Proposal to the 2010 North Central Region Canola Research Program

Proposal #10 – Dennis Wiesenborn, $25,000

Engineering Analysis, Design and Equipment Assembly of the Scaled-up Process of Canola-based Resins for Bio-based Plastic Composites

Principal Investigator: Dennis P. Wiesenborn, Professor
Department of Agricultural and Biosystems Engineering
North Dakota State University, Dept. 7620
Fargo, ND 58108-6050
Ph. 701.231.7277, d.wiesenborn@ndsu.edu

Chad A. Ulven, Assistant Professor
Department of Mechanical Engineering and Applied Mechanics
North Dakota State University
Ph. 701.231.5641, chad.ulven@ndsu.edu

Judith D. Espinoza-Perez, Postdoctoral Researcher
Department of Agricultural and Biosystems Engineering
North Dakota State University
Fargo, ND 58108
Ph. 701.231.8927, judith.espinozaperez@ndsu.edu

Project Duration: 1 year

Amount Requested from NCCRP: $25,000

Introduction

Currently, canola-oil based resins are not commercially available. This research group has established a lab-scale process to produce canola resins. The canola resins have been blend with synthetic resins and applied in the preparation of E-glass reinforced composites. In order to increase the level of canola resin and maintain high mechanical properties in the composites, different canola resins-hardeners systems will be analyzed. Our previous results have shown that high levels of canola resin (30-40% wt) provide composites with mechanical properties comparable to other resins systems. These results show the opportunity of canola resin to be incorporated into composite formulations. The need for a large production of canola-resins appears when large panels for machinery are required. Therefore, the lab-process was scaled-up from 300g to 1kg. The resin from the scaled-up process resulted in a lower quality than the resin from the lab-scale process. Due to these results, improvement of the scaled-up process is required. Factors that contributed to the decrease in quality in the scaled-up process were inadequate mixing and temperature control. The specific objective of this project is to design and assemble the scaled-up system to a 2 kg production of canola-resin applying engineering principles. The assembled process will include recycled streams which will decrease waste streams and therefore increase the profitability of canola resin production. The design will be focused on the equipment required.

This project has generated publications in journals and scientific meetings, as well as the conclusion of a doctoral student program in 2009. In 2009, two manuscripts were submitted to *Transactions of the ASABE*, a refereed scientific journal. The first publication: "Production and characterization of epoxidized canola oil" was accepted and published in *Transactions of the ASABE* in 2009. vol. 52, no4, pp. 1289-1297. The second manuscript: "*E*poxy resins from vegetable oils applied to composites" is in the revision process.

Recently, a process model and a risk analysis simulation were performed based on the lab-scale process (Figure 1). The model quantifies the reagent and product streams of the process. The developed model also identifies which materials contribute the most to the raw material resin cost, therefore helping to prioritize future research aimed at reducing cost. This developed process is an excellent tool for the engineering design step.

	A	B	G	H	I	J
3	User-specified data		Results			
4	Epoxidation Process		Epoxidation Process			
5	5000	Vegetable oil (kg/h)	kg/h			
6	80	Yield (%)	5000.00	Input 1	Stream 1,2	Vegetable oil
7	100	Conversion (%)	675.65	Input 2	Stream 3	Acetic acid
8	0.5	Molar ratio AA:U	3062.96	Input 3	Stream 4	Hydrogen peroxide
9	2	Molar ratio HP:U	934.65	Input 4	Stream 5	Catalyst
10	50	HP aqueous solution (wt%)	90000.00	Input 5	Stream 12	Water
11	25	Catalyst %	5850.00	Input 6	Stream 16	Sodium carbonate
12	Fatty acid composition (wt %)					
13	4.3	Palmitic (16:0)	2004.74	Output 1	Stream 7	Catalyst Waste
14	2	Stearic (18:0)	2786.11	Output 2	Stream 9	Aqueous Acid Waste
15	64	Oleic (18:1)	50285.04	Output 3	Stream 18	Sodium carbonate Waste
16	18.4	Linoleic (18:2)	45802.72	Output 4	Stream 20	Water Waste
17	7.2	Linolenic (18:3)	532.46	Output 5	Stream 22	Water Waste
18	0.6	Arachidic (20:0)	111.65	Output 6	Stream 24	Water Waste
19	1.1	Gadoleic (20:1)	4000.00	Output 7	Stream 25	Epoxide

Figure 1. Developed model of canola-resin production.

The risk analysis simulation showed that the raw material cost to produce 1 kg of canola-resin was lower than for soybean-resins (Figure 2). The risk analysis was based on fixed costs of the raw materials and historical price data of the vegetable oils. These results confirmed that canola oil has a great opportunity as resin-raw materials compared with other resins such as those from soybean oil. The process model and the risk analysis data discussed above will be part of a third publication which is in process.

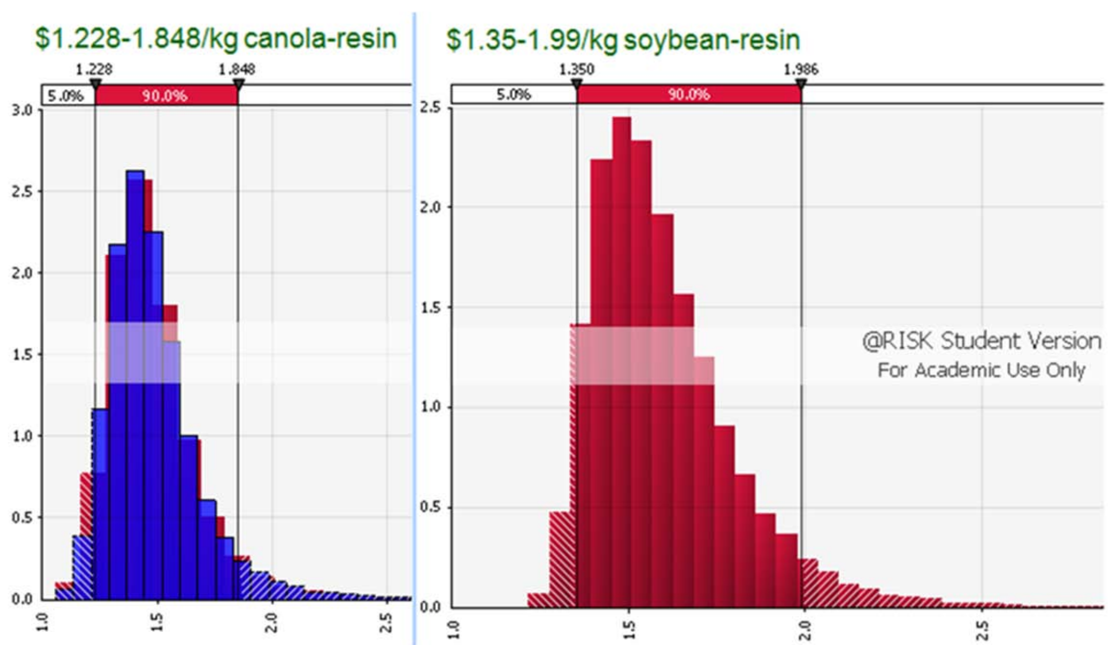

Figure 2. Raw material cost analysis of 1 kg of bio-based resin.

Objective for 2010-2011

Based on the obtained results of the process model and the scaled-up system the objective of this stage is:

- *Perform an engineering analysis, and design and assembly the equipment of the scaled-up canola-resin process.*

Rationale and Significance

Canola-resins are not commercially produced. The risk analysis simulation confirmed that the production of resins from canola oil shows advantages over current available resins. The fabrication of panels for agricultural machinery would require large quantities of canola resin that can be produced through the assembled system.

Approach

Engineering analysis

The first step towards the engineering design of the canola-resin production is the evaluation of the developed process model (Figure 3). This evaluation is required because the process model, as mentioned before, was based on data obtained from the lab-scale process. Additionally, the proposed equipment units were a theoretical approach. Each unit will be analyzed to define if waste streams can be recovered and recycled to the process.

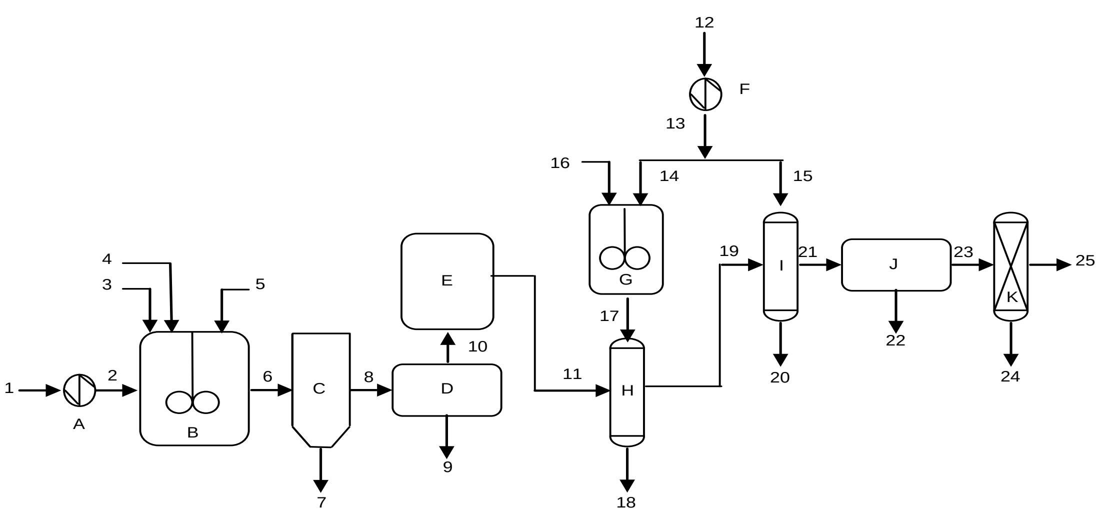

Figure 3. Semi-continuous epoxidation of canola oil. Equipment: (A) Heater I, (B) batch reactor, (C) hydroclone, (D) continuous gravity separator I, (E) storage tank, (F) heater II, (G) mixing tank, (H) wash column I, (I) wash column II, (J) continuous gravity separator II, (K) vacuum dryer. Streams: (1) Vegetable oil, (2) heated vegetable oil, (3) acetic acid, (4) hydrogen peroxide, (5) catalyst, (6) epoxy-catalyst-aqueous acid mix, (7) catalyst waste, (8) epoxy-aqueous mix, (9) aqueous acid waste, (10) acidic epoxy,(11) acidic epoxy, (12) water, (13,14,15) heated water, (16) sodium carbonate, (17) sodium carbonate saturated solution, (18) sodium carbonate waste, (19) neutralized epoxy, (20) water waste, (21) wet epoxy, (22) water waste, (23) wet epoxy, (24) water waste, (25) dried epoxy.

During the engineering analysis, tools such as mass and energy balances will be applied to each equipment unit to optimize the production and consumption of energy. A third step of the process will analyze and define the recycled and waste-streams treatment. The impact of the recycled streams in the cost of production of the canola-resins will be evaluated.

Design and assembly of the equipment units

Based on the engineering design the proposed equipment units to produce 2 kg of canola-resin will be assembled. To accomplish this objective, the equipment units will be assembled from inexpensive components. Some units, such as an impeller stirrer, pumps, or other specialized units will be purchased. The final step of the project is the validation of the process. The validation will involve the engineering analysis of each stream of the process as well as the characterization of the canola-resin produced to verify its quality.

Outreach/Extension Audiences

As mentioned above the information generated by the developed process model, as well as the risk analysis simulation, will be included in a third publication submitted to a journal in the area of agricultural products and economy. The results of the application of the canola-resin in composites will be presented at the 2010 National Canola Research Conference on October 31st-November 4, Long Beach, California. The results of the study of the different canola-resins hardeners systems can be submitted for presentation at the 2011 ASABE annual meeting. A publication, including the results of the objective of this proposal, will be submitted to the journal: *Resource: Engineering and Technology for a Sustainable World.*

Total Requested: **$25,000**

Section B: Other Personnel ($17,340)

The project requires an M.S. student who will contribute substantially to the work listed under objective 1, while completing other requirements of the ABEN M.S. program. The requested amount is $17,000/yr plus $340/yr (2%) for fringe benefits, which is within the ABEN department guidelines for graduate research assistantships.

Section D1. Domestic Travel ($1,000)

A travel is budgeted at $1,000 to present results at the 2010 National Canola Research Conference.

Section F1. Materials and Supplies ($6,660)

Units such as an impeller to improve the mixing of the reaction, stainless steel tanks, and connectors for the process are required to assembly the process. Chemicals and catalyst for producing and analyzing epoxy resins from canola oil are also required.