

Use of Agricultural Materials in Flexible Polyurethanes and Composites for Automotive Applications

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Abstract

The use of renewable materials in commercial products has gained attention over the past several years. Biomaterials can offer significant advantages over conventional materials such as: sustainability, reduction of petroleum dependence, lighter weight of components and potential lower cost. In our studies, we demonstrate the use of soy-derived materials in two primary thermoset applications: sheet molding compounds (SMC) and polyurethane foam. SMC composites were produced using soy resin in place of a portion of the vinyl ester resin, to evaluate mechanical performance, process capabilities and component performance. In addition, composite reinforcements of continuous hemp fiber, non-woven hemp mats, fiberglass, and hybrids (fiberglass/continuous hemp twine mixtures) were examined. Results indicate that the soy resin composites demonstrate equivalent properties to those of the vinyl ester resin composites and are equally able to be molded into complex geometries. While substitution of glass reinforcement with natural fibers was found to reduce the mechanical performance of the composites, hybrid composites of glass and hemp fibers provided promising results. Hydroxylized soy oil has also been used as a polyol in flexible, polyurethane foam formulations. Foam formulations have been optimized for mechanical and processing performance. One of the key technical challenges of soy foams are their inherent odor. Two odor reduction methods will be discussed, including a novel, low odor method to functionalize soybean oil.

Introduction

The use of renewable materials such as soy, corn and natural fibers in polymer or composite materials has received increasing attention. These "green" materials may enable companies to reduce their dependency on petroleum and to explore potential cost or performance advantages. Several original equipment manufacturers within the automotive and agricultural industries have advertised the use of biomaterials in their products: John Deere has utilized soy resin for body panels on its balers, Toyota has demonstrated the use of bio-resins for floor mats¹ and DaimlerChrysler has shown the use of natural fibers in headrests². While several components using biomaterials have been successfully demonstrated, there are many other applications for automotive thermoset materials that could potentially use these renewable materials.

Polyurethane foams and thermoset sheet molding compound (SMC) are two primary areas for using an agricultural product such as soy in plastics and composites. Both materials are used extensively in automobiles—urethane foams are used for seating, head and armrests, soft instrument panels and door trim, while SMC is used for hood and decklids, underbody shields and grill support panels. Crops such as

soybeans, corn and rapeseed are currently being used to produce thermoplastic resins and polyols for use in polyurethanes. The benefits of using an agricultural crop such as soybeans in the manufacture of plastics include the potential for providing raw material cost savings and utilization of a renewable resource. In addition, soybeans are plentiful; forty billion pounds of soybean oil are produced globally each year, with nearly half of that supply from U.S. production.

Bio-Based Sheet Molding Compound

In our study, we have examined the performance of thermoset, sheet molding compounds (SMC) using a soy based resin in lieu of a portion of vinyl ester resin (approximately 20%), for both natural fiber and glass fiber reinforcements. The mechanical properties of the soy resin composites are compared to two commercially available SMC resins. Natural fibers provide a promising mechanical reinforcement material in place of fiberglass for composite applications. In addition to being a renewable material, natural fibers have lower cost, lower density and require less energy to manufacture (grow) than glass fibers. The reduction in fiber density, and thus composite density, is especially favorable for automotive applications, where fuel economy improvements through weight reduction may be achieved.

Materials

Resin Types

Three commercial resins were examined to compare composite mechanical properties, as molded and after moisture exposure. The resins screened in the current study were: Arotech 2000 (denoted as A2000), Envirez 1807 (a soy-based resin, denoted as Soy), and Arotech 2002 (denoted as A2002). A2002 resin is essentially the same system as A2000 with additional low profile additives (LPAs) that can enhance the surface smoothness of the finished composite. The resins were combined with different additives, including calcium carbonate, LPAs, catalysts and water to generate three different formulations: "vinyl ester A", "vinyl ester B" and "soy." All resins are commercially available grades from Ashland Specialty Chemical Company.

Fiber Types

Hemp fibers were compounded in two forms – continuous, twisted twines and non-woven mats – to replace either all or a portion of the fiberglass in vinyl ester and soy based SMC (sheet molding compound) formulations. Hemp mats had an overall mat density of 59.2 kg/cm². The mats were needle punched at a density of 30 – 35 punches/cm² in order to hold the fibers together for ease of handling. The hemp twine had a construction of six twisted, continuous strands, each strand itself twisted. Glass fibers of 2.54 cm length were used as the baseline fiber type. Hemp fibers were oven dried at 80 °C for at least 12 hours prior to processing in order to eliminate moisture.

A custom chopper manufactured by Brenner International for Ford Motor Company was used for continuous distribution of hemp, glass, and a hybrid mixture of fibers to the compounding line.

Processing

Compounding was performed on a 61 cm-wide, laboratory scale Model 600 Series SMC compounding line from Brenner International. Hemp mat, hemp twine, glass roving, and hemp twine/chopped glass hybrids were compounded continuously (Figures 1a-c)^{3,4}. A first layer of resin paste was doctor bladed onto a carrier film, fiber materials were delivered atop the resin paste, and a second layer of resin paste was doctor bladed onto a second film before sandwiching the fiber materials. The resin-fiber-resin sandwich traveled through several compaction rollers before exiting the line. Fibers in mat form were fed continuously onto the resin paste layer from a large roll (Figure 1a), while continuous fibers (both hemp twine and glass rovings) were distributed onto the resin automatically by the custom chopper (Figures 1b and c.) Nominal fiber loadings were 40 – 45 weight percent for all of the SMC composite formulations. Compounded materials were allowed to mature for 24 – 72 hours prior to compression molding at 300 °F and 75 tons into 30.5 cm by 30.5 cm plaques.



Figure 1. Continuous SMC compounding line utilizing: (a) non-woven hemp mat; (b) chopped hemp twine; and (c) hybrid mixture of chopped hemp twine and glass.

Properties

Mechanical Testing

Tensile (ASTM D638, 5 mm/min) and compressive (ASTM D3410) tests were performed on the soy and vinyl ester resin SMC composites^{5,6}. Tensile specimens were prepared by sectioning samples on a diamond blade band saw and milling them using a high speed router. Fine filing was used on the milled edges to reduce potential stress risers. Tensile tests were performed on an Instron 3300 Model load frame with a 10-kN load cell and 5 cm extensometers. Compressive samples were cut from molded

panels using a diamond blade saw and polishing edges with a 320 grit polishing paper. A MTS 810 load frame with a 5000-lb load cell and a 5.0 stroke cartridge was used to perform the compressive tests.

Mechanical Properties of Soy Resin-Hemp Mat Composites

The mechanical performance of the soy resin composite using hemp mat reinforcement was compared to that of the vinyl ester composite. Samples were tested as received and after immersion in water at room temperature for 168 hours, in order to assess the affect of moisture absorption on the mechanical properties. Figure 2a shows the tensile modulus results comparing the natural fiber reinforced composites using the renewable (soy) and petroleum (vinyl ester) resins.

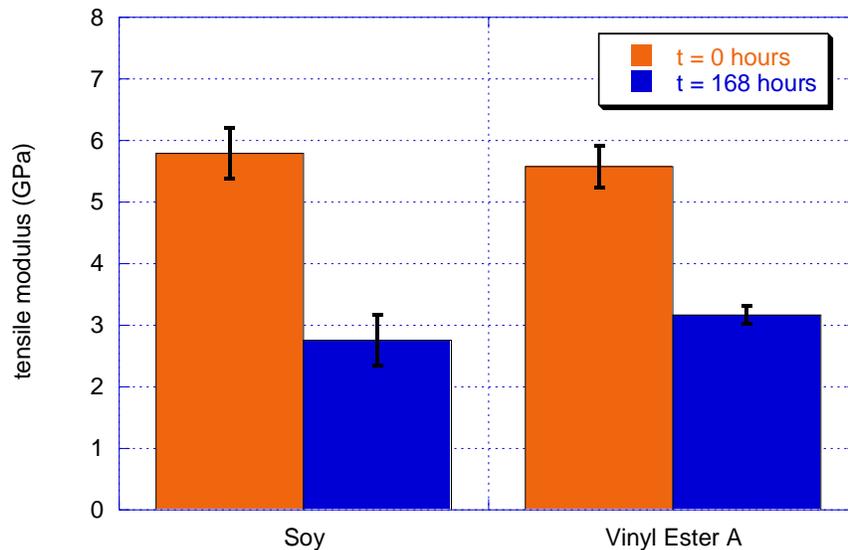


Figure 2a. Tensile modulus of hemp mat SMC composites with different resin formulations; before and after immersion in water at RT.

Similarly, Figures 2b and c show plots for the tensile strength and compressive strength, respectively. It is important to note that since CaCO_3 filler was not added to these formulations, the mechanical properties are not indicative of commercial SMC materials, but rather can only be compared relative to one another. Figures 2a and b show that there is a significant reduction in the tensile properties for both the soy resin and vinyl resin composites after water immersion, indicating that the significant moisture absorption has a deleterious effect on the mechanical performance. The compressive strength is also decreased after immersion, although not to as great an extent.

Comparison of tensile properties of the soy and vinyl ester resin composites indicates that the soy resin has similar mechanical properties to those of its petroleum

counterpart. However, the compressive strength of the vinyl ester resin composite is better than the soy composite both before and after moisture absorption.

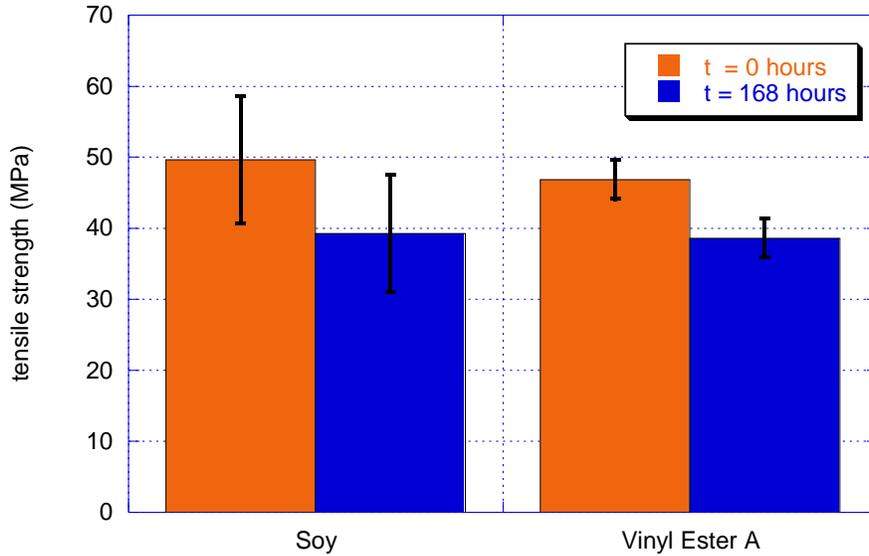


Figure 2b. Tensile strength of hemp mat SMC composites of different resin formulations; before and after immersion in water at RT.

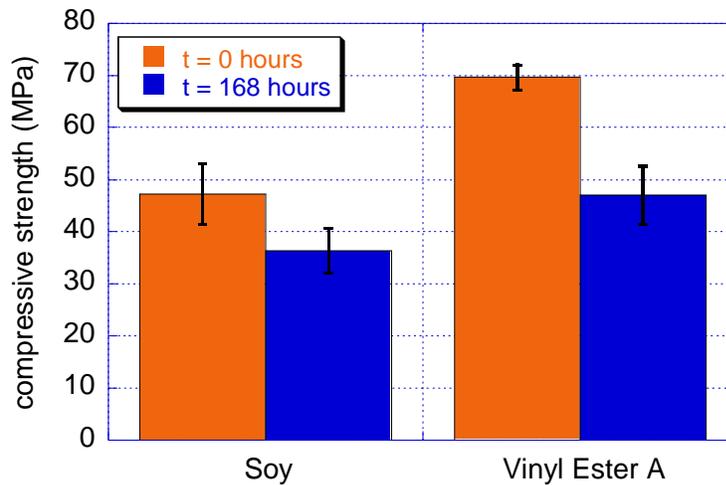


Figure 2c. Compression strength of hemp mat SMC composites of different resin formulations; before and after immersion in water at RT.

Mechanical Properties of Soy Resin-Chopped Natural Fiber Composites

Our results have demonstrated that soy resin can be utilized for composites reinforced with hemp mat. Because traditional SMC processing uses a chopped glass fiber of approximately one inch length, we developed a novel processing method to deliver chopped natural fibers within the SMC process. In our study, glass fibers, hemp fibers, and a hybrid mix of hemp and glass fibers were chopped and continuously delivered to the compounding process. During processing, it was noted that the fiber delivery onto the carrier film displayed slightly uneven transverse distribution. Composites were processed using two different vinyl ester resins (A2000 and A2002) and the soy resin system, each with a nominal 40 weight percent fiber loading.

Figures 3a and 3b show a comparison of the tensile modulus and tensile strength, respectively, of the three resin composites reinforced with the chopped hemp, chopped glass, or hybrid mixtures of chopped hemp and glass. The glass fiber reinforced composites clearly exhibit superior tensile strength and higher tensile modulus as compared with hybrid reinforced or hemp reinforced composites. The primary contributing factor to the large discrepancy of tensile strength may be attributed to resin rich areas in the composite (due to poor dispersion of the hemp fibers). Since the hemp fibers are formed by twisting up to six strands together, the fibers tend to remain "clumped" as they are cut and dropped onto the resin layer.

As shown in Figures 3a and 3b, a comparison of the resins shows that Vinyl Ester A (A2000) is clearly the best resin for the chopped glass system. For the hemp and hybrid materials, however, the soy resins performed as well as the two vinyl ester resin systems.

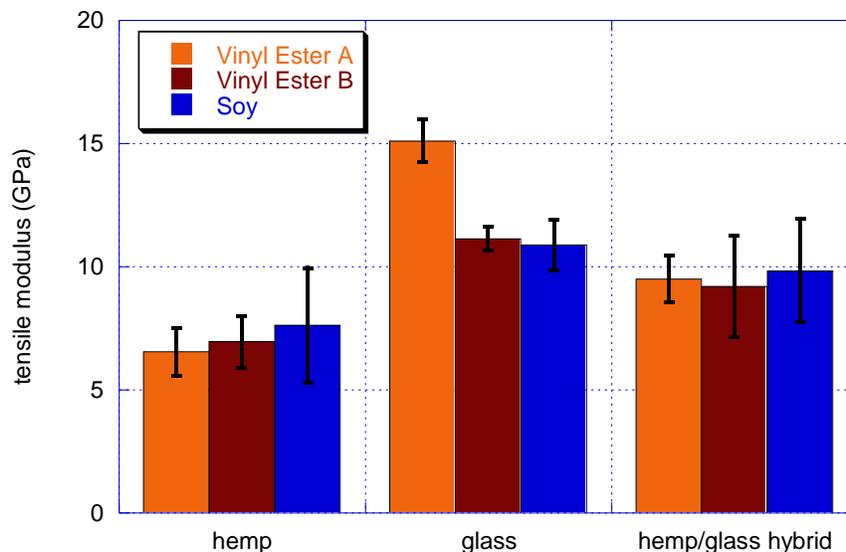


Figure 3a. Tensile modulus of chopped fiber SMC formulations produced by continuous compounding; comparison of resin systems.

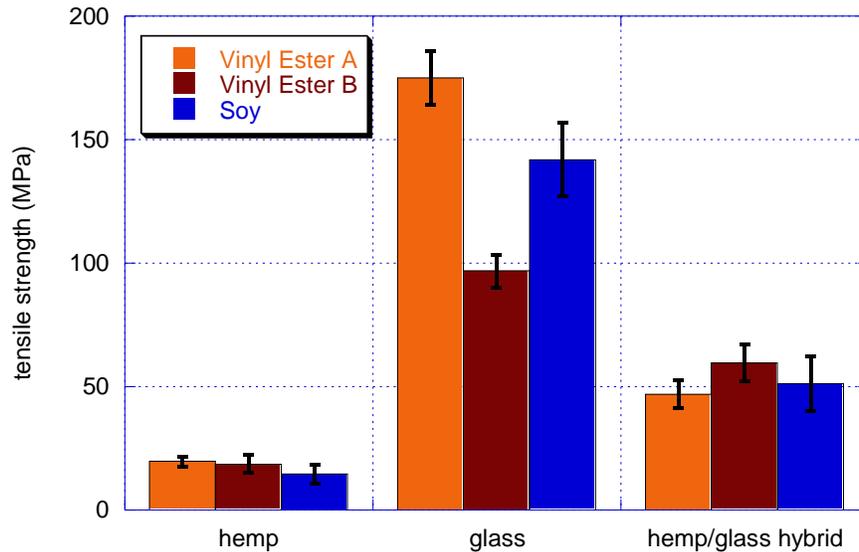


Figure 3b. Tensile strength of chopped fiber SMC formulations produced by continuous processing; comparison of resin systems.

Component Testing

One of the potential applications for SMC bio-composites is structural or semi-structural, exterior automotive parts. After assessing the mechanical performance of these materials, it is important to understand the material testing requirements applicable to the application. Since one potential application was an exterior, underbody shield, the composites were subjected to stone impact testing to evaluate stone chip performance.

Soy resin and vinyl ester resin plaques with hemp mat and chopped glass reinforcement were cut into 10.16 cm by 30.48 cm samples for gravel-o-meter testing. The samples were tested for stone chip resistance following the SAE J400 method using 3 pints of stones at room temperature. Samples included: soy resin with hemp mat reinforcement (denoted SH), soy resin with glass fiber reinforcement (denoted SG), vinyl ester resin with hemp mat reinforcement (denoted VH), and vinyl ester resin with glass reinforcement (denoted VG.) The composites were molded with approximately 30 percent fiber loading. Table I indicates the rating and number of chips on the plaque after completion of the test.

Chip Analysis	
Rating	Number of Chips
10	0
9	1
8	2-4
7	5-9
6	10-24
5	25-49
4	50-74
3	75-99
2	100-149
1	150-250
0	>250

Table 1: Number Categories for Chip Ratings, Per SAE J400

As shown in Figure 4, the soy resin/hemp composites, soy resin/glass hybrid composites, vinyl ester/hemp composites and vinyl ester/glass composites received the same ratings for the stone impact test. For each category, three different panels were assessed. These results indicate that using the soy resin, and/or the hemp mat reinforcement does not have a negative affect on the stone impact resistance in the plaques.

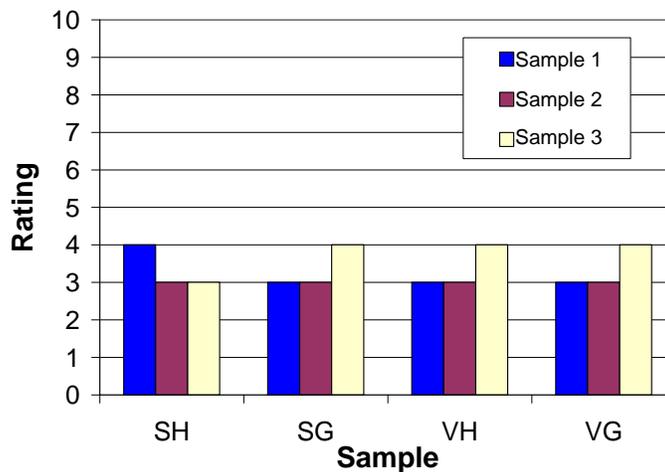


Figure 4: Stone impact test rating results for four samples: soy resin/ hemp mat composite (SH), soy resin/ glass fiber composite (SG), vinyl ester resin/ hemp mat composite (VH) and vinyl ester resin/ glass fiber composite (VG).

Similarly, the stone impact test was repeated for molded, prototype underbody shields. Again, the soy resin SMC received the same rating as the vinyl ester resin component. For these parts, glass fibers were used as the reinforcement material.



Figure 5: Prototype underbody shields using vinyl ester resin (L) and soy resin (R), after stone impact gravelometer testing

Overall, the results have shown that the soy resin offers a viable alternative to vinyl ester resin in terms of moldability, mechanical performance and stone impact resistance. By using a soy resin in conjunction with the natural fiber reinforcements, we are able to produce a bio-composite with renewable content in both the resin and fiber and properties that meet certain automotive requirements. Optimization of the formulations, processes and fiber types should improve the mechanical performance (*ie* compressive strength) and moisture resistance of these composites. Hybrid formulations (glass/hemp) were shown to improve the mechanical properties of the composites over hemp fibers alone.

Soy Based Polyurethane Foam

Background

Polyurethane foams provide another opportunity to utilize an agricultural product in a thermoset application for automotive usage. Flexible foam applications for vehicles include foams for seats, headrests, headliner and instrument panels. Currently, the materials used to form flexible polyurethane foams are derived from petroleum based chemical resources such as glycerin and ethylene oxide. The limited reserve and price fluctuations of fossil fuels and oils has prompted many companies to begin investigating sustainable or agriculturally derived materials for their applications.

We have focused our work on determining whether soy-based polyols can be utilized in the manufacture of flexible foams for interior applications. One of the inherent concerns of using these natural materials is their detectable odor. In our study, we investigate a novel method for manufacturing a low odor soy polyol, discuss additional odor reduction methods and evaluate the mechanical performance of molded foams.

A Novel, Synthetic Method to Form Soy Polyol

Petroleum polyurethane foams are formed by reacting diisocyanate with a polyol blend, which includes a polyether polyol, surfactants, catalysts and blowing agent. Recently, several companies and universities have developed polyol products that are derived from crushed soybean oil instead of from glycerin or propylene oxide^{7,8}. One inexpensive method to hydroxylate the soybean oil includes blowing air through the oil at elevated temperatures. With this method, undesirable side products are formed including aldehydes and ketones, which can contribute to a rancid odor in the polyol. For the blown soybean oil process, the hydrogens next to the double bonds within the soybean oil are removed, yielding free radicals. Oxygen from the air reacts at these radical sites on the lipid molecules to form peroxides. When heat is applied, the peroxides break down to form the hydroxyl groups and secondary oxidation products such as aldehydes. Typically, this type of process requires either a metal catalyst, which is expensive, or temperatures greater than 82 °C to initiate the reaction. In our work, we have developed a novel method to synthesize soy polyols at room temperature, thus reducing the likelihood of unfavorable, secondary oxidative products.

Soy-based polyols were produced within our facility using degummed soy oil from Thumbseed Oil Producers. As shown in Figure 6, the soy oil is placed in a quartz column and is exposed to ultraviolet light within the range of 290 nm to 350 nm, as air is bubbled through the material at room temperature⁹. This route enables us to add hydroxyl groups to the oil using a well-controlled reaction in which heat and metal catalysts are not needed.

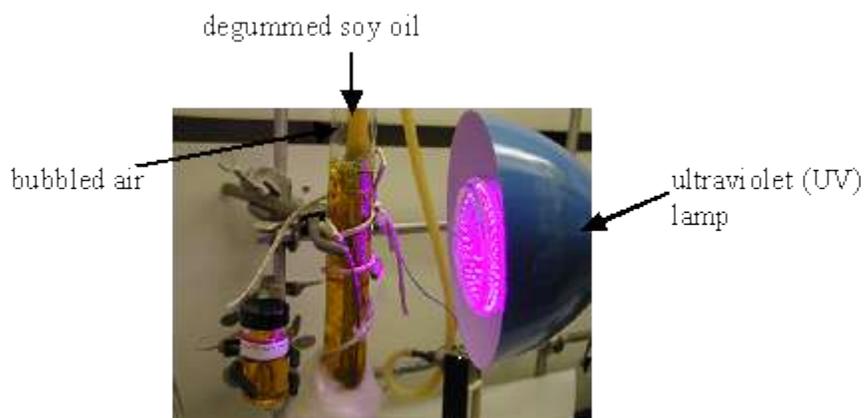


Figure 6: Laboratory setup to add hydroxyl groups to degummed soy oil using ultraviolet light.

The viscosities of the polyols were recorded as a function of reaction time and ultraviolet light exposure, seen in Figure 7. The data shows that for soy oil that is not exposed to ultraviolet light but has air bubbling through the column, there is no change in the viscosity of the material. However, with the introduction of ultraviolet light, there is a marked increase in viscosity around 180 hours, which correlates to the addition of hydroxyl groups in the oil. The change in hydroxyl groups was determined through standard titration methods. Overall, the method produced a lower odor polyol, as confirmed through odor test panel results in comparison to commercial soy polyol products.

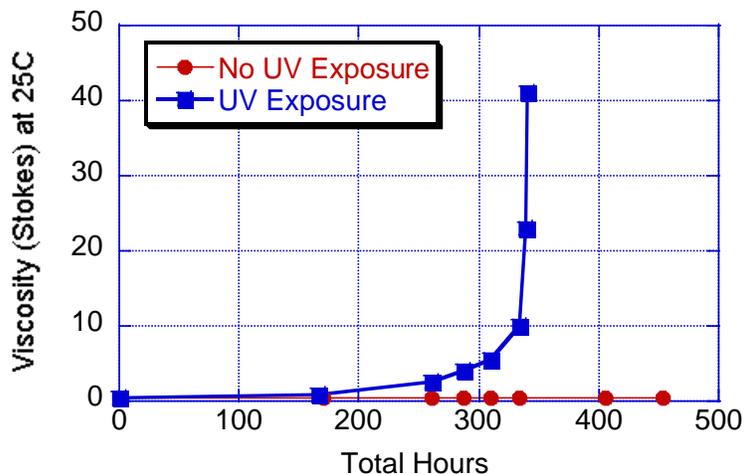


Figure 7: Measurement of viscosity of degummed soybean oil as a function of exposure to ultraviolet (UV) light.

A chemical analysis of the UV catalyzed soy polyol was completed, as shown in Table II. The samples showed a hydroxyl number in the range of 40-50 mgKOH/g, and viscosity of 2700 cps, which is suitable for molding flexible polyurethane foams. Also, the soy polyol exhibited excellent color characteristics (clear to slightly pale yellow color). The chemical results show that the UV method for catalyzing the hydroxylation of the soy oil produces an acceptable polyol for flexible foams.

Table II: Chemical analysis of UV catalyzed soy polyol.

Analysis	
Hydroxyl Number (mgKOH/g)	47
Color (Gardner)	1
Viscosity (cps)	2700
Acid Value (mgKOH/g)	5.4
Karl Fischer Water (%)	0.064

Odor Reduction Method for Soy Polyols

One of the main technical challenges of incorporating soy polyol into commercial automotive applications is reducing the inherent odor of the renewable material. For interior automotive plastics, one key criteria that is used to assess odor is the SAE J1351 method. Samples were cut into 5.08 cm by 2.54 cm by 12.7 cm blocks and conditioned in a sealed, glass jar for one hour at 57°C. Five panelists evaluated and ranked the perceived odor of the samples on a scale from 1 to 5, according to the chart shown in Table III. A rating of "2" or lower is considered acceptable for these applications.

Table III: Odor Rating for Interior Plastics

Odor Rating Criteria SAE J1351	
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

Early on, we attempted to remove volatiles from soy oil by heating the material to 57 C for one hour. As shown in Figure 8, this was not an effective method for improving the odor rating. As another method to improve the soy polyol product and reduce odor of the material, we identified a method to remove the low molecular weight, volatile, odor containing species (with chain lengths of ten carbons or less.) Soy polyol samples were post-treated at ChemTech, a chemical processing company in Joliet, IL, using a high efficiency stripping method. Using a wiped film evaporator (WFE), samples were processed at a variety of temperatures until optimized parameters were determined. Odor evaluation of the stripped polyol samples showed that two passes through the WFE at 88 C produced optimal reduction in odor.

Samples from this study were evaluated by the set of panelists and were compared to the degummed soy oil and crude soy polyol. As shown in Figure 8, odor panel results indicate that using the WFE aids in decreasing the perceived odor of the soy polyol to an acceptable level (rating of 2 or less.)

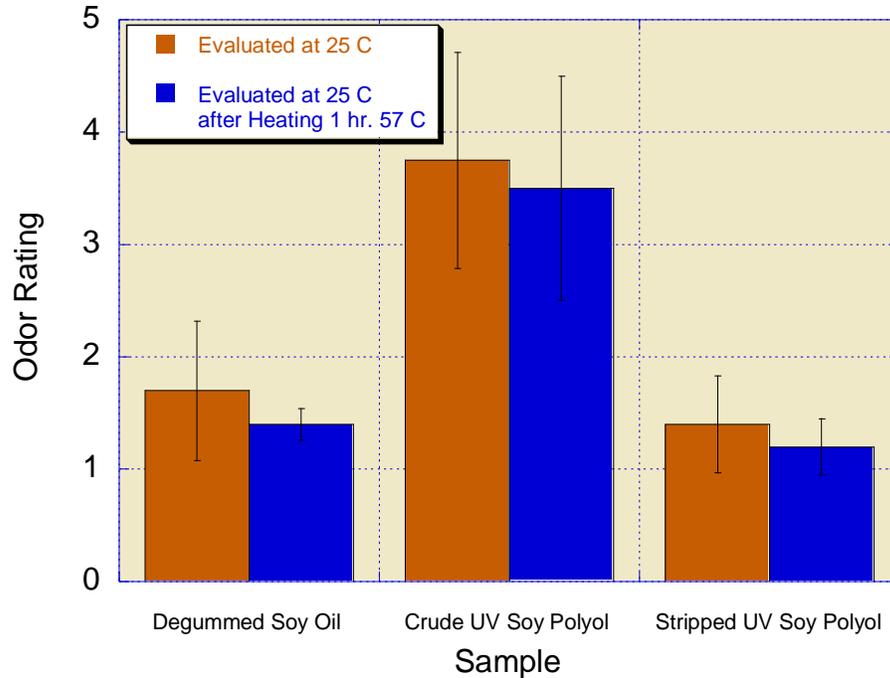


Figure 8: Comparison of odor ratings following SAE J1351 method for soy oil, crude soy polyol and stripped soy polyol.

Processing and Properties

In order to assess the properties and processing requirements of molding flexible foams from soy polyols, foam formulations were developed within our laboratory and in partnership with Bayer Corporation. Unlike rigid foams, flexible polyurethane foams are extremely sensitive to the quantity and nature of the formulation reactants and additives. We have studied a current MDI (diphenyl methane diisocyanate) seat cushion foam formulation to optimize the mechanical performance when soy-based polyol is substituted at various levels. Optimized formulations included 40 percent soy polyol in the polyol blend. Foams were produced by reacting a polyol blend of petrochemical and soy based material with petroleum-derived diphenyl methane diisocyanate with appropriate combinations of blowing agent, amine/tin catalysts, cross-linker and silicone surfactant, as shown in Figure 9. The side reaction of isocyanate and water yields a urea linkage and evolution of carbon dioxide, which acts as the principal blowing agent in the foaming process. The targeted density of the foams was between 32-40 kg/m³.

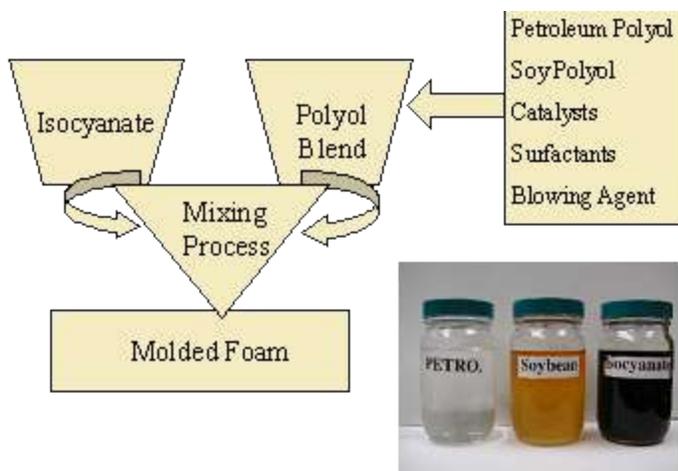


Figure 9: Process for molding soy-based polyurethane foam.

While the details of the formulation are proprietary, the chemicals for the foams included soy polyol, R2-052B from Urethane Soy Systems Company, polyether polyols, Multranol 5168, Multranol 3901 and Multranol 9199 from Bayer Corporation, diphenyl methane diisocyanate from Bayer Corporation, amine catalyst, 33LV from Air Products and Chemicals, Inc., Niox A-1 and A-4 from GE Silicones, and surfactant, DC5943 from Air Products and Chemicals, Inc.. Chemicals were mixed in ratios according to Table IV. A commercial, blown soy polyol was utilized in the molding trials described in this section due to the limited availability of the ultraviolet light catalyzed soy polyol.

Table IV: Basic Formulation for Flexible Soy Foam.

Components with Parts by Weight	
Soybean Oil Polyol	40
Petroleum Polyol	60
Water	3-4
Silicone Surfactants	1-1.5
Amine Catalysts	0.5-1.0
Cross-Linker	0.25-0.35
Isocyanate	100 Index

Polyol blends, catalysts, surfactants and water were blended using a 2300 rpm stirring lab mixer for approximately three minutes before adding the MDI. The reactants were stirred until a color change was visible in the viscous blend, indicating the onset of creaming. The blended chemicals were immediately poured into an aluminum box mold with dimensions of 38.1 cm x 38.1 cm x 10.16 cm. Foams were cured at 70°C for 10 minutes, followed by room temperature cure for 48 hours before sectioning.

The optical appearance of the cellular structure of the foams was recorded using an LCD camera connected to a Nikon microscope. Images were taken at 50 times magnification. Figure 10 shows a comparison of the microstructures in the petroleum and soy foams. The images indicate that the microstructure looks very similar between the two samples, and both foams exhibit an open cell structure, which is desirable for seating foams.

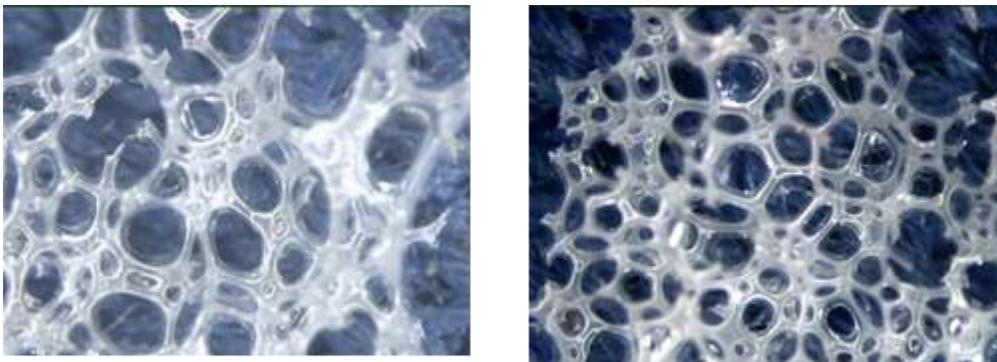


Figure 10: Comparison of polyurethane foam cellular structure for petroleum (L) and soy (R) foam at 50x magnification.

With the promising microstructural appearance of the soy foam and initial laboratory scale testing results, one of the 40 percent soy polyol blend formulations was molded at Lear Corporation using an impingement mixing system and headrest tool. The purpose of this trial was to mold parts using production tooling and to test the processing window of the soy foam in a production part geometry. Figure 11 depicts the foaming process in which a) the headrest stake is inserted into the tool, b) the chemicals are poured into the tool and the lid is closed and c) the foam is demolded from the tool. It was found for the soy system studied that the optimal molding parameters included a mold temperature of 60-65 C, and isocyanate/ polyol blend ratio of 90-100 index, to create parts with acceptable surface appearance.

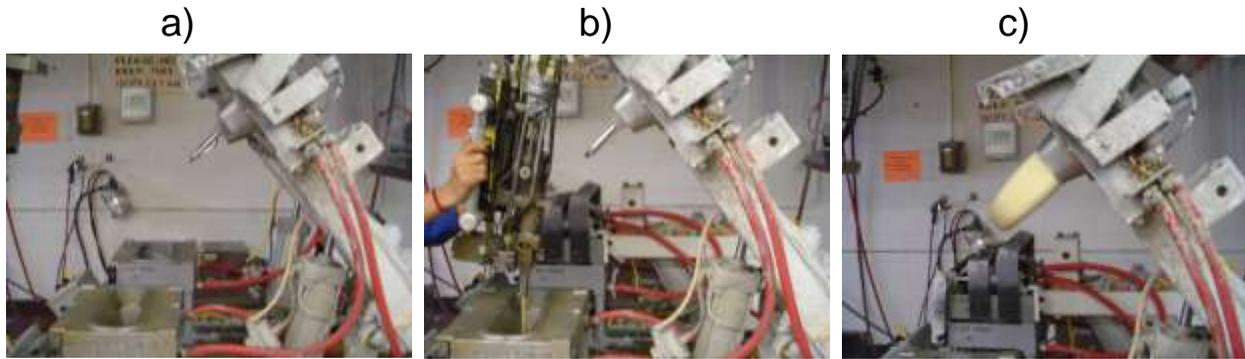


Figure 11: Process of forming headrest foam using an impingement mixing system. a) insertion of metal frame into tool lid b) pouring of chemicals into open mold c) demolding reacted polyurethane foam.

In addition to the part surface appearance, the material properties of the soy foam were also evaluated. Several of the key screening properties include: detectable odor, staining of vinyl in contact with the foam, fogging of low molecular weight species and flammability of the material. The properties of soy-based foam containing a blend of 40 percent soy polyol and 60 percent petroleum based polyol are compared to a petroleum foam and typical seating requirement in Table V. The soy foam exhibited comparable properties to the benchmark standard in all of these categories except for the fogging requirement. Since the control sample of the petroleum foam exhibited oily droplets as well, it is likely that the catalyst or surfactant additives are contributing to this negative fogging result.

Table V: Material Testing of Polyurethane Foams

	Density (kg/m ³)	Odor	Staining	Fogging	Flammability (mm/min.)
Method	ISO 845	FLTM BO131-01	SAE J1885	SAE J1756	ISO 3795 SAE J369
Requirement	Drawing Specified	Maximum Rating 2.	Control and Test Samples must have same visual appearance.	Minimum # 70; No droplets.	100 mm/min. maximum
Petroleum Foam	N/A	N/A	Pass= No staining	99; oily droplets	N/A
Soy Foam	49.1	Immediate=2 24 hours=2	Pass= No staining	83; oily droplets	69

Summary and Next Steps

The use of agricultural materials such as soy and natural fibers offer promising, alternative material sources for select thermoset, polymer applications within the automotive industry. We evaluated the potential use of soy in both flexible polyurethane foam applications as well as in sheet molded composites. The results using these renewable materials were very promising, with each application having unique technical issues that need to be addressed.

For thermoset SMC composites, the soy based resin offered comparable mechanical properties to one of the benchmark petroleum-based, vinyl ester resins. The soy resin composites molded into plaques and parts showed equivalent stone impact resistance as the petroleum based resins as well. To increase the bio-content of the composites, natural fibers were used to replace either part or all of the glass fiber reinforcement. These composites also showed promising results. Natural fibers offer many benefits over traditional glass fillers: weight savings (natural fibers have a lower density than glass), material cost savings, and utilization of a material derived from renewable resources. While material forms and processing conditions have not been optimized, the mechanical performance of natural fiber composites indicates that the hemp fibers do offer significant reinforcement within the vinyl ester and soy based resin systems. Comparison of the samples to traditional SMC indicates that the compression and tensile properties of these composites are consistently less than glass fiber composites. Creating hybrids of hemp fibers with glass improves the mechanical performance of the composites, by increasing the tensile modulus. One of the technical challenges of natural fiber composites is their tendency to absorb moisture. By conditioning samples through immersion in water, our results have shown that there is a significant decrease in mechanical properties of the composites in both vinyl ester and soy resin matrices. Future work will include identifying methods to reduce moisture uptake in these composites.

Soy-based polyurethane foams offer a promising alternative to petroleum-based foams. Not only do they utilize a renewable resource as one of the basic components, but they offer the potential of being favorable from an economic perspective as well. In this paper, we discussed a novel, synthetic route for hydroxylating soybean oil. While the chemical analysis of the product looks promising, foams need to be molded in order to assess the mechanical properties and processing ease for making foam. Using a commercially available soy polyol, our results have shown that flexible, polyurethane foams containing soy may be formulated to pass several of the material requirements necessary for interior, automotive applications. Optimized foam formulations were able to meet benchmark standards for interior seating applications such as: density, flammability and odor. Technical issues such as durability and fogging of the foam under heated conditions will need to be addressed in order to utilize the foam in automotive applications.

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