FOR ADMINISTRATIVE USE
Program Area Code Proposal Code

Minnesota Wheat Research and Promotion Council

RESEARCH PROPOSAL GRANT APPLICATION

1. NAME AND ADDRESS OF ORGANIZATION TO WHICH AWARD SHOULD BE MADE

Name: South Dakota State University
Address: 1015 Campanile Ave, Brookings, SD 57007

2. TITLE OF PROPOSAL

Innovative uses for Wheat biomass: A new income path for farmers

3. PRINCIPAL INVESTIGATOR(S)

Srinivas Janaswamy

PI# 2 Name:

PI# 3 Name:

4. PI #1 BUSINESS ADDRESS

Department of Dairy and Food Science
South Dakota State University
Brookings, SD 57007

5. PROPOSED PROJECT DATES (calendar years)

March 1, 2024 – Feb 28, 2025
Note: Research Reports are Due November 15th of Each Year

6. TOTAL PROJECT COST

$50,955

7. PI #1 PHONE NO.

765-409-2590 (M)
605-688-4910 (O)

8. RESEARCH OBJECTIVES: (List objectives to be accomplished by research grant)

The long-range goal of the PI's research program is to develop an economical and sustainable solution to treat plastic contamination and improve human health. This phase of the project aims to develop and establish protocols to extract lignocellulose from renewable agricultural residues and make strong and biodegradable films. We will isolate and characterize lignocellulose from wheat biomass (e.g., Spring wheat) and prepare strong and biodegradable films. To this end, two specific objectives have been selected: **(1) To extract and solubilize lignocellulose of wheat biomass, complex with wheat gluten, soy protein isolates, and whey protein isolate, and to understand the role of salts on the solution properties, and (2) To determine the tensile strength, elongation at break and water vapor permeability of films, and demonstrate the biodegradability in soil.**

Signature Of Principal Investigator	Date	Phone Number
DocuSigned by: Srinivas Janaswamy 972896650686488...	1/5/2024 | 13:01 PST	605-688-4910

Signature Of Authorized Representative	Title	Date
DocuSigned by: 7670CD5E2E48405...	Assistant Vice President for Research Development and Administration	1/5/2024 | 15:15 CST

Address Of Authorized Representative	Phone Number
Morrill Hall 200, Division of Research & Economic Development, Box 2201 University Station, Brookings, SD 57007	605-688-5051

Minnesota Wheat Research and Promotion Council
RESEARCH PROPOSAL GRANT APPLICATION
(2-pages maximum)

Project Title: Innovative uses for Wheat biomass: A new income path for farmers

Importance of this project to the profitability of wheat producers: Plastics are used for convenience in every household, but many are not appropriately recycled and are dumped everywhere around the globe. They take over 700 years to degrade, and the consequent perils are alarming. Plastic waste is a transboundary, complex, social, economic, and environmental problem that needs to be addressed effectively. Before worsening, meaningful methods of developing consumer-friendly packaging materials far from plastic are required. Many countries around the globe have imposed restrictions on the use of plastics. Despite these concerted efforts, a pressing scientific need still exists to find alternatives to plastics. Toward this end, lignocellulose residue from renewable agricultural biomass, such as wheat, stands out as a viable option. It is biodegradable, has a low density with a strong and stiff structure, and meets the desirable qualities of plastics. However, the intrinsic structural functionality of plastics outweighs the lignocellulosic-based materials in creating versatile products mainly due to the higher structural flexibility. Instead, plant-based products tend to be more rigid, presumably having been specifically processed from the lignocellulosic segments, but their safely biocompatible nature and readily biodegradable properties make them potential alternatives. The primary source of lignocellulosic material is trees, and if harvested for any invention, their depletion will lead to deforestation, another severe environmental issue to be concerned about. In this regard, finding an alternative and sustainable lignocellulose source is a priority. To this end, agricultural biomass, e.g., wheat biomass - instead of trees - presents as a suitable source, which could be reformulated satisfactorily to replace plastics. This proposal is to develop value-added functional products such as biodegradable films by extracting lignocellulose from wheat biomass and solubilizing using the economical and versatile inorganic salt methodology developed by the PI. The flexibility of the films will be enhanced by complexing with proteins such as wheat gluten. **The project will directly benefit Minnesota Wheat producers by leading to an economical multi-function conservation method with the potential for wheat biomass management toward gaining value while addressing the plastic perils.** Agricultural producers can incorporate our scientifically proven and environmentally friendly conservation practices in their operations. The results will be incorporated into our ongoing extension programming and other SDSU outreach activities and disseminated through various outlets aimed at producers, policymakers, and the public.

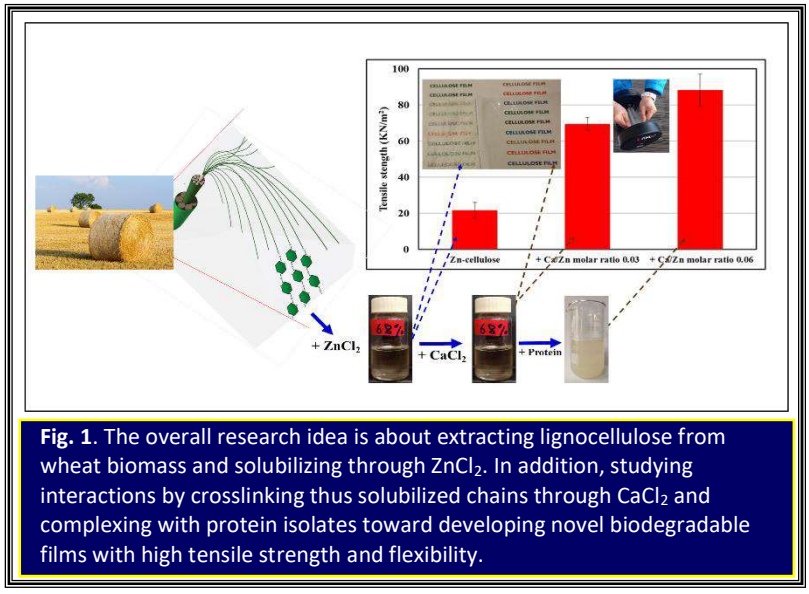

Fig. 1. The overall research idea is about extracting lignocellulose from wheat biomass and solubilizing through $ZnCl_2$. In addition, studying interactions by crosslinking thus solubilized chains through $CaCl_2$ and complexing with protein isolates toward developing novel biodegradable films with high tensile strength and flexibility.

With a total yield of 1.2 B tons, the USA ranks 4th among the 10 wheat-producing countries worldwide. [1] In the USA, wheat ranks third among the field crops, and in 2023/24, the production was 1.81 billion bushels. [2] Among the top-producing states, Minnesota ranked 6th with 73.8 million bushels, which was 33% up from 2021. [3] Indeed, wheat is a productive crop with high levels of biomass accumulation of around 2.5 tons/acre. Thus, a farmer with 1000 acres will have a projected agriculture residue income of $6x2.5x1000=$15,000 per year, assuming the value of wheat straw as $6 per ton. [4] However, wheat biomass contains about 35-45% lignocellulose, 20-30% hemicellulose, and 15% lignin. Thus, valuable lignocellulosic material could be envisioned for developing functional products, e.g., packaging films. However, wheat biomass is predominantly used as bedding for animals, garden mulch, building material, and ethanol production, to name a few. It also protects soil from wind and water erosion, adding organic matter and nutrients. However, if 50% of biomass was used for these purposes, and with the remaining 50%, roughly $7,500 of extra income a year could be envisioned, which certainly improves the economic status of wheat farmers. More value-addition could be anticipated after developing biodegradable films using the lignocellulose residue of wheat biomass. A full-scale techno-economic analysis will be carried out in subsequent years to establish the advantages of lignocellulose extract compared to other uses of wheat biomass.

Procedures: Wheat biomass: The PI has a good amount of biomass collected from Brookings, SD. During the project period, the PI would scout for contacts in MN and procure wheat biomass for further experiments. The samples will be

dried and ground to a fine 60-mesh particle size. Lignocellulose extraction: Three different protocols will be used to extract cellulose. Acid hydrolysis (e.g., 30% H_2O_2 + 70% glacial acetic acid) coupled with NaOH extraction and 20 and 50% NaOH extraction would be employed. Compared to acid hydrolysis, the NaOH extraction could retain a significant amount of hemicellulose and lignin, which certainly aids in improving the strength of the prepared films. The dried cellulose residue will be used for further use. Salts and organic solvents: $ZnCl_2$ will dissolve the extracted cellulose, and calcium ions crosslink the cellulose chains. Ethanol will be used for film preparation. The required amounts will be purchased from Sigma-Aldrich. Solubilizing cellulose: A pre-weighed amount of cellulose (*e.g.*, 200-800 mg) will be added to predetermined weights of $ZnCl_2$ to make solutions with a weight percentage of 50-78%. Before mixing, solutions will be equilibrated at 65-85 °C in a water bath. Later, $ZnCl_2$ solution will be added to the cellulose paste and mixed thoroughly for 30 mins. Crosslinking cellulose chains: At room temperature, various amounts of $CaCl_2$ (200-800 mM) will be added to the Zn-Cellulose solution. The solutions will be mixed thoroughly and set aside for film casting. In addition, proteins and protein isolates such as wheat gluten, soy protein isolate, and whey protein isolate will be tested to understand their role in improving film flexibility and elongation. Cellulose film preparation: Films will be hand-cast on a glass plate using a thin-layer chromatographic plate applicator, available in the PI's lab. The glass plate and film will be immersed in 500 mL ethanol (200 proof). The film will be coagulated for 30 mins and immersed in a fresh ethanol bath (500 mL) for another 30 mins. The film will then be fixed on a frame and air-dried at room temperature. It will be placed in a water bath for 30 mins to remove any excess salt and subsequently soaked in glycerol (5% v/v), a plasticizer, for another 30 mins. Finally, the film will be air-dried, and thickness, transparency, moisture content, water-solubility, moisture absorption, and water vapor permeability will be measured. Tensile strength: The films will be cut into 8 cm long and 1 cm wide strips. The MTS EM Tensile Testing System will measure tensile strength and film elongation by adapting the ISO1924-2:2008 protocol. Average values from triplicate measurements will be reported. Biodegradability: The films will be cut into 8 cm x 8 cm strips, and weight will be measured weight, and later will be buried in the soil. They will be taken out on the 1st, 3rd, 5th, 7th, 15th, 30th, 45th, and 60th day to assess the leftover product and determine their weight.

The timeline for completion:

Specific objective		March -May 2024	June-Aug 2024	Sep-Nov 2024	Dec 24-Feb 25	Feb 2025
1	Lignocellulose Extraction					REPORT
	Characterization					
	Films preparation					
2	Tensile strength, biodegradability, and other studies					

Regional linkages to other research activities: The PI is actively pursuing research on developing biodegradable films to replace single-use plastic bags using lignocellulose residue from biomass such as corn, wheat, oat, alfalfa, soyhulls, prairie cordgrass, and switchgrass, and avocado peels, banana peels and spent coffee grounds.

List any other secured, pending, or planned submissions to outside funding sources for this work: None.

Research Group: Functional Carbohydrates Laboratory, Department of Dairy and Food Science

Relationship to past projects: Currently, the PI has (i) NIFA-USDA, (ii) Minnesota Soybean Research and Promotion Council, and National Alfalfa & Forage alliance-funded projects focusing on lignocellulose residue-based films from various biomass sources.

Estimate the budget requirements: $50,955 is requested. One Ph.D. student ($25,033) will focus on extracting and characterizing lignocellulose fraction from wheat biomass, preparing films, and characterizing them with the help of one undergraduate student (he/she will spend about 200 hours, $16/h for $3,200). $282 fringe benefits are requested for the students. The tuition remission for the graduate student is $7,940. The general supplies ($8,000) include chemicals, salts, organic solvents, glass beakers, glass rods, gloves, paper towels, filter papers, etc., and contractual expenses ($3,000) of scanning electron microscopy and Fourier-transform infrared spectroscopy. To disseminate the research at national conferences and other meetings to peers, scientists, agricultural producers, and other stakeholders, $3,500 is requested.

References:

1. https://www.weforum.org/agenda/2022/08/top-10-countries-produce-most-wheat/
2. https://www.ers.usda.gov/topics/crops/wheat/wheat-sector-at-a-glance/
3. https://www.nass.usda.gov/Statistics_by_State/Minnesota/Publications/Crops_Press_Releases/2022/MN-Small-Grains-09-22.pdf
4. https://www.ams.usda.gov/mnreports/ams_3183.pdf

Minnesota Wheat Research and Promotion Council

RESEARCH PROJECT PROPOSAL BUDGET

Project Title: Innovative uses for Wheat biomass: A new income path for farmers

Principal Investigator(s) / Project Director(s) Srinivas Janaswamy	Funds Requested For Year 1 (2024)	Year 2 (2025)	Year 3 (2026)
A. Salaries and Wages	$ 28,233	$	$
1. Co-principal Investigator(s)			
2. Senior Associates			
3. Research Associates – Post Doctorate			
4. Other Professionals			
5. Graduate Students	25,033		
6. Prebaccalaureate Students			
7. Secretarial - Clerical			
8. Technical, Shop and Other (Undergraduate Student)	3,200		
B. Fringe Benefits	282		
C. Consulting and Professional Services	3,000		
D. Supplies and Services	8,000		
E. Travel	3,500		
F. Sub-Contracts			
G. Repairs & Maintenance			
H. Rentals & Lease			
I. Other Expenses: Tuition for the Graduate student	7,940		
TOTAL AMOUNT OF THIS REQUEST (per year)	**$ 50,955**	**$**	**$**

Approved : Brian Sorenson Int'l:_____ Date _____