TAPPI INTERNATIONAL FLEXIBLE PACKAGING & EXTRUSION DIVISION

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Extrusion Coating with PVOH to Produce High-Barrier Paper-Based Packaging

Presented by Aquapak Polymers Ltd., Mica Corporation, and SAM North America

Outline:

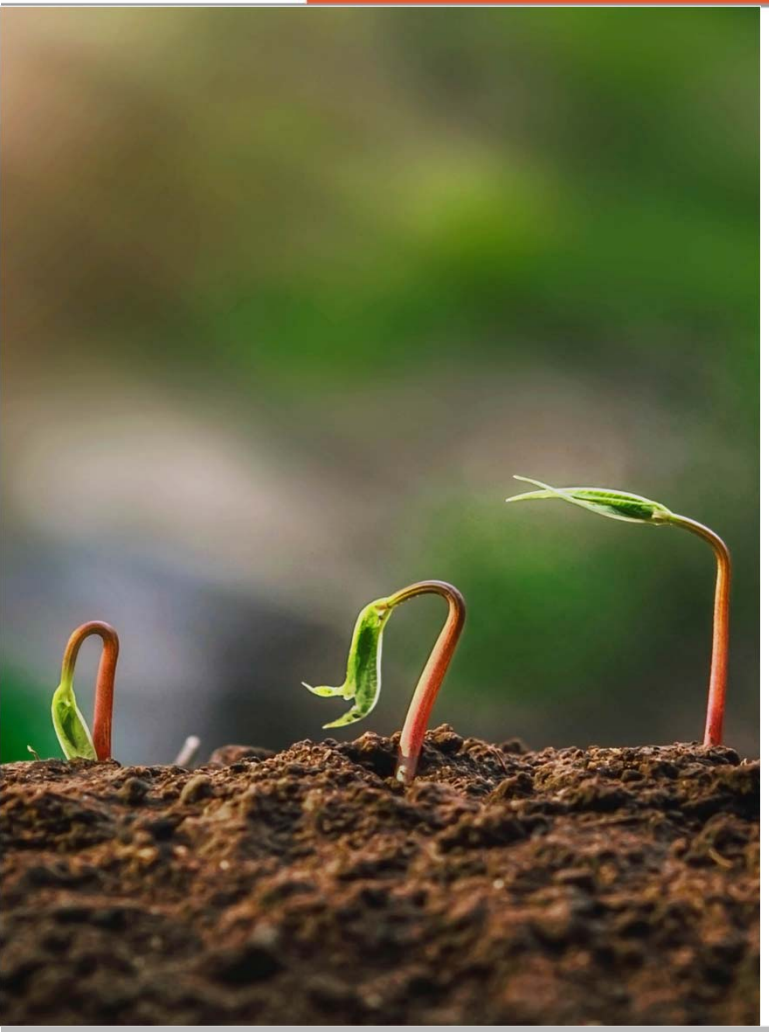
- Background of study
  - Benefits of PVOH functional coating
  - Challenges associated with PVOH extrusion coating
- Experiment and Results

Phase I: **Evaluate PVOH adhesion with various water-based extrusion coating primers**

Phase II: **Test adhesion of PVOH on various primed paper substrates**

Phase III: **Determine machine and coat weight parameters and processing conditions**

- Conclusion



Background of study

- Demand for sustainable flexible packaging is increasing globally
- Companies are shifting to paper-based substrates and biopolymers, bio-based resins, or water-soluble PVOH
- PVOH is an excellent alternative to traditional plastics

Benefits of Extrudable PVOH

Functional

- Excellent barrier against oxygen, oil and grease
- High heat seal strength and mechanical strength

Compatible

- With extrusion coating process
- With paper recycling and repulping process

Sustainable

- Fully soluble in warm water (at 40°C)
- Compostable and marine safe

Examples of Extrudable PVOH Applications

- Light weight mailer bags
- Paper based air pillow
- Pet food packaging
- Confectionary packaging
- Snack food packaging

Challenges of PVOH Extrusion

- Low adhesion to paper under normal conditions
  - High crystallization rate, high crystallization temperature and low processing temperature
- PVOH degrades at temperature >220°C

Solution

This study will identify a water-based primer to promote adhesion and determine machine parameters, coat weights, and processing conditions necessary for success.

Phase I

Evaluate PVOH adhesion with various water-based extrusion coating primers

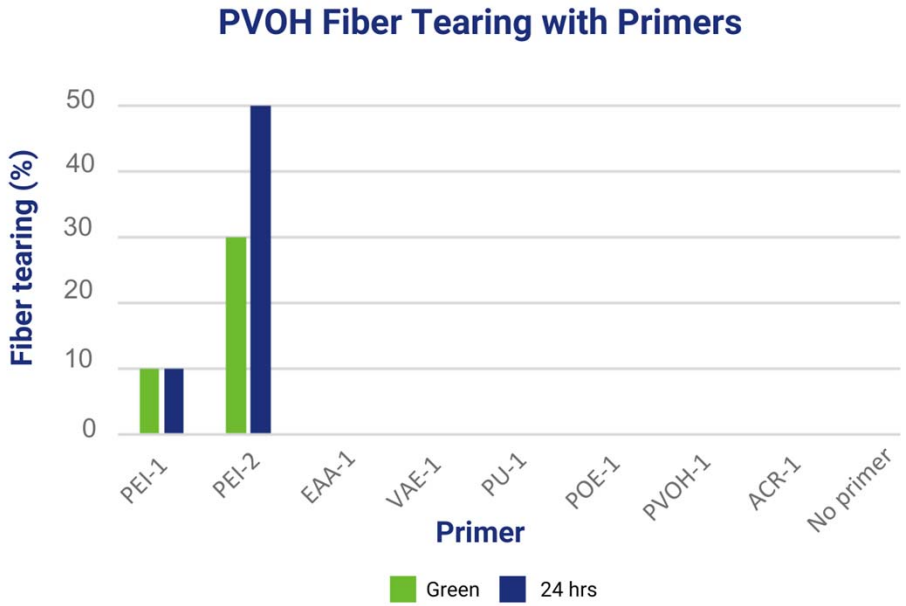
- Seven **primers** were evaluated against the control and bare substrate.

Primer	Solids (%)
PEI-1 (control)	5
PEI-2	12
EAA-1	10
VAE-1	50
PU-1	30
POE-1	40
PVOH-1	8
ACR-1	40
No Primer	0

- Fiber tearing checked immediately and one day after extrusion coating.

Experiment	
Substrate	68 gsm kraft paper, Corona treated
PVOH resin	
Density	1150-1250 g/cm^3
MFR	10.0-14.5 g/10 mins
Melting temperature	170-180°C
Extrusion (on Randcastle extrusion coater) three heated and cooled barrel zones, 1" general purpose screw with L/D ratio of 24, and 25 cm width slot die.	
Extrusion temperature	410°F (210°C)
rpm	35 rpm
Line speed	33 fpm (10 mpm)
Coating thickness	~1 mil (25.4 µm)

Results: Fiber Tearing with Different Primers



Primer	PEI-1	PEI-2	EAA-1	VAE-1	PU-1	POE-1	PVOH-1	ACR-1	No primer
Solids (%)	5	12	10	50	30	40	8	40	0
Coat Weight (gsm)	2.6	3.0	1.6	6.7	4.6	5.4	1.2	1.6	0

Phase I Results

- **PEI-based primers** can help PVOH achieve fiber tearing.
- Higher solids PEI primer shows better results than the lower solids PEI primer.
- Hydrogen bond acceptors and low crystallinity of PEI molecules can be attributed to its affinity to PVOH.

Phase II

Test adhesion of PVOH on various primed paper substrates

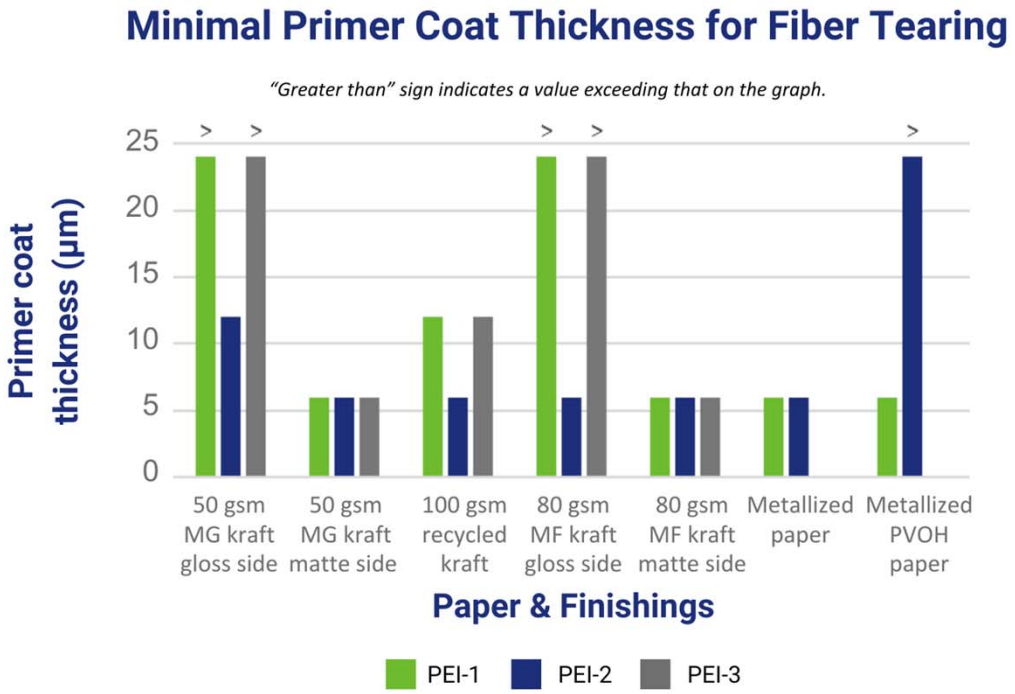
- **PEI-1, PEI-2, PEI-3** were evaluated on various papers and finishings

Paper	Basis Weight (gsm)	Finishing
MG kraft	50	Gloss
MG kraft	50	Matte
Recycled kraft	100	--
MF kraft	80	Gloss
MF kraft	80	Matte
Unidentified Paper	--	Metallized
Unidentified Paper	--	Metallized PVOH

- Primers were compared by the minimal wet coating weights required for the onset of fiber tearing.

Experiment	
Coat weight of primer	
Yellow K bar	6 µm wet
Red K bar	12 µm wet
Green K bar	24 µm wet
Extrusion Coater (lab-scale) Five heated and cooled barrel zones, 1" general purpose screw with L/D ratio of 24 , and 20 cm width slot die.	
Extrusion Temperature	205°C
Line speed	10 mpm

Results: Fiber Tearing with Different Papers



Phase II Results

- Higher solids PEI primers were more effective across all paper substrates and finishings.
- High efficiency means less water in coating, and thus less wrinkles, higher line speed and paper strength.
- Paper finishing has an impact on adhesion. For example, fiber tearing from matte finishing requires less primer than the gloss finishing.

Phase III

Determine machine and coat weight parameters and processing conditions

- Extrusion coating trial to determine primer coat weight and processing parameters.

Fpm (mpm)	Coat weight
200 (61)	~1 mil (25.4 µm)
300 (91)	~1 mil (25.4 µm)
400 (122)	0.75 mil (19 µm)
500 (152)	0.6 mil (15.2 µm)
600 (183)	0.5 mil (12.7 µm)

- The paper-PVOH laminates were checked for fiber tearing and adhesion strength measured by T-peel.

Experiment	
Priming station	
Applicator	Direct, banded gravure (see Image-1) Chambered doctor blade
Dryer	Two-zone heated air dryer
Extrusion Coater (Pilot scale) Three extruders of 2 ½", 2" and 1 ¼" in diameter each at 34:1 L/D, 5-layer vane adjustable feed block, and 40" NordsonEDI EPC internally deckled die.	
Extrusion Temperature	430°F (221°C)

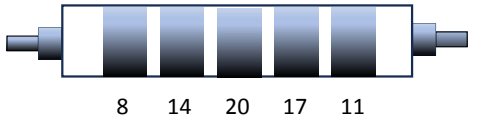
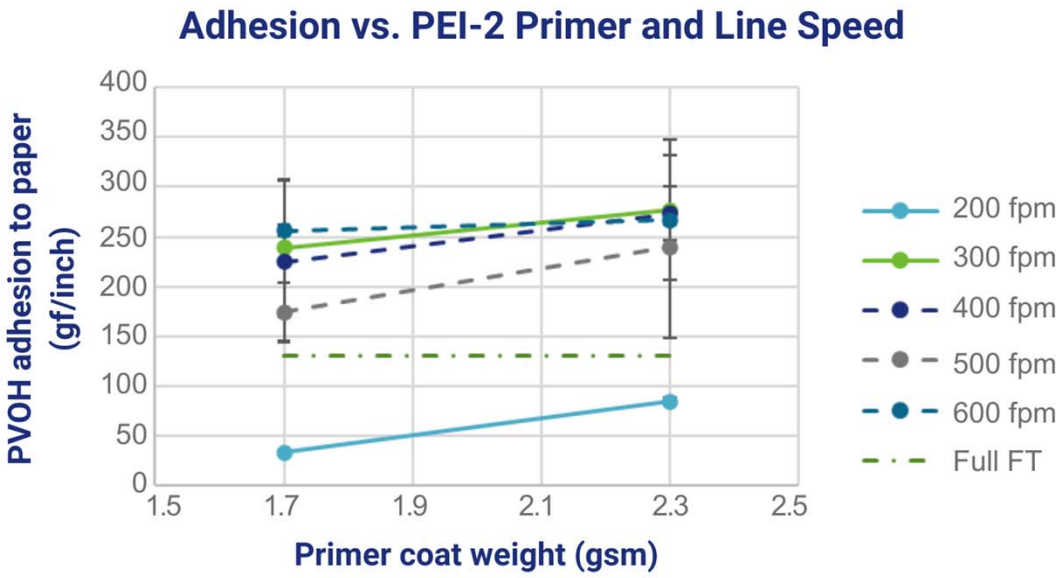


Image-1: Banded gravure patterns (BCM)

Results: Effects of Primer Coat Weight and Line Speed

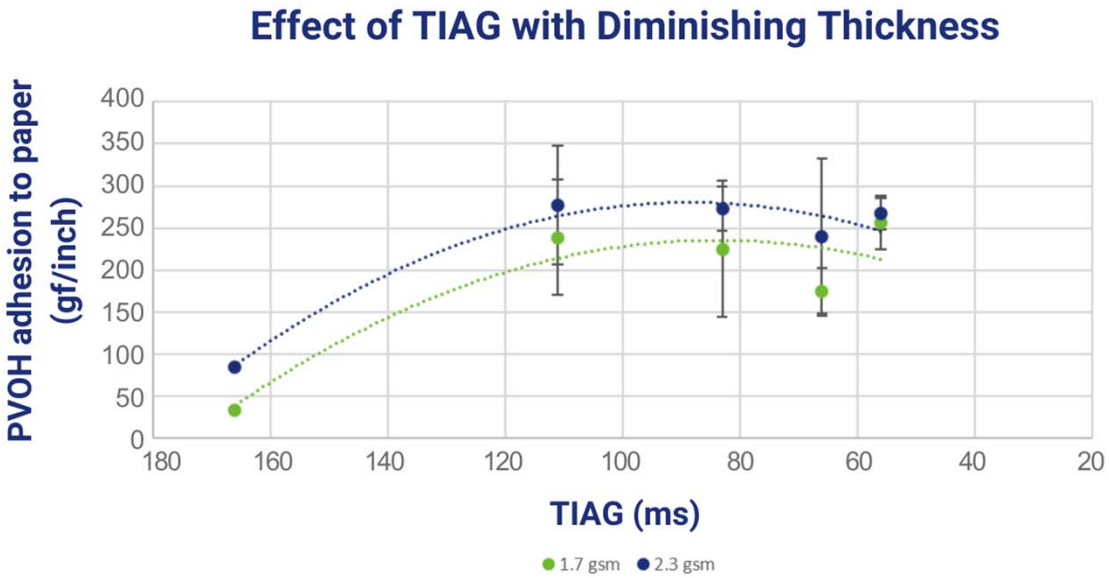


Green dashed and dotted line corresponds to the estimated fiber tearing seal strength

Phase III Results

- Both primer and line speed are important for PVOH adhesion to paper.
- Bond strength increases with the coat weight of primer.
- Primer alone cannot generate full fiber tearing without increasing line speed above 300 fpm.
- Coextrusion and downgauging does not affect fiber tearing

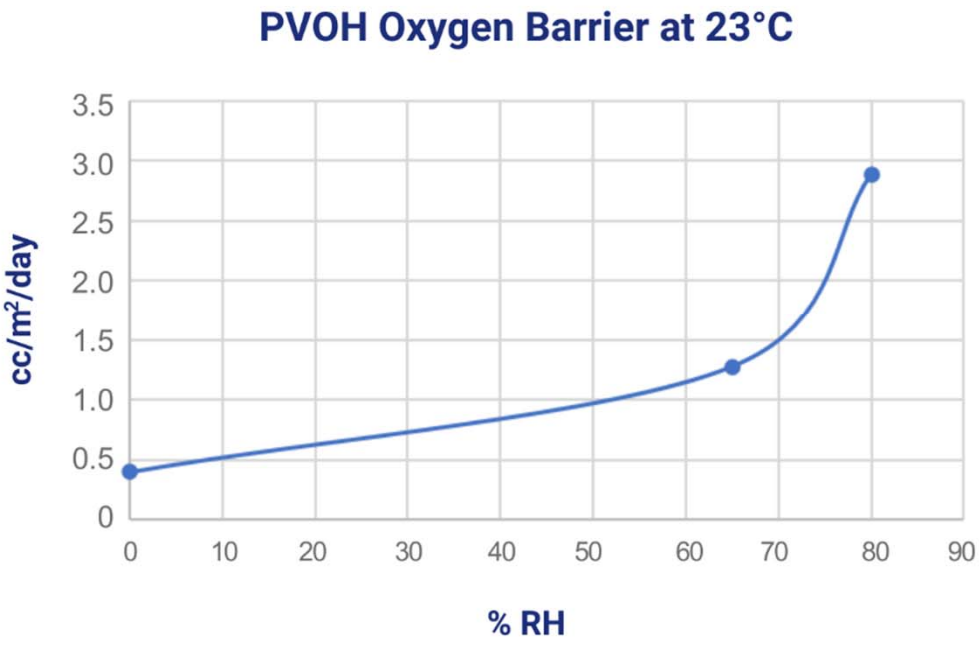
Results: Effects of TIAG



Phase III Results

- As time in the airgap (TIAG) decreases, adhesion increases.
- TIAG affects cooling and re-solidification of polymer coating.
- Small TIAG with high extrusion speed, high line speed and small airgap favors higher temperature at nip, and thus adhesion of PVOH
- Full fiber tearing can be achieved at 130 ms of TIAG with 1.7 gsm of primer or 150 ms with 2.3 gsm of primer.
- Diminishing thickness needs to be compensated by smaller TIAG and more primer.

Results: Oxygen barrier of PVOH coated paper



Phase III Results

- Paper/PEI-2/PVOH <0.5 cc/m^2/day RH=0%

Oxygen barrier of bare substrates

Bare Substrate	OTR (cc/m^2 /day, RH=0%)
Paper (25#)	>100,000
BOPP (1 mil)	1100
BOPE (1 mil)	1500
OPET (0.5 mil)	120

Conclusions

- **High line speed** and **more primer** are important for achieving full fiber tearing of paper with PVOH
- **Small TIAG**, namely high extrusion speed, high line speed, and small airgap favors adhesion via higher melt temperature at nip.
- The use of **primer provides guarantee** for good fiber tearing
- These **results pave a way for adoption of PVOH extrusion coating** for many packaging applications.
  - Light weight mailer bags
  - Paper based air pillow
  - Pet food packaging
  - Confectionary packaging
  - Snack food packaging

Thank you!

Questions?

Acknowledgements

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