Full Research Project Final Report

Section A: Project overview

1. Project number: 2016C025R
2. Project title: Oatmeal Coffee Additive
3. Research team leader: Lingyun Chen
4. Research team leader's organisation: University of Alberta
5. Project start date (yyyy/mm/dd): 2016/07/01
6. Project completion date (yyyy/mm/dd): 2017/12/31
7. Project final report date (yyyy/mm/dd): 2018/01/23

Section B: Non-technical summary (max 1 page)

Provide a summary of the project results which could be used by the funders for communication to industry stakeholders (*e.g.*, producers, processors, retailers, extension personnel, etc.) and/or the general public. This summary should give a brief background as to why the project was carried out, what were the principal outcomes and key messages, how these outcomes and key messages will advance the agricultural sector, how they will impact industry stakeholders and/or consumers, and what are the economic benefits for the industry.

Coffee is one of the highest consumed beverages in North America. In 2013 65% of Canadians (18-79 years) claimed they drank at least one cup of coffee within the last 24 hours. The number of cups consumed increases with age, with people 69-75 years old most frequently consuming the beverage. In 2013 approximately 65% of the consumed cups of coffee were drank by Canadians at home. In 2010 55% of the coffee was consumed at breakfast, with an additional 19% being consumed during the morning. Growth within the coffee industry can be seen in terms of the expansion of the specialty coffee market, increased sales of home single cup brewers (Tassimo, Keurig, etc.), and increases in assess to new flavors, and beans.

Flavour innovation within the coffee industry can be seen in terms of the use of creamers, sweeteners, and whiteners. In 2015 65% of global coffee drinkers added creamers to their coffee to improve flavors, sweetness or creaminess. The majority of these additives are made from dairy or soy ingredients, and it is estimated that non-dairy creamers are added to 37 million cups of a coffee annually. The majority of the creamers on the market are dairy or soy based. The

increasing demands for allergen free products has created an opportunity for the development of non-dairy creamers and beverage additives.

Oats is the logical choice to development of a non-dairy creamer. Oats have functional/nutrition proteins, they have high levels of beta glucan, and they can be utilized fairly well in beverage applications. The main objective of this research was to develop a non-dairy oat-based creamer with at least 6-10g of protein/serving, that is soluble in coffee, and has comparable flavouring, whitening, and creaminess to the available dairy and soy creamers. A comparison of oat protein functionalities to faba bean, canola, and an oat/faba bean protein blend showed that oat proteins were the most suitable choice to replace the milk and dairy proteins within the creamer. The knowledge generated through this research can be applied to the development of other non-dairy oat based products, such as yogurts, cheeses, frozen desserts, and ready to drink beverages.

The future commercialization of the developed creamer will generate new market demands for Canadian produce oats, contribute towards developing commercial scale oat fractionation and processing capacity within Alberta, and providing consumers with more nutritious additives to their coffee.

Section C: Project details

1. Project team (max ½ page)

Describe the contribution of each member of the R&D team to the functioning of the project. Also describe any changes to the team which occurred over the course of the project.

Dr. Lingyun Chen has served as the scientific leader of the research program to manage the project and budget, coordinate the research activities and supervise the research staff working for the program. She is also responsible for the project reporting. Darren Walkey has served as the business manager of the program to coordinate industry collaborations by regular sharing of the research findings with industry partners and identification of industry specific requirements for the coffee creamer product. Dr. Chen has weekly meetings with Walkey to discuss research progress and plan, and make adjustment in terms of research focus.

2. Background (max 1 page)

Describe the project background and include the related scientific and development work that has been completed to date by your team and/or others.

Coffee is one of the highest consumed beverages in North America. In 2013 65% of Canadians (18-79 years) claimed they drank at least one cup of coffee within the last 24 hours. The number of cups consumed increases with age, with people 69-75 years old most frequently consuming the beverage. In 2013 approximately 65% of the consumed cups of coffee were drank by Canadians at home. In 2010 55% of the coffee was consumed at breakfast, with an additional 19% being consumed during the morning. Growth within the coffee industry can be seen in terms of the expansion of the specialty coffee market, increased sales of home single cup brewers (Tassimo, Keurig, etc.), and increases in assess to new flavors, and beans.

One of the growing areas of innovation for the coffee industry is creamers, flavors, whiteners and other additives. Based on 2015 statistics (from studies conducted by Starbucks and Dean Foods) 65% of global coffee drinkers add creamers to their coffee to improve flavors, sweetness or creaminess. The majority of these additives are made from dairy or soy ingredients. It is estimated that non-dairy creamers are added to 37 million cups of a coffee annually. Two companies control 82% of the creamer market share, Nestles' with their Coffee Mate products, and Dean Food's International Delights products. The majority of the products owned by both companies are made from dairy or soy protein and do not have any significant levels of protein, fiber and they lack probiotics. Forecasted creamer sales for 2017 are estimated at $3.3 billion.

The market movement towards healthier coffee creamers is creating a new category of creamers. With protein based creamers becoming established in the market there is a growing opportunity to develop a more nutritious coffee additive that provides the benefits of protein and dietary fiber. These ingredients have significant market demand within the beverage and food industries. Developing a coffee additive meets consumer demands for convenience and ease of use.

Oats is the logical choice to develop such a product from. Oats have functional/nutrition proteins, they have high levels of beta glucan, and they can be utilized fairly well in beverage applications. To be competitive in the creamer market the developed product will need to have at least 6-10 grams of protein/serving, and have comparable taste, color, and texture properties to other coffee creamers.

3. Objectives and deliverables (max 1 page)

State what the original objective(s) and expected deliverable(s) of the project were. Also describe any modifications to the objective(s) and deliverable(s) which occurred over the course of the project.

The objectives of this research include:

- Develop an oat based beverage additive with oat protein
- The additive formulation will have at least 6-10g oat protein without impacting solubility, taste or other sensory properties
- The additive will ideally be lactose free
- Have a good taste and replicate the sensory/functional properties of coffee creamer

Deliverables:

- Development of a coffee additive formulation that is composed of at least 6-10g oat protein
- The additive will be lactose free
- The additive will have desirable taste and sensory/functional properties, which will be comparable to those of coffee creamer

4. Research design and methodology (max 4 pages)

Describe and summarise the project design, methodology and methods of laboratory and statistical analysis that were actually used to carry out the project. Please provide sufficient detail to determine the experimental and statistical validity of the work and give reference to relevant literature where appropriate. For ease of evaluation, please structure this section according to the objectives cited above.

5. Development of coffee creamer formulation using oat protein as cream stabilizer ingredient.

Hypothesis: In our previous work, oat protein demonstrated good emulsifying properties. Thus, it is hypothesized that oat protein can be used as a non-dairy emulsifying ingredient in coffee creamer formulations.

Formulation: We will use basic coffee creamer formulations (vegetable oils, emulsifiers, protein powders, sugar, stabilizer and buffer) to develop a set of model formulations that incorporate oat protein ingredient to replace dairy proteins. The oat protein hydrolysates will also be tested due to their better solubility, thus could increase protein content in the formulation for health claims without significantly impact the cream stability and sensory quality. The emulsions will be prepared by treating with high speed mixer followed by the high-pressure homogenizer. The protein molecular weight and its content in the formulation, and the high-pressure homogenization processing parameters (pass numbers and pressure for each pass) will be optimized to stabilize the emulsion system.

Analysis: The coffee creamer properties alone and together with coffee will be evaluated. First, the emulsifying properties of oat protein will be evaluated in comparison to other plant proteins. For coffee creamer properties in coffee, coffee will be made at different concentration (e.g. 4-8%, w/v) with distilled, deionized water and coffee creamer (0.6 mL) of will be added to 20mL of hot coffee and stirred. Feathering and whitening effects will be focused which are important quality characteristics for coffee creamer products. Feathering is used to describe the precipitation of proteins in coffee, which gives an undesirable appearance, whereas, high whitening capacity is favorable. During these studies, a pictorial guide will be developed in the laboratory to visually evaluate performance of coffee creamer in coffee and a scale for monitoring feathering and whitening quality of coffee creamer in coffee will be developed (A scale from 0 to +++, with 0 and +++ indicating no feathering/whitening and very severe feathering/high whitening, respectively).

6. The feasibility of developing dry powder creamer product based on oat protein and beta-glucan will also be evaluated. The finally optimized creamer formulation(s) with oat protein and beta-glucan will be spray dried to get dry powder formulation and then desirable amount of probiotics will be added in the powder to minimize the impact on probiotics which are generally sensitive to outside environment. The creamer dry powder rehydration in coffee product and the overall creamer functionality will be evaluated.

7. Results, discussion and conclusions (max 8 pages)

Present the project results and discuss their implications. Discuss any variance between expected targets and those achieved. Highlight the innovative, unique nature of the new knowledge generated. Describe implications of this knowledge for the advancement of agricultural science. For ease of evaluation, please structure this section according to the objectives cited above.
NB: Tables, graphs, manuscripts, etc., may be included as appendices to this report.

1. Development of coffee creamer formulation

1.1 Screen of plant proteins for coffee creamer

To prepare a plant protein-based coffee creamer, the emulsifying properties of several kinds of plant proteins were tested and their compatibility with coffee were also evaluated. Oat protein, pea protein, Faba bean protein, canola protein were selected in the trials. The emulsions were prepared by a pre-mixing of protein solution with oil, followed by a high-speed homogenization treatment. After homogenization, the crude emulsions were settled at room temperature for 5 min before observation. Feathering occurs when protein precipitate from solution in the presence of an acid-salt environment such as coffee. Thus, dipitassium hydrogen phosphate was added to each protein emulsion to neutralize the acidity. Then 1 ml of fresh protein emulsions were added to 10 ml fresh brew coffee to test their stability and whitening ability. In these trails, fresh Tim Horton coffee was used with pH value of 5.3-5.4.

Table 1 Emulsifying properties and different plant proteins

Proteins	Emulsifying properties	Emulsion stability in coffee
pea protein	Good	Feathering, flocculation after several minutes
Faba bean protein	Good	stability for >2h
Oat protein	Good	Feathering, flocculation occurred after several minutes, after shaking no more flocculation appear
Canola protein fraction1 (napin)	poor, phase separation occurred in 5 minutes	-------
Canola protein fraction2 (cruciferin)	Good	Feathering, flocculation immediately

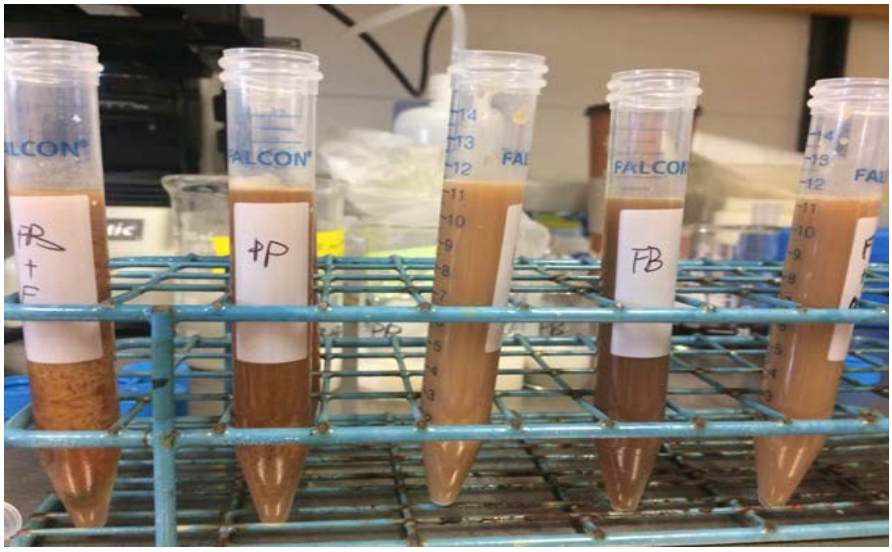


Figure 1 Appearance of coffee with addition of protein emulsions (left to right: pea protein + emulsifier, pea protein, oat protein, faba bean protein, faba bean protein + oat protein)

As shown in Table 1, all the selected plant proteins showed good emulsifying properties, except for canola protein fraction 1 (napin) in which phase separation occurred within 5 mins. When adding creamer in coffee product, feathering and flocculation occurred for pea and canola protein fraction 2. Faba bean protein showed good stability during >2h of the test. Feathering and flocculation occurred for oat protein after several minutes, but after minor shaking, no more flocculation appeared. As shown in Figure 1, oat protein showed the best whitening effect. The pea and faba bean protein did not show obvious whitening effect. When mixing faba bean proein and oat protein, whitening effect became obvious again.

1.2 Coffee creamer formulas with Faba bean protein and oat protein

Faba bean protein and oat protein emulsions were selected in this step. A series of formulas were prepared and tested as coffee creamer including different protein to oil ratios and faba bean/oat protein mixing ratios.

Table 2 Feathering and whitening effect of faba bean and oat proteins based coffee creamer formulas

Formula	Feathering	Whitening*
Faba bean protein: oil=1:1	No feathering	+
Faba bean protein: oil=1:2	No feathering	++
Faba bean protein: oil=1:3	++	+++
Protein (FB:oat=1:1): oil = 1:1	++	No whitening
Protein (FB:oat=8:1): oil = 1:1	No feathering	++
Oat protein :oil =1:2	No feathering	++

* “+” indicated the whitening ability. The more “+”, the whither.

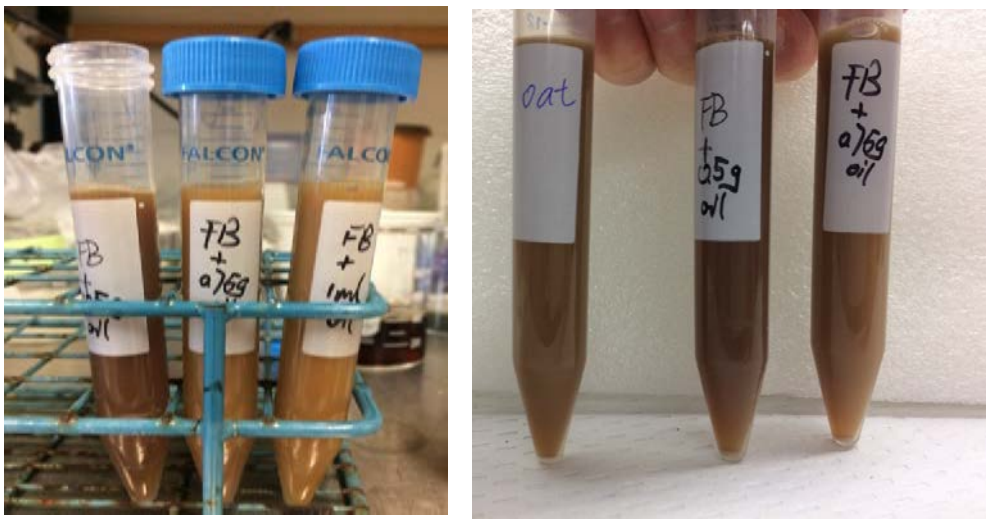


Figure 2 Appearance of coffee with addition of creamer formula (FB: faba bean based formula, oat: oat protein based formula)

As shown in table 2, no feathering occurred at the protein to oil ratio of 1:1 and 1:2 for both faba bean and oat proteins. When the ratio increased to 1:3 feathering occurred. Feathering was also observed for the formulation of mixing proteins at the ratio of 1:1 and the protein to oil ratio of 1:1.

Summary: Based on above results, faba bean protein and oat protein are two promising candidates for plant protein based coffee creamer. Faba bean protein has high resistance to feathering due to its high solubility and emulsion stability even at pH near isoelectric point. The advantage of oat protein emulsion is the whitening effect at the same protein-to-oil ratio. The formulation was also optimized as protein to oil ratio of 1:2 with both good stability (no feathering) and whitening effect.

8. The feasibility of developing dry powder creamer product

2.1 Spray drying was applied to obtain dry creamer powder. To improve the wettability of the powder, surfactants such as lecithin were added. The formula contains (based on dry weight): ~30% protein (faba bean protein and oat protein mixture) and ~30% oil, and the other additives such as sugar and lecithin.

The dry samples were sent to Oatdeal for industry evaluation. The feedback indicated that the creamer powder was ready to be dispersed in warm coffee without feathering effect, but clumps in hot coffee. Also the smell and taste was obvious for some dry powder samples. Based on the discussions with industry partner, the team decided to focus research effort on these issues in the second stage of this research.

2.2 Sensory evaluation coffee creamer

Table 3 Preliminary sensory evaluation of the coffee creamer formulations from different proteins

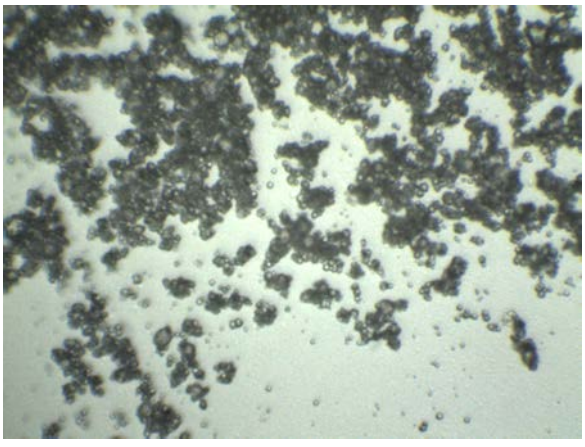
Treatments and proteins	Smell*	Colour**
Faba bean proteins from machine dehulled Faba bean	XX	brown
Faba bean proteins extracted at pH 10	X	brown
Faba bean proteins extracted with ethanol pretreatment	XX	brown
Industrial deflavored Faba bean protein	X	light brown
Industrial deflavored pea protein	XX	yellow
oat protein	OK	light brown

*Smell: one 'X' means sample has bean flavour when dissolved in water. 'XX' means sample has strong bean flavour even in powder.
**Color referred to the color of protein isolate powder.

To solve the flavor issue, dry coffee creamers from different proteins were evaluated for the smell and color. As shown in Table 3, faba bean proteins from both lab and industry processing showed beany smell. Thus only oat protein was used for dried coffee creamer formula design due to its relatively neutral flavor.

2.3 Formulation improvement of dry coffee creamer powders

Oat protein based coffee creamer showed flocculation in hot coffee. The pH of fresh brew coffee was 5.5 (30g of Maxwell coffee powder and 6 cup of water, 72°C), which was closed to the isoelectric point of oat protein. Thus, higher amount of buffer salt was added in the formula to bring the coffee pH to 6.5. To overcome the clumping problem of creamer powder in hot coffee, both formula and the spray drying condition was adjusted.



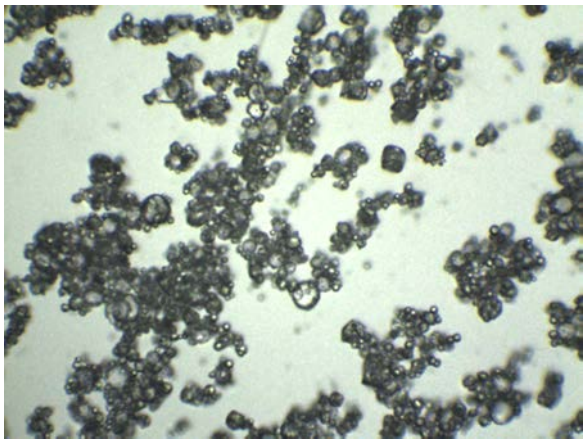


Figure 3 Microscopic photos of dried coffee creamer powders, Left: creamer powder prepared by method in 2.1, Right: creamer powder prepared by improved method in 2.3), the magnifications of both images were 400X.

From Figure 3, the amount of larger granules was increased. This allowed good dispersing of the powders in both hot coffee and hot water. The attached video showed the good dispersing capacity of the creamer powders. Hot water was used for demonstration for better observations.

Summary: Above results demonstrate good potential for oat protein as an emulsion stabilizer for coffee creamer. The current developed formation contains 30g of plant protein per 100g powder, which is much higher than the coffee creamer products in the market and allows protein claims for the future developed products. No animal ingredients are involved in the formulation, thus product is lactose free and suitable for vegan and vegetarian.

9. Benefits to the industry (max 1 page; respond to sections *a)* and *b)* separately)

a) Describe the impact of the project results on Alberta's agriculture and food industry (results achieved and potential short-term, medium-term and long-term outcomes).

The results of this research, and the successful commercialization of the developed non-dairy creamer will provide oat producers with access to new non-dairy markets. For example: the information generated on the emulsifying effects of oat and oat/faba bean protein blends can be applied to other food applications such as the development of non-dairy yogurts, frozen desserts, beverages, snacks, etc. In the short term as the non-dairy creamer is commercially launched the initial supply of oats will be obtained on a contract basis, and in the longer term as production volume increase larger more stable supply chains will be built. Launching the non-dairy creamer in the medium to long term in the United States and China will significantly increase the demand for Canadian produced oats and oat fractions. This level of demand may lead to the development of Alberta or western Canadian based oat fractionation and processing facilities. Commercial scale processing will generate a stable supply of oat starches and fibers that can be utilized in a variety of value added food and non-food applications.

In the short and medium terms consumers will have the options of a healthier non-dairy creamer product, which has higher levels of protein. In the longer term the development of different variations of the oat based non-dairy creamer with the addition of fiber and probiotics will provide a nutritional boost for coffee drinkers.

b) Quantify the potential economic impact of the project results (*e.g.,* cost-benefit analysis, potential size of market, improvement in efficiency, etc.).

Based on the 2013 statistics 65% of Canadians consumed at least 1 cup of coffee daily, and of 65% of these coffee drinkers added a creamer. Canada's population in 2013 was 35.16 million, which equates to 22,856,000 daily coffee drinkers and 14,855,100 people who use creamers. We will conservatively estimate that 25% of the creamers used are non-dairy. As the oat based non-dairy creamer is launched we anticipate that it will be initially tried by innovator (2.5% of consumers), and early adopter (13.5% of consumers) segments of the non-dairy creamer

consumers within the first year. This market segment would be composed of approximately 600,000 people within Canada. With approximately 6g of oat protein per creamer and a consumption of one cup of coffee and one creamer per day, 30 days of consumption would require 3.5 tonnes of oat protein. As the early majority starts to consume the non-dairy oat-based creamer under the same consumption rates the demand for oat protein will increase to 11.14 tonnes per month within the Canadian market. Selling the creamer into the United States and China will significantly increase the demand for Canadian oats and fractionated ingredients.

10. Contribution to training of highly qualified personnel (max ½ page)

Specify the number of highly qualified personnel (*e.g.*, students, post-doctoral fellows, technicians, research associates, etc.) who were involved in the project.

This research has provided a unique training opportunity for one Postdoctoral Fellow (Dr. Sarah Yang) in a dynamic academic-industrial collaborative environment. She has designed and conducted experiments in the lab, analyzed and interpreted data and prepared draft research reports. She has also communicated findings in a group workshop involving university and government scientists and industry partners.

11. Knowledge transfer/technology transfer/commercialisation (max 1 page)

Describe how the project results were communicated to the scientific community, to industry stakeholders, and to the general public. Organise according to the following categories as applicable:

a) Scientific publications (*e.g.*, scientific journals); attach copies of any publications as an appendix to this final report
b) Industry-oriented publications (*e.g.*, agribusiness trade press, popular press, etc.) attach copies of any publications as an appendix to this final report
c) Scientific presentations (*e.g.*, posters, talks, seminars, workshops, etc.)
d) Industry-oriented presentations (*e.g.*, posters, talks, seminars, workshops, etc.)
e) Media activities (*e.g.*, radio, television, internet, etc.)
f) Any commercialisation activities or patents

N.B.: Any publications and/or presentations should acknowledge the contribution of each of the funders of the project.

Invited industry-oriented oral presentations:

1. Chen, L. Value-added processing and applications of oat proteins, Prairie Oat Growers Association (POGA) Annual General Meeting, December 7, Banff, Alberta.
    a. This was also presented to General Mills scientists by invitation on January 17, 2018 (Telephone conference, 1.5h)
2. Chen, L. Oat protein food applications, Alberta Oat Growers Association Annual General Meeting, January 29, Edmonton, Alberta.

Media:

1. Oats may join $8 billion plant protein market, The Western Producer, December 21, 2017.
2. Braun, L. (2016) “Adding Value with Value-Added.” OatScoop. Nov 2016

Industry Workshops:

1. $(CP)^2$ Industry Workshop, Edmonton, AB September 28, 2016

Section E: The next steps (max 2 pages)

Describe what further work if any needs to be done.

a) Is new research required to deal with issues and opportunities that the project raised or discovered but were not dealt with within the current project?
b) Is there related work that needs to be undertaken to continue advancement of the project technology or practice?
c) Did the project identify any new technology or practice that needs to be developed?
d) What suggestions do you have that increase commercial use of results by farmers and/or companies. These may be:
    1. commercial uptake.
    2. further research toward commercial use.
    3. extension and information disbursement.

The developed creamer can benefit from additional research in the areas of shelf stability, flavouring, and scale up processing before the product is commercialized. Accelerated shelf life testing is necessary to determine how shelf stable the non-dairy creamer is in powdered and pasteurized liquid forms, and how it compares to the shelf stability of other commercially available creamers. In powdered form the industry partner would like to see the product shelf stable for 12-18 months, and at least 3 months in liquid form. Sensory feedback on month old liquid (one that was pasteurized and one that was not), and powdered samples that were shared with an R&D Chef at the Northern Alberta Institute of Technology's (NAIT) Culinary Arts Program indicated that there was no detectable rancidity or off putting odor/taste when mixed with coffee. The accelerated testing will also assist with confirming whether or not the oat oils that are contained in the sample are slowly oxidizing to generate the rancid sensory properties. If it is the oil then options such as pasteurizing, ultra high temperature treatment and removing the oils during processing will need to be further considered. We will conduct the accelerated shelf life testing in our lab over the next several months.

As part of the next step towards in the formulation process we are working collaboratively with NAIT to make the creamer more appealing to consumers in terms of flavours and taste. Through this collaboration we will develop a selection of different flavoured prototypes, such as vanilla, toffee, pumpkin spice, etc., and a prototype that utilizes a low glycemic sweetener in place of the sugar.

Scale up processing is required for the production of the oat proteins, and the manufacturing of the creamer product itself. The oat proteins, which are currently available on the market have low or limited functionalities and are not suitable for use within the creamer. As a result, the program's oat fractionation process will need to be scaled up in collaboration with the industry partner and the Leduc Food Processing Development Centre to the pilot scale. Longer term commercial production of the oat proteins will be obtained through contract manufacturers or from the waste streams of larger oat processors.

Scaling up the production of the non-dairy creamer with dairy industry equipment could improve the creamer's sensory properties and improve its solubility and whitening functions in coffee. We are currently looking for a dairy industry partner who has the capacity to produce creamers and who is willing to assist us with the scale up.

The industry partner has done some extensive work generating industry and market interest in the creamer. The industry partner has received significant interest from a major US based food manufacturer and a national food service company based in China who are interested in the creamer product. The industry partner also has strong connections with food service companies in Canada and the United States who are looking to purchase the creamer for use in hotels, cafes, and restaurants. Market uptake of the product could be fairly quick once the commercialization and manufacturing processes begin.

The knowledge generated through this project about the emulsification properties of oat and oat/faba bean protein blends can be applied to developing other non-dairy ingredients or products, which can be incorporated in the growing "free from" food markets. The fractionation of proteins will create a supply of functional oat fiber and starch, which can be utilized in other value-added product development applications.