



Society of Plastics Engineers, Inc.
Promoting the Scientific and Engineering Knowledge of Plastics

800-798-1241
706-238-9101

SPE Plastics Environmental Division

P.O. Box 441
Lindale, GA 30147
www.spercycling.org

Student Poster Awards: GPEC® 2010

Richard C. Bopp, Education Chair & Student Poster Awards

The SPE Global Plastics Environmental Conference (GPEC 2010) was held this year on March 8-10 at The Florida Hotel and Conference Center in Orlando Florida. The conference theme was "*Sustainability & Recycling: Raising the Bar in Today's Economy.*"

We were quite pleased with the number and quality of the student posters. Excellent poster presentations were given by undergraduate and graduate students representing seven schools in the US and UK. All were worthy of awards, but the judges selected the following winners for special recognition and cash prizes:

Graduate Awards:

1st Place: Mihir A. Oka, *Georgia Institute of Technology, Atlanta, GA USA*, "Properties of PLA and Cellulose-Based Degradable Polymer Deposits," \$300 Prize.

2nd Place: Kodikara Manjula Dilkushi Silva, *Brunel University, Uxbridge, Middlesex, United Kingdom*, "A Bio-Based Polymer Composite from Renewable and Sustainable Resources," \$200 Prize.

3rd Place: Bo Liu, *Washington State University, Pullman, WA USA*, "Investigations of Properties and Foam Extrusion of Novel Soy Protein Blends," \$100 Prize.

Undergraduate Awards:

1st Place: Robert D. Aldi, *Rochester Institute of Technology, Rochester, NY USA*, "Characterization of Virgin Polyethylene Terephthalate (PET), Post-Consumer PET and their Blends: *In Situ* of Processing Effects," \$300 Prize.

We extend our great appreciation to all the student authors and their advisors for their hard work in preparing for this event with special congratulations to all the contest winners.



Society of Plastics Engineers, Inc.
Promoting the Scientific and Engineering Knowledge of Plastics

SPE Plastics Environmental Division

800-798-1241
706-238-9101

P.O. Box 441
Lindale, GA 30147
www.sperecycling.org

Student Posters: GPEC[®] 2010

Join us for ***“Sustainability & Recycling: Raising the Bar in Today’s Economy”*** at GPEC[®] 2010 on March 8-10, 2010 at **The Florida Hotel & Conference Center**, Orlando, Florida, USA

Student Poster Session (Tuesday, March 9, 2010)

Richard C. Bopp, GPEC[®] 2010 Poster Session Chair, Tel: +1 (952) 742-0454

Email: Richard_C_Bopp@NatureWorksLLC.com

Posters will be judged by jury. Cash awards offered for posters of exceptional quality.

K. Teodoro et al., "Sisal Cellulose Whiskers Extracted at Different Times and Temperatures," Federal University of Sao Carlos (UFSCar), Sao Carlos, Brazil (Graduate Student)

S. Muthu, "Eco-impact of Plastic and Paper Shopping Bags," The Hong Kong Polytechnic University, Hong Kong, China (Graduate Student)

D. Moyer, "Sustainable Packaging Opportunities in the Restaurant Industry." Michigan State University, School of Packaging, (Graduate Student)

R. Aldi, " Characterization of Virgin Polyethylene Terephthalate (PET) , Post-Consumer PET and their Blends: in situ of Processing Effects," Rochester Institute of Technology, Rochester, NY. (Undergraduate in 5th year B.S. Program)

K. Silva, " A Bio-Based polymer Composite from Renewable and Sustainable Resources," Brunel University, Uxbridge, Middlesex, United Kingdom (Graduate Student)

C. Venkatesan, "Student Perspectives on an Environmentally Conscious Design Course," Kettering University, Flint, MI.

C. Lotti, "Thermoplastic Corn Starch Reinforced with Cotton Whiskers," Federal University of Sao Carlos (UFSCar), Sao Carlos, Brazil. (Authors' student status under review.)

E. Kostyukova, "Polymer Waste and Fly Ash Mixtures for Manufacturing of Artificial Wood," Irkutsk State Technical University, Irkutsk, Russia.

M.J. Joo, "Blends of Poly(lactic acid) and Modified Starch," Michigan State University, East Lansing, MI.

S. Modi, "Thermal and Rheological Properties of Poly-(3-hydroxybutyrate-co-3-hydroxyvalerate) and Poly (Lactic Acid) blends for Food Packaging Applications," Ohio State University, Columbus, OH.

B. Liu, "Investigations of properties and foam extrusion of novel soy protein blends," Washington State University, Pullman, WA.

M. Oka, "Properties of PLA and Cellulose Based Degradable Polymer Composites," Georgia Institute of Technology, Atlanta, GA.

A. Arena, "Effects of Nanoclays and Nano-Calcium Carbonate (CaCO₃) on Glycerol-Plasticized Thermoplastic Cornstarch (TPS) Polymer Blends," Rochester Institute of Technology, Rochester, NY.

SP1

Sisal Cellulose Whiskers Extracted at Different Times and Temperatures

K.B.R. Teodoro

*National Nanotechnology Laboratory for Agribusiness (LNNA)
and Federal University of Sao Carlos (UFSCar)*

Suspensions of sisal whiskers were obtained by acid hydrolysis after the bleaching of sisal fibers. The original fibers were pre-treated with alkaline peroxide solution to remove other non-cellulosic components. The extractions were performed using a fixed sulfuric acid concentration of 6M. The temperature and time of extraction were as follows: 45°C and 60 minutes (SW_{45/60}); 45°C and 75 minutes (SW_{45/75}); and 60°C and 30 minutes (SW_{60/30}). The sisal whiskers were morphologically characterized by scanning transmission electron microscopy (STEM). The crystallinity index was measured by x-ray diffraction (XRD) and thermal stability in air atmosphere was investigated by thermogravimetric analysis (TG). The results indicated that the length of sisal whiskers were in the range of 150-450 nm independently on extraction condition, oppositely to the measured diameters. For the sisal whiskers extracted at 45°C the diameter range was about 12-20 nm whilst for those extracted at 60°C, it was around 4-8 nm resulting in higher aspect ratio (37.5-56.2) for this last condition. On the other hand, the crystallinity of SW_{60/30} sample was lowest among the sisal whiskers and the bleaching sisal. It suggests that this of procedure can affect the integrity of the cellulose nanofiber despite more rod-liked morphology. There was no significant difference in the thermal stability among the samples.

Co-Authors

E. de Morais Teixeira, C. Lotti, A.C. Corrêa, J.M. Marconcini and L.H.C. Mattoso

SP2

Eco-impact of Plastic and Paper Shopping Bags

S.S. Muthu

The Hong Kong Polytechnic University

This research work revolves around the study of the eco-impact of plastic and paper bags using life cycle impact assessment (LCIA) technique under three different options such as usage and disposal criteria with the existing usage behaviour to reuse and governmental policies to recycle (option1), usage and disposal criteria as per consumer's perception if systems are in place (option2) and usage and disposal criteria in case of absence of recycling systems (option3). The first case, which is the bottom-line for other options, is the study of the eco-impact of plastic and paper bags in their manufacturing phase, without considering their usage and disposal phases. LCIA has been accomplished by the Eco-indicator 99, a damage oriented method for LCIA in SIMAPRO 7.1. The single score values calculated by the Eco-indicator 99 are considered as a directive to compare the environmental impact made by these bags and a detailed explanation of results is provided in this article. The next stage is the study of the eco-impact of these bags including their usage and disposal phases. This was done under three different options as stated above and the results derived were compared with the results derived from baseline case, which is the focus of the study. The values for usage and end-of-life phases were obtained from the survey questionnaire performed amongst different user groups of shopping bags in China, Hong Kong and India. The study shows that the eco-impact of plastic and paper bags is very high if there are no usage and disposal options provided. When the eco-impact values from options of existing possibilities and consumer's perception are compared, the eco-impact value is lower in option 1 in all the three countries for both types of bags, which is mainly attributed to the fact that in option 1, a higher percentage of reuse is preferred to recycle and landfill categories. Also the eco-impact of these two types of bags is studied with and without the presence of recycling systems in China, India and Hong Kong, where the eco-impact is lower in the presence of recycling systems. These results indicate that a higher percentage of reuse could significantly trim down the eco-impact of plastic and paper bags. Consumers' perceptions and behaviours in connection with the respective government's policies and implementation of recycling systems could be critical in reducing the eco-impact of plastic and paper shopping bags.

SP3

Sustainable Packaging Opportunities in the Restaurant Industry

D. Moyer

Michigan State University School of Packaging

As the Earth's population becomes aware of its potentially harmful impact on the planet, corporations are adding sustainability objects to their usual business-oriented objectives. Corporations that can simultaneously emphasize people, planet, and profits (i.e. triple bottom line) can also endear themselves with ecologically minded consumers and shareholders. Corporate sustainability objects can emphasize improvements in the areas of packaging, transportation, and products. As more corporations reap the benefits of sustainability initiatives, the popularity of sustainability expands to more industries. The restaurant industry is one example.

Large restaurant management companies are beginning to realize the benefits of having triple-bottom-line sustainability objectives. In many industries packaging is not the primary focus or product. Instead, packaging is a necessary byproduct of corporate endeavors. For restaurants that specialize in dining in, packaging is simply the means by which foodstuffs are delivered to the restaurants or the way patrons take leftovers home. Packaging-based sustainability opportunities can be uncharted territories for restaurateurs. The following summary documents one restaurant management company's quest to better understand its sustainable packaging opportunities.

SP4

Characterization of Virgin Polyethylene Terephthalate (PET), Postconsumer PET and their Blends: in situ of Processing Effects

R. Aldi

Rochester Institute of Technology

There is an increased emphasis on humans reducing our dependence upon petroleum and their resultant products. Consequently, any effort to produce earth-compatible processes, technologies and materials can help appease this world-wide concern. One example is through the recycling of commonly utilized polymeric materials such as polyethylene terephthalate (PET). This presentation focuses upon the property changes displayed by virgin PET, postconsumer PET and their blends in the results of different processes such as: extrusion and injection molding.

In order to study the effects of the processes, the polymer samples of virgin PET, post consumer PET and their blends were prepared by different processing routes; injection molding or combined extrusion then injection molding. The blends were prepared through extrusion blending where the post-consumer content varied by mass from 10-50%. After extrusion the blends were injection molded. Each sample was then characterized before and after the respective processes through the use of mechanical and thermal analysis in accordance to ASTM standards. These tests included tensile and impact testing, thermogravimetric analysis (TGA), differential scanning calorimetry (DSC), melt flow index (MFI) and heat distortion temperature testing (HDT). From the results, the post-consumer PET and the blended virgin and postconsumer PET displayed noticeable characteristic changes due to the two different processing routes. However, some of the changes in the blends were also very minimal for the mechanical and thermal properties. We will present more or the details for this study at the 2010 GPEC conference.

SP5

A Bio-Based Polymer Composite from Renewable and Sustainable Resources

K.M.D. Silva
Brunel University

Increasing awareness of green issues and environment preservation needs are pressurizing packaging materials to be eco-friendly and sustainable. As a result, scientists are working to produce biodegradable polymers as a substitute for petrochemical based plastics. It is difficult to manufacture polymers that are fully biodegradable with versatile properties. One of the typical biodegradable polymers, Polylactic acid (PLA) is being considered for various applications. PLA was first used only in biomedical applications where its bioabsorbability and biocompatibility properties were exploited. Development of methods to derive the monomer from bioconversion which leads to large scale production has enabled expansion of PLA use in many applications including packaging. However, PLA by itself does not exhibit properties that are required by the packaging industry. Efforts are being taken to develop cost effective composites by incorporating starch with PLA matrix but properties are not yet suitable for commercialization. This study is being undertaken as a part of the process of improving compatibility and processability of starch and PLA blends with conventional polymer processing equipment to develop a novel packaging material.

Genetically modified organisms (GMO) free PLA and wheat starch blends were prepared and characterized in the presence of adipic acid. Wheat starch and adipic acid were mixed with PLA and successfully extruded using a lab-scale co-rotating twin screw extruder. Extruded strands were pelletized and injection moulded into standard tensile test bars and plaques. Differential Scanning Calorimetry (DSC) tests demonstrated significant improvements in the thermal behaviour with adipic acid (AA). Crystallization over a broad temperature range is observed in the blends and it is very prominent at higher adipic acid levels. Thermal Gravimetric Analysis (TGA) gave 1% weight loss with and without isotherm at 180°C for 30 minutes. The heating of the blends at 180°C for 30 minutes show no discolouration of the materials by visual inspection. Rheology of blends measured by parallel plate geometry demonstrated increased viscosity with the inclusion of starch with PLA, but adipic acid considerably reduces the blend viscosity and at a certain concentration equals to that of virgin PLA viscosity. However, by further increasing adipic acid levels in the blend lowered viscosity, storage modulus and loss modulus has been observed. Impact properties measured by the falling weight technique showed improved peak force on the starch PLA blend with AA, moreover, improved energy absorption and deformation were detected in the starch and PLA blends. In conclusion, it can be stated that the present experimental results demonstrate that a bio-based composite material with PLA and starch can be made with better properties.

Co-Authors

K. Tarverdi, R. Withnall and J. Silver

SP6

Student Perspectives on an Environmentally Conscious Design Course

C. Venkatesan
Kettering University

Contemporary words like carbon footprint, sustainability, recycling, ocean debris, green engineering, alternative energy, cap and trade, global warming and climate change have become common in popular media. In this information era, it is easier to hear about sensitive issues but more difficult to understand the depth of the issues and possible solutions to the complexities of environmental degradation. Current college students, the next generation of decision-makers, can become confused and caught in the politics of media, legislators and researchers. In fact, engineering students have the potential to truly make a difference with innovative solutions to improve the environment.

This paper summarizes a National Science Foundation (NSF) funded multi-disciplinary course IME 540 – Environment Conscious Design at a private, Midwestern university. The course helps students to understand the actual meaning of sustainable engineering and changes their thought process for a positive contribution to the environment. Many schools and colleges emphasize leadership, ethics and social science to build a good citizen, and environmental consciousness must be added as an item of importance.

The Environmentally Conscious Design Course is designed to clarify the uncertainties among students through active learning methods that allow students to re-design common products throughout the course. The course is designed into seven modules including (1) historical, social and ethical implications (2) life cycle analysis, (3) material selection, (4) process design, (5) end of life, (6) responsible management and (7) Green Chemistry. Upon completion of the course, the student is immediately prepared to analyze and implement innovative ideas related to improving the environmental impact of common products.

SP7

Thermoplastic Corn Starch Reinforced with Cotton Whiskers

E. de Morais Teixeira

National Nanotechnology Laboratory for Agribusiness (LNNA)
and Federal University of Sao Carlos (UFSCar)

The aim of this work was to investigate nanocomposites based on thermoplastic corn starch (TPS) plasticized by 30% of glycerol reinforced with cotton whiskers. These were extracted by acid hydrolysis in different compositions viz. 1 wt%, 3 wt%, 5 wt%, 7 wt% and 10 wt% based on dry starch. The cotton whiskers were morphologically characterized by scanning transmission electron microscopy (STEM). The crystallinity index was measured by x-ray diffraction (XRD) and thermal stability in air atmosphere was investigated by thermogravimetric analysis (TG). For TPS and nanocomposites preparation, the final water content was fixed in 20% wt (dry starch basis). This water was comprised of finely dispersed whiskers (using a sonicator) in different concentrations. The samples were prepared in a co-rotating twin-screw extruder using a temperature profile between 140-160°C. The nanocomposite's morphology and properties were characterized by field emission scanning microscopy (FEG), thermal stability (TG analysis) and rheology. The results indicate that the cotton whiskers showed length in the range of 85-225 nm and diameter in the range of 6-18 nm. A good fiber-matrix interaction was observed in the FEG images, as well as in the improvement of TPS performance. The 10 wt% nanocomposite presented an outstanding increase of 49%, 145% and 65% in the elastic modulus, tensile strength and elongation at break, respectively. There was no significant difference in the thermal stability of the nanocomposites in comparison to neat TPS. The shear viscosity against shear rate (flow curve) of both TPS and its nanocomposites showed a small Newtonian plateau followed by a transition to the pseudoplastic behavior. It could be clearly noted an increase of zero-shear viscosity for all nanocomposites in comparison to neat TPS. The highest and lowest increase in the zero-shear viscosity, of about 42% and 18%, were observed for the nanocomposites with 3 wt% and 10 wt%, respectively. Also, it could be noted a highly pseudoplastic behavior of nanocomposites, probably due to the orientation of the whiskers in direction of flow during the rheological measurements.

Co-Authors

C. Lotti, A.C. Corrêa, J.M. Marconcini and L.H.C. Mattoso

SP8

Polymer Waste and Fly Ash Mixtures for Manufacturing of Artificial Wood

E.O. Kostyukova
Irkutsk State Technical University

Novel strategy for recycling of polymer waste is its simultaneous recycling with mineral waste for production of ready-to-use composite materials. We have developed materials based on the mixtures of thermoplastic polymer wastes as binder (content - up to 30 %) and fly ash as filler (content - up to 70%). Fly ash is a very inexpensive by-product of coal power stations. The final articles (boards) are produced by regular extrusion technique; they have controllable porous structure and density, any length, width and cross-section as well as the texture and color of natural wood. The developed Porous Artificial Porous Wood (APW) is able to replace other types of commercial non-porous artificial wood (such as WPC - Wood Plastic Composites) and some species of natural wood. The APW, which does not contain any natural wood as filler (fibers, flour, sawdust, etc.) exhibits some unique complex of technical properties such as lightness, magnificent heat- and cold insulation, buoyancy. However, APW being much cheaper than natural wood and WPC exceeds these materials in terms of fire- and temperature resistance, frost and water resistance, as well as chemical and biological (rotting, mould formation) resistance and longevity. The main usage of the developed APW is construction industry both for outdoors and indoors application - decking, siding, fencing, window and door frames, furniture, etc. The project was funded by Russian federal contract ? 02.740.11.5080.

Co-Author

V.V. Barahtenko

SP9

Blends of Poly(Lactic Acid) and Modified Starch

M.J. Joo

Michigan State University

Poly(lactic acid), PLA, has received many attention as an alternative polymer to the petroleum-based ones due to its mechanical properties which are comparable to those of PET and PS, to be glossy, and its biodegradability. Starch, another polymer derived from renewable agricultural feedstock, has been used as filler to have both biodegradability and lower cost for environmentally friendly plastics. Many efforts have been done to develop a biodegradable polymer by blending PLA and typical starch because of the immiscibility of those two-phase polymers. Cyclodextrins (CDs), an enzymatically modified starch, have successfully been used for encapsulation of different compounds from cavities as host molecules. CDs are mainly used to enhance the delivery of specific components such as drugs and flavors at the pharmaceutical and food industries controlled by temperature and relative humidity. This study is to have better dispersed blends of PLA and modified starch which have a function of encapsulation. Dried resins of PLA and modified starch at various ratios (1:0.4, 1:0.2) were premixed to increase dispersion. Second step of blending was done by using a pilot-scale twin extruder and the samples were stored as a pallet. Scanning electron microscopy was used to check different dispersions of modified starch to the polymer matrix. Also, melting temperature, glass transition temperature, percent of crystallinity were determined by differential scanning calorimeter and the blends had only one melting point which means well-blended to put together each melting point.

SP10

Thermal and Rheological Properties of Poly-(3-hydroxybutyrate-*co*-3-hydroxyvalerate) and Poly (Lactic Acid) Blends for Food Packaging Applications

S. Modi

The Ohio State University

Poly (L-lactic acid) (PLA) and Poly (3-hydroxybutyrate-*co*-3-hydroxyvalerate) (PHBV) are bio-derived semi-crystalline polymers of interest to the food packaging industry looking for alternatives to the petroleum based materials. The PHBV polymer is too brittle and temperature sensitive to be used for potential film applications. Therefore, the blends of PHBV with PLA were explored as an alternative way of achieving desired properties. The objective of this study was to characterize the thermal and rheological properties of PHBV (Tianan 5%) blended with PLA (6202D) resin at 20, 30, 40, and 50% PLA and relate these findings to potential food packaging applications. The thermal analysis showed increasing concentration of PHBV resulted in lower thermal stability of PLA. Several melting transitions for the blends were observed representative of phase separated polymers. The viscosity of all the blends remained unchanged during the one hour time sweep at 170°C, but the complex viscosity was lower than Tianan 5%. The frequency sweep showed no improvement in the complex viscosity of the blends compared to Tianan 5%. The use of PHBV food packaging applications has been limited due to its performance and processing compared to traditional thermoplastics. These blends were processed in a lab scale extruder at 175°C. The brittleness and low melt strength made it difficult to extrude blown films. The various blends started to fracture immediately exiting the blown film die. In addition, the low melt strength caused the molten polymer to sag as the polymer was cooled by the reel system.

Co-Authors

K. Koelling and Y. Vodovotz

SP11

Investigations of Properties and Foam Extrusion of Novel Soy Protein Blends

B. Liu

Washington State University

In this study, soy protein concentrate (SPC) was blended with poly(butylene adipate-co-terephthalate) (PBAT) and poly(lactic acid) (PLA), respectively. The foam extrusion of the resulting blends was also investigated. SP can be processed either as filler or plastic in blending with PLA, depending on the water content in the pre-compounding SP. When containing extra amount of water, SPC behaved like a plastic in the compounding and experienced significant deformation. Consequently, the resulting blends displayed higher mechanical properties than the blends in which SPC only functioned as filler. Morphology, mechanical, dynamic mechanical and thermal properties of the blends were studied. The extrusion foaming process was studied and the effects of various additives on density and mechanical properties of the foams were studied. The results showed that the addition of compatibilizer led to a decrease in foam density and increases the specific mechanical properties. The effects of chemical blow agent (CBA) content on foam properties were also investigated on the SP/PLA foams. It was found that 47% void fraction was achieved with 1 phr CBA and 0.5 phr pMDI.

Co-Author

J. Zhang

SP12

Properties of PLA and Cellulose Based Degradable Polymer Composites

M.A. Oka
Georgia Tech

We studied PLA-microcrystalline cellulose composites, focusing on the effects of processing, particle size and surface modification. The thermal and mechanical properties of these PLA based composites were studied and the effect of cellulose addition on PLA degradation was analyzed. The degradation rate was found to depend on initial sample crystallinity, pH of the degradation media and cellulose content of the composite.

Composites were prepared using solution processing and melt mixing methods. The processing methods influenced the polymer's ability to crystallize affecting the mechanical properties. Isothermal crystallization studies carried out to study the kinetics of crystallization showed melt processed samples to have lower half time for crystallization and higher value for the Avrami exponent. The crystallization rate of PLA was also found to depend on surface chemical composition of cellulose particles and the particle size. Influence of filler surface modification on the composite properties was studied via grafting of lactic acid and polylactic acid to cellulose particles and the effect of filler size was studied using hydrolyzed microcrystalline cellulose particles. A simple esterification reaction that required no external catalyst was used for surface modification of cellulose particles. Surface modification of cellulose particles enhanced the static and dynamic mechanical properties of the composite samples due to improvement in the PLA-cellulose compatibility that resulted in better interfacial interactions. The utility of cellulose, available from a renewable resource, as an effective reinforcement for PLA is demonstrated.

Co-Author

Y. Thio

SP13

Effects of Nanoclays and Nano-Calcium Carbonate (CaCO₃) on Glycerol-Plasticized Thermoplastic Cornstarch (TPS) Polymer Blends

A. Arena

Rochester Institute of Technology

There is a need for new, more sustainable polymeric materials that decrease the amount of solid waste in landfills and reduce dependence on petroleum. Recently, thermoplastic corn starch has been studied with various types of reinforcements not only to improve the thermal and mechanical properties, but because it is a readily biodegradable material made from corn starch and glycerol. This study presents the effects of the nanoclays and calcium carbonate (CaCO₃) on the mechanical and thermal properties of the TPS blends.

The effects of various reinforcements (nanoclay and nano-calcium carbonate powders) in the glycerol plasticized thermoplastic corn starch (TPS) polymers were investigated by tensile testing and thermal analysis (differential scanning calorimetry (DSC), and thermogravimetric analysis (TGA)). The reinforcements studied were bentonite nanoclay, montmorillonite nanoclay, and calcium carbonate powder in order to produce various reinforcement-TPS blends. Also, the reinforced blends were compared to the thermoplastic starch polymer (TPS) with no reinforcement. In the results, the thermoplastic starch (TPS) polymers with nano-powder exhibited an increase in tensile strength and modulus over the TPS polymer. Thermogravimetric analysis showed that the addition of montmorillonite nanoclay caused the TPS blend to display improved thermal resistance. A more detailed study will be discussed in the conference.