Missouri Soybean Merchandising Council

Final Research Report

I. Title of Grant

Development of Soy Protein–Nanocellulose Composites as Active Food Packaging

II. Period Covered

5/1/2017– 8/31/2018

III. Project Leader and Co-Primary Investigators

Mengshi Lin (PI)
Azlin Mustapha (Co-PI)

IV. Layman's Summary (limit to one page)

This project aimed to develop soy protein-nanocellulose nanocomposites containing antimicrobial and antioxidant compounds from pine needle extracts. These multifunctional nanocomposites can be used as food packaging materials to inhibit the growth of foodborne pathogens and reduce lipid oxidation to prolong the shelf life of foods. This project was finished on August 31, 2018. Promising results were obtained that have good commercialization applications and can benefit the Missouri soybean growers and the industry.

Soy protein-based films have some interesting properties of being biodegradable, biocompatible, and inexpensive. However, their mechanical property and active functions still need to be improved for real-world applications in the food industry. We solved this problem by developing soy protein-based films incorporated with nanocellulose and pine needle extract. Many types of soy protein-based films were developed and evaluated in this project. Among them, two best soy protein-based films were selected, optimized, and characterized.

The composition of the film #1: 6% soy protein isolate, 15% cellulose nanocrystals (CNC), and 10% *Cedrus deodara* pine needle extract (PNE). This soy protein film was loaded with CNC and PNE. The filling effect of CNC led to a significant increase of mechanical properties. When a high content of PNE was incorporated in the films, the water vapor permeability was decreased. Moreover, the PNE-added films contained phenolic compounds and displayed strong antioxidant activities. The results demonstrate that this soy protein-based film has significantly enhanced mechanical property, antioxidant ability, and water vapor barrier capacity.

The composition of the film #2: 6% soy protein isolate, 15% cellulose nanofibril (CNF), 15% PNE, and 3% lactic acid. This acidic soy protein film was added with CNF and PNE. The tensile strength of the film was significantly enhanced due to the filling effects of CNF. CNF and PNE significantly improved the light barrier property. This film exhibited remarkable antioxidant activity due to phenolic compounds in PNE. Lactic acid and PNE enabled the film to possess notable antimicrobial effects on foodborne pathogens. The results demonstrate that this soy protein-based film incorporated with CNF and PNE can be used as active biodegradable packaging materials in the food industry.

V. State your objectives in question form and discuss how your results answer these objectives.

#1: Did this project successfully develop soy protein nanocomposites containing antimicrobial and antioxidant compounds?

Yes. Two novel types of soy protein-based nanocomposites were developed in this study. The mechanical properties of both films were significantly improved by the addition of cellulose nanofibril (CNF) or cellulose nanocrystals (CNC). The incorporation of pine needle extract (PNE) greatly enhanced the active functions of the films. The Film 1 displayed remarkable antioxidant and water vapor barrier capacities. The Film 2 showed notable antioxidant, antimicrobial and light barrier properties.

#2: Can these multifunctional nanocomposites be used as food packaging materials to inhibit the growth of foodborne pathogens in foods and prolong the shelf life of food products?

Yes. Our results of two active soy protein films can be applied in the food industry as active food packaging materials. These findings can also be used for potential patent applications. Further research is needed to use these novel soy protein films and test in real food products (cheese, fruits, snack, etc.) and evaluate their performance. For example, it can be used as a film on the surface of solid foods such as semi and hard cheeses and dried sausages during storage.

VI. Please answer the following.

A. How do your results benefit Missouri soybean growers?

Two novel types of soy protein-based films were developed in this study. This will expand the applications and new uses of soy protein isolates to improve food safety, which will help enlarge the market of soy-derived products and increase consumer's confidence in our food supply.

B. Estimate financial return for the average Missouri soybean producer.

We don't have an exact number of financial returns for the soybean producer at this time. The estimated return could be significant because in the long run, these multifunctional nanocomposites can be used as food packaging materials to inhibit the growth of foodborne pathogens in foods and prolong the shelf life of foods. The results from this project will eventually benefit the Missouri soybean growers and the industry as a whole.

C. Do your results benefit the environment?

Yes. These results demonstrate that this green technology of soy protein-based films can be used as active biodegradable packaging materials in the food industry. They are biodegradable and can replace the plastic packaging materials and reduce pollution in our environment.

D. What products or processes can be commercialized from this research?

1. List disclosure(s) of inventions or plant varieties submitted to the MU Tech Transfer Office.

At this time, there is no disclosure of inventions or plant varieties submitted to the MU Tech Transfer Office.

2. Identify potential disclosure(s) of inventions or plant varieties. Please note that credit must be given to MSMC for any inventions or discoveries resulting from this research.

Two potential disclosures of inventions are listed below and the credit will be given to MSMC:

Disclosure	Soy protein isolate (%, w/v)	Cellulose nanocrystals (%, w/v)	Pine needle extract (%, w/w)
Film 1	6	15	10

Disclosure	Soy protein isolate (%, w/v)	Cellulose nanofibril (%, w/v)	Pine needle extract (%, w/w)	Lactic acid (%, w/v)
Film 2	6	15	15	3

E. How would you commercialize these products or processes?

These new novel films will be used in Food R&D process to design new food products that can be wrapped with this novel nanocomposites. Examples for use of a coating on foods include: cheese, fruits, snacks, sausages, etc.

F. If no specific products or processes were produced, how do you plan to make your results available to producers or industry?

The new products or processes will be made available to the food industry via publications, news report, and through extension services.

G. Is additional time or research required before your results can be used by producers and industry?

Yes, additional research is needed to commercialize these new products. Further research is needed to use these novel soy protein films in real food products (cheese, fruits, snack, etc.) and evaluate their performance.

VII. List publications by type (popular press, thesis, journals, other) written or planned.

The following scientific articles have been published based on the results from this project and the credit is given to MSMC in the Acknowledgements:

(1) Yu, Z., Sun, L., Wang, W., Zeng, W., Mustapha, A., Lin, M. Soy protein-based films incorporated with cellulose nanocrystals and pine needle extract for active packaging. *Industrial Crops and Products*. 2018, 112, 412-419.

(2) Yu, Z., Alsammarraie, F.K., Nayigiziki, F.X., Wang, W., Vardhanabhuti, B., Mustapha, A., Lin, M. Effect and mechanism of cellulose nanofibrils on the active functions of biopolymer-based nanocomposite films. *Food Research International*. 2017, 99(1), 166-172.

VIII. List cost of original project and actual expenditures. *The U.S. Department of Agriculture requires that we ask for budget information, including the number of hours spent on the project, the number of dollars remaining on account, as well as a breakdown of expenses. You are required to provide this information in your report.* Please also include names and titles/positions of those whose time has been charged to this project.

Expenses	
704000 - Graduate Student Assistants	23,695.80
700000 - S&W-Budget Pool	**23,695.80**
Total Salaries & Wages	**23,695.80**
721000 - Business travel	4,000.00
727000 - Copy Service	265.49
728000 - Business Meeting Expense-Food	200.00
730000 - Supplies	1,927.33
730500 - Lab supplies	10,242.58
739000 - Computing expense	32.99
739400 - Network charges/Chargebacks	41.25
740150 - Software - Non-Capital	30.00
740500 - Laboratory - Non Capital	0.00
742000 - Other misc expense	4,726.09
742101 - Vendor Discounts-Earned/Lost	-77.72
750000 - Professional &Consult services	544.69
789400 - Non-Contracted Service	146.65
720001 - Department operating expense	**22,079.35**
Total Other Expenditures	**22,079.35**
Total Expenses	**45,775.15**

Three graduate students who conducted the experiments were supported by this MSMC funds.
PhD student: Zhilong Yu; Master's student: Lin Sun, Ziyi Xiong

Payroll Summary

Emplid	Name	Pay End Date	Earnings	FTE
14295420	Sun,Lin	12/31/17	911.00	25%
14295420	Sun,Lin	11/30/17	911.00	
14295420	Sun,Lin	10/31/17	911.00	
14295420	Sun,Lin	9/30/17	911.00	
14295420	Sun,Lin	8/31/17	847.52	
14236197	Xiong,Ziyi	8/12/17	180.00	38%
14236197	Xiong,Ziyi	7/29/17	180.00	
14236197	Xiong,Ziyi	7/15/17	360.00	
14236197	Xiong,Ziyi	7/1/17	360.00	
14236197	Xiong,Ziyi	6/17/17	360.00	
14236197	Xiong,Ziyi	6/3/17	360.00	
14236197	Xiong,Ziyi	5/20/17	360.00	
14236197	Xiong,Ziyi	5/6/17	180.00	
14274797	Yu,Zhilong	5/31/18	-1,728.79	50%
14274797	Yu,Zhilong	5/31/18	2,003.00	
14274797	Yu,Zhilong	4/30/18	2,003.00	
14274797	Yu,Zhilong	3/31/18	2,003.00	
14274797	Yu,Zhilong	2/28/18	2,003.00	
14274797	Yu,Zhilong	1/31/18	2,003.00	
14274797	Yu,Zhilong	12/31/17	2,003.00	
14274797	Yu,Zhilong	11/30/17	2,003.00	
14274797	Yu,Zhilong	10/31/17	1,001.50	
14274797	Yu,Zhilong	9/30/17	1,001.50	
14274797	Yu,Zhilong	10/31/17	1,001.50	
14274797	Yu,Zhilong	9/30/17	1,001.50	
14274797	Yu,Zhilong	8/31/17	566.07	
Total			23,695.80	

The number of dollars remaining on account: $50.85

IX. List equipment purchased with MSMC funds, identifying inventory and serial number.

No equipment was purchased with the MSMC funds.