Maximizing seal strength of a commercial PET bottom web and top film with solid and liquid contamination

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Structure

- Introduction
- Materials
- Methods
- Results
- Conclusions

Structure

- **Introduction**
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- **Methods**
- **Results**
- **Conclusions**

Introduction

Commercial peelable packaging material: bottom web + top film

Used in the industry to pack raw meat and cheese

How to measure seal through contamination performance?

➔ Response surface model is used to compare maximum seal strengths with solid and liquid contamination

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Materials
Packaging

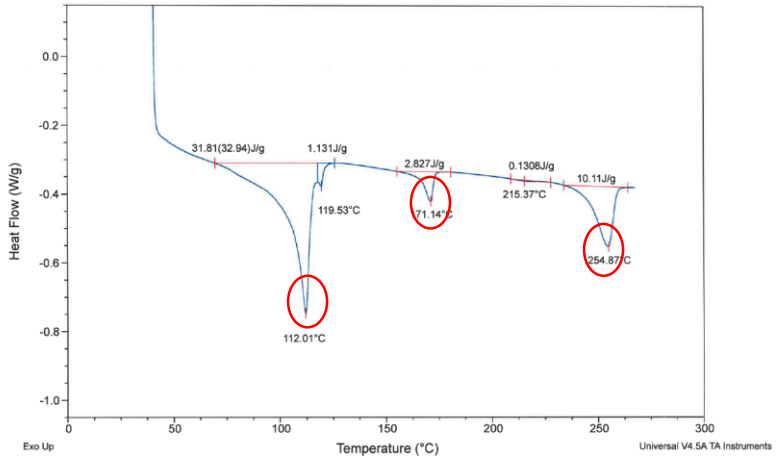
Commercial bottom web+top film with PET seal layer

Bottom web: monolayer APET 250 µm (sheet)

Top film: multilayer PET/PE-EVOH-PE/PETG 52 µm 12/20-4-10/6

Layer distribution top film

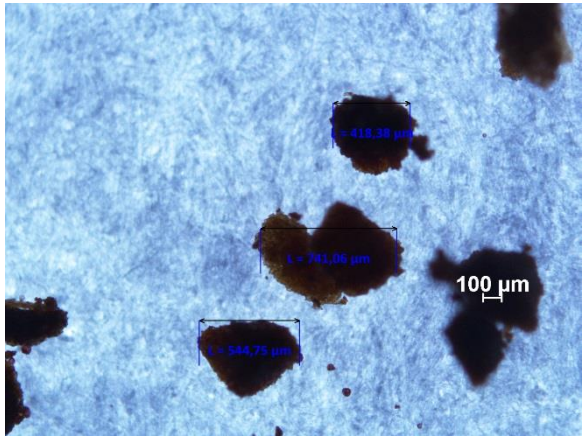
→Confirmed with DSC, ATR-FTIR and microscopy



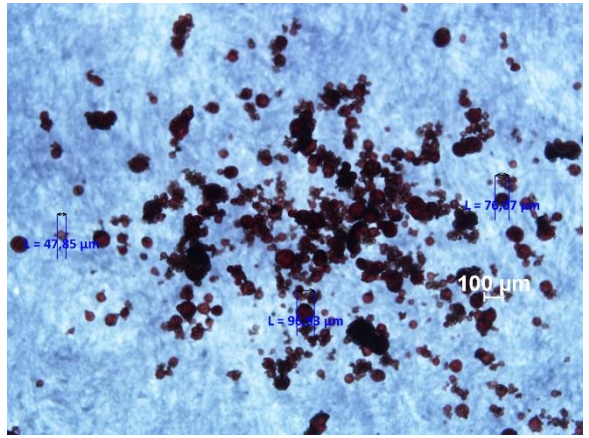
DSC thermogram of top film (second heating cycle)

Materials
Contamination

Solid contamination
Sieved ground coffee (particle diameter 500 µm < x < 630 µm)
Dried blood powder (particle diameter < 100 µm)



Coffee particles



Blood powder

Liquid contamination
Distilled water
Corn oil
Dissolved blood powder (1 part blood powder + 6 parts warm water)

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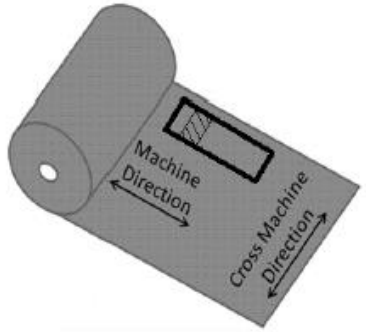
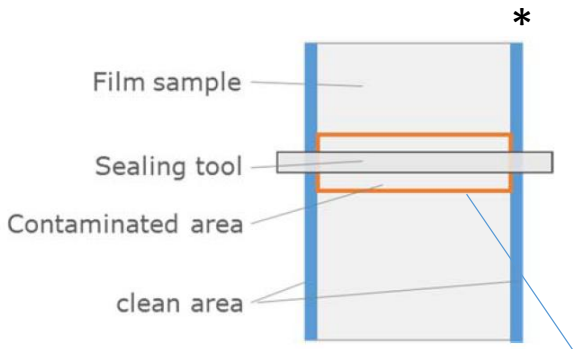
Methods

Sample preparation



Sample dimensions



Sample length: 7.5 cm
Machine direction

Sample width: 5 cm

Marked area: 40 x 20 mm²

Sealing jaws

Flat to flat alu jaws
Seal surface: 300x10mm²
Covered with silicon tape

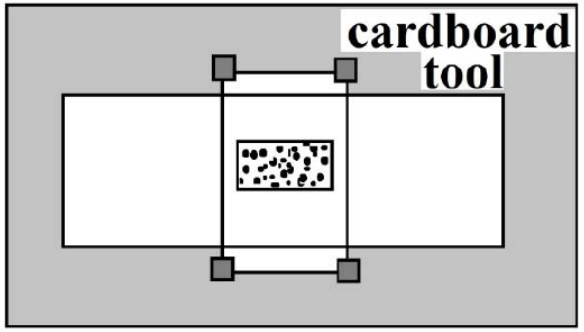
Heat conductive sealer
Labthink HST-H3
Temperature variation in upper jaw
Lower jaw at 50°C

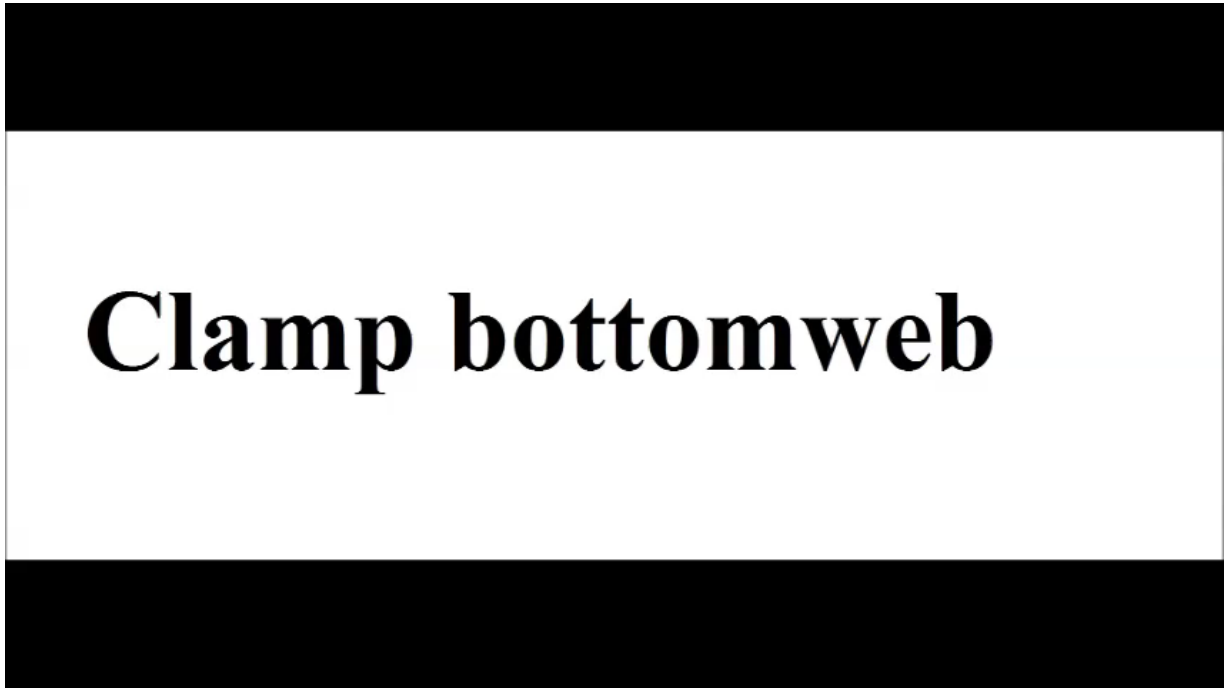
*IVLV Technical Bulletin No. 114/2019 “Method for analyzing the influence of contamination on seal properties of films for packaging applications”

Methods

Sample preparation

Use of sample holder (cardboard tool, surface rectangular hole > surface jaw area)*





- Clamp bottom web with tape
- Apply contamination (solid: 25 g.m^{-2} manually spread in the marked area; liquid: 3 droplets of 25 µl left-center-right in the marked area)
- Clamp top film with tape
- Sample is sealed, unsealed contamination is removed

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Methods

I-optimal design space

Limits of design space based on:

- Tray + top film concept (T_{max}, t) (220°C, 1.0 → 3.0 s)
- Preliminary tests (T_{min}) (140°C)
- Working range labsealer (p) (1.0 – 4.0 N/mm²)

Seal settings

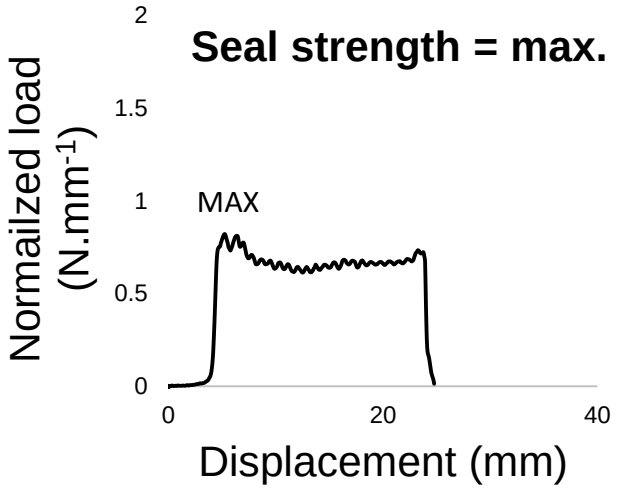
	Upper jaw temperature (°C)	Time (s)	Pressure (N/mm²)
1	178.4	2.1	1.9
2	220.0	1.0	3.2
3	140.0	1.3	1.6
4	179.9	2.0	3.3
5	180.0	2.0	3.2
6	195.5	3.0	3.4
7	171.7	3.0	1.9
8	140.0	2.1	3.1
9	220.0	2.0	1.0
10	177.8	2.1	1.8
11	172.0	1.0	4.0
12	140.0	3.0	4.0
13	220.0	1.0	1.9
14	220.0	3.0	1.0
15	180.0	1.0	1.0
16	140.0	3.0	1.0
17	220.0	3.0	2.4
18	220.0	2.0	4.0
19	140.0	1.0	3.3
20	180.3	2.0	1.8

Methods

Sample characterisation

Seal strength (ASTM F88)

MTS 10/M
Universal testing machine



- **Seal strength is maximized**
- **Corresponding seal parameters are obtained**
- **Validation of maximum n=10**

- 48h at 23°C, 50% relative humidity
- 15 mm samples are cut in the center of the sample
- Rate of separation of the sealing jaws: 300 mm/min
- Distance between grips: 10 mm
- Tail of the sample is not supported

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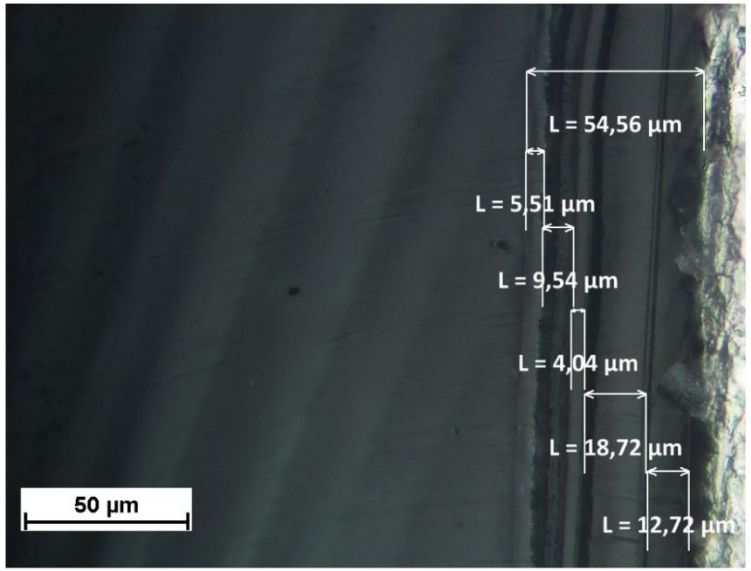
Results
Peel failure mechanism at high temperature

Sealed APET bottomweb - topfilm

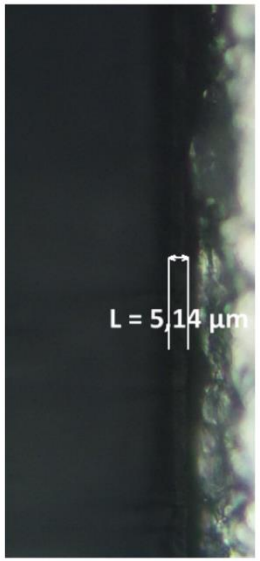


Bottom web
APET

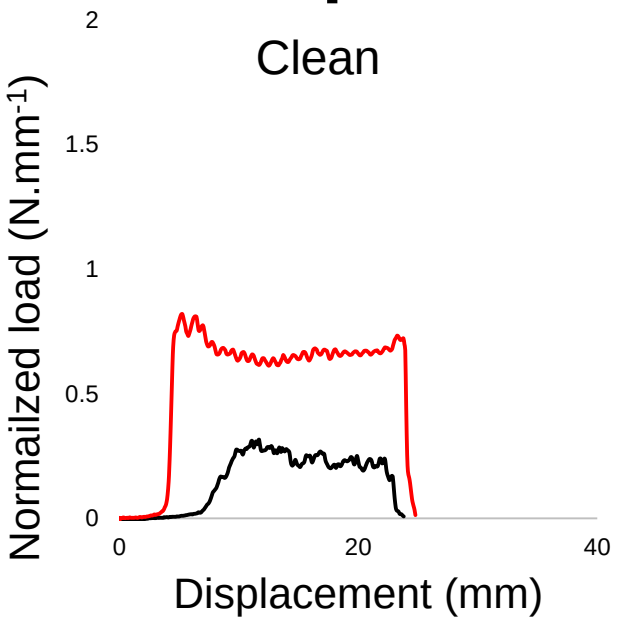
Top film
PETG/PE-EVOH-PE/PET

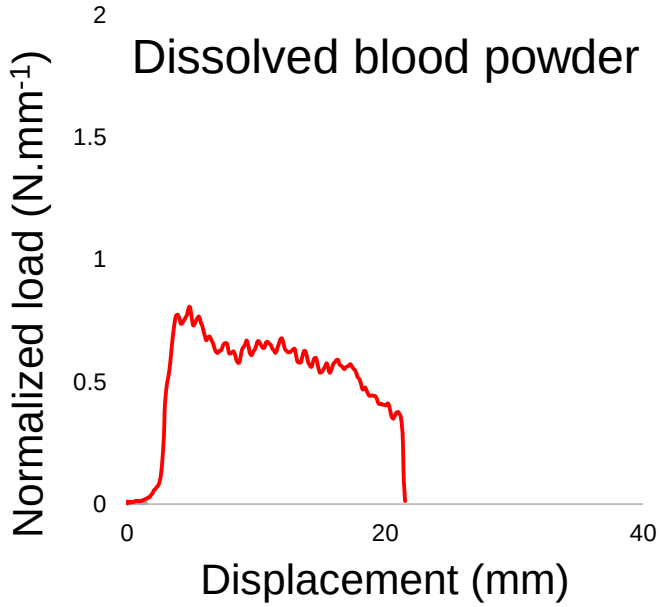
Peeling

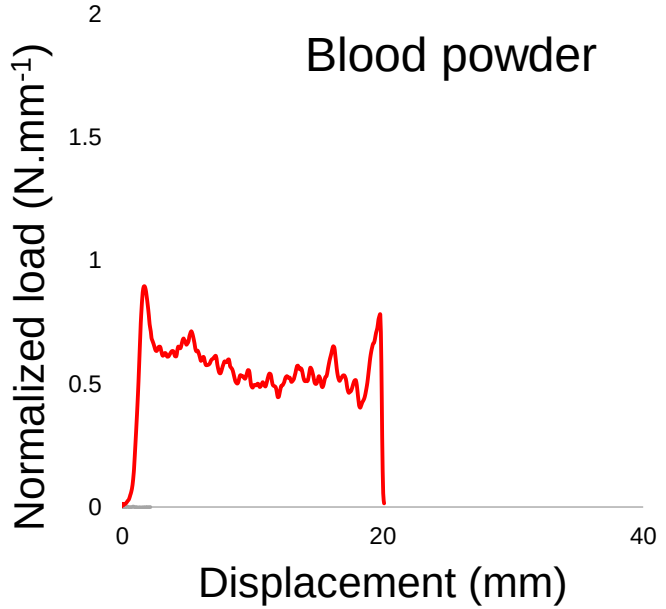
One 5-6 µm layer remains sealed against bottomweb (delamination peel)



Results
Load-displacement curves







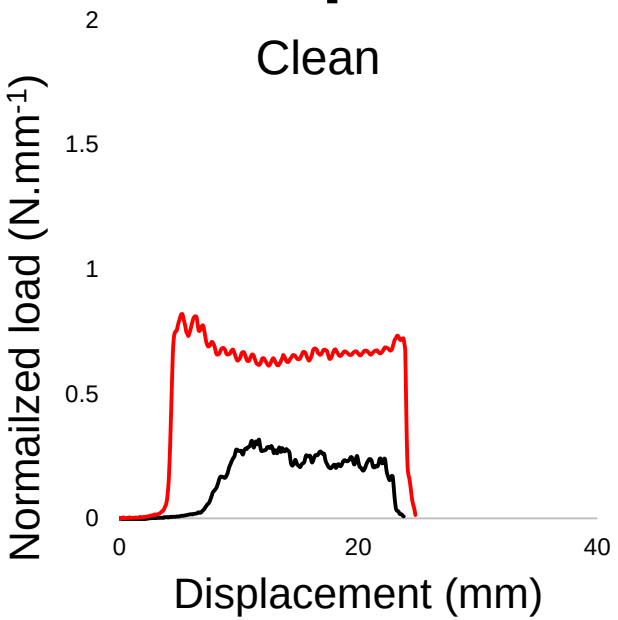
→ Pattern: peak → lower peel plateau
→ Peak: tearing of PETG layer?
→ 0.7 – 1.4 N.mm^{-1}
→ Peel plateau of ± 0.7 N.mm^{-1}

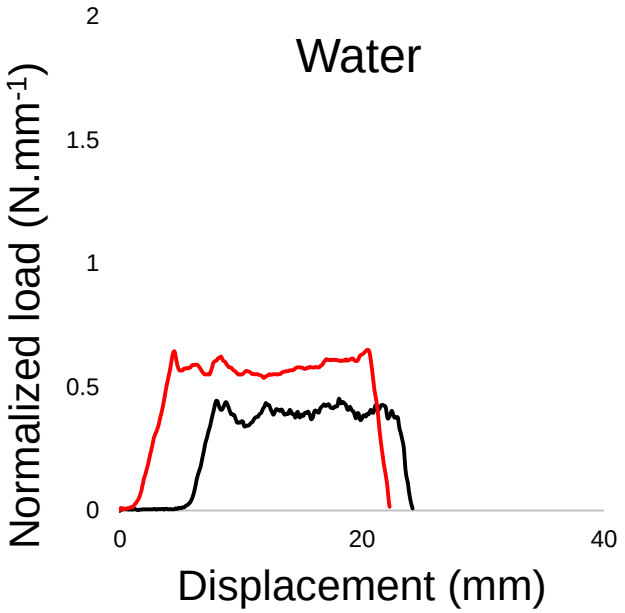
→ Similar to results blood powder
→ Higher $T_{seal\ initiation}$

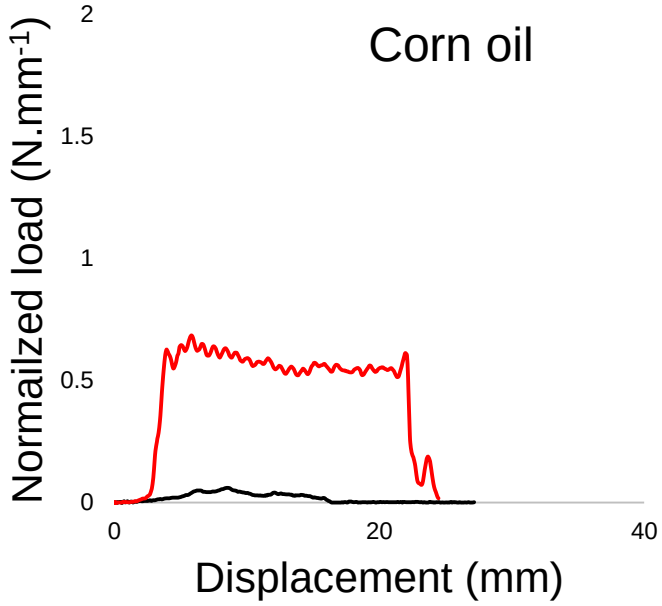
→ Similar peak values as clean seals with high settings
→ Peel plateau seems to decrease
→ Higher $T_{seal\ initiation}$

Parameter settings of shown curves
140°C_1.3s_1.6N.mm^{-2}
220°C_2.0s_1.0N.mm^{-2}

Results
Load-displacement curves







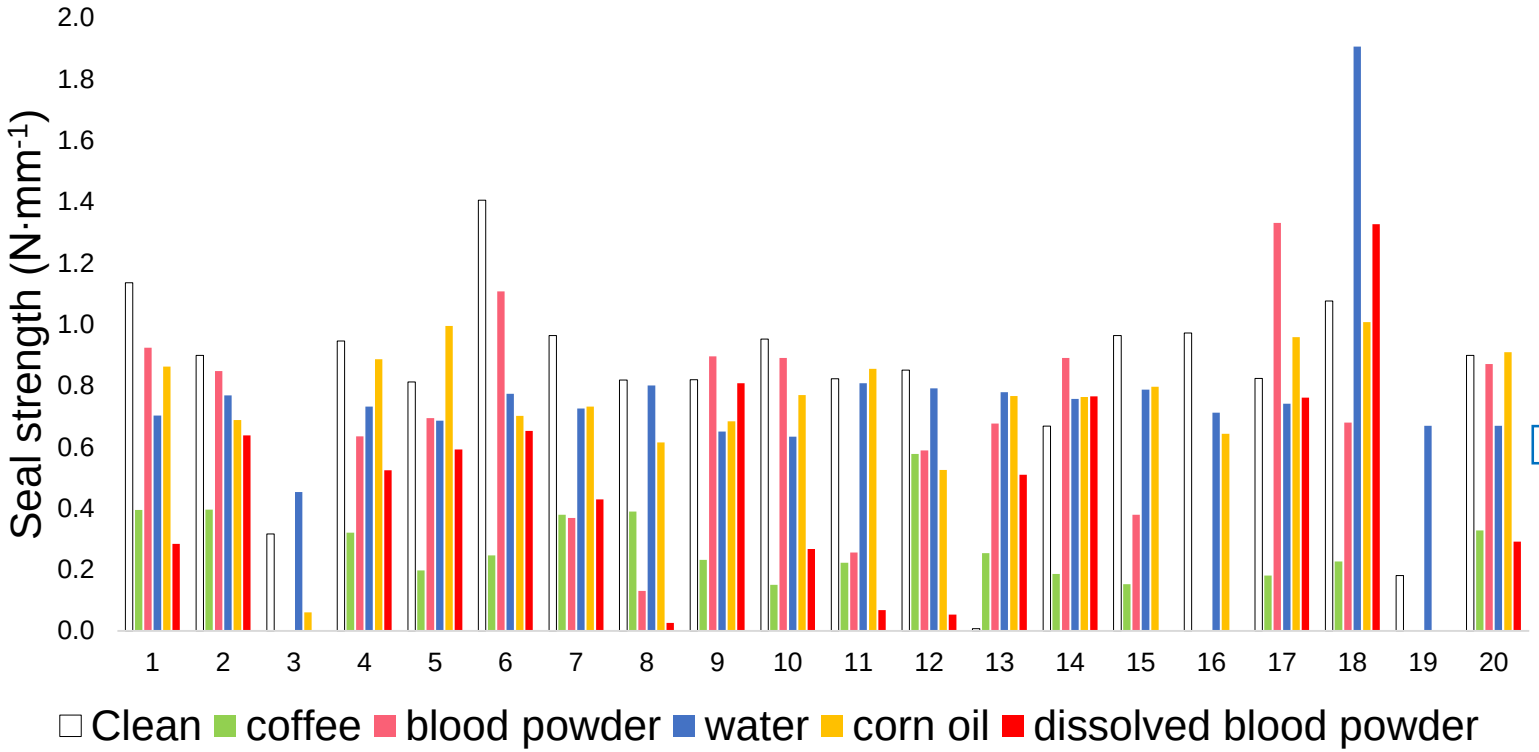
→ Pattern: peak → lower peel plateau
→ Peak: tearing of PETG layer?
→ 0.7 – 1.4 N.mm^{-1}
→ Peel plateau of ± 0.7 N.mm^{-1}

→ Similar to clean seals

→ Similar to clean seals
→ Slightly higher $T_{seal\ initiation}$

Parameter settings of shown curves
140°C_1.3s_1.6N.mm^{-2}
220°C_2.0s_1.0N.mm^{-2}

Results
Seal strength + selection of model



	Number of terms	R^2	AICc	BIC
Clean	6	0.75	-2.86	-5.23
Coffee	7	0.70	-8.78	-17.82
Blood powder	6	0.84	10.00	4.88
Water	6	0.77	2.77	-2.35
Corn oil	8	0.62	-12.70	-30.75
Dissolved blood powder	7	0.93	-2.51	-11.55

→ Difficult to make conclusions based on these results → these results are used as input for the model

→ Low seal strength for seals with coffee contamination

Selection of model based on:

- AICc (Akaike information criterion) ↘
- BIC (Bayesian information criterion) ↘
- R^2 ↗

Results
Maximum seal strength and corresponding parameters

	Upper jaw temperature (°C)	Time (s)	Pressure ($N.mm^{-2}$)	Predicted Seal Strength ($N.mm^{-1}$)
Clean	191.6	3.0	4.0	1.5
Coffee	140.0	3.0	4.0	0.5
Blood powder	220.0	3.0	2.8	1.2
Water	140.0	3.0	4.0	0.8
Corn oil	196.1	2.3	4.0	1.0
Dissolved blood powder	220.0	3.0	4.0	1.2

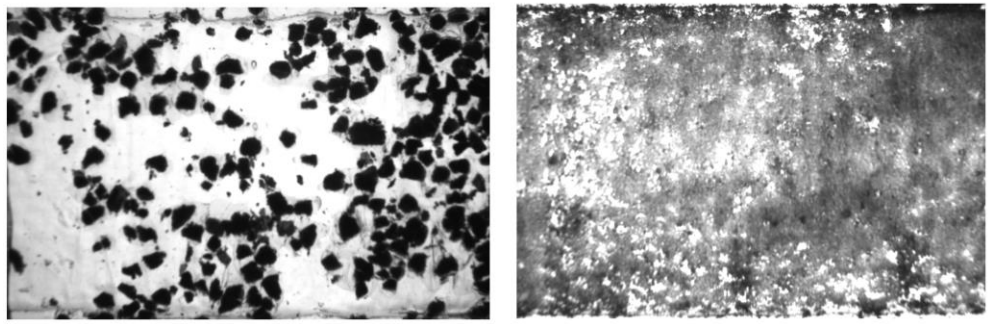
Seal strength is maximized + corresponding parameters are obtained

→ Upper jaw temperature dependent on used contamination (similarity in optimal settings blood powder and dissolved blood powder) → customized approach needed

→ High optimal seal time and pressure needed

→ Contaminated seal strength: high variation, especially with solid contamination (coffee – blood powder: 0.5 - 1.2 $N.mm^{-1}$)

High resolution digital imaging set up + LED backlight illumination: samples sealed at 220 °C, 3.0 s and 2.4 $N.mm^{-2}$



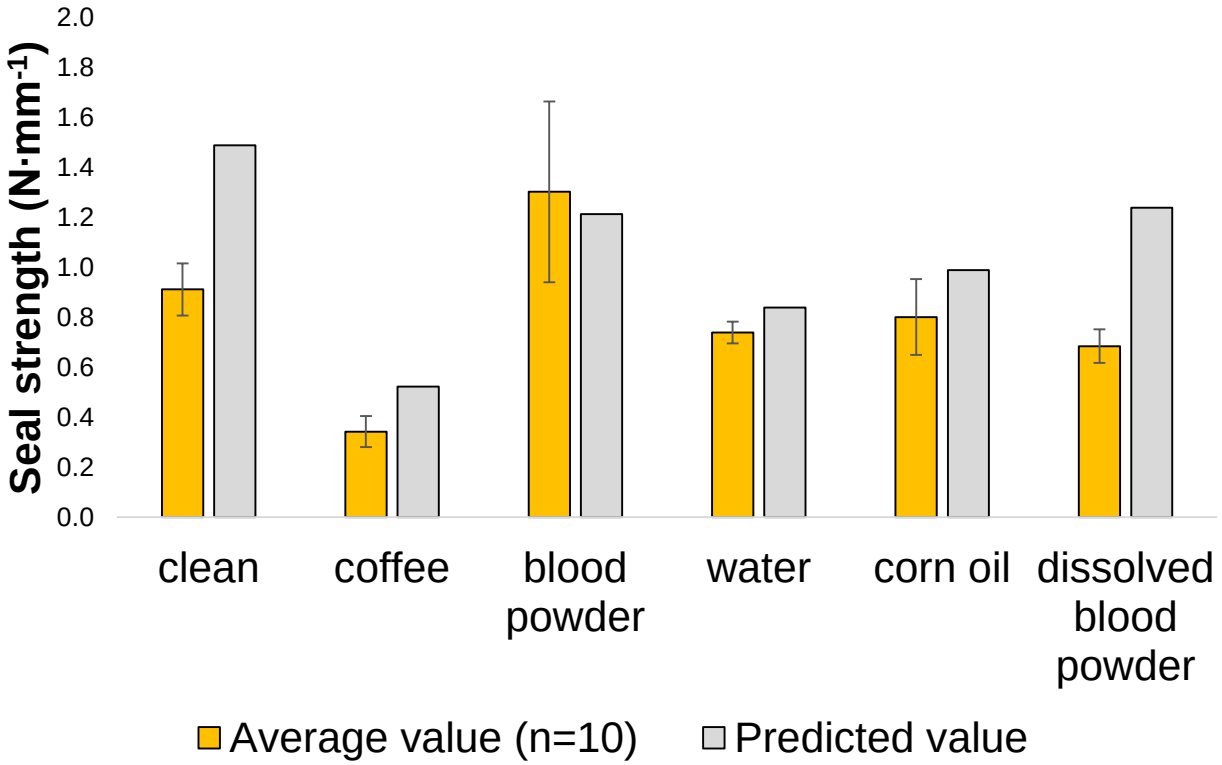
Coffee particles: encapsulated, no morphological change
Blood powder: particle→ smear with high temperature

Why?

- Thick coffee particles (> 500 µm) – thin seal layer (6 µm GPET) + stiffness PET seal layer?
- Chemical interactions?

But: more binding spots with coffee when applying same weight (25 $g.m^{-2}$)

Results
Validation of max. seal strength



- → Model has a tendency to overestimate the predicted values
  - → Higher accuracy: repetitions and/or extra experiments
- → Compared to clean seal strength only coffee has a clear negative impact on max. seal strength
- → What do you want to achieve: High peak values, high peel plateau values?
  - → use constraints
  - → adjust design limits
  - → maximize peel plateau

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Conclusions

- **A customized approach is needed to obtain a high seal strength in presence of contamination → A response surface methodology can be used to maximize seal strength and obtain the corresponding parameters**
- **Coffee powder has a negative impact on maximum seal strength**
- **Less/no clear negative impact of other contamination (blood powder, water, corn oil, dissolved blood powder) on maximum seal strength**
- **Similar optimum parameters for blood powder and dissolved blood powder (combination of high seal temperature, time and pressure)**

“Thank You” for listening

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