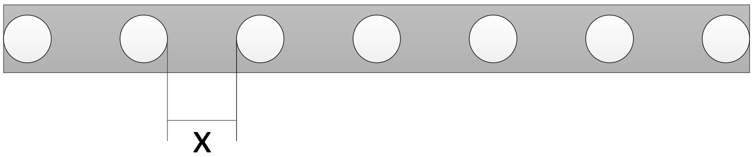


Figure 2: Schematic diagram of an NIR air nozzle bar; nozzle spacing ranges from 12.5 mm to 37.5 mm

4.2.2. Can the packaging be magnetised?

Sorting precision and yields will both be high for packaging that can be magnetised for removal from the packaging stream. Typically, an overband magnet is positioned downstream of the classification process above a conveyor belt or a discharge point, at a maximum distance of 1 m. To ensure that packaging items can be properly separated out and routed to the proper recycling process for ferrous packaging, the packaging must have adequate ferromagnetic properties.

Packaging typically uses tinplate (steel) in the form of metal cans, for example. As a rule, labels, wrappings or protective coatings made from plastics will not cause any problems with sorting using magnetic separators. The assumption here is that the iron content of tinplate packaging is usually high enough to ensure that magnetic separation works as intended.

4.2.3. Can the packaging be magnetised?

The electrical conductivity of packaging can also be used for the targeted separation of a non-ferrous metal fraction (especially aluminium). To separate out this fraction, eddy current separators are used, which work by using the generation of eddy currents in electrically conductive materials as a result of fluctuating magnetic fields. In this case, it is essentially irrelevant whether the conductive layer (e.g. aluminium foil) is enclosed by other layers (PPC, plastic). As a rule, separation success rises in proportion to surface area and the thickness of the non-ferrous metal layer, and the mass percentage of aluminium in the overall packaging. One key distinction here is whether the packaging contains aluminium foil or merely has a vapour-deposited aluminium coating[2].

Examples of packaging containing aluminium include yoghurt pot lids, vacuum packaging for coffee, aluminium foil/tubes, pet food trays, empty tablet packaging (aluminium/plastic blister packs) and coffee capsules. Aluminium may either be the packaging’s original target material or may only make up a lesser proportion, especially together with the target materials plastic and PPC[3]. When using aluminium both as the target material and in smaller proportions, its identifiability by means of conductivity should be tested.

[1] Either one large drum sieve with two sieve cross-sections is used, or, alternatively, two drum sieves, each with one cross-section.
[2] Vapour-deposited aluminium coatings have a high porosity, which significantly reduces their conductivity.
[3] Not LPB, however, which is generated as its own fraction upstream in the sorting chain by NIR detection.

4.2.4. Can the packaging be identified from its surface?

The surface properties of a material are crucial for the identification of plastic packaging, liquid packaging board (LPB) and paper composites (PPC). Most sorting plants use NIR (near-infrared) machinery to distinguish between various types of plastics (PET, PE, PP, PS, etc.) and their composites, and these are then discharged from the waste stream with compressed air. Successful sorting with NIR depends on a number of factors:

- Detectability of the target material on the surface
  - Type of surface material
  - Structure and layer thickness of (multilayer) composite materials
  - Surface colour
  - Reflectance properties
- Several detectable materials are present on the packaging surface (e.g. bottle made from PE with cap made from PP) and 'visible' depending on its orientation – particularly for flat packaging with a multilayer structure, various materials can be detected depending on which side is facing the separator.

The surface colour and its reflectance properties are decisive factors that will influence the sorting outcome. Surfaces that are reflective or have metallic coatings will simply scatter the near-infrared radiation, making any detection of the material impossible. Dark or black materials will absorb the near-infrared radiation, preventing its reflection back to the detector unit, the identification of the material and therefore its correct discharge into the target fraction. These kinds of plastics, which are either coated or dyed in dark colours, cannot be transferred to the correct recycling process and land in the 'sorting residue' or 'mixed plastics' fractions.

Packaging made from several materials also creates problems in terms of its identification. Essentially, packaging can consist of a multilayer part (various layers of material) and/or multiple packaging components – such as packaging aids, for example. NIR identification of multilayer packaging is influenced by the layer structure, the respective layer thickness, the materials used and the individual configuration of the NIR sorter itself. Even if the packaging is completely covered in some other material, correct identification of the target material could in principle work if the other material is not applied too thickly and its reflectance profile is unproblematic.

The specific points measured on the packaging surface will prove decisive here, however. The chance of correct assignment to the target fraction depends on the proportion of the target material in the surface area: if more than 30% of the target material's surface is covered by some other material[4], it is very likely that the target material will not be correctly identified. If labels, overprints or wrap-around labels are not made from the target material, they can therefore impact the detectability of the target material under NIR. Closure systems (lids, caps, screw caps, sealing films, spouts, dispensers, etc.) from other materials can also prevent the packaging item being assigned to the correct target fraction. In both cases mentioned, there is a risk that the packaging aid's material will be detected instead. Other important factors include the position of the packaging on the sorting conveyor belt (especially for flat packaging) and the technical specifications of the NIR separator.

A special case is presented by large, flat, highly flexible plastics (films).

[4] Plastics Recyclers Europe: www.plasticsrecyclers.eu

By covering other packaging, for example, flat packaging makes identifying this packaging either difficult or impossible. Plastic films are also hard to separate using NIR because they tend to change trajectory when being discharged with compressed air. At high belt speeds, highly flexible plastics can also shift position on the NIR detection belt. This again makes targeted discharge impossible. As a precaution against these effects, large, highly flexible plastics are removed at the start of the sorting process by air separators, and are usually sorted into a separate fraction for downstream recycling following manual product control.

For this kind of packaging, identification and sorting can also take place using the weight per unit area rather than NIR surface detection. If this grading method is used, sorting into a fraction is assumed for surfaces larger than A4 in size, independently of the plant-specific sorter settings.

4.3. Level 3: Recycling

Stage 3 starts from the assumption that the packaging is routinely sorted into the fraction envisaged for the target material.

In special cases such as LWP material, where sorting success is not assured for the target material, the sorting fraction or recycling method actually expected for the packaging is evaluated directly at Stage 3 rather than the fraction envisaged for the target material.

4.3.1. Is high-quality recycling expected for the packaging?

Recycling is now the next stage for the fractions generated and baled up by the LWP sorting methods, as well as the PPC and container glass packaging collected as separate materials. Recyclate marketing is crucially dependent on material quality and current market prices. Currently, sorted plastics (PP, PE, PET, PS, films), metals, beverage cartons, PPC and container glass (ignoring for the moment any other materials present) are mechanically recycled into secondary products that are sold to the plastics processing industry or makers of aluminium, steel, glass or paper.

The method introduced here for evaluating recyclability promotes mechanical recycling methods, thereby envisaging the potential reuse of the recycled products as substitutes either for the original primary material or for other materials. As a rule, packaging that is only incinerated (energy recovery) is evaluated as non-recyclable in accordance with this method.

All evaluations of recyclability are based on the relevant material-specific collection and recycling processes that are presently in use in Germany. Mechanical recycling methods are currently available only for certain kinds of packaging materials. Such packaging materials include iron, aluminium, container glass, PPC, beverage cartons, and the plastics PE, PP, PS and PET (e.g. transparent bottles). Other packaging materials (such as PVC or PLA) must therefore be evaluated as non-recyclable at the moment.

As for sorted mixed fractions consisting of transparent PET bottles and other PET packaging types (e.g. trays, blister packs), few buyers are currently available, since different kinds of PET are used and mechanically recycling them collectively is either very difficult or impossible.

As a result of these problems, mechanical recycling for PET currently focuses almost exclusively on PET bottles, while other PET fractions (such as PET trays) almost always end up in sorting residue and are therefore simply incinerated [Oeko-Institut 2016].

4.3.2. Does the packaging contain non-recyclable parts that must be separated out during processing?

The processing of standard packaging plastics necessarily involves the handling of a number of non-plastic packaging components that either disrupt processing or could potentially impair the quality of the recycled product. Some of these non-recyclable packaging components can typically be separated out in the various steps within processing, however (such as washing, sink-float separation and melt extrusion).

- The washing step is typically performed in an aqueous medium. The purpose of these washes is to clean off product residues and detach or remove labels, foreign materials and other problematic components such as overprints.
- The now shredded and washed packaging then usually passes through a density separation step (sink-float separation) to achieve the further concentration of the target plastics fraction. Water is used to separate types of plastics with a density larger or smaller than 1 g/cm³ from each other. When processing polyolefins (density <1 g/cm³), plastics and other materials with a density >1 g/cm³ can be separated out as the sink fraction. Density separation is not suitable for separating types of plastics whose densities differ only marginally: PP and PE have similar densities, for example, and cannot be separated in this way. While specialised liquids can be used that have a density lying between the densities of the target plastics, this method is not often met in practice. For PET recycling (>1 g/cm³), sink-float separation is especially effective at separating out caps for recycling, since these caps are usually made from HDPE. The shredded cap material is added to the lightweight fraction and so separated from non-floating PET material. PS (>1 g/cm³) is also collected as a sink fraction and treated to remove certain lighter PO components. Alterations made to the density of the original packaging material – by the use of blends and additives, for example – can also result in impurities being introduced into the separated-out target fraction or even in the ejection of technically desirable types of plastics from the target fraction.
- Further downstream treatment of plastics fractions focuses on the production of regranulates (without additives) or regenerates (with additives) by means of a melt process. During the extrusion/melt process, components from the original packaging are included in the regranulate if their melting point is lower than the processing temperature: their presence there can downgrade the properties of the final product. Potential problems arise in this context with the processing of composite materials, blends and plastics with additives. While components with a higher melting point can be separated and removed as a residue by melt filtration, they do increase the cleaning effort required for the filter sieve while also reducing target material yields as a result of this filtration. Components with a lower melting point either decompose beforehand or end up in the final recyclate – which can work to impair the mechanical and optical properties of the recyclate.

4.3.3. Does the packaging result in the input of (non-separable) impurities with a concomitant risk of contaminating the recycled product or disrupting the recycling process?

This method defines substances with a low risk of contamination as those substances contained in packaging that, at their usual concentrations, typically do not appreciably impair the optical, mechanical or other properties of the recyclate and therefore its marketability. As such, the recyclate exhibits only minor limitations in terms of workability and downstream fields of application.

Likewise, substances with a substantial risk of contamination are defined as those substances contained in packaging that (potentially only at certain concentrations) impair optical and mechanical properties to such a degree that the processing end product is potentially no longer marketable as a recyclate and usable only for energy recovery (incineration). As such, the recyclate will exhibit major limitations in terms of workability and downstream fields of application.

5. Evaluation

The quantitative evaluation of recyclability is completed by using a scoring model to assign points to the packaging item. This evaluation is based on the stated criteria for evaluating recyclability (section 4). The scoring model specifies a percentage weighting of these evaluation criteria that is independent of the evaluation of a specific packaging item.

The quantitative evaluation of recyclability is completed in the following steps:

- The criteria set out in section 4 are first used to make a qualitative estimate of the extent to which the packaging item in question fulfils these individual criteria.
- This qualitative estimate of the degree of fulfilment for the packaging item in question is then used to make a graded quantitative evaluation that ranges from 20 (highest grade, level 1) and 0 or 'KO' (lowest grade, level 5) for each evaluation criterion.
- An individual score is then calculated for each criterion by multiplying the packaging's criterion-specific grade with the corresponding weighting for this criterion.
- An overall score for recyclability is then calculated as the sum of all of the individual scores.

Criterion	**A: Criterion weighting [%] Total = 100%**	**RS-ID 965: cupsforyou PP-Becher/>50% BIO PE**	
		B: Rating (0 to 20)	**A*B: Points**
Level 1: Assignment of packaging to collection system			
Collection matchable	**10%**	20	2
Level 2: Sortability of mixed packaging (LWP)			
Minimum size	**10%**	20	2
Identifiability	**20%**		
Tinplate (ability to be magnetised)			
Aluminium (conductivity)			
Plastics, LPB, PPC compound (surface property)		20	4
Level 3: Suitability for mechanical recycling and provision of secondary products			
Quality of the recycling method	**20%**	20	4
Separable parts that cannot be recycled	**20%**	20	4
Non-separable components, impurities	**20%**	15	3
			Evaluation
Overall recyclability			**19 von 20**
Recyclability level 1			2 von 2
Recyclability level 2			6 von 6
Recyclability level 3			11 von 12

Figure 3: Quantitative evaluation of recyclability

Packaging Components:										
			Front	Back	Front and back are the same	Material		Mass [g]	Share [%]	Note
Packaging 1:	Cup				x	LDPE+PP		25,96	84%	
Packaging 2:	Top				x	LDPE+PP		4,82	16%	
Packaging 3:										
Packaging 4:										
Packaging 5:										
Summe								30,78	100%	
* Indication of which side has been examined, e.g. front or back or inside or outside of a paper/plastic film in NIR examination										
Packaging material with highest share:		PP	= Target material		Highest share:		84%			
* According to [ZSVR 2018], for tinplate or aluminum packaging as well as metalliferous composite packaging (excluding metallization), the respective metal is always the target of recycling										

Figure 4: Determination of packaging components and target fraction

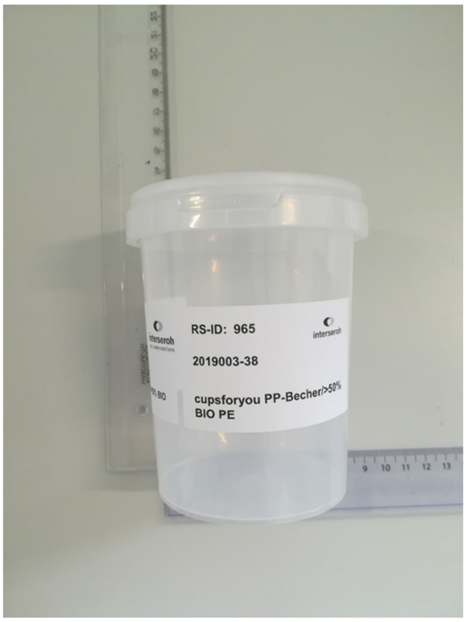


Figure 5: Picture of the analyzed packaging

5.1. Collection matchable

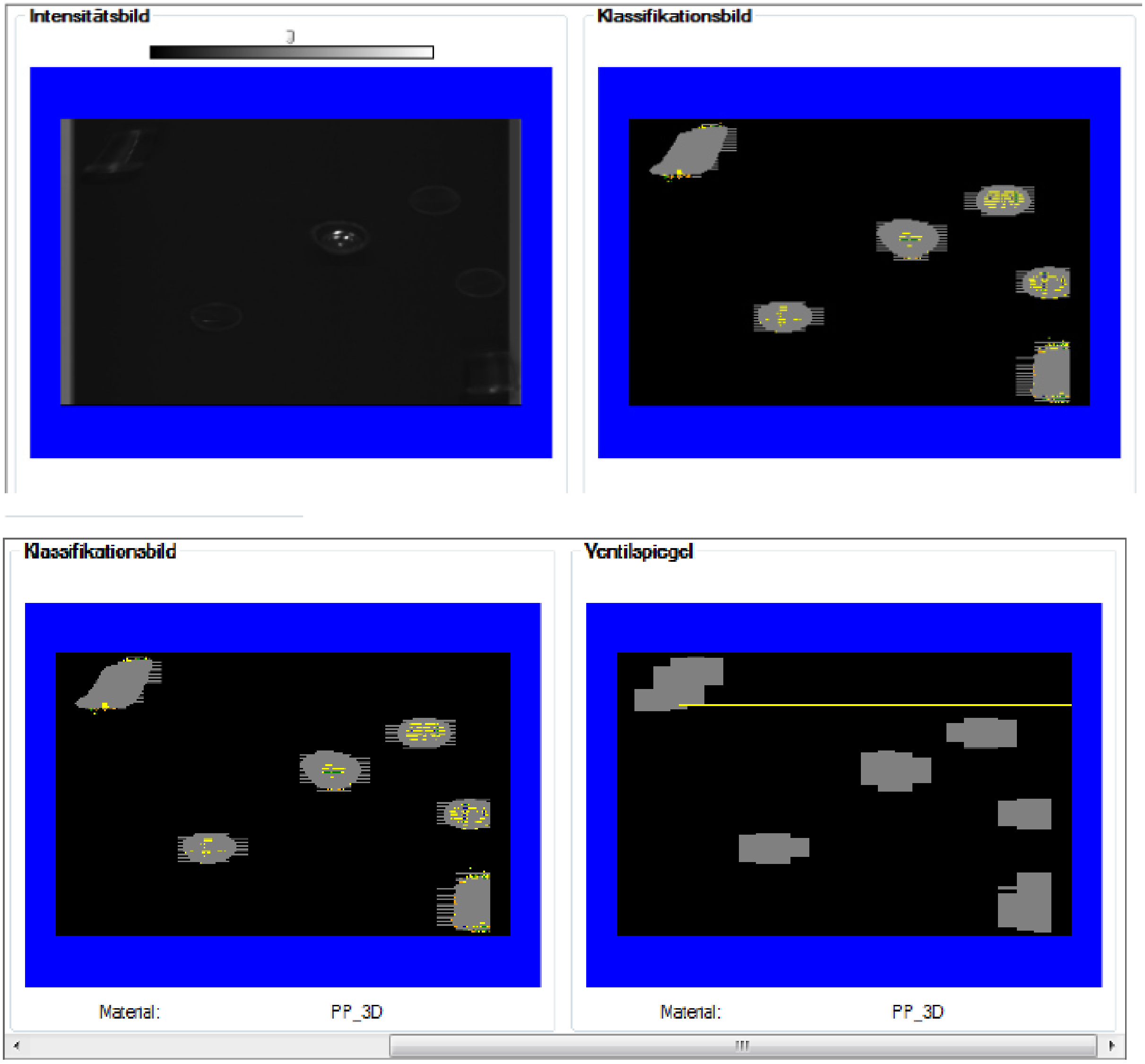
The packaging is a cup made of PP and can be intuitively assigned to the yellow bag for the consumer. (20 points)

5.2. Minimum size

As described in section 4, sorting plants use an NIR scanner and an air nozzle system to first detect packaging and then discharge it into the corresponding fraction. For technical reasons, these nozzles cannot be spaced at distances much smaller than 20 mm. Packaging that is smaller than this distance runs the risk of being undetected and therefore sorted into the incineration fraction. This packaging item is substantially larger than the minimum size and therefore receives the full 20 points.

5.3. Identifiability

The target material PP is unrestrictedly identified despite the material blend of LDPE and PP and can be sorted to the PP fraction. The packaging thus receives 20 points in this evaluation criterion. The gray color shows the identification of the PP by the NIR scanner.



5.4. Quality of the recycling method

It can be expected a high quality recovery. 20 points

.5.5. Separable parts that cannot be recycled

The packaging contains no separable, non-usable shares and thus gets 20 points.

5.6. Non-separable components, impurities

The packaging contributes PE content, which is > 8%, so there are impurities with low risk of contamination and therefore receives 15 points.

6. Recommendations for action

With 19 of 20 possible points a very good recyclable packaging.

This packaging ends up in the PP fraction. An increase in recyclability can be optimized by reducing the PE content to below 8%. Thus, in the criterion impurities the full score could be achieved.