» New Research on Miracle Soy Bean Will Expand Us

by Russell J. Fisher

For the last few decades, soybeans have played an increasingly diverse role in American life. Most of this miracle bean's benefits lie, as one might expect, in the field of nutrition. The United Soybean Board (USB), which represent some 600,000 U.S. farmers and is the main motivator for many projects, has published many articles on how soy can benefit everyday health. Soy can help lower cholesterol and reduce the effects of perimenopause, coronary disease, and hypertension. In July, the Journal of the American Dietetic Association recommended a daily intake of 25 g/day of soy protein to reduce cholesterol. Today's consumer can purchase soymilk, tofu, and soy protein bars during a regular run to the grocery store.

But this little miracle bean has far-reaching potential, much further than simply as a nutritional staple or supplement. It has industrial uses as well, and this includes applications in composites and plastics. Matter of fact, the history of soybean-based plastics goes back to Henry Ford, who was always looking for ways to use renewable resources in his automobiles. The rear deck of a Ford was prototyped with a soybean-based resin without reinforcement. It was more like a thermoplastic type material, but he was able to take a hammer and beat the part without failure. At that time, it was not cost effective to use it in production, but this prototype gave him the opportunity to show the value of new

Photos courtesy of Ashland

ideas in the neophyte plastics industry.

Soy is currently used in industrial applications such as paints, stains, and adhesives. But it also is used in certain resin formulations. How did soy, an agricultural marvel, come to be used in the composites industry?

In 1997, the USB contracted the University of Delaware to do research in the use of soy oil as a matrix in a composite system. They developed a resin system using a soy-based polymer after initial investigations yielded an epoxy-based resin. The USB approached John Deere and Co. in Waterloo, Iowa to test sample parts made with the soy resin. The first engineer, Gene Ream, used an aftermarket fan shroud as an alpha part for data. The parts were retrieved in December of 2003 from two South Dakota farmers. Test results showed good physical properties compared with standard polyester systems.

Cost-Effective Challenges

John Deere and Company was interested in further use of bio-systems. They formed a "bean team" to look more closely at soy, this new type of renewable resource. John Deere proceeded to manufacture a hay baler side door. This project was lead by John Cerny, at the John Deere Technical Center in Moline, Ill. The door was successful, but still not cost effective compared to standard resin systems.

After a time, resin manufacturers began to see some advantages to using non-petroleum based resin systems. There was enough interest to develop several unsaturated systems based on soy oils and corn alcohols or "bio-systems." The first production use was resin manufactured by Ashland Chemicals in Dublin, Ohio.

John Deere has worked to complete extensive testing of soy-based composite systems in the last seven years. The SMC formula is used in a piece of agricultural equipment for the Combine Gullwing doors, in production since 2001. The resin is 75 percent petroleum based, 17 percent soy based, and 8 percent ethanol (corn) based. The tensile strength comparing standard SMC to soy-based SMC is 72 to 81 MPU. The Notched Izod was lowered from 961 to 657 J/M. The Possion's ratio is about the same at 0.245 compared to 0.223. Flexural Strength is similar at 173 versus 208 MPA. Both systems have similar paint adhesion. This test data is courtesy of John Deere and Company, Moline, Ill.

There has been considerable work and testing on RIM (Reaction Injection Molding). These resins systems have between 10-20 percent soy content. The primary users are the agricultural industry. The soy is on the polyol side of the urethane. Much of this research and development was conducted by Urethane Soy Systems and the Bayer Corporation. In addition, flexible foams are being molded with similar success to standard products. The increase use of soy on the agricultural side of composites is material cost driven.

Basic Chemistry

How does the basic chemistry of the resin system work? The soy oil is converted in to a glycol and reacted with a dibasic acid. The monomer is generally styrene or an acrylic type system. The properties are between a polyester and vinyl ester resin. The corrosion testing is still taking place with the results to be finalized in about a year. Soy oil is a long chain system, which requires careful review of

in Composites Industry

ENVIREZ® 1807 resin is the first commercial unsaturated polyester that uses a significant amount of soybean oil and ethanol in its production, with 25 percent in weight raw materials coming from renewable sources rather than petroleum sources. This resin is currently being used to produce body panels for combines and hoods for tractors for the agricultural equipment market.

the initiator (catalyst) and accelerator ratios. The addition of corn alcohol helps reactivity with the resin. The percentage of soy oil is between 5 and 40 percent of the resin formula. There is testing being done on a fire retardant version, which requires Antimony Trioxide (SB_2O_3) to give a Class 1 fire rating. Smoke density tests will be run on this fire retardant version in the near future.

> New processes are being researched such as filament winding, RTM, pultrusion, vacuum infusion, and hand layup. One of the first filament winding processes is being implemented by GPI in Wausau, Wisc. on a tank system as an exterior barrier. One of the first production vacuum bagging systems is being conducted by FabriGlass Composites in Moline, Ill.

The current processes being developed are RTM, filament winding, pultrusion, vacuum infusion, open molding, and SMC. The RTM process is currently being field-tested. Filament winding has been tested and we are waiting for the corrosion tests to be finalized. As stated earlier, bio-based SMC is in current production in the agriculture market, but other areas are being investigated.

Revolutionary Research

There is research going on that promises a breakthrough in the making of soy-based plastic thermosets. To date the conversion of soy oil to functional sites for bonding has been costly. The cost of soy-based unsaturated polyesters used in composites are only cost effective for high end systems such as isophthalic resins.

Research is going on to genetically change the soybean oil to eliminate a such costly conversion. The epoxy-type oil is being developed at the University of Kentucky by Dr. David Hildebrand. His near-term objective is to develop a seed with 50 percent reactive oil. The balance would be protein. Currently, for one bushel of soybeans there is 10.4 lbs of oil per 60 lbs. of beans. This is achieved by changing the DNA sequencing of the bean plant. Work is being done on planting, growing and harvesting the seeds.

This highly valued soybean seed is changing levels of natural desirable organic compounds. This research will not happen overnight, but will require several years before the development of a commercial product can proceed. Research costs of these studies are funded by the Department of Energy Consortium for Plant Biotechnology Research, the United Soybean Board, Owensboro Grain, and Ashland Specialty Chemicals. Omni Tech International out of Midland, Mich. has consulted the United Soybean Board and monitored this project.

Ashland Specialty Chemicals received a patent on the oil-based polyester resin in early 2001. Since that time Ashland management has committed to commercializing the product for the reinforced plastics industry. Since 2004 over one million pounds of compound has been used in agricultural machines such as combines. Both John Deere and Case New Holland have used this SMC process. This results in about 500 lbs per combine and tractor that uses soybean based resins. This has been a collaborative plan by Ashland, Deere and Company, Ashley Industrial Molding, ThyssenKrupp Budd Company, Case New Holland, and United Soybean Board.

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Eclectic Applications

The construction industry is another area of interest for soy-bean based resins. Some companies have developed building systems that comply with new guidelines to include recyclable or renewable resources. Advantage points are given during the bid process to companies that have included renewable resources or "green" systems.

One of the newest "hot news" for soy-based resins is the development of a soy-based powder coating. The unusual property of this material is it can be cured at 250 degrees Fahrenheit. The standard petroleum systems need to be cured at 350 to 400 degrees Fahrenheit. This feature will now allow coating of composites, wood, and other plastics.

The powder coating material is polyester based. Battelle Memorial Institute in Columbus, Ohio, developed this coating. Currently, the formula has only been tested in the clear state. Further work is currently being done to add pigments to the system. Test results on the clear version of the coating passed the MEK wipe test. The test panels were comparable to the standard control. The gloss was higher because the material has a lower viscosity at cure temperature. Other tests are being run to meet the requirements and goals needed for many end users. The exciting feature is having a renewable resource product that requires a lower oven temperature, which saves energy costs. In addition, the option of using a powder coating in place of wet spray systems can reduce the use of solvents currently needed in the wood and plastics industries. It should take about one more year of development before this material will be commercially available.

Other areas are bio-diesel and adhesive polymers. Bio-diesel has grown from one million to 25 million gallons in the last three years. The adhesive polymers include wood adhesives formulated to bond green lumber and foamed plywood glue, which replaces animal blood. For more information on industrial uses of soy, contact *www.unitedsoybean.org.*

What Do Markets Hold?

Markets open to new resins shall be dependent on costs and the government's regulations and incentives. At the current time, the overall costs of soy-based resins are higher. They range from 5 to 15 percent higher compared to standard petroleum products. As the cost of crude oil increases, this ratio will decrease.

The average bushel of soybeans weighs in at 60 lbs. From this bushel, 10.7 lbs of soy oil can be converted to plastic resin systems. There are billions of bushels of soybeans harvested every year.

Industrial plastics have the potential to use 75 million bushels per years. At an average yield of 50 bushels per acre, industrial plastics uses can account for 1.5 million acres of farmland. The check off system charges farmers 0.5 percent of the market price per bushel sold. This means no tax dollars are used for research projects, which are needed to expand soy production. The five major areas that are in the check off program are production researches, communication, marketing, international marketing, and new uses. The plastic development comes under the new uses area.

Historical data and current costs are the main conflicts limiting the use of soybean-based composite systems. Constant discussions are taking place considering profit versus environmental, social perception, and the long-term dependency on imported oil. Many articles and seminars have been presented recently concerning bio-based materials such as soybean resin systems. The future looks good because the availability is there, the research has been done, the data is being compiled, and the end users are interested. At the end of the day, it comes down to costs. If government regulations insist on the use of bio-based resins like soy, the growth will increase significantly.

On the application side, the main driver is the interest of resin manufacturers. There are several companies investigating bio-systems realizing the impact of rising costs of crude along with the historically stable costs of soy and corn oil. Of course, their research takes time and capital. Once the option of purchasing bio-systems resins is available, composite molders will consider adding them to their list of laminates.

At present, there is only one known company whose owners are composite molders, thermo-formers and soybean farmers. Terry and Nancy Keiffer own these companies located in Preston, Iowa. Their mission is to grow the beans and use the soy-based resins systems in their molding process. Their companies, Fabri-Glass Composites, and Plastics Unlimited, represents a complete circle in renewable resources. They are members of the American Composites Manufacturers Association (ACMA).

There are at least 35 composite molders currently reviewing and testing soy-based resin systems in the United States. Hopefully, there are even more internationally.

So there it is, salad oil is now converted to plastic resins, powder coatings, paints, stains, adhesives, and bio-diesel. There is no end to the use of the long chained soy oil. In the next several years you should expect more products from the miracle bean that has covered our nation's farm fields for many years. CM

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