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# Fibre-based packaging and barrier coatings: influence on the converting and recycling

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# AGENDA

- Context
- Materials
- **Converting: heat-sealing, folding, creasing, tray forming**
- **Recyclability: UNI 11743 and Aticelca 501, CEPI v.2 and 4evergreen**
- Conclusions

# CONTEXT

**Fibre-based packaging**
Paperisation process, where polymeric packaging is substituted with fibre-based counterparts

**Monomaterial**:
non-cellulosic content <5%

**Recyclable**:
Different testing methodologies, e.g., CEPI version 2 and UNI 11743

- Reduced non-cellulosic content
- Thinner coatings
- Inorganic/Mineral coatings
- Nanomaterials*

* There still exist issues for applications in food packaging

# CONTEXT

## One possible solution

Dispersion coatings are waterborne dispersions composed of a polymeric latex, possible filler, and other chemicals

**Advantages:**

- Applied on the substrate using conventional printing technologies
- Low dry coat grammages

**Disadvantages:**

- Typically, more expensive as against extruded or laminated coatings
- Coating evenness influenced by substrate/primer

Dispersion coatings can provide good barrier properties, but

**how do they behave when converted or recycled?**

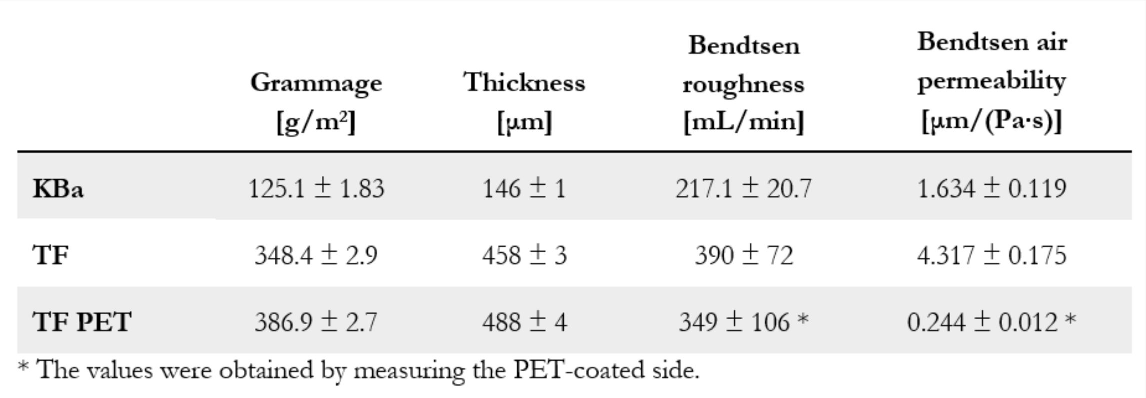
# MATERIALS

**Substrates**: Paper (125 g/m$^2$) and paperboard (350 g/m$^2$) substrates

**Dispersion coatings**: commercial (SA-B1, A-H, SA-H, SAP-H), and experimental grades filled with kaolin

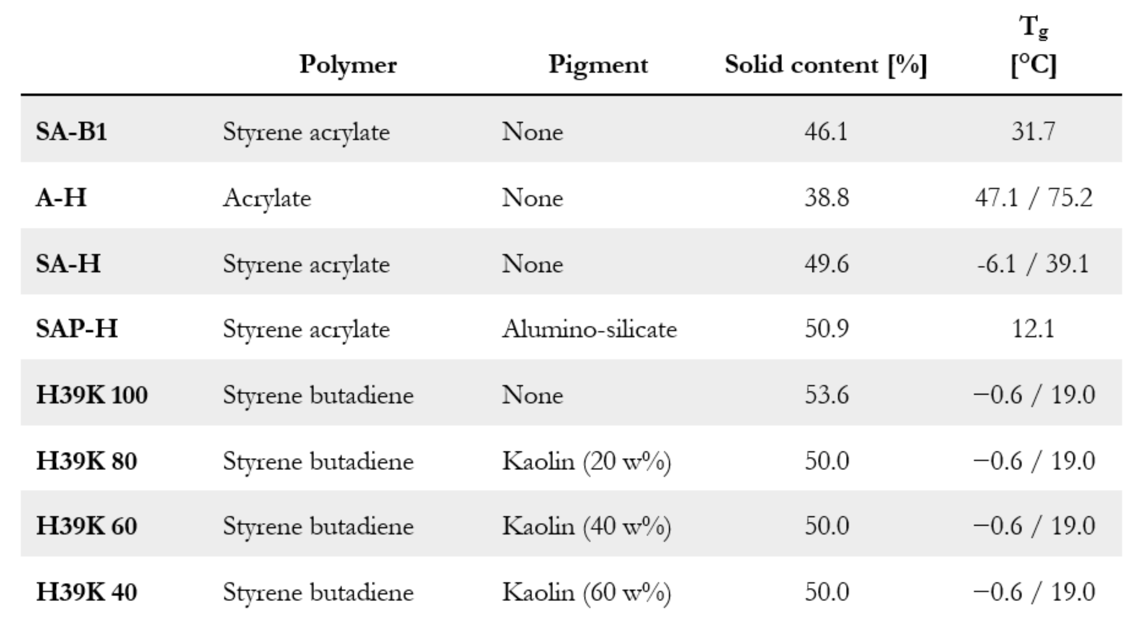
Single layer application with **rod coating** technology at a laboratory scale

Conditioning and testing at 23±1 °C and 50±2% relative humidity.



| | Grammage [g/m$^2$] | Thickness [µm] | Bendtsen roughness [mL/min] | Bendtsen air permeability [µm/(Pa·s)] |
|---|---|---|---|---|
| **KBa** | 125.1 ± 1.83 | 146 ± 1 | 217.1 ± 20.7 | 1.634 ± 0.119 |
| **TF** | 348.4 ± 2.9 | 458 ± 3 | 390 ± 72 | 4.317 ± 0.175 |
| **TF PET** | 386.9 ± 2.7 | 488 ± 4 | 349 ± 106 * | 0.244 ± 0.012 * |

* The values were obtained by measuring the PET-coated side.



| | Polymer | Pigment | Solid content [%] | $T_g$ [°C] |
|---|---|---|---|---|
| **SA-B1** | Styrene acrylate | None | 46.1 | 31.7 |
| **A-H** | Acrylate | None | 38.8 | 47.1 / 75.2 |
| **SA-H** | Styrene acrylate | None | 49.6 | -6.1 / 39.1 |
| **SAP-H** | Styrene acrylate | Alumino-silicate | 50.9 | 12.1 |
| **H39K 100** | Styrene butadiene | None | 53.6 | −0.6 / 19.0 |
| **H39K 80** | Styrene butadiene | Kaolin (20 w%) | 50.0 | −0.6 / 19.0 |
| **H39K 60** | Styrene butadiene | Kaolin (40 w%) | 50.0 | −0.6 / 19.0 |
| **H39K 40** | Styrene butadiene | Kaolin (60 w%) | 50.0 | −0.6 / 19.0 |

# CONVERTING PROPERTIES

# CONVERTING PROPERTIES AND TRAY FORMING

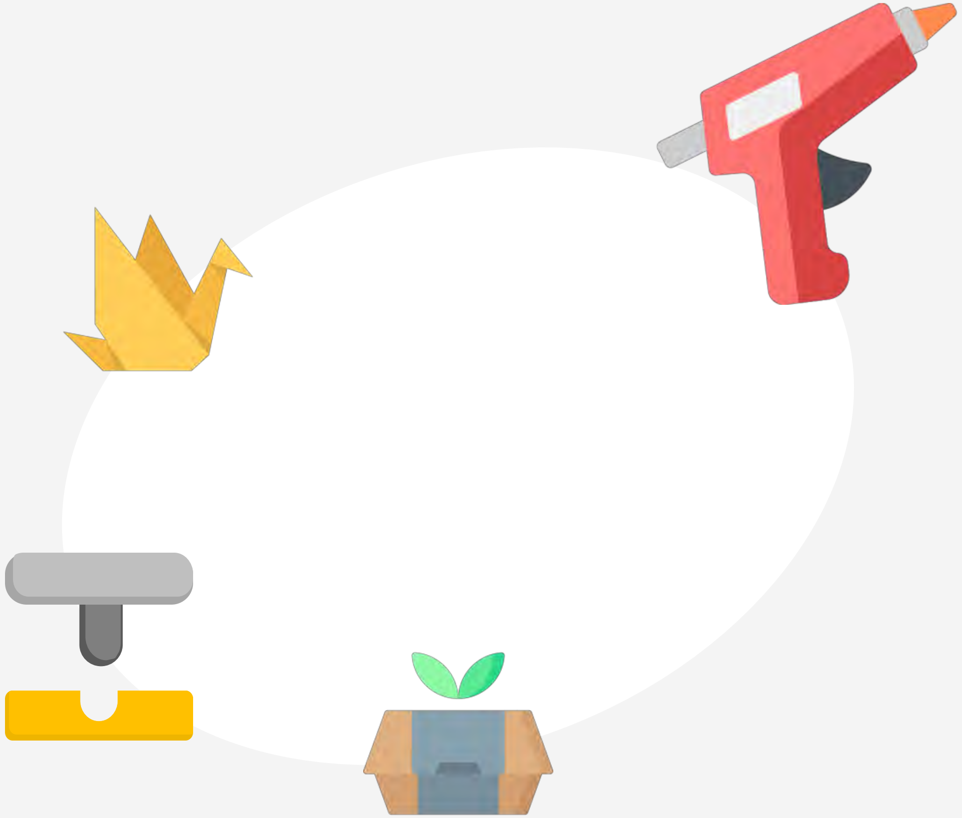
**Heat-sealing**

**Fold cracking**

**Creasing**

**Tray forming**

# CONVERTING PROPERTIES AND TRAY FORMING



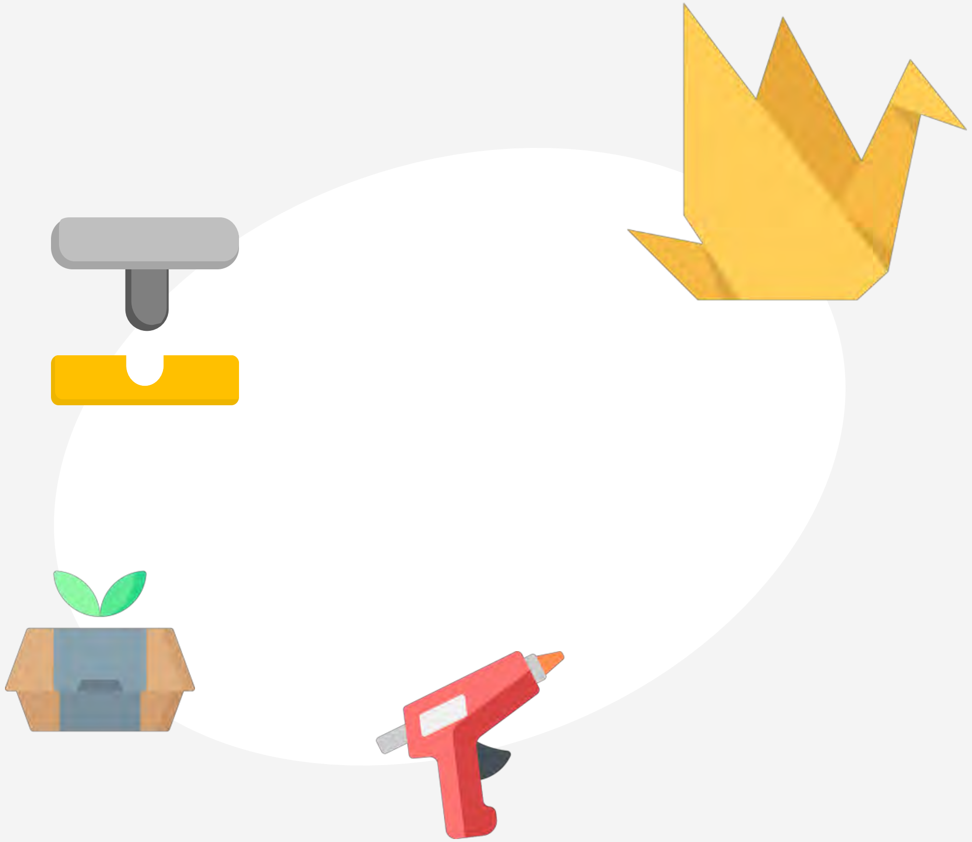
## Heat-sealing

Involves the softening and sealing of a thermoplastic polymer. Process parameters include **sealing temperature, time, and pressure**

Top tool: heated, flat. Bottom tool: flexible.

Measured with an **unsupported T-peel test**

# CONVERTING PROPERTIES AND TRAY FORMING



## Folding

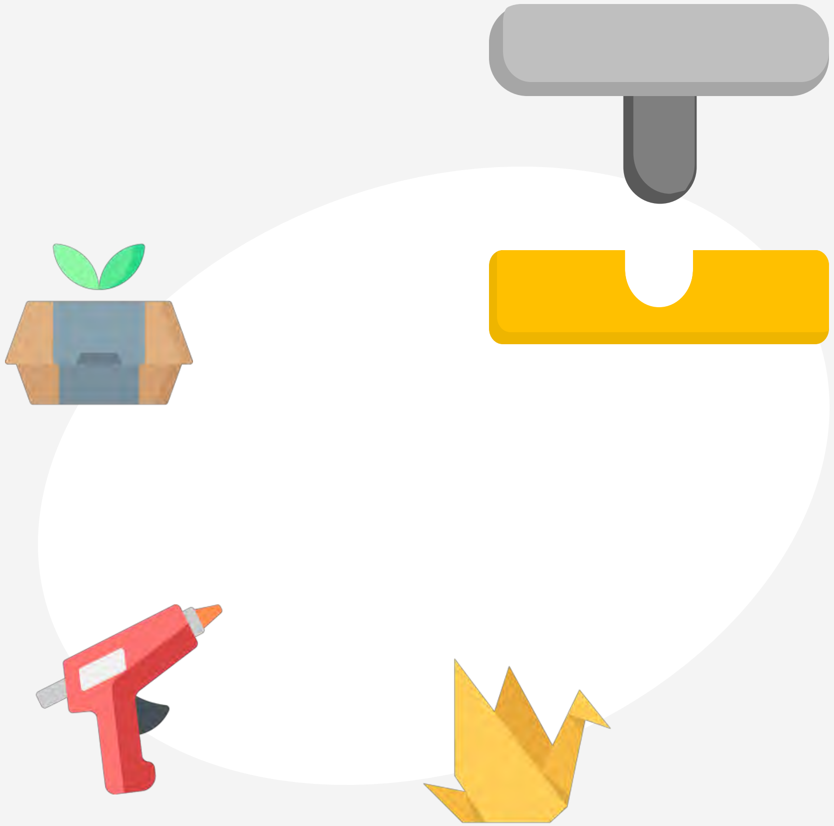
Involves tensile (compression) stresses on the outside (inside) of the fold line. It is influenced by the **coating orientation** and the **fold line orientation**, in addition to material properties and pressing speed and force.

Typically, fold cracking resistance testing is not standardised. In this study: a force of 10 N is applied along the fold line for 1 s; fold cracking assessed through optical measurement.

# CONVERTING PROPERTIES AND TRAY FORMING

In collaboration with:

LUT University



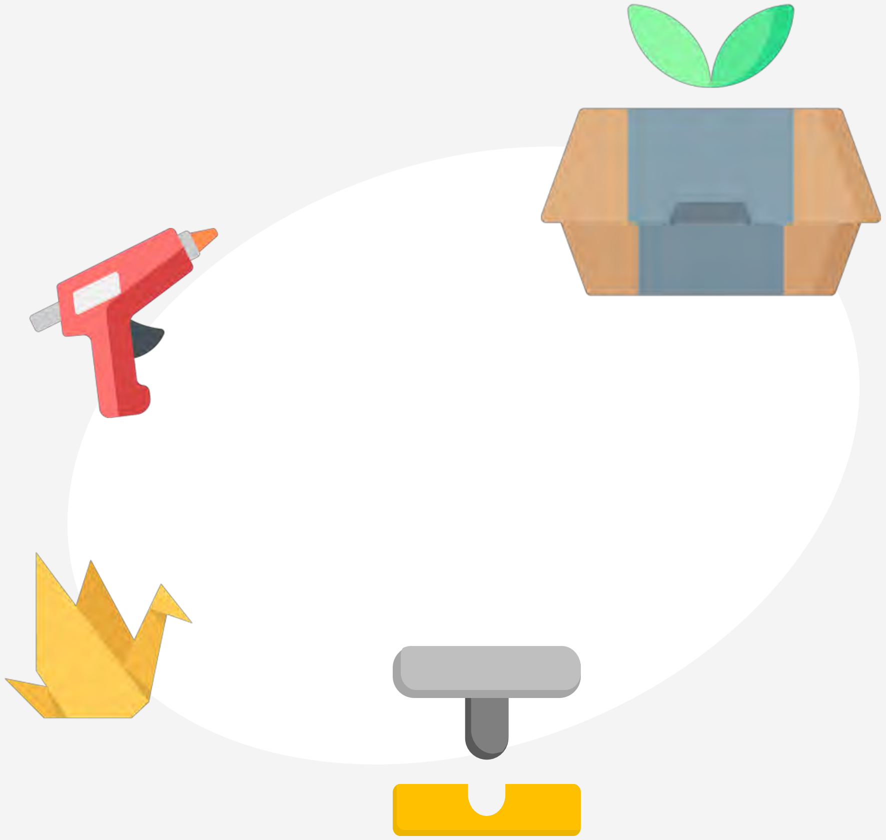
## Creasing

Performed to locally reduce bending stiffness of, e.g., paperboard and board through **delamination of the substrate layers.** Influenced by **crease rule and matrix geometry, crease stroke**, and material properties

In this study: 2 pt creasing rules.

Induced defects assessed with OGR test at 60 °C

# CONVERTING PROPERTIES AND TRAY FORMING



In collaboration with:

LUT University

## Tray forming

Press-forming of paperboard trays using heated moulds to impart a shape to a die-cut blank. Parameters that influence the performance are **mould temperature, pressing speed, blank holding force, as well as blank humidity content**

In this study, it was carried out on a pilot machine at industrial processing parameters. Possible coat defects marked with ethanol-based dye solutions

# RESULTS

## Paper – Heat-sealing

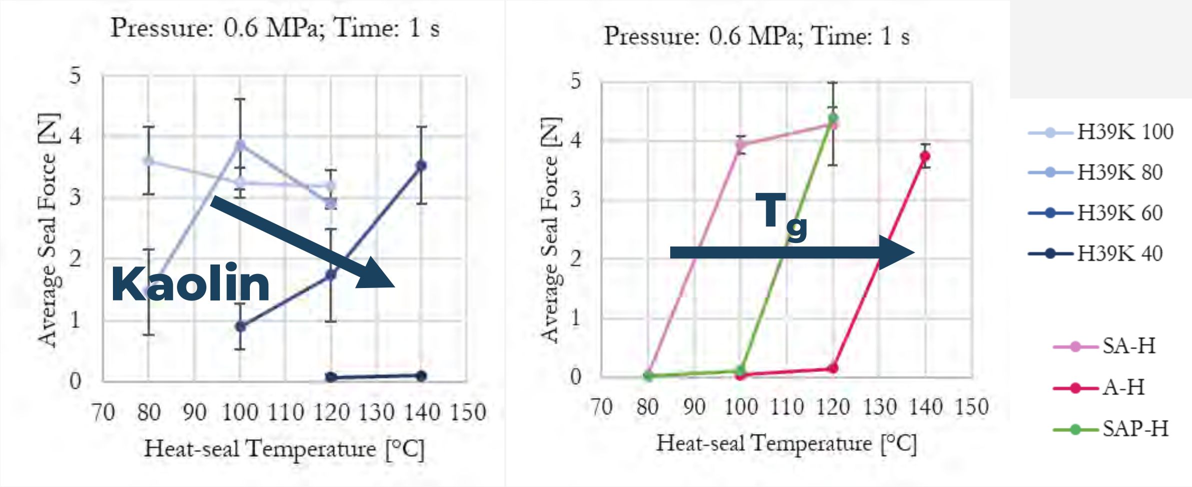
**Cohesive failure** occurred at the highest measured forces (**F ≥ 2.5 N/10 mm**), suggesting the low fibre tear resistance of the substrate

**Kaolin content** is the major factor affecting heat-seal ability. Generally, it is clear how the $T_g$ plays a crucial role

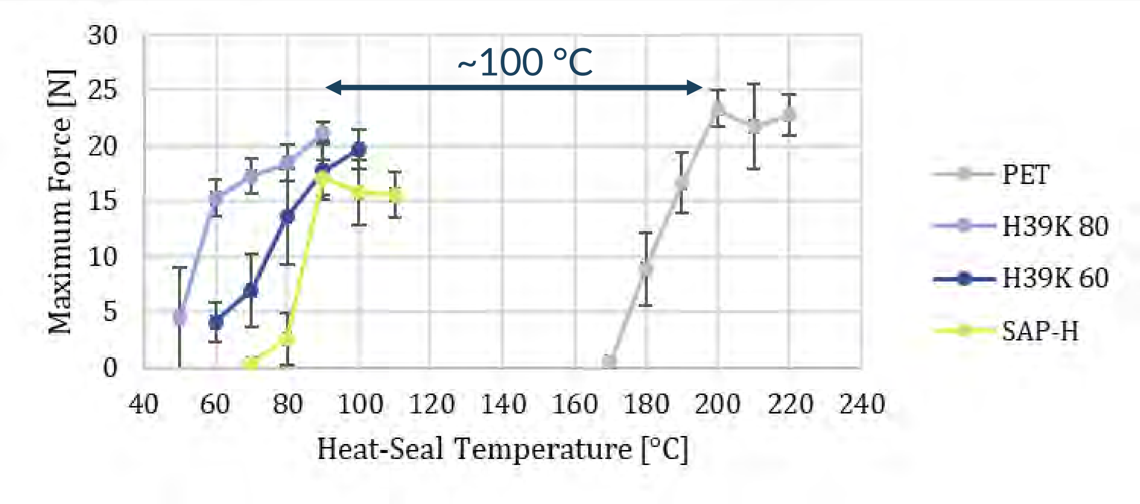
## Paperboard – Heat-sealing

The results were similar and coherent to coated paper ones

The graph shows how dispersion coating seal at **~100 °C lower compared to PET**, possibly beneficial for heat-sensitive content



*Average seal F of disp. Coat. (t = 1 s; P = 0.6 MPa)*



*Max seal F of disp. Coat. vs extrusion coated PET (t = 1.5 s; P = 2.5 MPa)*

# RESULTS

## Paper – Fold cracking

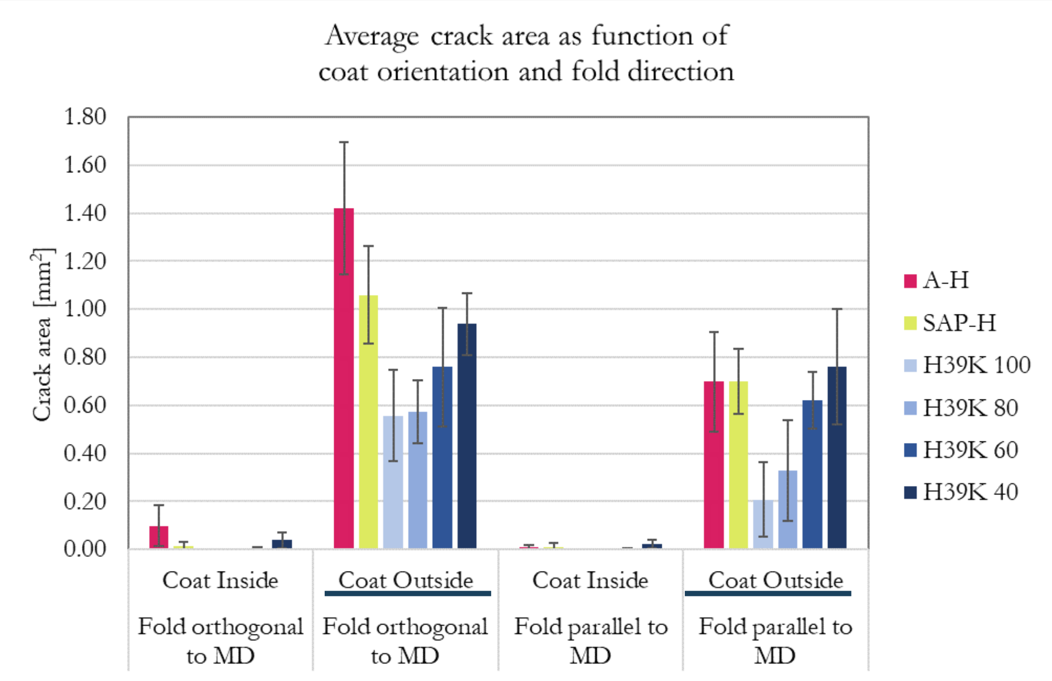
Fold under 10 N for 1 s. Dyed water was applied and overall crack area measured with ImageJ

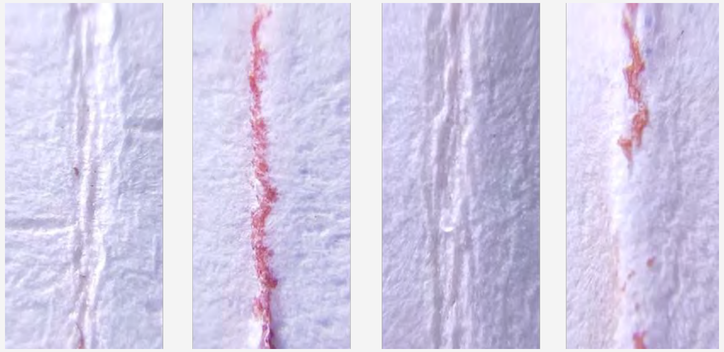
**Coat outside** is subjected to tensile stresses, showing how they broadly affect coat intactness. Cross Direction (CD⊥MD) folding leads to more damage

Commercial grades show poorer fold resistance due to lower **latex flexibility** (i.e., higher $T_g$)

**Kaolin content** embrittles the coating

Fold cracking influence barrier properties, e.g., **WVTR**, leading to an increase of up to twofold




H39K 60

# RESULTS

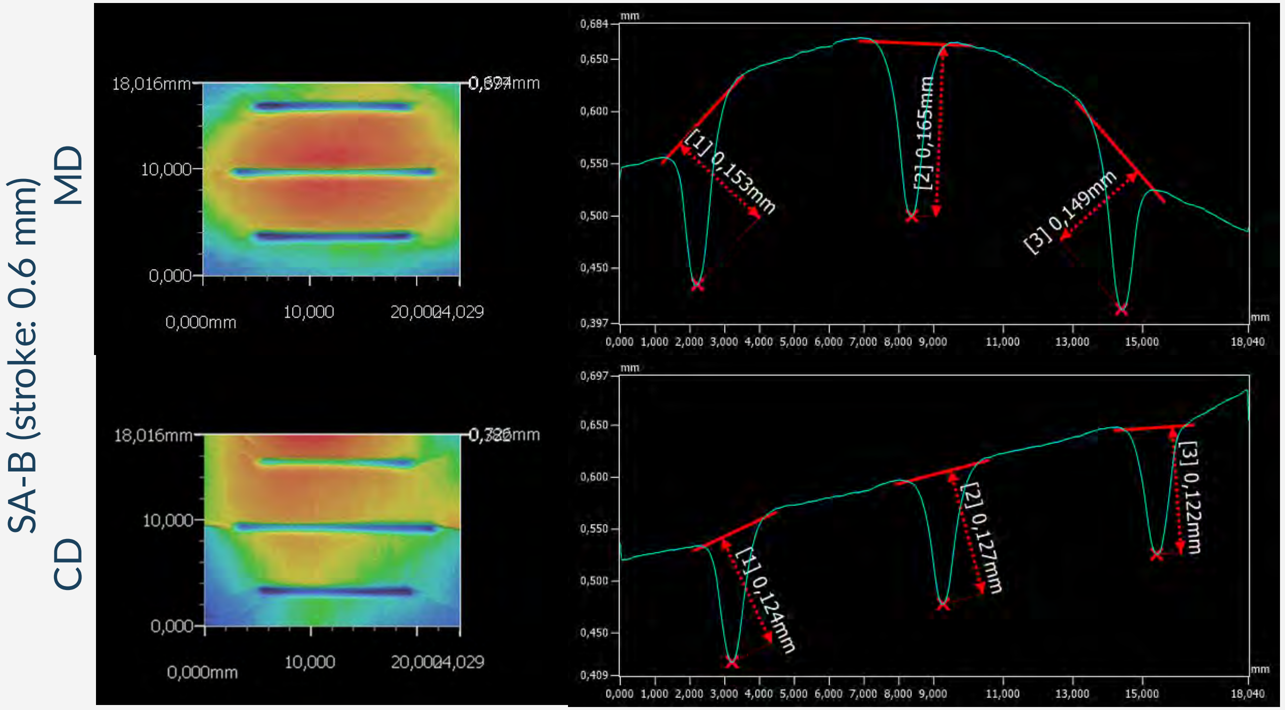
## Paperboard – Creasing

**Conventional creasing tool** parameters (2 pt., 0.4/1.2 crease matrix)

Crease depth was **up to 160 µm**. Machine Direction (MD) achieved higher residual depth compared to CD

**Coat integrity** (modified version of BS ISO 16532-1) provided quite outstanding results for both experimental and SAP-H grades

Due to higher brittleness at $T_{amb}$ ($T_g > T_{amb}$), **SA-B** showed some crease-induced defects



# RESULTS

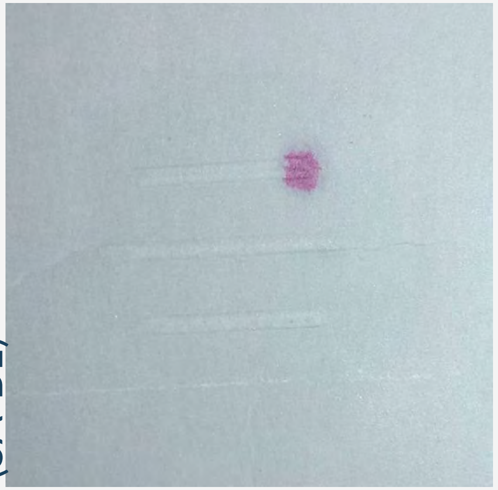
## Paperboard – Creasing

### Grease permeation resistance

| Stroke [mm] | Direction | H39K 80 | H39K 60 | SA-B1 | SAP-H | SA-B1+SAP-H | PET |
|---|---|---|---|---|---|---|---|
| 0.5 | MD | 6 < X < 24 h | 6 < X < 24 h | 180 | >24 h | 6 < X < 24 h | >24 h |
| 0.5 | CD | 6 < X < 24 h | 6 < X < 24 h | 180 | >24 h | 6 < X < 24 h | >24 h |
| 0.6 | MD | 6 < X < 24 h | 6 < X < 24 h | 150 * | >24 h | 360 * | >24 h |
| 0.6 | CD | 6 < X < 24 h | 6 < X < 24 h | 180 * | >24 h | 360 * | >24 h |

* Crease-induced defects were observed.


Grease permeation at 24 hours (TF PET)


Crease-induced defect (SA-B1)

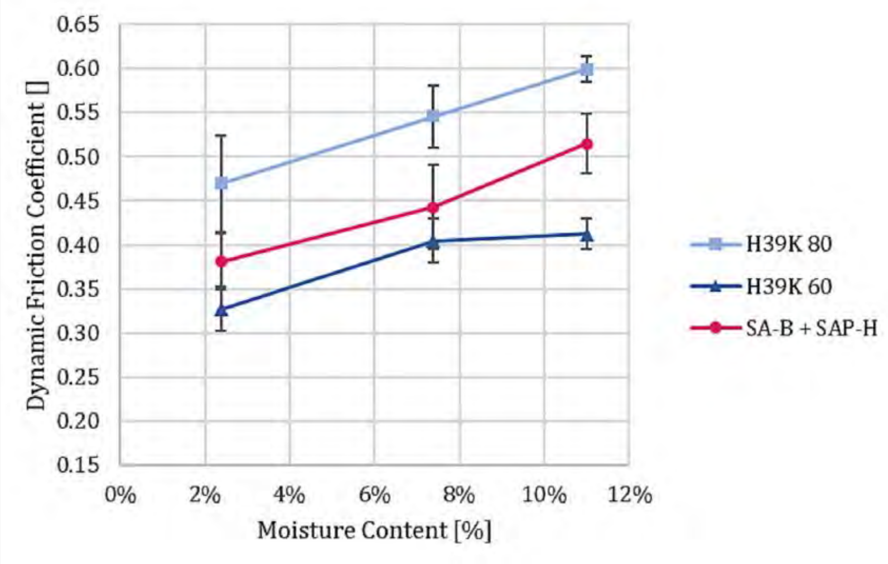

Crease-induced defect (SA-B1) – front side


Grease permeation at 24 hours (H39K 80)

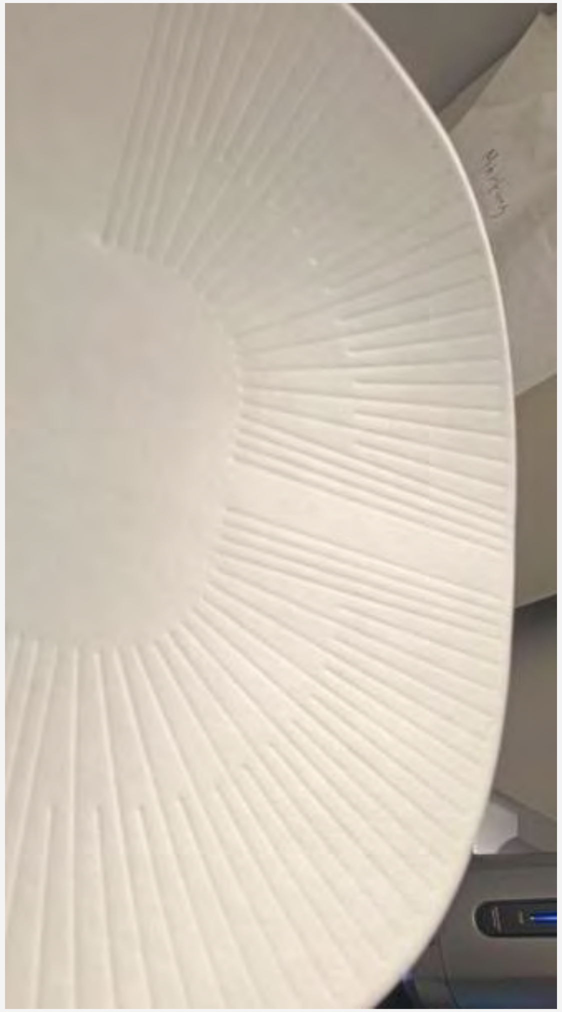
## Paperboard – Tray forming

**Performed on die-cut tray blanks** to achieve 1/9 foodstuff container

**Humidity content (HC)** is crucial not to have blocking. Dispersion coatings required ~4.5% HC, whereas extrusion coating requires ~9% HC



* The dispersion coating was placed against stainless steel plate.



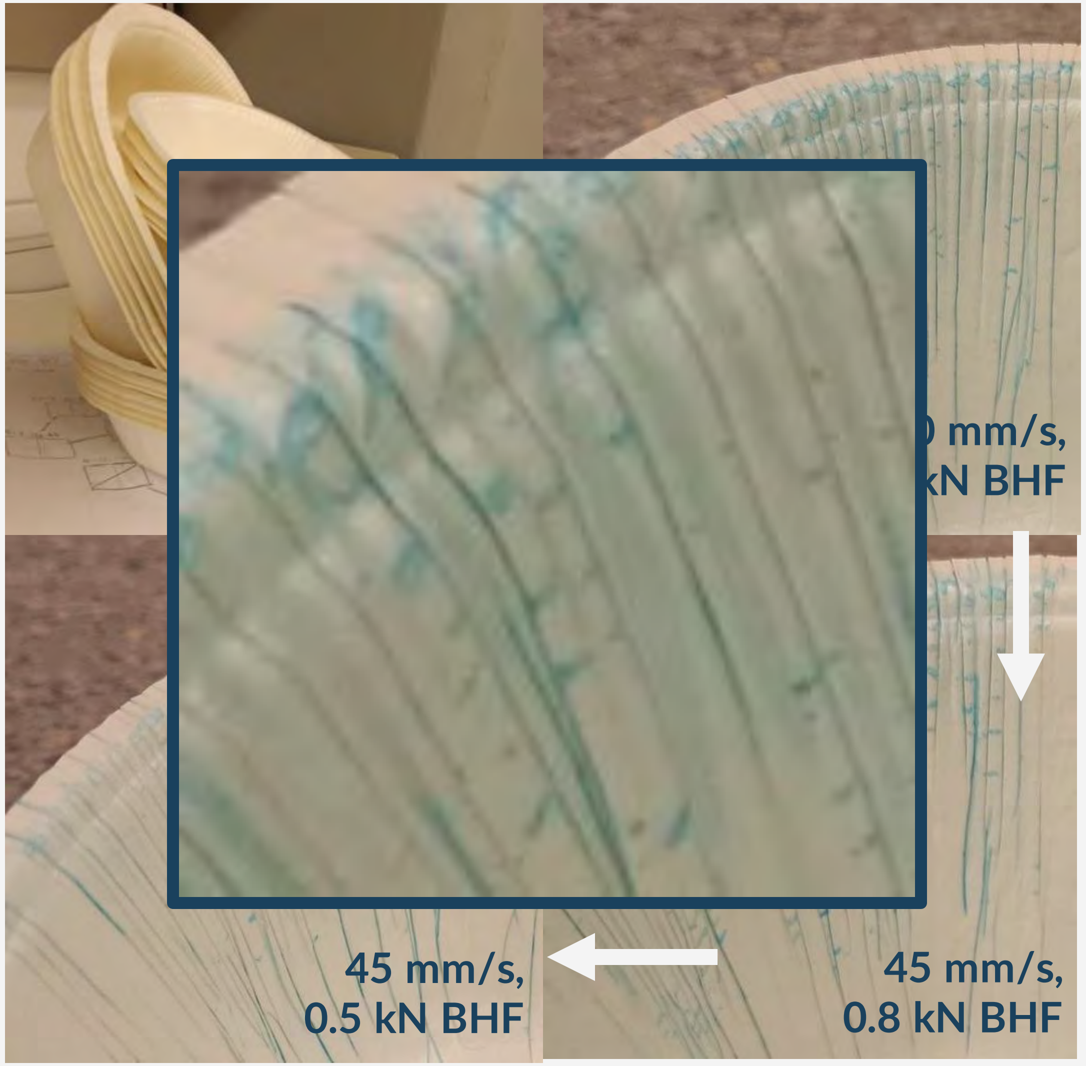
## Paperboard – Tray forming

**Blank Holding Force (BHF)** and **forming speed** are the main parameters to be adjusted. The lower, the better for dispersion coating integrity

This means, however, lower production yields and lower flange smoothness.

**Coat defects** suggested that the thin coatings cannot withstand tensile stresses during the forming process, especially for parameters typically used for extrusion-coated samples

*H39K 60*
*Humidity Content: 4.5 %*
*Mould Temp.: 120 °C*



# RECYCLING AND RECYCLABILITY

# RECYCLING

## Testing methodologies

### Italy

UNI 11743

### Europe

CEPI version 2

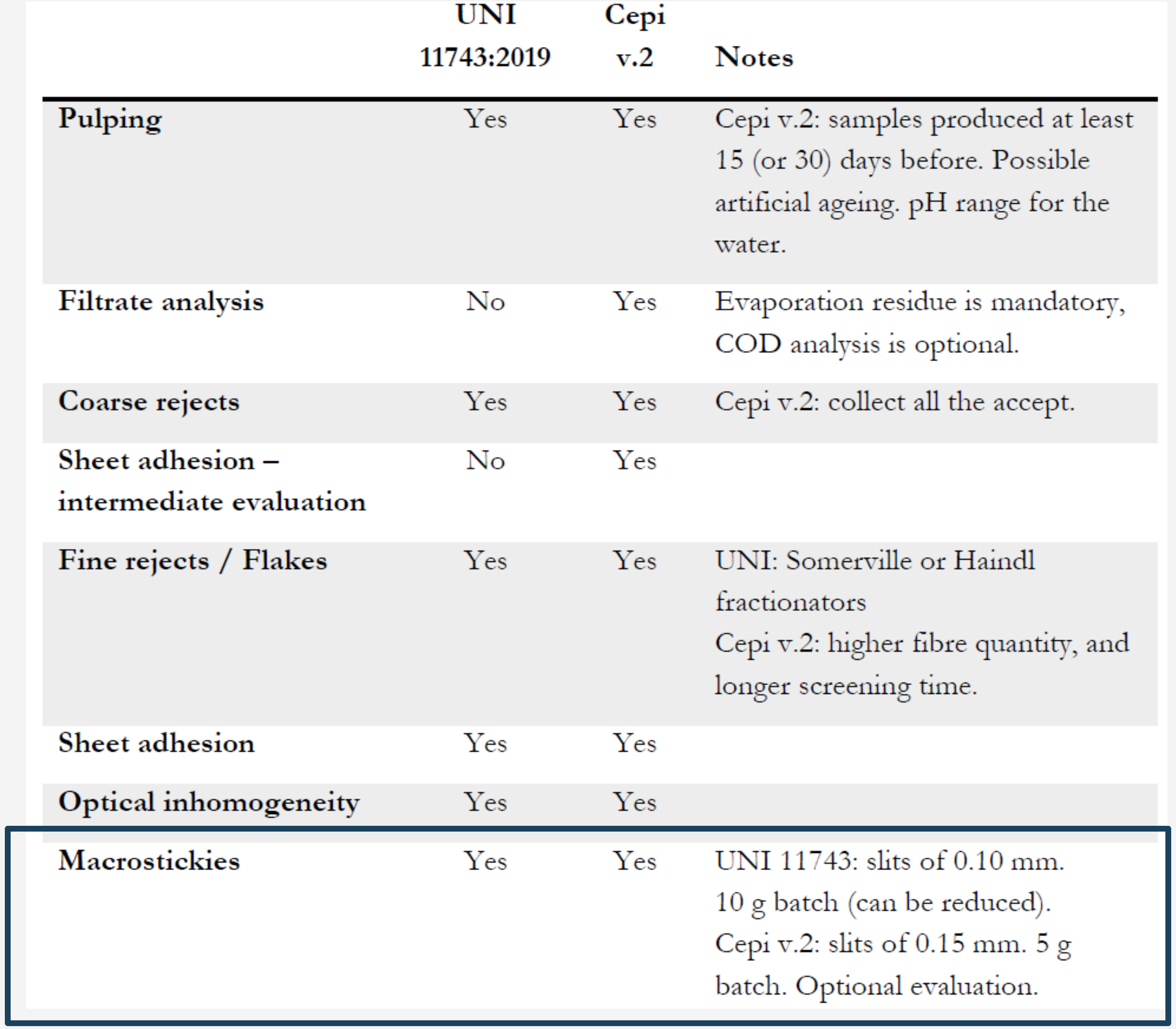
## Evaluation systems

### Italy

Aticelca 501

### Europe

4evergreen alliance



| | UNI 11743:2019 | Cepi v.2 | Notes |
|---|---|---|---|
| **Pulping** | Yes | Yes | Cepi v.2: samples produced at least 15 (or 30) days before. Possible artificial ageing. pH range for the water. |
| **Filtrate analysis** | No | Yes | Evaporation residue is mandatory, COD analysis is optional. |
| **Coarse rejects** | Yes | Yes | Cepi v.2: collect all the accept. |
| **Sheet adhesion – intermediate evaluation** | No | Yes | |
| **Fine rejects / Flakes** | Yes | Yes | UNI: Somerville or Haindl fractionators<br>Cepi v.2: higher fibre quantity, and longer screening time. |
| **Sheet adhesion** | Yes | Yes | |
| **Optical inhomogeneity** | Yes | Yes | |
| **Macrostickies** | Yes | Yes | UNI 11743: slits of 0.10 mm. 10 g batch (can be reduced).<br>Cepi v.2: slits of 0.15 mm. 5 g batch. Optional evaluation. |

# RECYCLING

| | H39K 80 | H39K 60 | SA-B1+SAP-H |
|---|---|---|---|
| **Coarse reject** | 2.8 % | 0.2 % | 0.2 % |
| **Fine reject / Flakes** | 7.6 % | 9.8 % | 8.2 % |
| **Macrostickies <2000 µm** | 58,487 mm²/kg | 21,271 mm²/kg | 127,313 mm²/kg |
| **Sheet adhesion** | Absent | Absent | Absent |
| **Optical inhomogeneity** | Level 1 | Level 1 | Level 1 |

✗ ✓ ✗

**Level C**

It could be expected, since they heat-seal quite easily (the kaolin content is crucial)

| | H39K 80 | H39K 60 | SA-B1+SAP-H |
|---|---|---|---|
| **Coarse reject** | 1.3 % | 0.3 % | 0.2 % |
| **Fine reject / Flakes** | 4.8 % | 5.9 % | 3.5 % |
| **Dissolved and colloidal solids <10 µm (evaporation residue)** | 0.8 % | 0.8 % | 1.1 % |
| **Macrostickies <2000 µm** | 113,110 mm²/kg | 10,060 mm²/kg | 108,410 mm²/kg |
| **Sheet adhesion – intermediate evaluation** | Absent | Absent | Partial |
| **Sheet adhesion** | Absent | Absent | Absent |
| **Optical inhomogeneity** | Level 1 | Level 1 | Level 1 |

✓ ✓ ✓

**90/100** **87/100** **93/100**

# CONCLUDING REMARKS

- Dispersion coatings represent an **interesting technology**
- **Processing properties** were good; **tensile stress resistance** is crucial, as visible in fold cracking and tray press forming results. **Latex softness** was positively correlated to coat stress resistance. **Fillers** reduced coating resistance
- **Heat-sealable** grades could heat-seal at temperatures as low as 80 °C, meaning possible energy savings for converters
- **Recyclability** is limited (to date) by macrostickies content for heat-sealable grades

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# Any question?

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