New Soy-lutions for Sustainability in Automotive Applications

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Materials and Nanotechnology
Ford Research and Advanced Engineering

U-Mass Amherst, IGERT Lecture Series
February 26, 2009
Roadmap

- Why biomaterials?
- Historical perspective
  - Soy foam research and development
  - Soy foam implementation
  - Soy meal applications
  - Looking ahead

Photo by Scott Bauer, courtesy of USDA
Ford N.A. Plastics Research

Objective: Develop novel materials and processing techniques supporting lightweight, sustainable, high performance automotive plastics

**Novel Materials**

- Develop materials that are lighter in weight, cost effective, greater performance, and provide a competitive advantage

  - Nanocomposites
  - Shape Memory Polymer

**Biomaterials**

- Develop materials from renewable crops that can replace petroleum-based plastics and will also reduce weight and cost

  - Soy Based Polyurethane Foams
  - Natural Fiber Composites
  - PLA

**High Strain Rate Performance**

- Optimize materials selection and materials-based design for impact applications

  - Flex
  - Tensile
  - Impact

**Polymer Processing Optimization**

- Optimize polymer processing through the use of effective models and novel processing methods. Understand the relationships between processing, microstructure, and performance.

  - Virtual Plastics Processing
  - Aluminum Tooling for Injection Molding
  - Super Critical Fluid Processing
  - Mucell
Why Biomaterials? Why Now?

- Increased use of renewable feedstocks and agricultural products
- Reduce dependence on foreign petroleum ($150 barrel ?)
- Reduce the negative effects on human health and the environment
  - respiratory illnesses
  - carbon sequestration
- Improved performance in select functions
- Increased consumer awareness
"Ford is committed to offering customers affordable, **environmentally friendly technologies** in vehicles they really want. We are focused on providing solutions that can be used not for hundreds or thousands of cars, but for millions of cars because that is how Ford can truly make a difference."

-Alan Mulally
President & CEO
Ford Motor Company
Ford Biomaterials Overview

PLA (fabric, resin, carpet)

Natural Fiber
- thermosets
- thermoplastics

Biobased Resins
- Soy
  - foams
  - thermoset resin
  - fillers

Soybeans

hemp

switch grass

flax
Soybeans have been part of Ford Motor Company’s history...

- Henry Ford’s “cars growing from the ground” project

- Investigated crops for fuels, plastics and textiles

Henry Ford testing the impact strength of a soy flour composite decklid, 1940.
Henry Ford’s Interest in Soybeans

• Henry Ford spent $1.25 Million from 1932-1933 to research soy crops

• 7,400 acres of Ford soybeans farms in Southeastern Michigan

• Ford established soy processing plant at the Rouge
Current Interest in Bio-materials

• Reduced environmental footprint
• Increased use of renewable feedstocks and agricultural products
• Reduce dependence on foreign petroleum
• Competitive pricing of soy products versus petroleum products
• Marketing differentiation
Increase in bio-diesel demand has resulted in excess in soy meal availability.

* Reference www.soystats.com
Using Soybeans in Plastics

SOYBEANS

Soy Resin
- Sheet
- Molding Compound

Soy Polyol
- Polyurethane Foam

Soy Meal
- Reinforced Rubber

Soy Resin

Soy Polyol

Soy Meal

20% Soy Flour
No Additional Filler
Roadmap

- Why biomaterials?
- Historical perspective
- **Soy foam research and development**
- Soy foam implementation
- Soy meal applications
- Looking ahead

Photo by Scott Bauer, courtesy of USDA
Soy-Based Foam Technology

- Can we use oil from soybeans to make seats?
- Technology Overview: Use of soy polyol in formulating flexible polyurethane foam for seating applications.

Photo by Lynn Betts, USDA Natural Resources Conservation Service.
Soy-Based Foam Benefits

- Reduction of environmental footprint (CO$_2$ improvement)
  - For 1kg polyol produced: soy removes 2kg CO$_2$, petro increases 3.5kg CO$_2$
- Use of renewable resource (soy) to decrease U.S. dependency on petroleum
- Competitive pricing of soy products versus petroleum products
- Ability to migrate technology across all vehicle lines
- Marketing differentiation of products
The difference in global warming potential is due to the CO$_2$ being taken up (sequestered) during the soybean agriculture phase. Excerpts from the soy and petro polyl LCI spreadsheets (Figure 4) show over 2 kg of CO$_2$ being taken out of the atmosphere per kg of soy polyl produced. In contrast, the LCI shows over 3.5 kg of CO$_2$ added to the atmosphere per kg of petro polyl produced.
Soy-Based PU Foam: Environmental Benefit

Net CO₂ Decrease by Using Soy Foam

- Chart shows seat back and cushion applications only; potential for greater impact with all foam applications
- Reduction of carbon dioxide emissions (life cycle analysis)
- Use of sustainable, agricultural materials

<table>
<thead>
<tr>
<th>CO₂ REDUCTION (Million lbs.)</th>
<th>Mustang Program</th>
<th>Programs Using Soy Foam in 2008</th>
<th>If Migrated to all FMC Vehicles</th>
</tr>
</thead>
<tbody>
<tr>
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<td>0.6</td>
<td>5.3</td>
<td>14.3</td>
</tr>
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</table>

Soy-Based PU Foam:
Environmental Benefit

- Environmentally friendly
- Sustainable, agricultural materials

Chart shows seat back and cushion applications only; potential for greater impact with all foam applications.

Reduction of carbon dioxide emissions (life cycle analysis).

Use of sustainable, agricultural materials.
What are Soy Polyols?

- Functionalized soybean oil used in reaction with isocyanate to form urethane linkage

- Soybean oil is a triglyceride with fatty acid distribution including:
  - 23.4% Oleic Acid (18 C: 1 double bond)
  - 53.2% Linoleic Acid (18 C: 2 double bonds)

- Various methods have been used to functionalize soy oil:
  - Blown with air and heat and/or catalyst
  - Ozonolysis
  - Epoxidation
  - Hydroformylation
Potential Applications

- Soft, Flexible PU Foam
  - Seating Foam
    - Seat Back
    - Seat Cushion
    - Head Rest
  - Instrument Panel Foam
  - Headliner Foam
  - Arm Rest Foam
- Rigid PU Foam
  - Package Tray
Potential Agricultural Usage

2.9 Million Vehicles  ~30 lbs. foam/vehicle

54 Million lbs. polyol

Assume: 20% soy polyol in blend

11 Million lbs. soy polyol

~90 Million lbs. foam

Photo courtesy of USDA
Soy Polyurethane Chemistry

Polyols (Soy, Petroleum)
Blowing Agent
Surfactants
Chain Extenders
Catalysts

Soy Polyol Blend
OH-R-OH

Replacing up to 40% of Petroleum Polyol with Soy Polyol

SOY
PETRO standard foam

Soy-Based Polyurethane Foam
C-N-R'-N-C-O-R-O

diisocyanate
OCN-R'-NCO

PETRO
Soybean
Isocyanate
Microstructure of Soy Foams
Prior to Formulation Optimization

YIKES!!!

Petroleum Foam (0% Soy Polyol)

Soy Foam (25% Soy Polyol)
What’s Happening?

R = fatty acid chain

* From Ann R. Fornof and Timothy E. Long “Synthesis and Characterization of Polyols via Air Oxidation of Triacylglycerides”
Key Technical Challenges

- **Formulations:**
  - Optimizing formulation for levels of soy used
  - Balancing gel/blow reactions for soy formulation
  - Blend stability between bio-polyol and petroleum-polyol

- **Odor:**
  - Odor of blown soy oil and resulting foam

- **Properties:**
  - Passing material specifications
  - Meeting performance and plant requirements
Formulation Development Process

1. Polyol and additives are mixed together

2. Add iso to polyol blend and pour in mold

3. Evaluate “foaming” characteristics
Balancing Gel and Blow Reactions

Reaction 1: Gel Reaction

Isocyanate + Polyol → Polymer w/ high MW

Reaction 2: Blow Reaction

Isocyanate + Water → Carbon dioxide Gas (promotes foaming)

If $R_2 >> R_1$, CO$_2$ evolution too rapid compared to gel reaction, foam collapses.

If $R_1 >> R_2$, gel extension reaction too rapid compared with CO$_2$ generation, foam rise is restricted and will form high density foam.
How can we improve the foam?

Changing Index, 50% Soy Polyol

60 Index  70 Index  80 Index  90 Index  100 Index  110 Index

Changing Percent Soy Polyol, 70 Index

100% Soy  75% Soy  50% Soy  25% Soy  0% Soy
## Optimizing Properties Through DOEs

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<tr>
<th>StdOrder</th>
<th>RunOrder</th>
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<th>S8715 (g)</th>
<th>S5943 (g)</th>
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<td>27</td>
<td>100</td>
<td>1.5</td>
<td>0.50</td>
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</tbody>
</table>

**Index** – ratio of polyol to isocyanate (100=one-to-one ratio, below 100=excess polyol, etc.)

**S8715** – surfactant; controls/stabilizes size of gas bubbles; lowers surface tension of iso/polyol

**S5943** – surfactant; enables fine, consistent cells in foam; provides consistent air flow through foam
Optimized Polyurethane Foam: Optical Micrographs

- Similar appearance in microstructure
- Open celled foams, as desired for seating foam
Microstructure looks good … now what?

Odor, fogging and staining are 3 key issues!

- **Concern**: “rancid” odor detected in soy foam by foam odor panelists; cause for material rejection

- **Cause**: low molecular weight side products in polyol produce odor

- **Technical accomplishments**:
  - Masking of odor through addition of volatile fragrances and neutralizing agents
  - Encapsulation of foam with gas impermeable layers
  - Ultraviolet light synthesis method
  - Stripping of polyol with thin film evaporation method
Industry Standard for Evaluating Odors: SAE J1351

**Ford R&A Odor Test Panel**

- Foams cut to 1” x 0.5” x 5”
- Samples placed in sealed jar
- Conditioned 1hr. at 70 °C
- Odor evaluated by 5 panelists

**Odor Ratings**

1= No Noticeable Odor  
2= Slight, but Noticeable Odor  
3= Definite Odor, but Not Strong Enough to be Offensive  
4= Strong Offensive Odor  
5= Very Strong Offensive Odor
New Synthetic Route for Soy Polyol

• Reaction Set Up:
  – Degummed soy oil placed in quartz long glass column
  – Column heated to 100F
  – Air bubbled through column
  – UV light applied to column in range 290-350nm

• Process:
  – Initiation of reaction as hydroperoxides form
  – Increase in hydroxyl number, visually seen with color change from amber to pale yellow
  – Termination of reaction at hydroxyl number ~50 by removing heat and switching from air to nitrogen gas flow.

Patent Filed 2005

Low odor
Simple Method
Inexpensive
Synthesis of Soy Polyol

- **Viscosity (Stokes) at 25C**
  - Graph showing viscosity over time with and without UV exposure.

- **Hydroxyl Number**
  - Graph showing hydroxyl number over time with and without UV exposure.

- UV exposure impacts the properties of soy polyol.

- **Key Observations**:
  - UV exposure significantly increases the viscosity after a certain period.
  - The hydroxyl number also increases steadily with UV exposure.

Ford collaboration highlights the potential applications in environmentally friendly materials.
# UV Catalyzed Soy Polyol

**Analysis**

<table>
<thead>
<tr>
<th>Analysis</th>
<th>“UV” Crude Polyol</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hydroxyl Number (mgKOH/g)</strong></td>
<td>47</td>
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<tr>
<td><strong>Color (Gardner)</strong></td>
<td>1</td>
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<tr>
<td><strong>Viscosity (cps)</strong></td>
<td>2700</td>
</tr>
<tr>
<td><strong>Acid Value (mgKOH/g)</strong></td>
<td>5.4</td>
</tr>
<tr>
<td><strong>Karl Fischer Water (%)</strong></td>
<td>0.064</td>
</tr>
</tbody>
</table>

![Image of soy polyol and degummed soy oil](image)
Odor of Oils: Commercial vs. UV Polyols

<table>
<thead>
<tr>
<th>Material</th>
<th>Odor Rating</th>
<th>Room Temperature (25 C)</th>
<th>Heated 1 hr. at 100 F</th>
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</thead>
<tbody>
<tr>
<td>Degummed Soy Oil</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td>Blown Soy Polyol</td>
<td>3.5</td>
<td>3.5</td>
<td>3.5</td>
</tr>
<tr>
<td>Soy Polyol from UV Synthesized Polyol</td>
<td>2.5</td>
<td>2.5</td>
<td>2.5</td>
</tr>
</tbody>
</table>
Wiped Film Evaporator Process

- Completed trial using WFE to “clean up” the soy polyols

- Determined optimized processing temperature for odor reduction (double pass through equipment at 190°C)

- Conducted odor tests on Ford’s polyols
Using WFE to Improve Odor

Polyol sample was stripped of low molecular weight volatiles using a Wiped Film Evaporator Technique.

Stripping polyol reduces odor.

- Degummed Soy Oil
- Crude UV Soy Polyol
- Stripped UV Soy Polyol

Evaluations were conducted at 25°C and after heating for 1 hour at 135°F.
Formulation Development: Typical Soy Foam Formulation

<table>
<thead>
<tr>
<th>Components with Parts by Weight</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Soybean Oil Polyol</td>
<td>40</td>
</tr>
<tr>
<td>Petroleum Polyol</td>
<td>60</td>
</tr>
<tr>
<td>Water</td>
<td>3-4</td>
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<tr>
<td>Multiple Silicone Surfactants</td>
<td>1-1.5</td>
</tr>
<tr>
<td>Multiple Amine Catalysts</td>
<td>0.5-1.0</td>
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<tr>
<td>Cross-Linker</td>
<td>0.25-0.35</td>
</tr>
<tr>
<td>Isocyanate</td>
<td>100 Index</td>
</tr>
</tbody>
</table>

Petroleum

40% Soy

Design of Experiments for Optimization
## Isocyanate Comparison

<table>
<thead>
<tr>
<th>Property</th>
<th>MDI</th>
<th>TDI</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Name</strong></td>
<td>Methylene diphenyl diisocyanate</td>
<td>Toluene diisocyanate</td>
</tr>
<tr>
<td><strong>Component</strong>*</td>
<td>European seats, N.A. headrests and armrests</td>
<td>North American seats</td>
</tr>
<tr>
<td><strong>Foam Attribute</strong></td>
<td>Thin, firm seats (favorable hardness/density)</td>
<td>Cushioning, plush seat (high tensile strength)</td>
</tr>
<tr>
<td><strong>Maximum % of soy</strong></td>
<td>40%</td>
<td>5%</td>
</tr>
<tr>
<td><strong>Health/ Environment Assessment (MSDS)</strong></td>
<td>Moderate</td>
<td>Serious</td>
</tr>
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</table>

*Asia Pacific uses TDI/MDI blend for seats*
Required Property Tests of New Foam Formulations

- Density
- Optical Microscopy
- Tensile Strength, Elongation
- Compressive Modulus
- Tear Resistance
- Compression Set (50% deflection at 70°C, 22hrs.)
- Fogging
- Odor
# Ford R&A Lab Scale Soy Foam Properties

## 40% soy polyol in polyol blend in MDI formulation

<table>
<thead>
<tr>
<th>Ford Spec. Test</th>
<th>Density (kg/m³)</th>
<th>Compression Set at 50% Deflection (%)</th>
<th>Tensile Strength (kPa)</th>
<th>Elongation (%)</th>
<th>Tear Resistance (N/m)</th>
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</thead>
<tbody>
<tr>
<td>Benchmark</td>
<td>40</td>
<td>&lt; 14%</td>
<td>&gt; 110</td>
<td>&gt; 100</td>
<td>&gt; 170</td>
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<tr>
<td>40% Soy Foam</td>
<td>37</td>
<td>11</td>
<td>113</td>
<td>100</td>
<td>190</td>
</tr>
</tbody>
</table>

Formulation Patent ApplicationFiled 2005
Demonstrating Soy Foam Seats on Model U Concept Vehicle
"With all the crop-based materials, we added a scarecrow option to keep the crows away."

Henry Payne, Detroit Free Press
Roadmap

- Why biomaterials?
- Historical perspective
- Soy foam research and development
  - Soy foam implementation
- Soy meal applications
- Looking ahead

Photo by Scott Bauer, courtesy of USDA
Teamwork to Move Forward

Ford R&A

- Bayer
- Renosol
- Huntsman
- Lear
- JCI
- USSC
- Woodbridge/Cargill
- Dow
- FGTL
- Materials Engineering
- Purchasing
- Engineering/Product Development
- Program 1
- Program 2
- Program 3
- Intier
- Ford R&A

Materials Engineering/Development
Processing Optimization for Soy Foam Headrests

- Optimized formulations and processing conditions
  - Cycle Time: meets production requirement
  - Reactivity profile meets manufacturing setup
  - Molded HR meets production level quality
- Issues identified: blend separation, surface skinning, tear resistance

Impingement mixing
Temperature controlled tool

Polyol/iso mixture is poured into tool

Molded polyurethane using 20% soy in foam (40% b-side)
Headrest Trimming Process

• “Foam on stick” placed on fixture
• Vacuum compresses foam
• Plastic covering placed on foam
• Final trim piece inserted over foam
• Vacuum released
**Foam Tests from Each Trial**

- Density
- Tensile Strength
- Elongation
- Heat Aged Tensile
- Heat Aged Elongation
- Tear Resistance
- Compression Set (as received -50%)
- Compression Set (steam autoclave aged -50%)
- Compression Set (as received -75%)
- Compression Set (steam aged -75%)
- Sag Factor
- Recovery
- Staining
- Fogging
- Odor
- Load Indentation
- Aged Loss
- Flammability
# Material Performance of MDI Soy Foam Headrests

<table>
<thead>
<tr>
<th>Property Description</th>
<th>Units</th>
<th>Target</th>
<th>Soy Foam</th>
<th>Comments</th>
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<tbody>
<tr>
<td>1. Core Density</td>
<td>Kg/m³</td>
<td>As per drawing</td>
<td>37</td>
<td>Pass</td>
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<tr>
<td>2. Tensile Strength</td>
<td>kPa</td>
<td>82 min</td>
<td>174</td>
<td>Pass</td>
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<tr>
<td>3. Elongation</td>
<td>%</td>
<td>80 min</td>
<td>112</td>
<td>Pass</td>
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<tr>
<td>4. Compression Set</td>
<td>%</td>
<td>10 max (cushions)</td>
<td>2.8</td>
<td>Pass</td>
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<tr>
<td>5. IFD @ 50% Deflection</td>
<td>N</td>
<td>As Per Drawing</td>
<td>280</td>
<td>Pass</td>
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<td>7. Fogging</td>
<td>%</td>
<td>70 min.</td>
<td>98 (dried droplets)</td>
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<td>8. Odor</td>
<td>Rating</td>
<td>2 max</td>
<td>2</td>
<td>Pass</td>
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<tr>
<td>9. Aged Flexibility</td>
<td>Visual</td>
<td>No Splitting or Crumbling after Aging</td>
<td>OK</td>
<td>Pass</td>
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</table>
TDI Based Soy Foam Seat: 
Process Optimization

• Completed 2 trials at Renosol Seating Plant with Mustang Front Seat Cushion and Back Foam
• Molded TDI formulation with 5% Soy contents
• Adjusted minor process parameters
• Parts molded met current production quality appearance
### Material Performance of TDI Soy Foam Seats

<table>
<thead>
<tr>
<th>Properties</th>
<th>Target</th>
<th>Soy Foam</th>
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<tr>
<td>1. Density (kg/m³)</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>2. Hardness (N)</td>
<td>280</td>
<td>285</td>
</tr>
<tr>
<td>3. Tensile: (kPa)</td>
<td>82 min</td>
<td>172</td>
</tr>
<tr>
<td>4. Elongation: (%)</td>
<td>80 min</td>
<td>150</td>
</tr>
<tr>
<td>5. Tear Strength: (N/m)</td>
<td>450 min</td>
<td>664</td>
</tr>
<tr>
<td>6. Compression Set 75%:</td>
<td>10% max</td>
<td>10%</td>
</tr>
<tr>
<td>7. Compression Set HA 75%:</td>
<td>25%</td>
<td>9%</td>
</tr>
<tr>
<td>8. Flammability: (mm/min.)</td>
<td>100 max</td>
<td>SE</td>
</tr>
</tbody>
</table>
TDI Based Soy Foam Seat: Process Optimization

- Completed prototype molding trials with Lear using front seat cushion tooling
- Molded TDI formulation with 5% soy contents
- Parts molded met current production quality standards
- Passed property requirements including flammability and tensile strength
Key Steps Towards Implementation

- Formulation development
- Technical issues
- Cost and supply analysis
- Vehicle component level testing
- Vehicle level testing
- Physical and mechanical properties
Challenges of Soy Foam: Business Considerations

• 1st implementer paving the way
  – Materials specifications
  – Program support

• Cost evaluation of final product
  – Quantity of material needed

• Plant complexity
  – Additional chemical line or tank
  – Multiple products

• Supply chain availability
Ford Motor Company
Soy Foam Progression

- 2002: R&A initiates research project on soy foam
- 2003: Model U concept vehicle
- 2004: Completed MDI trials & testing with Lear & Bayer
- 2005: Materials Engineering approval TDI
- 2006: Component approval; Processing Evaluation completed
- 2007: United Soybean Board awards R&A 3yr. $230k grant
- Completed TDI trials & testing with Lear & Renesol
- Press release on Mustang soy foam seats
Implementation of Soy Foam on 2008 Mustang

- Seat supplier: Lear Corporation
- Applications: seat cushion, seat back
- Soy content: 5% by pad weight
- Implemented August, 2007
Times Square, New York, July 2007
Ford puts the green under your seat
Written October 14, 2006 by Via Ford Motor Co.
While many in the auto industry are experimenting with a 5% soy-based polyol — one of the many ingredients used to make the foam used in vehicles — Ford researchers have formulated the chemistry to replace a staggering 40% of the standard petroleum-based polyol with a soy-derived material.

Ford Mustang Press on Soy Foam
• CNN, Forbes, Wall St. Journal
• Finance, Farming, Auto Articles
• Over 200 media outlets covered soy foam story

Ford and Honda Join Toyota as Leaders in Using Environmentally-Friendly, Safe Plastics for Car Interiors
Second Annual Ecology Center Report Grades Auto Manufacturers On Use of Sustainable, Non-Toxic Materials for Interior Parts Leaders Appraised for Use of Bio-Based Materials

Press Release
Lear Corp.
Release date: December 14, 2006

Lear Introduces SoyFoam(TM) Technology for Automotive Seating Applications
SOUTHFIELD, Mich., Dec. 14 -- Lear Corporation (NYSE:LEA), one of the world’s leading automotive interior suppliers, today announced it has developed SoyFoam(TM), a soybean oil-based flexible foam material for automotive interior applications.
Technology Migration: Programs Using Soy Foam

- Ford Mustang
- Ford Expedition
- Lincoln Navigator
- Ford F-150
- Ford Escape
- Mercury Mariner
- Mazda Tribute
- Ford Focus
Soy-Based Foam Awards

- "The Excellence in New Uses Award" by the New Uses Committee, United Soybean Board, Tampa, Florida, February 2007.

- “Plastic Materials from Renewable Resources Award” by the SPE Global Plastics Environmental Conference, March 2008 to Ford Motor Company and Lear Corporation.


- “SPE Innovation Award in Environmental Category” by SPE Automotive, November 2008 to Ford Motor Company and Lear Corporation.
Opportunities for Soybeans

- Increased levels of soy polyol in foam applications
- Use of soy oil in other flexible foam applications
- Use of soy meal and soy flour as filler in thermoplastics, rubber and thermosets
- Rigid polyurethane foams using soy polyols
**Roadmap**

- Why biomaterials?
- Historical perspective
- Soy foam research and development
- Soy foam implementation
- **Soy meal applications**
- Looking ahead

Photo by Scott Bauer, courtesy of USDA
Can we use the other part of the bean?

- Technology Overview: Use of soy meal in formulation and processing of automotive plastics.

Photo by Lynn Betts, USDA Natural Resources Conservation Services
Soy Protein Filler for Plastics

• **Technology Overview:** Use of soy meal in formulation and processing of automotive plastics.

• **Benefits:**
  – Low cost alternative filler
  – Use of agricultural byproduct

• **Goals:**
  – Determine properties of automotive components using soy protein fillers
  – Assess mechanical properties and overcome processing challenges
  – Identify specific automotive components for soy protein filler
  – Mold components in collaboration with automotive Tier 1 suppliers
Molding Soy Meal - EPDM Parts

Radiator Air Deflector
Engine & Alternator Splash Shield
Front Valance Panel
Engine Splash Shield

Schematic courtesy of Hematite mfg.
Next Steps For Biomaterials

- Continued Research support for three main thrust areas in biomaterials projects
- Leverage biomaterial development with material suppliers and non-competing partners
- Work jointly with our Product Development partners to further develop the internal market at Ford for biomaterials
- Complete Ford material and component level testing to obtain material approvals
- Communicate our work and progress to our customers!
Supplier Acknowledgments

Soy Reinforced Rubber
• Hematite Manufacturing
• USB New Uses Committee
• Zeeland Farm Soya
• Lion Copolymer
• CHS Oilseed Processing
• Michigan Soybean Board
• Prof. Amar Mohanty (MSU)

Soy Based Polyurethane Foam
• Ford R&A
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  – Matt Schwalm
  – Brian Witkowski
• Bayer Corporation
• Lear Corporation
• Renosol Corporation
• Urethane Soy Systems Co.
• United Soybean Board
• Omni Tech International
Questions?