Missouri Soybean Merchandising Council

Research Pre-Proposal

2020

Project Title: **Value-added applications of soybean for golf industries**	
Principal Investigator Name: **Dr. Ram Gupta**	
Principal Investigator Title, Employer: **Associate Professor of Chemistry** **Department of Chemistry and** **Kansas Polymer Research Center** **Pittsburg State University**	
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Co-Investigator Name:
Co-Investigator Title, Employer:

New Project ___**X**_____ Ongoing Project _____ MSMC Project No.	
Proposed Funding Start Date: **1st Nov, 2020**	Proposed Project End Date: **31th Oct, 2022**
Total Funding Requested: Year 1 – $58,622 (2020-2021)	Year 2 – $58,622 (2021-2022)
Description of Project: **Golf is one of the very popular games played around the globe with the golf ball market worth about $550 million per year. In the United States alone more than 24 million people play golf. Utilizing soybeans for golf balls will significantly enhance the demand for soybeans.**	
List of Project Partners, Institutions, Organizations, Businesses and Agencies: **Pittsburg State University, Pittsburg, Kansas**	
Principal Investigator: **Dr. Ram Gupta** Associate Professor of Chemistry Department of Chemistry and Kansas Polymer Research Center Pittsburg State University	Authorized Organizational Representative: **Dr. Tim Dawsey** Executive Director for the Advancement of Applied Science & Technology Kansas Polymer Research Center Pittsburg State University
Signature: RGupta Date: 09/08/2020	Signature: Tim Dawsey Date: 9/8/20

For assistance, contact Ebby Neuner with the Missouri Soybean Merchandising Council at eneuner@mosoy.org.

I. PROJECT SUMMARY

Golf is one of the most played sports around the globe. Golf is played by over 60 million people around the world. In the United States alone over 24 million people enjoy playing this game, including over 8,000 professional players. The global golf equipment market size was around USD 6.5 billion in 2018 with a golf ball market of about USD 550 million. Over 850 million golf balls are produced every year to fulfill the demand for this game. This project plans to utilize soybeans as main components for manufacturing golf balls. In general, golf balls are made of three layers: core, inner layer, and outer layer. We plan to use soybeans based composites for the core and soybean oil-based polyurethane coating as the outer layer for a golf ball. The weight of a single golf ball is around 1.62 oz (45.93 g), therefore to manufacture 850 million golf balls, a huge quantity of soybeans will be required which will be beneficial for soybean growers.

II. PROJECT OBJECTIVE

The objective of this project is to develop new materials from soybean which can be used for the production of golf balls. In general, a golf ball is made of three layers: core material, inner layer, and an outer layer (**Figure 1**). We plan to use soybean-based materials for core and outer layer. The task is broadly divided into four sections to achieve the objective of this project:

a) Development of core material for golf balls using soy meals or soybean-based chemicals
b) Development of outer layer for golf balls using soybean-based polyurethanes
c) Testing and optimization of properties of soybean-based golf balls
d) Develop technology/products for commercialization

Soybeans contain about 20% oil, 34% carbohydrates, 40% protein, and 4.9% ash. Soybean meals are generated during the soybean oil extraction process. In general, for every ton of soybean oil extraction, 4-5 tons of soybean meals are produced. Soybean meals are mostly used as feed for animals and there is a huge amount of soybean meals which are wasted every year. The value-added applications of soybean meals and oils for the sports industries such as golf will provide financial benefits to the soybean growers.

Soybean meals are high in protein (in the range of 40-70 w/w%) which makes them very suitable as core material for golf balls. Soybean meals contain a large number of functional groups such as amines, carboxyl, and hydroxyl groups which act as binding sites for cross-linking to increase the mechanical strength as the core material for golf balls. The use of soybean meals provides the additional benefits of being low cost, easy handling, low-press temperature, eco-friendliness, and easy to recycle. However, the low mechanical and impact strength of the soybean-based materials needs to improve. We plan to improve these properties by physical and chemical modifications of soy meals.

Figure 1: Structure of a golf ball.
(Figure adopted from goggle for just demonstration purpose)

Soybean meals will be physically and chemically modified to improve mechanical strengths so that it could be used in the production of golf balls. For physical modifications, soy meals (protein) will be uncoiled to expose more functional groups on the surface which will act as sites for crosslinking to improve mechanical strength. **Figure 2** shows a schematic of the denaturing and unfolding of soy meal. The denaturing and unfolding will be performed under acidic or alkaline conditions. The effect of acid and alkali concentrations, type of acid and alkali, and reaction time will be studied in detail to understand their effects on the properties of soy meal as core material for golf balls.

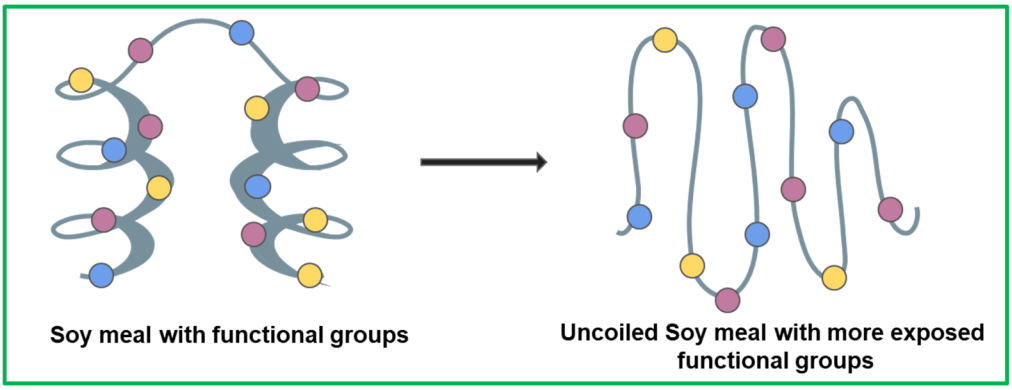

Figure 2: A schematic of denaturing and unfolding of soy meal.

Chemical modifications of uncoiled soy meal will be performed to significantly improve the strength needed to use as a core material for golf balls. Different types of crosslinkers will be used. The crosslinkers can combine with the functional groups of soy meals to improve mechanical strengths. We plan to use phenolic and epoxy-based crosslinker in soy meals. The phenolic groups in phenolic compounds act as hydrogen donors which can be functionalized with carboxyl, hydroxyl, and amino groups of soy meals through covalent and hydrogen bonding and thus will improve the mechanical strengths (**Figure 3**). The epoxy resin also can react with the functional groups on the soy protein and can form a crosslinked structure, which will provide improved mechanical strength, and impact resistance. The density of the modified soy meal will be optimized by adding low-cost fillers to meet the standard of a commercial golf ball.

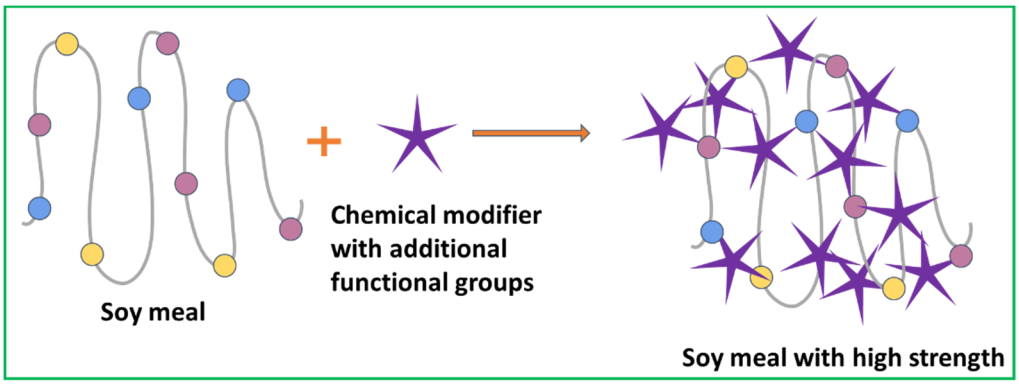

Figure 3: Chemical modification of soy meal to use in the core of a golf ball.

The outer layer of the golf ball will be developed using soybean oil derived polyols or byproducts of soybean. The polyol from the soybean oil will be reacted with different types of isocyanates to prepare a durable coating on the golf balls. Different types of isocyanates will be used along with polyols form soybean to understand the coating properties, durability, impact, and weather resistance properties. A mold will be designed to provide a similar texture and dimensions close to commercial golf balls. Standard scientific and industrial methods will be used to characterize the materials and test the prepared soybean-based golf balls. The timeline for this project is given below:

1st six months: Physical modifications and characterizations of soy meals using acids and alkalis. The effect of types and concentration of acids and alkalis on the denaturing and unfolding of soy meal will be studied.

2nd six months: Chemical modifications of soy meals using different crosslinkers. Different types of crosslinkers and various concentrations of crosslinkers will be used to optimize the process. Cost-effective fillers will be used to match the density and weight of a golf ball to a standard golf ball. Standard testing and characterization methods will be used to understand the properties of chemically modified soy meals.

3rd six months: Synthesis and characterizations of soybean derived polyols and chemicals. These compounds will be reacted with different isocyanates to make an outer layer for the golf ball. The characteristics of soybean-based polyurethane coatings will be studied using standard methods.

4th six months: Fabrication and testing of golf balls using soybean meal based materials as core and soybean oil/chemical-based polyurethanes as the outer layer.

III. PROJECT DELIVERABLES

The Kansas Polymer Research Center at Pittsburg State University is a leading institution in bio-polymers and vegetable oil-based research and development. The center is equipped with all the necessary equipment for physical/chemical modifications and analysis of soybean-based compounds for their applications in golf balls. For physical/chemical modifications of soy meal and characterizations, we have the needed glassware and laboratory equipment. The synthesized soybean meal-based compounds, crosslinker, and epoxy will be analyzed and characterized using various state-of-the-art instruments located at the Kansas Polymer Research Center and several analytical and testing instruments at the Chemistry Department.

Mr. Randy Robinson, Executive Director of EnterprisePSU, a unit that helps to commercialize ideas at Pittsburg State University, will be involved in business development. EnterprisePSU is housed in Block 22 at Pittsburg State University. Mr. Robinson works closely with Dr. Gupta to find the right partners for commercialization and business development of the technology/products developed. Kansas Polymer Research Center works with several industries such as Chevron Philips, Honeywell, Cargill, BiOH® polyols, Cessna and have developed several paths/materials/technology for commercialization. Dr. Gupta is working with Missouri Soybean Merchandising Council for the last few years and has developed two new technology/products. Dr. Gupta has filed one patent in partnership with Missouri Soybean Merchandising Council for using bio-wastes generated in soybean crops for batteries and supercapacitors industries and

working to file a second patent on soybean oil-based flame-retardant polyurethanes developed using cost-effective methods. With the help of this funding, we plan to deliver the followings:

a) Soybean meal based compounds for the inner core of a golf ball
b) Soybean oil/chemicals based polyurethanes coatings for the outer layer of a golf ball
c) File a patent and work towards commercialization of the developed technology/products in partnership with Missouri Soybean Merchandising Council
d) Involve undergraduate and graduate students along with research associates in this project
e) Create a public awareness regarding value-added applications of soybean by presenting the outcome of the project in seminars at Pittsburg State University and in conferences (after protecting intellectual properties)

IV. BENEFIT TO SOYBEAN FARMERS

Golf is one of the most popular sports in the world with a global golf balls market of around USD 550 million. This project plans to utilize soy meals which are mostly considered as low-value materials and used for animal feed for the preparation of core material for golf balls. We proposed to use the soybean-based chemicals such as soybean oil and other byproducts to prepare the outer layer of golf balls. In general, a golf ball weighs around 45 grams, and to meet a demand of 850 million golf balls/year for golf industries, a huge amount of soybean will be required. We estimate to generate a demand of about 38 million kilograms of soybean-based products for the golf industries. Utilizing low-cost soybean materials for such value-added applications will provide significant financial benefits to soybean growers.

V. INTELLECTUAL PROPERTY

Dr. Gupta is working with Missouri Soybean Merchandising Council for a few years and has already developed two technology/products which will benefit soybean growers. Dr. Gupta and his team have filed a patent on the technology to fabricate high-performance batteries and supercapacitors using bio-wastes generated in soybean crops. The patent is filed in partnership with Missouri Soybean Merchandising Council. The team is now working to file a second patent on flame-retardant soybean oil-based polyurethanes which is one of the fastest-growing polymer industries with a global market of over 70 billion dollars.

The technology/products developed through this proposal are planned to share with Missouri Soybean Merchandising Council in similar ways as it was partnered in the past. The initial seed money from the Missouri Soybean Merchandising Council will help us to develop technology/products for commercialization in partnership with the Missouri Soybean Merchandising Council. We expect to file a patent with Missouri Soybean Merchandising Council upon technology/products development to use in golf balls. In general, the rights are shared between Pittsburg State University and Missouri Soybean Merchandising Council in 50:50 ratio when Missouri Soybean Merchandising Council is covering the cost of patent filing.

VI. PROJECT FOCUS

Dr. Gupta is using several soybean-based materials for product development and commercialization. Dr. Gupta is using bio-wastes generated in soybean crops for energy storage devices. The team has used various bio-wastes generated in soybean crops such as leaves, stem, and shell for the synthesis of high-performance carbon using facile and cost-effective methods for batteries and supercapacitors industries. Dr. Gupta is also using soybean oil for the preparation of polyurethane foams which show properties better than many commercial foams with the added advantage of non-flammability. Seeing the market and demand for the golf balls, the team believes that their expertise on polymers using vegetable oils, presence of all necessary equipment, and skills in technology development will certainly help to develop new materials and technology based on soybeans for golf balls.

VII. BUDGET

Proposed Budget Summary	**Year 1 (2020-2021)**	**Year 2 (2021-2022)**
A. Salaries and Wages: Total* (show hours x rates)		
Research Associate (1044 h x $25/h)	$ 26,100	$ 26,100
Graduate Student(s) (960 h x $16/h)	$ 15,360	$ 15,360
Undergraduate/high school (300 h x $8/h)	$ 2,400	$ 2,400
B. Fringe Benefits (17.424% of salary for Research Associate and 1.204% of salary for Students)	$ 4,762	$ 4,762
C. Materials Testing and Services	$ 2,000	$ 2,000
D. Expendable Materials, Lab Supplies, custom designed mold to fabricate golf balls, etc.	$ 8,000	$ 8,000
E. Travel	$ 0	$ 0
F. Capital Equipment	$ 0	$ 0
G. Total Amount of This Request	$ 58,622	$ 58,622
Grand total(s)	**$ 58,622**	**$ 58,622**

VIII. PI INFORMATION

Dr. Gupta has a track record of working with polymers and nanomaterials over 15 years which resulted in over 200 peer-reviewed journal publications, over 250 national/international/ regional presentations, chaired many sessions at national/international meetings, wrote several book chapters, and received over two million dollars for research and educational activities from external agencies. All the projects were completed on time with the expected outcome. With the reduced teaching load for Dr. Gupta (half compared to other faculty members) and the presence of all necessary facilities and characterization instruments, Dr. Gupta and his team don't anticipate any problem in completing this project. Please find below two page summary of Dr. Gupta's achievements.

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(A) Professional Preparation

Education

Banaras Hindu University, India	Physics, Chemistry, Mathematics	B.S.(Honors)	1997
Banaras Hindu University, India	Chemistry	M.S.(Honors)	1999
Banaras Hindu University, India	Chemistry	Ph.D.	2005

Postdoctoral Training

Banaras Hindu University, India	Senior Research Fellow, Chemistry	2005-2006

(B) Appointments

2018-Present	Associate Professor, Pittsburg State University, KS
2013-2018	Assistant Professor, Pittsburg State University, KS
2011-2013	Senior Research Scientist, North Carolina A&T State University, NC
2006-2011	Research Assistant Professor, Missouri State University, MO

(C) Award

2019	Outstanding Faculty Scholarship Award, Pittsburg State University
2018	Excellence in Creative Activity, Pittsburg State University
2017	Excellence in Teaching Award, Pittsburg State University
2016	Excellence in Research Award, Pittsburg State University
2016	Outstanding Undergraduate Research Mentor Award, Pittsburg State University
2015	Outstanding Faculty Scholarship Award, Pittsburg State University

(D) Annual Performance

2018	Exceptional Performance Awarded for Teaching, Research, and Service
2017	Exceptional Performance Awarded for Teaching, Research, and Service
2016	Exceptional Performance Awarded for Teaching, Research, and Service
2015	Exceptional Performance Awarded for Teaching, Research, and Service
2014	Exceptional Performance Awarded for Teaching, Research, and Service
2013	Exceptional Performance Awarded for Teaching, Research, and Service

(E) Selected Publications *(total publications exceeds 200)*

1. "Plasma-derived graphene-based materials for water purification and energy storage", Nikolas Natter, Nikolaos Kostoglou, Christian Koczwara, Christos Tampaxis, Theodore Steriotis, Ram Gupta, Oskar Paris, Claus Rebholz, Christian Mitterer, C 5 (2019) 16
2. "Sustainable Flame-Retardant Polyurethanes using Renewable Resources", Sanket Bhoyate, M. Ionescu, P. K. Kahol, Ram K. Gupta, Industrial Crops and Products 123 (2018) 480
3. "Highly flame-retardant polyurethane foam based on reactive phosphorus polyol and limonene-based polyol", Sanket Bhoyate, M. Ionescu, P. K. Kahol, J. Chen, S. R. Mishra, Ram K. Gupta, Journal of Applied Polymer Science 135 (2018) 46224
4. "Orange-peel-derived carbon: Designing sustainable and high-performance supercapacitor electrodes", C. K. Ranaweera, P. K. Kahol, M. Ghimire, S. R. Mishra, Ram K. Gupta, C, The Journal of Carbon Research 3 (2017) 25

5. "Synthesis of novel bio-based polyol via thiol-ene chemistry for rigid polyurethane foams", N. Elbers, C. K. Ranaweera, M. Ionescu, X. Wan, P. K. Kahol, Ram K. Gupta, Journal of Renewable Materials, 5, Supplement 1 (2017) 74-83
6. "Bio-based polyols using thiol-ene chemistry for rigid polyurethane foams with enhanced flame retardant properties", C. K. Ranaweera, Mihail Ionescu, N. Bilic, M. Wan, P. Kahol, Ram K. Gupta, Journal of Renewable Materials 5, Supplement 1 (2017) 1-12
7. "High performance and flexible supercapacitors based on carbonized bamboo fibers for wide temperature applications", Camila Zequine, Charith Ranaweera, Z. Wang, Sweta Singh, Prasant Tripathi, O.N. Srivastava, Bipin Kumar Gupta, K. Ramasamy, P. Kahol, P.R. Dvornic, Ram K. Gupta, *Scientific Reports* 6 (2016) 31704
8. "Efficient hydrogen evolution in transition metal dichalcogenides via a simple one-step hydrazine reaction", Dustin Cummins, Ulises Martinez, Andriy Sherehiy, Rajesh Kappera, Alejandro Martinez-Garcia, Roland Schulze, Jacek Jasinski, Jing Zhang, Ram K. Gupta, Jun Lou, Manish Chhowalla, Gamini Sumanasekera, Aditya Mohite, Mahendra Sunkara, and Gautam Gupta, *Nature Communications* 7 (2016) 11857

(F) Synergistic Activities

1. Reviewers for various journals such as Journal of Applied Physics, Journal of Physical Chemistry, Materials Letters, Synthetic Metals, etc.
2. Judged several science fairs and symposium for high school, middle school, and undergraduate students
3. Served as Senior Editor for *Physics Express(Optoelectronics and Photonics)*
4. Editorial Board Member for *Journal of Materials*, *Thin Films Science and Technology*

(G) Collaborators and Other Affiliations

i) Collaborators and Co-Editors: R. Delong (Missouri State University), L. Dong (Missouri State University), K. Ghosh (Missouri State University), S. Guha (University of Missouri), A. Gupta (University of Alabama), B.K. Gupta (National Physical Laboratory, India), G. Gupta (University of Louisville), P. Kahol (Pittsburg State University), J. Kargul (University of Warsaw, Poland), D. Kumar (North Carolina A & T State University), R. Mayanovic (Missouri State University), K. Mensah-Darkwa (Kwame Nkrumah University of Science and Technology, Ghana), S. Mishra (Memphis University), A. Mohite (Los Alamos National Laboratory), K. Ocakoglu (Mersin University, Turkey), K. Ramasamy (Los Alamos National Laboratory)

ii) Graduate Advisor and Postdoctoral Sponsors:
Ph.D. and Postdoc advisor: R.A. Singh, Banaras Hindu University, India

iii) Thesis Advisees and Postgraduate-Scholar Sponsors:
Graduate Students: S. Abdalla (Ph.D., 2011-2013), T. Haywood (Ph.D. 2011-2013), K.M. Darkwa (Ph.D. 2011-2013)

MS students: T. Insgel, J. Choi, M. Sulman, F. DeSoza, S. Ramanujam, X. Martinez, M. Altamar, N. Albeladi, J. Candler, C. Zequine, D. Alqahtani, C. Zhao, S. Bhoyate, C. Zhang, C. Ranaweera, Z. Wang, S. Aloqayli, J. Aldream, N. Aljehany, S. Alkhalaf, M. Albalawi, E. Alqurashi, N. Elbers, A. Hinckey, H. Bhatta, A. Bhattacharya, A. Ghosh, N. Nag, S. Ganti, U. Ndubuisi, Y. Dhopade, C. Vera, G. Mundada, K. Paul, L. Fadiga, N. Mamidi, S. Manchiraju, S. Pulugam

Undergraduate students: L. Williston, K. Morey, J. Poli, B. Neria, Z. Choi, T. Morey, C. Zequine, F. De Souza, A. Jimenez, J. Candler, T. Elmore, E. Mitchell, S. White, M. Giffin, I. Lemongo, M. Onstott, H. Gemar, J. Graber, M. Langhoff, D. Brown, J. Doak, L. Shawn, A. Manivannan, D. Horst, J. Alaboson, J. Harkin, S. Jahnke