RecyClass

RECYCLABILITY EVALUATION PROTOCOL

FOR EPS WHITE GOODS & FISH BOXES

STANDARD LABORATORY PRACTICE

REP-EPS-01

VERSION 1.0

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RecyClass

CONTENT

RecyClass

GLOSSARY

A.0	100 % control
A.25	Blend 75/25 control/innovation
A.50	Blend 50/50 control/innovation
A.100	Blend 100 % innovation
ASTM	American Society for Testing and Materials
B.0	Sheet made of 50 % of virgin pellets and 50 % of B.0 pellets
B.25	Sheet made of 50 % of virgin pellets and 50 % of B.25 pellets
B.50	Sheet made of 50 % of virgin pellets and 50 % of B.50 pellets
B.100	Sheet made of 50 % of virgin pellets and 50 % of B.100 pellets
Control Sample	PS resin that has already been thermally processed once used as benchmark
C.0	Plate made of 100 % control pellets
C.25	Plate made 75 % control and 25 % innovation pellets
C.50	Plate made 50 % control and 50 % innovation pellets
C.100	Plate made 100 % innovation pellets
EN	European Standard
EPS	Expanded Polystyrene
EPS fragments	Expanded Polystyrene blocs after compaction
EPS particles	Expanded Polystyrene parts obtained after grinding
Innovation Sample	Container containing the innovative technology
ISO	International Organization for Standardization
MFI	Melt Flow Index
PS	Polystyrene
PVC	Polyvinyl Chloride
TC	Technical Committee
TGA	Thermo Gravimetrical Analysis
Virgin Material	PS resin that will for the first time be converted to a plastic product (no thermal pre-treatment)
wt%	Weight Percentage

DISCLAIMER

"RecyClass is a non-profit, cross-industry initiative advancing recyclability, bringing transparency to the origin of plastic waste and establishing a harmonized approach toward recycled plastic calculation & traceability in Europe. The Recyclability Evaluation Protocols will promote recyclability by encouraging the industry to test new plastic technologies, materials or products, providing recommendations on improving their recyclability before market launch.

The Recyclability Evaluation Protocols are freely available to download on the RecyClass website. Companies developing new plastic concepts are encouraged to use them to self-assess the impact of their solutions on recyclability and highlight potential issues. **However, compliance with a Recyclability Evaluation Protocol is not a replacement for an official assessment and may not be used as a marketing tool.** The RecyClass Steering Board, following the recommendations of the Technical Committees, will decide on the compatibility of the innovation with recycling according to the evaluation results, granting a Recyclability Approval Letter to the Applicant.

All tests must follow the Evaluation Protocols recommended by the RecyClass Technical Committees and be conducted by an independent laboratory recognised by RecyClass which has no legal affiliation to the applicant.

More information is reported in the RecyClass Internal Procedures available on the *RecyClass website."*

RecyClass

1. INTRODUCTION AND PURPOSE OF THE PROTOCOL

The "RecyClass[1] Recyclability Evaluation Protocol for EPS White Goods & Fish Boxes" referred to in this document as "The Protocol" describes the methodology that must be followed by the applicant at a laboratory scale in order to determine if a plastic packaging innovation is compatible with the post-consumer EPS recycling stream. The Protocol targets companies responsible for introducing a packaging product into the market. The applicant shall proceed with the Protocol as established in the Assessment Process for Applicants of Recyclability Evaluation in the RecyClass Internal Procedures[2] and RecyClass Technology Approval Quality Management & Procedures document[3].

The Protocol analyses whether an innovation will undergo the necessary pre-treatment, extrusion and conversion steps described in this methodology at a laboratory scale without negatively impacting the recycling process. It aims to guarantee recyclability[4] of plastics packaging while encouraging innovation in the EPS market. The overall goal is to maintain the protection of packaged goods and their marketing display functions without obstructing the proper functioning of the EPS recycling process.

This document provides guidance on the tests methodology that shall be followed, including benchmark recommendations to guide the interpretation of the results.

Please note that all units in this protocol are expressed following the International System of Units[5], from the Bureau International des Poids et Mesures.

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[1] RecyClass assesses the recyclability of a plastic package providing a ranking from A to C. RecyClass also provides specific indications and recommendations on how to improve packaging design to fit current recycling technologies. More information at https://recyclass.eu/

[2] RecyClass Internal Procedures

[3] RecyClass Technology Approval Quality Management & Procedures

[4] Recyclability definition according to PRE & APR: Plastics must meet four conditions for a product to be considered recyclable: 1. The product must be made with a plastic that is collected for recycling, has market value and/or is supported by a legislatively mandated program. 2. The product must be sorted and aggregated into defined streams for recycling processes. 3. The product can be processed and reclaimed/recycled with commercial recycling processes. 4. The recycled plastic becomes a raw material that is used in the production of new products.

[5] SI Brochure - BIPM

2. SCOPE OF THE PROTOCOL

The scope of the Protocol covers any innovation introduced to the existing packaging solutions for EPS white goods and fish boxes. Prior to initiating the evaluation, the applicant shall review the Design for Recycling Guidelines for EPS white goods and fish boxes[6] in order to confirm that the EPS innovation is compatible with these requirements.

The following packaging solutions and/or innovations are covered by the scope of this Protocol:

1. Barrier materials
2. Additives and mineral fillers
3. Non-PS closure systems
4. Non-PS labels and sleeves
5. Adhesives
6. Inks

Following the RecyClass methodology[7], packaging containing aluminium, metal, degradable plastics, black carbon surface, as well as PVC and PVDC layers are considered as disqualified for recyclability. By consequence, packaging containing one of these features do not fall under the scope of this Protocol.

3. DISCLAIMER

The Protocol is created to represent as accurately as possible how the current EPS recycling works at an industrial scale. RecyClass PS Technical Committee reserves the right for further testing, if necessary, to issue a final opinion on the recyclability of the tested packaging.

4. LABORATORY TEST METHODOLOGY

This methodology aims to reproduce the recycling process at laboratory scale to determine the suitability of an innovation for the EPS recycling stream. The methodology described below shall be followed precisely and any modifications or problems must be noted during the testing phase. A Laboratory Evaluation Report compiling objectively all the results obtained shall be prepared to report to the RecyClass Technical Committee which will interpret the final results. Any remarks during the laboratory tests described in the Protocol shall be also noted down.

See below in Figure 1 a diagram where the flow of the methodology is described.

[6] *Design for Recycling Guidelines*

[7] *RecyClass Methodology*

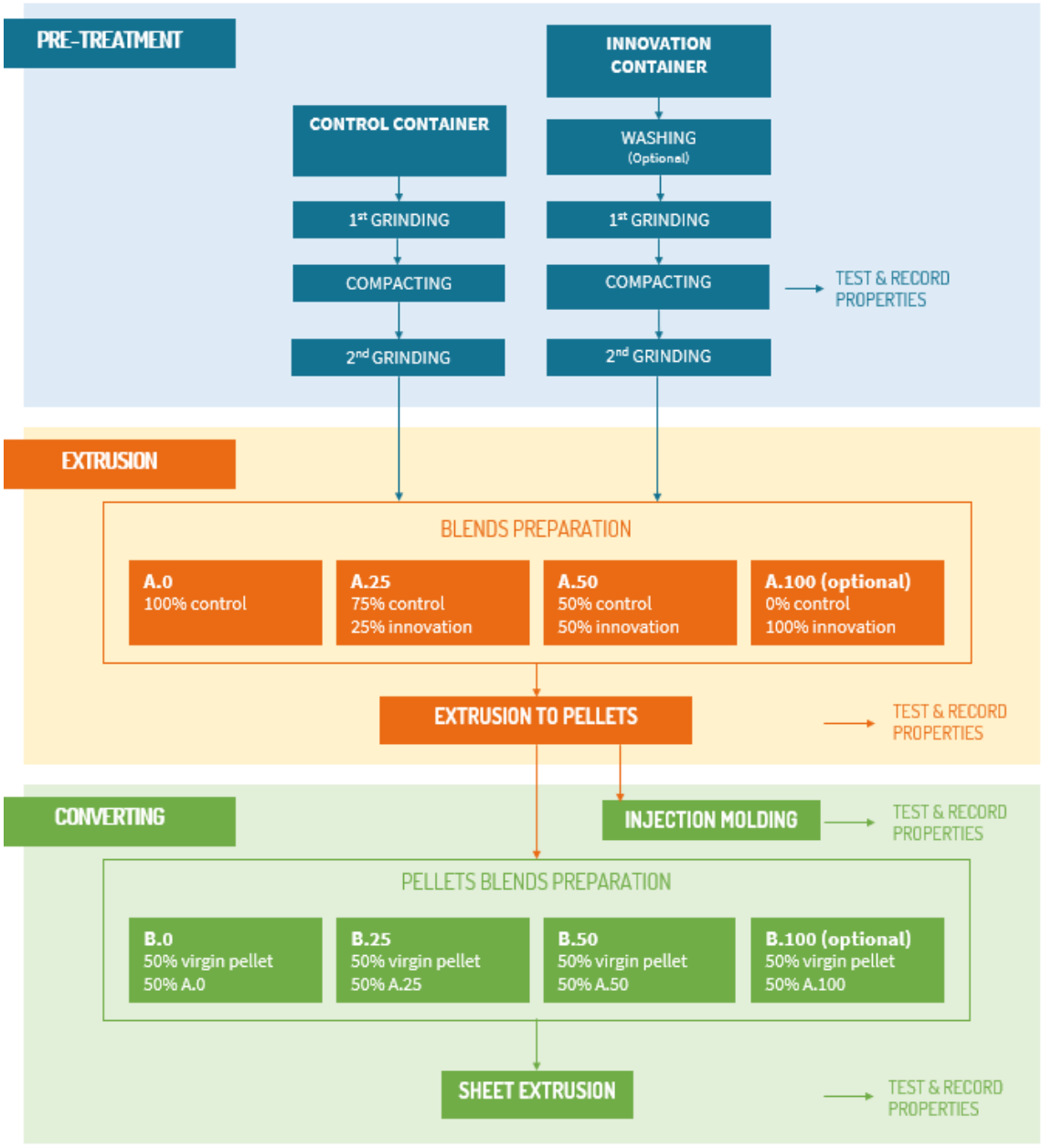

Figure 1. Methodology Diagram

4.1 CONTROL SAMPLE SELECTION

The Applicant can select a PS resin typically used for EPS applications with the same critical technical specifications for MFI and density as the innovation article, ±0.5 MFI and ±0.01 density can be used as the control for this Protocol, with/upon the approval of RecyClass PS TC. A selection of control samples to be used is reported in Annex I. A mixture of the resins listed in Annex 1 reflecting the innovation structure can also be proposed as control, upon the approval of the Technical Committee. The selected material must be extruded at 220 °C to obtain the control sample. This step is necessary to realistically represent a material already used as packaging by erasing its previous thermal history.

These options are to be used to make both the control material and the blends with innovation sample that will contain the innovative feature(s) (additive, coating, label, adhesive, multilayer resin, etc.) for the recyclability study.

For the purpose of the tests the Applicant should provide at least 15 kg amount of innovation material (as packaging) and 25 kg amount of control material (as packaging) which allows for blend preparations of 5 kg each. More innovation material could be requested if optional tests are required by the RecyClass PS Technical Committee. It is worth pointing out that the innovation to be tested is not limited to the main body of the packaging but to all its parts. Therefore, the innovation has to be submitted to the laboratory procedures with labels, adhesives, closure system, liners, seals, valves. If it can be correctly argued that labels and adhesives have no impact on the innovation, the innovation samples can be processed without the presence of labels and adhesives.

4.2 VIRGIN SAMPLE SELECTION

The virgin PS sample for use following the Protocol can be selected by the PS resins listed in the Annex and used as it is (i.e. without applying any thermal pre-treatment). The PS Technical Committee can propose a mix of HIPS and GPPS resins for the sheet extrusion process, considering the brittleness of the GPPS resin and the potential issues related to it during the processing of the samples.

5. LABORATORY TEST PROCEDURES

5.1 PRE-TREATMENT STEPS

5.1.1 WASHING (OPTIONAL)

Under request of the PS TC, innovation EPS sample might be washed to test the impact on wet washing operations. The procedures take care of labels, adhesives, coatings, paper and printing present in the innovation EPS container. If the Technical Committee does not request a washing step to be performed, go directly to step 5.1.2.

The following procedures have to be utilized only for innovation samples.

Procedure:

- Prepare the washing water in a vessel of 20 l minimum with tap water. No added detergents or caustic soda.

- Heat the water at 40 °C.

- Wash innovation sample separately at a maximum ratio of 1:4 (5 kg sample vs 20 l water) at 200 rpm for 5 minutes. Avoid damaging the integrity of the samples.

- Rinse the samples in the strainer with cold running tap water and stir vigorously for 5 minutes using manual stirring bar. Then drain the material.

- Take photos at each step.

- Record the moisture content.

Save the washing and rinsing water separately for visual observation. Record the presence of suspended particles or fibres within the water as well as any water coloration. Check and record if the glue has been diluted after the rinsing or it remains attached to beads.

5.1.2 1ST GRINDING

Innovation sample is ground in order to further be compacted and extruded.

Procedure:

- Grind innovation sample into particles.

- Store in separate containers.

- Record the masses.

5.1.3 COMPACTING

Reduce the particles moisture uptake with ambient air to release surface moisture. Innovation sample is compacted.

Procedure:

- Analyse moisture content. Moisture content of samples should be lower than 8 % before compacting. If moisture is above 8 %, apply mild heating conditions (40 °C without vacuum) to decrease the moisture content under the threshold.

- Spread the EPS particles collected after grinding in large trays.

- By using compaction moulding, compress the EPS fragments up to have an average density around 0.3 ± 0.05 g/cm³. This represents approximately a 1:20 volume reduction of the material. Ensure that the pressure is evenly shared on all the particles present in the tray. Report the pressure used to compact innovative samples.

5.1.4 2ND GRINDING

After compaction, innovative sample must be reground in order to obtain fragments that can be fed into a standard laboratory extruder.

Procedure:

- Grind innovation sample.

- Store the fragments in separate containers.

- Record the masses.

5.2 EXTRUSION

5.2.1 FRAGMENTS BLENDS PREPARATION

For each sample obtained, to evaluate and record the properties of innovation EPS white goods and fish boxes against control as laid out in this Protocol, a set of EPS fragments blends is prepared as described in Table 1. Blends shall be produced once the innovation has gone through all pre-treatment steps described above.

Keep separated the control and innovation fragments obtained following the previous steps, and air dry for 24 h at ambient air. Then, according to the values reported in Table 1 prepare three different blends with 100 % control (and 0 % innovation), 75 % control – 25 % innovation, and 50 % control – 50 % innovation, and tag them respectively as A.0, A.25 and A.50.

Eventually, depending on the application and its market penetration, the TC can ask the Applicant also to perform the tests with a sample of 100 % innovation (i.e. A.100, by replacing the test with A.25).

For the purpose of the tests the Applicant should provide enough innovation and control materials which allows for the blend preparations (cf. section 4.1.).

5.2.2 FRAGMENTS BLENDS COMPOSITION

Three different blends 0 %, 25 % and 50 % of innovation EPS container (optionally 100 % innovation) will be prepared as described in Blends composition for the production of pellets in Table 1.

Eventually, depending on the application, the TC can ask the Applicant also to perform the tests with a sample of 100 % innovation (i.e. A.100, by replacing the test with A.25).

Table 1. Blends composition for the production of pellets

BLEND	COMPOSITION	% CONTROL	% INNOVATION
A.0	100 % Control	100	0
A.25	75 % Control 25 % Innovation	75	25
A.50	50 % Control 50 % Innovation	50	50
OPTIONAL A.100	100 % Innovation	0	100

5.2.3 PELLET PRODUCTION

Both control and innovation fractions can be mixed manually before extrusion for blends preparation. If moisture uptake is superior to 8 %, the fragments will be dried at the same conditions with a desiccant bed drying unit or with hot air and then extruded using co-rotative twin-screw extrusion at temperatures of 220 °C. The extrudate will be melt filtered (about 180 µm filtration). Control bead sample A.0 has to be extruded first. Further size reduction before extrusion is acceptable if needed to allow good feeding of the material into the extruder. Nevertheless, the fragments size should be kept constant between all samples. See additional information in Table 2.

The extruder has to be cleaned before starting the extrusion process. This involves pulling the screws out of the barrel and then mechanically cleaning them with brass brushes until they reach a glossy finish. The barrel has to be also mechanically cleaned with round brass brushes from the mandrel to the run-out zone.

Table 2. Pellet production purpose & overview

BEAD COMPOSITIONS	KG OF BLEND REQUIRED	PURPOSE OF BLEND
A.0 100 % Control bead	Per laboratory requirement for a 30-minute run time	All tests compared to control values
A.25 75 % control with 25 % innovation	Per laboratory requirement for a 30-minute run time	Required for comparison to control values
A.50 50 % control with 50 % innovation	Per laboratory requirement for a 30-minute run time	Required for comparison to control values
OPTIONAL **A.100** 100 % innovation	Per laboratory requirement for a 30-minute run time	Optional, to evaluate the impact of higher concentration of innovation on recycling.

Procedure:

- If moisture uptake superior to 8 %, dry samples A.0, A.25 and A.50 (optionally A.100) with a bed desiccant for 1 hour at 80 °C or with hot air at 80 °C for 1 hour.

- Extrude for first the sample A.0 (the control blend) at a temperature of 220 °C and with a 180 µm melt filter pack, for no less than 30 minutes.

- Monitor the extrusion process for heat stability.

- Rapidly cool the extrudate in a water bath and fed into a pelletizer.

- The pelletizer speed has to be controlled to get a final pellet with a diameter of 3 mm.

- Monitor pressure build-up during pelletizing and report significant differences.

- Randomly collect the pellets to perform all the characterizations reported in Table 3.

- Change the melt filter pack between samples for visual examination.

- Be sure to produce enough pellets for all the tests, including the conversion tests.

Record properties' results in Table 3. The processing conditions used for all the samples must be identical. If some operating conditions have to be modified for A.25 and A.50 (optionally A.100) samples, this information must be

documented in the report. A small amount of each sample (50 g) will be retained for RecyClass Technical Committee and the Applicant. The extruded pellets will be tested for pellet properties evaluation (Table 3). The pellets of the test samples will be compared with the pellets of the control sample. All pellets should meet the requirements reported in the Table 3.

If filterability is seen as a potential problem for the innovative samples, a dedicated filter test should be requested by the RecyClass PS Technical Committee.

5.2.3.1 PELLET PROPERTIES EVALUATION

Table 3. Pellet properties evaluation

ASSESSMENT	RESULT	STANDARD	BENCHMARK RECOMMENDATION
Density (kg/m^3)		ISO 1183-1	Between 1 and 1.08 g/cm^3
Melt Index (g/10 min)		ISO 1133-1 (200 °C/5 kg)	Between 3 and 15 g/10 min No more than a 25 % delta variation to A.0
Ash content (wt%)		ISO 3451-1 by TGA	A.25, A.50 and A.100 respectively lower than 0.75, 1.5 and 2.5 wt%
Filtration (µm)		Visual inspection	No build-up on screen
Moisture (wt%)		ISO 11358-1	<1 wt%
Impurities		Visual inspection	Record
Surface appearance		Visual inspection	Record
Volatiles (wt%)		10 g air-dried pellets exposed to 200 °C for 10 minutes	±0.1 wt% for A.25 and A.50 respect to A.0
Average Pressure (MPa)		Average Pressure it after extruding through 120 microns for the stable 30 minutes run time, compared to 100 % control	No more than a 10 % delta increase to A.0
Pressure Variation (MPa)		($\Delta P_{5\ \text{last minutes}} - \Delta P_{5\ \text{first minutes}}$)	No increase higher than 25 % compared to start in 30 min

5.3 CONVERTING

5.3.1 INJECTION MOULDING

Pellets A.0, A.25 and A.50 (optionally A.100) have to be tested for injection moulding to evaluate tensile properties, colours, as well as defects.

Control pellets A.0 have to be moulded first.

Procedure:

- Dry the samples A.0, A.25 and A.50 (optional: A.100) at 90 °C for 2 hours.

- Mould sample A.0 at 210-260 °C to multipurpose specimens' type 1A according to EN ISO 527-2 and to plates with measures of about 60 x 60 x 2 mm^3.

- The run time is variable, but should be not less than 30 min. The specimens should be completely filled without any shrinkage, overspray, and inclusions.

- Samples A.25 and A.50 (optionally A.100) have to be moulded following the identical operating conditions of the control sample A.0.

- Tag the plates produced by A.0, A.25 and A.50 (optionally A.100) as C.0, C.25 and C.50 (optionally C.100), respectively.

- Small variations in operating conditions could be acceptable but have to be documented in the report.

- For each material monitor the heat stability and the injection pressure.

Record properties' results in Table 4. Mechanical data must be analysed on the 1A specimen, while colour, inclusions, and surface should be analysed on the plate. If some operating conditions have to be modified for A.25 and A.50 (optionally A.100) samples, this information must be documented in the report.

5.3.1.1 INJECTION MOULDED PARTS PROPERTIES EVALUATION

Table 4. Injection moulded parts properties evaluation

ASSESSMENT	RESULT	STANDARD	BENCHMARK RECOMMENDATION
Flexural modulus (MPa)		ISO 178 or ISO 24022-2:2020	No more than 10 % delta decrease to A.0
Tensile Strength at Yield (%)		ISO 527 or ISO 24022-2:2020	No more than 25 % delta decrease to A.0
Tensile Stress at Break (MPa)		ISO 527 or ISO 24022-2:2020	No more than 25 % delta decrease to A.0
Reflection Colour		(L*, a*, b*)	Record
Surface Appearance		Visual inspection	No black specks
Inclusions of extraneous material		Visual inspection	Record

5.3.2 SHEET EXTRUSION

Since the Protocol aims to assess the most demanding recyclate application, PS sheet extrusion will be a priority. In any case, three blends of innovation and control pellets will be produced aiming to assess different innovation concentration in the recycling stream, as following reported.

5.3.2.1 PELLET BLENDS PREPARATION

Once PS pellets have been produced and tested, three additional blends of 50 % virgin – 50 % blend A shall be produced for converting tests. Keep separated the pellet samples previously produced and dry them for 10 minutes at 60 °C. Then according to the values reported in following Table 5 prepare three different blends with 0 % innovation (50 % virgin and 50 % A.0 pellets), 12.5 % innovation (50 % virgin and 50 % A.25 pellets), and 25 % innovation (50 % virgin and 50 % A.50 pellets), and tag them as samples B.0, B.25 and B.50 respectively.

Eventually, depending on the application and its market penetration, the TC can ask the Applicant also to perform the tests with a sample of 50% innovation (i.e. B.100, by replacing the test with B.25).

5.3.2.2 PELLET BLENDS COMPOSITION

Three different blends at 50 % virgin pellet – 50 % Blend A shall be produced as described in Table 5. Blends will be composed of 0 %, 12.5 % and 25 % content (end eventually 50 %) by weight of the initial innovation PS container.

Table 5. Pellet blends composition for the application tests

BLEND	COMPOSITION	% VIRGIN RESIN	EFFECTIVE % CONTROL	EFFECTIVE % INNOVATION
B.0	50 % Virgin Pellet 50 % A.0	50	50	0
B.25	50 % Virgin Pellet 50 % A.25	50	37.5	12.5
B.50	50 % Virgin Pellet 50 % A.50	50	25	25
OPTIONAL B.100	50 % Virgin Pellet 50 % A.100	50	0	50

The Applicant has to submit its innovation primarily to sheet extrusion to test the recyclate obtained by the innovation in a closed-loop application.

Control pellet blend B.0 has to be extruded first. See more information in Table 6.

Table 6. Sheet production purpose & overview

PELLET COMPOSITIONS	KG OF BLEND REQUIRED	PURPOSE OF BLEND
B.0 50 % A.0 pellet and 50 % Virgin pellet	Per laboratory requirement for a 30-minute run time	All tests compared to control values
B.25 50 % A.25 pellet and 50 % Virgin pellet	Per laboratory requirement for a 30-minute run time	Required for comparison to control values
B.50 50 % A.50 pellet and 50 % Virgin pellet	Per laboratory requirement for a 30-minute run time	Required for comparison to control values
OPTIONAL **B.100** 50 % A.100 pellet and 50 % Virgin pellet	Per laboratory requirement for a 30-minute run time	Optional, to evaluate the impact of higher concentration of innovation on recycling.

Procedure:

- Dry samples B.0, B.25 and B.50 (optionally B.100) at 60 °C for 10 minutes.

- Extrude sheets at 220 °C with thickness of 800 µm under conditions determined for the control sample B.0. Temperature of the rollers should be fixed between 30 and 45 °C.

- Extrusion run time per variable, no less than 30 minutes.

- Samples B.25 and B.50 (optionally B.100) have to be extruded following the identical operating conditions of the control sample B.0.

- Small variations in operating conditions could be acceptable but have to be documented in the report.

Record properties' results in Table 10. If some operating conditions have to be modified for B.25 and B.50 samples, this information must be documented in the report.

5.3.2.3 SHEET PROPERTIES EVALUATION

Table 7. Sheet properties evaluation

ASSESSMENT	RESULTS	STANDARDS	BENCHMARK RECOMMENDATION
Thickness			Variations lower than 3 %
Tensile Modulus (MPa)		ISO 527-3 or ISO 24022-2:2020	No more than a 10 % delta decrease to B.0
Tensile Stress at Yield (TD*) (MPa)		ISO 527-3 or ISO 24022-2:2020	No more than a 25 % delta decrease to B.0
Tensile Stress at Yield (MD**) (MPa)			
Tensile Stress at Break (TD*) (MPa)			
Tensile Stress at Break (MD**) (MPa)			
Colour		Visual inspection	No discolouration
Surface Appearance		Visual inspection	No black specks
Fisheyes		Visual inspection	Record the amount and size distribution per m^2. No fisheyes should be bigger than 1 mm^2.
Inclusions of extraneous material		Visual inspection	Record

**TD: transverse direction*

***MD: machine direction*

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DOCUMENT VERSION HISTORY

VERSION	PUBLICATION DATE	REVISION NOTES
1.0	July 2025	Recyclability Evaluation Protocol for EPS White Goods and Fish Boxes release

ANNEX I – CONTROL SAMPLES SELECTION

Type of PS	**PS**	Density, g/cm³	MFI, g/10min (190 °C/2,16 kg)
GPPS	Styrolution Taxed 1050	1.04	2.8
GPPS	Styron™ 660	1.04	7.0
GPPS	EDISTIR® N3560	1.05	3.8
GPPS	EDISTIR® N3840	1.05	10

RecyClass

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