Water based soy inks for packaging

Rahul Pingale, Veronika Husovska, Alexandra Pekarovicova, and Paul D. Fleming III.
Western Michigan University
Center for Coating and Printing Research

The aim of the work
Petroleum-based raw materials are not sustainable.

Petroleum based chemistry represent:
- Environmental pollution
- Human health problems

New sustainable chemistry is needed to replace petroleum based polymers in water based inks

The aim of the work
- The printing industry sometimes feels shortage of acrylic polymers used for water based inks formulations.

- The aim of this project is to determine if a particular soy protein (ProSoy 7475) can be used to replace acrylic resins (AC0073) in water-based flexo inks, mainly in the letdown portion of the ink.

Soybean composition

80% of soy oil is utilized for cooking, the rest for industrial uses.
How is soy protein made

A complex 3-D shape, 19 different amino acids

Soy protein structure

Primary Protein Structure

Soy Protein Amino Acids Profile

Glutamic acid
Aspartic acid
Lysine

Soy oil / Protein in inks

- Soy oil - in litho inks for printing newspapers and books.
- Soy protein - new raw material for water-based inks.

Soy oil / Soy protein in inks
Building blocks of acrylic polymers used in water-based inks

```
<table>
<thead>
<tr>
<th>Monomer</th>
<th>Final Property</th>
</tr>
</thead>
<tbody>
<tr>
<td>Styrene</td>
<td>Water resistance, block resistance, hardness, gloss retention, fast dry speed</td>
</tr>
<tr>
<td>Acrylic Acid</td>
<td>Water, block resistance, hardness, initial high gloss, poor gloss retention, fast dry speed</td>
</tr>
<tr>
<td>Butadiene</td>
<td>Flexibility, stain, rub resistance, adhesion</td>
</tr>
<tr>
<td>Makrolon Acrylate</td>
<td>Adhesion, resolubility, hardness, solvent, and grease resistance</td>
</tr>
<tr>
<td>Alpha-Olefins</td>
<td>Water resistance, flexibility, adhesion</td>
</tr>
</tbody>
</table>
```

Function of Acrylic Resins in Water-Based Inks

```
Water based ink composition
```

```
Physical and chemical properties of ProSoy 7475 powder
```

```
Physical and chemical properties of pigment dispersion (PB15-44)
```

```
Acrylic Ink Formulation using AC 0073 Vehicle
```

```
Flexo commercial water based ink formulation
```

```
Dry Appearance: Off White to Tan Granular Powder
Solution Color: Opaque Light Brown
Bulk Density: 672 kg/m³
Moisture: 15% Max.
Solution Solids: 20%
Particle size: 325 mesh

ProSoy 7475 Donated by ARRO, Ltd

```
```
Acrylic Varnish (AC 0073) and other materials donated by American Inks & Technology Ltd.

```
```
Pigment Dispersion PB-15-44 Provides Color
H₂O (DI water) Carries Pigment to the Substrate
Acrylic Varnish (AC 0073) Holds pigment on substrate
WAX (AIT-PE-35) Provides elasticity
Defoamer (FC-613) Controls foaming issues
```

```
Physical and chemical properties of pigment dispersion (PB15-44)
```

```
Appearance: Blue Liquid
pH: 8-10
Solubility in Water: Miscible
Specific Gravity (g/cm³): 1.11
Viscosity (cP - Centipoise): 15-25
```

```
PB15-44 Donated by American Inks & Technology Ltd
```
### Soy vehicle formulation

<table>
<thead>
<tr>
<th>Material</th>
<th>Parts</th>
</tr>
</thead>
<tbody>
<tr>
<td>ProSoy</td>
<td>15</td>
</tr>
<tr>
<td>Amine (for pH adjustment)</td>
<td>0.4 to 1.0</td>
</tr>
<tr>
<td>Isopropyl Alcohol</td>
<td>4</td>
</tr>
<tr>
<td>Bicoides</td>
<td>As needed</td>
</tr>
<tr>
<td>Antifoam</td>
<td>As needed</td>
</tr>
</tbody>
</table>

### Soy vehicle formulation trials

<table>
<thead>
<tr>
<th>Vehicle Formulation using ProSoy 7475 @ 76°C</th>
<th>Standard</th>
<th>Trial 1</th>
<th>Trial 2</th>
<th>Trial 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>ProSoy 7475</td>
<td>15</td>
<td>25</td>
<td>15.4</td>
<td>15.6</td>
</tr>
<tr>
<td>Water (DI Water)</td>
<td>80</td>
<td>87.4</td>
<td>80</td>
<td>78.45</td>
</tr>
<tr>
<td>Ammonia (27%)</td>
<td>0.6</td>
<td>0.6</td>
<td>0.4</td>
<td>1.6</td>
</tr>
<tr>
<td>IPA</td>
<td>4</td>
<td>6.6</td>
<td>4</td>
<td>4.1</td>
</tr>
<tr>
<td>Defoamer (FC-613)</td>
<td>0.4</td>
<td>0.4</td>
<td>0.2</td>
<td>0.25</td>
</tr>
<tr>
<td>Total Weight</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

These formulations were observed for a time duration of twenty days for pH & viscosity stability.

### Acrylic Ink Formulation with ProSoy 7475 vehicle increments

<table>
<thead>
<tr>
<th>Material</th>
<th>Standard</th>
<th>Ink 1</th>
<th>Ink 2</th>
<th>Ink 3</th>
<th>Ink 4</th>
<th>Ink 5</th>
<th>Ink 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>PB-15-44</td>
<td>43.5</td>
<td>Same</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DI water</td>
<td>7</td>
<td>Same</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AC: ProSoy</td>
<td>48.1</td>
<td>100:0</td>
<td>20:80</td>
<td>40:60</td>
<td>60:40</td>
<td>80:20</td>
<td>0:100</td>
</tr>
<tr>
<td>Wax</td>
<td>1</td>
<td>Same</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Defoamer</td>
<td>0.4</td>
<td>Same</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total weight</td>
<td>100</td>
<td>Same</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Solids of inks [%]

<table>
<thead>
<tr>
<th>100% Acrylic</th>
<th>80% Soy</th>
<th>60% Soy</th>
<th>40% Soy</th>
<th>20% Soy</th>
<th>100X Soy</th>
</tr>
</thead>
<tbody>
<tr>
<td>33.84</td>
<td>33.5</td>
<td>33.29</td>
<td>33.3</td>
<td>33.4</td>
<td>32.3</td>
</tr>
</tbody>
</table>

### Efflux time on Zahn #2 cup

<table>
<thead>
<tr>
<th>Day 1</th>
<th>Day 10</th>
<th>Day 25</th>
<th>Day 60</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acrylic</td>
<td>26</td>
<td>26</td>
<td>27</td>
</tr>
<tr>
<td>20% Soy</td>
<td>26</td>
<td>26</td>
<td>27</td>
</tr>
<tr>
<td>40% Soy</td>
<td>27</td>
<td>27</td>
<td>27</td>
</tr>
<tr>
<td>60% Soy</td>
<td>28</td>
<td>28</td>
<td>28</td>
</tr>
<tr>
<td>80% Soy</td>
<td>28</td>
<td>28</td>
<td>28</td>
</tr>
<tr>
<td>100% Soy</td>
<td>28</td>
<td>28</td>
<td>28</td>
</tr>
</tbody>
</table>

**pH over time - Acrylic Ink Vs Soy Increments inks**

**Viscosity over time - Acrylic ink Vs Soy Increments inks**
Optical Density of Acrylic vs Soy Inks

Delta E - Acrylic Ink Vs Soy increments inks

Rub Test - 60 Strokes @ 4 lb weight (Scale 0-5)

Water Drop Test (Acrylic Vs Soy)

3M Tape Test - (Scale 0-5)
Viscosity and pH stability over time was comparable between 100% acrylic and soy/acrylic inks. The color comparison between the target acrylic ink and the increments of soy ink in terms of color difference was found below \( \Delta E_{	ext{cmc}} \) less than 1, which was in accord with the \( \Delta E \) standards used in the graphic and printing industry. End-use properties: Rub resistance of 20-60% soy vehicle inks were slightly worse than 100% acrylic or 80-100% soy.

Conclusion contd......

- Tape adhesion test was slightly worse at soy/acrylic mixed vehicle inks.
- Water resistance of soy ink was excellent up to 50 seconds.
- Soy vehicle had lower foaming tendency than acrylic one.
- Soy sustainable, biodegradable, and….more expensive?

Thank you for your attention!

Questions?

a.pekarovicova@wmich.edu