Development of an oat based beverage rich in dietary fiber and protein

Final Report

Sponsor:
Prairie Oat Growers Association
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PROJECT OVERVIEW

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SUMMARY

The first objective of the project was to develop a ready-to-drink beverage enriched in β-glucan and protein from oats. With the support of the Prairie Oat Growers Association (POGA) and the Alberta Crop Industry Development Fund (ACIDF), the University of Alberta was successful in developing oat milk drink prototypes from both whole oat flours and oat fractions concentrated with protein and β-glucan by air classification technique. The drink prototypes possess acceptable smell, viscosity and texture, and the storage stability tests suggest that the drink prototypes have a shelf-life of 6-12 months over refrigerator storage. The oat milk drink prototypes show higher protein content than the commercial oat milk products currently available in the market. Using oat fraction flours as the feedstock significantly enhanced the β-glucan content in the final oat drink prototype, which is qualified for β-glucan health claim.

Reduced food intake and malnutrition are frequent among patients with cancer. Inadequate nutrient intake among patients with cancer has been associated with malnutrition and decreased quality of life, reduced response to treatment and decreased survival. The best way to maintain or increase energy and protein intake is with normal food, however only a few food products have been developed for people with cancer. Therefore the second objective of the project was to enhance the oat beverage with nutrients known to be deficient in cancer patients and study the acceptability of the beverage with the cancer patients. Specifically this research designed oat beverages by mixing dry oat-based powder products with hot or cold water or milk. When mixed with milk, the protein and vitamin D contents are increased. Overall, the oat-based beverage were liked by patients at both cold and hot temperatures. Patients were aware of positive health benefits of oats and consumed them in some form frequently. The

addition of protein, EPA and vitamin D into the oat beverage product did not change liking compared to the unfortified product. Together, the positive sensory acceptance of flavored oat beverages and their perceived and established health benefits, reveal the potential for oats to be included in fortified and unfortified products targeted to patients with cancer. Future developed products must be evaluated by consumer panels of patients with cancer to confirm product and sensory attribute acceptance, which may differ from the healthy population. Furthermore, the evaluated oat-based beverages may be accepted by older adults and other populations with similar nutrient needs and eating challenges.

BACKGROUND

The majority of Canadian oats is currently used in the Canadian feed market. As traditional markets become increasingly challenging, development of value-added applications for human consumption is important to enhance revenue return to the producers. The human food market for oat has been gaining momentum due to recognition of health benefits of β-glucan for reducing blood cholesterol and regulating blood glucose levels. Oat also has higher protein level among cereals with a superior amino acid profile. Studies have demonstrated that oats are tolerated by the majority of people suffering from celiac disease. Beverages made from oats are popular in European countries. In Sweden, milk oat drink has been developed as a supplement for people who are intolerant to lactose. Efforts to develop oat beverages from Canadian oat are still limited. A ready-to-drink oat based beverage that is β-glucan/protein enriched is required, so that consumers will have access to nutritious beverage that is convenient. Cereal and pulse proteins are complementary in essential amino acids and represent close to optimum essential amino acid profile. Thus the oat drink supplemented with pulse protein will have further improved nutritive value.

Cancer is the leading cause of death in Canada. In 2015, nearly 200 000 Canadians will be diagnosed with cancer. Malnutrition remains the most frequent and inadequately managed problem that affects cancer patients. However, it is our view that restoring the status of nutrients known to be deficient improves nutritional status to enhance outcomes in people with cancer, as well as in those with other age-related chronic diseases. The majority of currently available nutritional products are not targeted toward the dietary needs of cancer patients and are unpleasant due in part to altered senses of taste and smell. The oat drink presents a good base to develop a nutritionally-enhanced beverage for cancer patients because both β-glucan and high protein diets are recommended and a ready to drink formula is appropriate for cancer patients. The challenges are to develop a feasible processing to make a ready-to-drink oat beverage with optimized protein and β-glucan content, and then further develop a nutritionally-enhanced beverage that meets the nutritive and sensory requirements of cancer patients.

OBJECTIVES

The research objectives were:

1. Develop a processing to concentrate protein and β-glucan from oat grains
2. Develop a ready-to-drink beverage enriched in β-glucan and protein
3. Enhance the beverage with nutrients known to be deficient in cancer patients and study the acceptability of the beverage with the cancer patients
4. An on-line survey to determine the desirable food product form to deliver oats and their nutrients to cancer patients

The anticipated deliverables include:

1. Optimized processing to concentrate protein and β-glucan from oat grains
2. Establishing a new technique to develop a ready-to-drink from oats
3. Basic drink platform to develop a nutritionally-enhanced beverage for cancer patient
4. Strengthen collaborations with oat and pulse producers and processors
5. This research will lead to training of highly qualified personnel, scientific papers, conference presentations

RESEARCH DESIGN AND METHODOLOGY

a. Develop processing to concentrate protein and β-glucan from oat grains

We proposed to combine air classification and wet extraction to develop a cost-effective processing for oat protein and β-glucan concentration. Air classification technique is energy efficient with lower capital investments. The use of fractions high in protein and β-glucan for their further purification through wet-method will increase the throughput of the process and thus cost efficiency. The grains were milled to flours and then subjected to air classification. The impact of particle size and air-classifying wheel speeds on concentration/recovery of protein and β-glucan was investigated. The optimized processing conditions were then selected to improve protein and β-glucan content in the oat fractions. Protein content were determined by the elemental analysis as nitrogen content (%) × 5.83 using a Leco nitrogen analyzer. Moisture content was measured with the Mettler-Toledo Moisture analyzer. Starch and β-glucan content were determined by the enzymatic kits.

b. Develop a ready-to-drink oat beverage

Both whole oat flours and the oat fraction flours enriched with protein and β-glucan were used for developing a ready to-drink oat beverage. A major challenge is to remove the starch which precipitates during storage. We proposed to remove starch by amylase hydrolysis. In addition, protease was applied to partially hydrolyze oat protein with the purpose to improve the oat protein solubility and beverage stability. The formula and processing were also optimized to make beverages qualified for fiber/protein claims. The visual stability of the drinks was evaluated by taking the ratio of the beverage height to that of the sediment during storage in refrigerator. The beverage viscosity determines its sensory quality, thus was also analyzed.

3.3. Enhance the beverage with nutrients known to be deficient in cancer patients and study the acceptability of the beverage with the cancer patients

A key requirement for the success of a food product in any market is that it must ‘taste good’ and be of the sensory quality desired by the target market. We will ensure that the taste and other sensory attributes of the oat beverage are liked by cancer patients using an iterative but rapid approach to optimize the product’s sensory appeal. Based on previous beverage flavor and functional product acceptance work with cancer patients, we will select beverage flavors preferred by cancer patients as flavor targets of the oat beverages. Flavoured oat beverages will be evaluated using well recognized and proven sensory science methodologies for rapid novel product optimization. Hedonic scales will be used to assess the liking of the appearance, aroma, taste, texture and overall acceptability of the beverages, just-about-right scales will be used to assess the appropriateness of the viscosity and flavor attributes and check-all-thatapply (CATA) scales will be used to identify other sensory drivers of liking. This rapid iterative process will yield an oat beverage with sensory acceptability optimized for cancer patients, with the likely development of more than one flavor of the beverage. The beverage will be evaluated by cancer patients at the Cross Cancer Institute, the cancer treatment centre for Northern Alberta.

The oat drinks will then be developed into a nutritionally-enhanced beverage designed to meet the nutritional needs of cancer patients by fortifying with vitamin D and omega-3 fatty acids with the dosage that meet their needs. In Northern climates, where there is limited sun exposure, there is a growing concern of vitamin D deficiency in the population. Studies suggested that omega-3 fatty acids are beneficial during cancer therapy. We will use commercial microcapsules of vitamin and omega-3 fatty acids. In addition, pulse protein will be added in the formulation to improve the protein nutritive value in the drink.

3.4. An on-line survey to determine the desirable food product form to deliver oats and their nutrients to cancer patients

Beverages are commonly available for nutritional support for cancer and other patients (e.g. dairy and plant-based milks, liquid oral nutritional supplements such as Boost, smoothie formulations) and their availability has grown rapidly since we first proposed our studies. Results of our first study, conversations with patients and studies in the literature suggest that cancer patients would prefer a variety of food product delivery forms for nutrients (e.g. puddings, bars, etc). The aim of the on-line survey is to identify specific food products desired by cancer patients to increase their food intake. The on-line survey will be completed by 150 cancer patients recruited from the Cross Cancer Institute and completed at the treatment centre or by patients in their home on their own computer or other device. The survey will identify specific food items (e.g. puddings, bars, beverages, hot cereals) and texture types (e.g. liquid, soft, coarse) desired by patients for between meal snacks. We will focus on snacks rather than meal items as our research group and others have previously established that snacks are the most efficient vehicle to increase patient calorie intake. Additionally, we will collect demographic and clinical information, symptom presence and interference with eating and general information about eating patterns. The study findings will identify specific food products desired by cancer patients as snacks into which oats can be incorporated to improve patient well-being and nutrition.

Statistic analysis: Accepted statistical data analyses were performed on all data. Statistical analyses of data provided by patients with cancer was guided by an oncology biostatistician.

RESULTS AND DISCUSSIONS

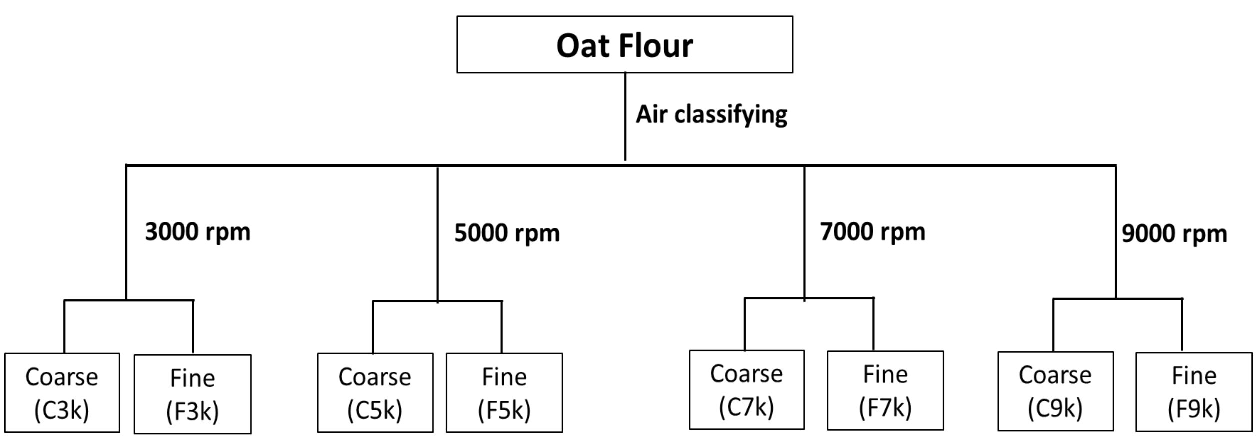


Figure 1. Air classification conditions of oat flour fractionation

4.1. Develop air classification processing to concentrate protein and β-glucan from oat flours

Processes for the isolation of highly concentrated β-glucan are based on wet extraction. However, wet processes are typically limited by high viscosity of the aqueous extracts even at low β-glucan concentration, thus large volume of liquid is used for wet extraction of β-glucan, which leads to high cost related to drying step and generation of large amount of waste water. Thus dry fractionation using air classification technique was applied to generate a fraction concentrated with β-glucan as a raw material for oat beverage preparation in this work. We also aimed to study the feasibility of concentrate protein in this same fraction.

Gluten-free oat grains were applied as raw materials and the whole oat flours contain 13.7% protein, 50.65% Starch and 3.42% β-glucan. A bench-top Hosokawa air classifier (Alpine multi-plex laboratory Classifier 100MZR, Augsburg, Germany) was applied as a dry-milling technique to separate protein, starch and fiber from oat grains based on their different shape and density. Previous research showed that oil removal could enhance oat component separation efficiency by air classification, thus both whole oat flours and defatted oat flours by hexane were applied as raw materials for air classification treatment. The whole oat grains were grounded using a Retsch centrifugal grinding mill with a screen aperture size of 0.25, 0.5, 0.75 mm to produce whole grain flour. Our experimental trials suggested that smaller particle size could facilitate oat component separation, however, the oat flours were burned due to the heat generated during oat milling when the screen aperture size was 0.25mm. Thus the flour size of 0.5mm was focused in this study. The classifier wheel speeds were set at 3000, 5000, 7000 and 9000 rpm and the air flow was fixed at 60 m^3/h. The detail processing steps are illustrated in Figure 1.

The protein, β-glucan and starch content of the generated coarse and fine fractions were analyzed, as well as the yield. The results are summarized in Table 1.

Table 1. Chemical composition of the oat fractions by air classification and the yield

Sample	Protein Content (%)	β-Glucan Content (%)	Starch Content (%)	Yield (%)
Gluten-free oat flour	13.70±1.42	3.42±0.26	50.65±3.68	
F3k	13.01±1.17	1.77±0.41	57.13±3.18	60.2±4.35

C3k	26.80±2.96	9.96±0.58	32.61±2.69	34.6±3.26
F5k	15.49±1.81	3.81±0.16	52.48±2.97	65.2±4.49
C5k	22.62±2.34	6.34±0.28	34.59±1.89	29.5±2.72
F7k	16.51±2.12	5.12±0.19	51.17±3.08	11.3±1.34
C7k	22.52±2.09	8.09±0.26	36.91±1.88	83.5±3.21
F9k	16.86±1.51	3.51±0.13	48.32±2.62	3.5±1.85
C9k	16.28±2.53	3.53±0.17	55.28±3.72	91.5±4.63
Defatted gluten-free oat flour				
F3k	9.79±0.85	0.85±0.01	73.1±4.23	58.3±2.61
C3k	22.10±1.75	6.75±0.30	41.0±2.78	38.7±2.39
F5k	9.44±2.03	2.03±0.06	71.8±3.28	24.8±1.59
C5k	15.08±1.77	5.77±0.01	47.7±2.17	71.0±4.23
F7k	14.20±2.30	2.30±0.06	67.4±3.51	9.5±1.08
C7k	15.28±1.33	5.33±0.42	52.4±2.83	76.0±2.98
F9k	34.58±3.23	3.23±0.18	48.1±3.51	3.0±1.12
C9k	14.58±1.39	4.39±0.38	60.2±3.76	87.8±5.29

The results indicate that that a wheel speed of 3000 rpm was most efficient to generate a coarse fraction (C3K) to concentrate β-glucan and protein. After air classification, the β-glucan in C3K fraction was concentrated 3 times with the content increasing from 3.42% to 9.96%. The protein content was doubled to 26.8% in the same fraction. Meanwhile the starch content was reduced to 32.6%. The yield of this fraction was 34.6%. The result suggests that β-glucan could be more efficiently concentrated by air classification technique, likely due to the fact that the fibers are selectively carried by air because of their flat shape in contrast to the spherical shape of protein and starch particles.

Previous research suggested that defatting of oat bran by Supercritical-CO_2 extraction modifies its structure so that the particle exterior becomes smoother, thus lipid removal can enhance separation of β-glucan from starch and protein. However in this work defatting of the oat flours did not increase the β-glucan and protein separation efficiency, instead the protein and β-glucan content in C3K fraction was slightly decreased. This result suggests that the lipid removal by hexane may not be able to improve oat fiber concentration by air classification technique.

The C3K fraction was also applied to pass a second air classification at various wheel speed, however, further treatment did not significantly enhance the protein and β-glucan content. Therefore, the optimum condition to generate a fraction enriched with both protein and ß-glucan from whole oat flours in this work was a combination of dry milling (Retsch centrifugal grinding mill at 0.5 mm) and air classification at the air flow of 60 m^3/h and wheel speed of 3000 rpm.

4.2. Develop a ready-to-drink oat beverage

4.2.a) Amylase treatment

Both whole oat flours (3.42% β-glucan and 13.7% protein) and the oat fraction flours obtained by above air classification in section 4.1 (9.96% β-glucan and 26.8% protein) were applied as feedstock for oat drink preparation. Poor solubility of starch in oat flours affect the beverage product stability during storage, thus hydrolysis of carbohydrates by amylases was conducted for cleavage of glycosidic bonds in starch into sugar molecules, thus to form a milky product based on oats. The detailed hydrolysis processes are illustrated in Figure 2.

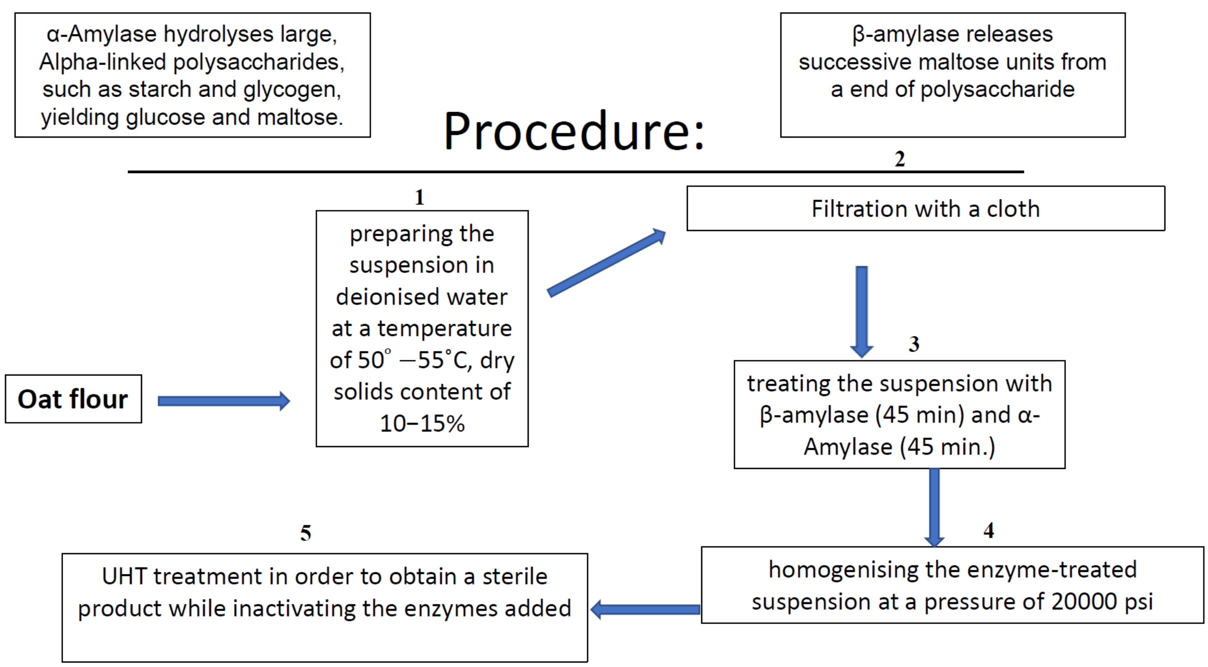


Figure 2. Amylase hydrolysis processes to prepare oat milk drink samples

The whole oat flour and the dry fraction were mixed with water and homogenized at speed 6 using a high speed homogenizer (PowerGen 1000, Fisher Scientific, Fairlawn, NJ). The flour-to-water ratios were selected to be 1:6-1:10 w/v with the dry solid content of 10-15% to ensure sufficient solid content in the final products, while maintaining an appropriate viscosity of the slurry for smooth mixing and further processing. The suspension was either directly treated by amylases or filtered by a filtration cloth before hydrolysis treatment. For amylase hydrolysis, the suspension was firstly treated by 1% β-amylase at ~50^{o} for 45 min, then treated by 1% α-amylase treatment at ~55^{o}C for another 45min. The solution after hydrolysis was heated at 100^{o}C for 15 min to inactivate the enzymes and then homogenized using a high pressure homogenizer at 20000 psi (nano DeBEE, Bee International Inc., MA, US). The final oat drink samples were stored in a refrigerator for study of their stability. In a second approach, oat flours were hydrolyzed by the same way as described above, but solution underwent high pressure homogenization treatment at 20000 psi to inactivate the enzymes instead of thermal treatment.

The results indicate that both filtration and high pressure homogenization steps improved the physical stability of the oat drinks. Without filtration step, but with homogenization treatment, the drink showed good stability over 10 days, however, obvious precipitation was observed afterwards. The drink with filtrations step, but without high pressure homogenization treatment showed a good stability over 8 days, but precipitation started afterwards. The drink sample with both filtration and high pressure homogenization treatment showed a good stability over 20 days without precipitation when stored in refrigerator without sodium azide (Figure 3). However, after 20 days, microbiological changes occurred (undesirable odor).

It was noted that the oat drink by both filtration and homogenization treatment was quite stable over refrigerator storage in the presence of antimicrobial reagent (sodium azide). After storage of 6 month, almost no precipitate was observed. From 6-12 months, minor sedimentation was observed, but after shaking, the precipitates were rapidly dispersed again in the solution (Figure 3). It was noted that the oat drink by both filtration and homogenization treatment was quite stable over refrigerator storage in the presence of antimicrobial reagent (sodium azide). After storage of 6 month, almost no precipitate was observed. From 6-12 months, minor sedimentation was observed, but after shaking, the precipitates were rapidly dispersed again in the solution. The oat milk drink prepared from fractionated oat flours concentrated in β-glucan and protein were much viscose due to significantly higher β-glucan content, but the samples also showed a good stability during 6 months of storage in refrigerator with antimicrobial reagent (Figure 4). It is suggested that Ultra High Temperature (UHT) treatment (135 °C for several seconds) could further prolong the shelf life by inactivating the microorganisms. Meanwhile due to very short heating time, UHT processing can preserve protein native structure, thus further decrease sedimentation to stabilize oat drink product.

18 days **20 days** **6 months** **12 months**

Stored in refrigerator without antimicrobial reagent

Stored in refrigerator with antimicrobial reagent

Figure 3. Storage stability of the oat milk drinks prepared from whole oat flours by amylase hydrolysis and treated with both filtration and high pressure homogenization processes

2 months **6 months**

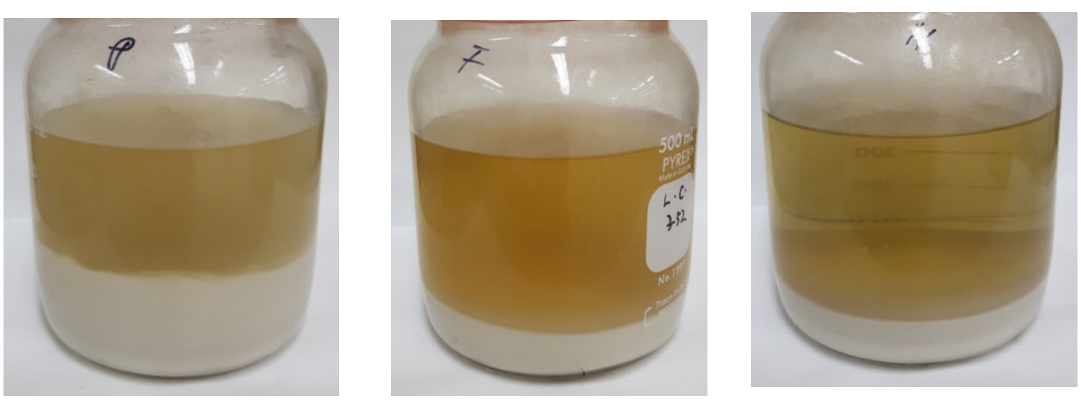
Stored in refrigerator with antimicrobial reagent

Figure 4. Storage stability of the oat milk drinks prepared from fractionated oat flours by amylase hydrolysis and treated with both filtration and high pressure homogenization processes

4.2.b) Combination of amylase and protease treatment

We further tested the approach of combining amylase and protease treatment for the oat milk beverage preparation. The use of proteases were supposed to partially hydrolyze oat protein to further improve the stability of the final drink products. For such combined treatment, oat flours were treated by amylases by the same way as described above in section 4.1. After starch hydrolysis, the temperature and pH were adjusted to optimum condition for specific proteinase, followed by addition of Papain (≥10 units/mg protein, optimum activity at pH 6.0-7.0 and 65°C), Flavourzyme (≥500 U/g, optimum activity at pH 6.6 at 50°C) or Neutrase (≥0.8 U/g; optimum activity at pH 6.5-7 at 55°C) at the concentration of 0.5% (w/v). The protease hydrolysis was carried out for 60 min followed by the enzymatic inactivation by heating at 100°C for 15 min. Afterwards, the prepared drink samples were treated by the same high pressure homogenizer at 20,000 psi and stored in a refrigerator without or without antimicrobial reagent (Sodium azide).

Degree of protein hydrolysis (%) was determined as the percentage ratio of protein soluble in 20% trichloroacetic acid (TCA) to total protein. The flours treated by flavourzyme showed the highest protein hydrolysis degree (14.93%), followed by neutrase (6.68%), then Papain (6.23%). However, combined hydrolysis with α- and β-amylases and proteinase was turned out to be not effective because the oat drink samples were stable only for 24 hours (Figure 4). It is likely the heating step (100°C for 15min) for protease inactivation resulted in oat protein denaturation that accelerated precipitation of solid components in the oat drink samples.



Papain treatment   Flavouzyme treatment   Neutrase treatment

Figure 5. Storage stability (after 48h) of the oat milk drink samples prepared by combined hydrolysis with α- and β-amylases and proteinase. The enzymes were inactivated by heating at 100°C for 15 min.

In a second approach, oat flours were hydrolyzed by α- and β-amylases, then followed by flavouryme treatment as described above. Instead of heating, the proteolysis was inactivated by decreasing the temperature to 4^{o} C followed by high pressure homogenization at 20,000 psi. The drink samples showed good stability over 25 days without precipitation when stored in refrigerator without sodium azide. However, after 25 days, microbiological changes occurred (undesirable odor). In the presence of antimicrobial reagent, the oat drink sample treated by amylases and flavourzyme showed good stability with only minor precipitates after 12 months. This is probably related to the higher hydrolysis degree by flavourzyme, leading to improved protein solubility.

4.2.c) Treatment by food additives

The food additives such as surfactants (e.g. lecithin), gums (e.g. carrageenan) and others (e.g. polyethylene glycol, casein sodium salt, triglycerol monostearate and sorbitan) were added in a concentration of 1% to the oat drink samples prepared in section 4.2a and 4.2b before high pressure homogenization. However, those treatments did not further improve the beverage stability. In industry practice, gums are normally added to the plant protein milk products to improve the stability by increasing the bulk viscosity. In this work, due to the high β-glucan content, the desirable viscosity was achieved for the beverage already, thus further addition of gums may not be required, which makes the beverage natural without additives.

Based on above experimental results, combining amylase and protease treatment improved the drink stability to certain extend, but the cost would be higher for the final products. Thus β-amylase + α-amylase treatment is recommended for preparing oat milk drink products in this research. There might be opportunity to generate bioactive peptide (e.g. ACE inhibitory and cholesterol binding activities) using the combined amylase + protease processing, which is worthy of future investigation for preparation of functional drinks from oats with additional healthy benefits such as lowering of blood pressure and blood cholesterol level.

4.2.d) Chemical composition analysis of the oat drinks

The shelf-stable at milk drink samples prepared from both whole oat flours and fractionated oat flours by β-amylase + α-amylase treatment were then analyzed for their chemical composition and results are demonstrated in Table 2. The oat milk drink samples prepared in this research showed significantly higher protein content (2.18-2.20%) than most of the commercial oat milk products in the market which typically contain 1-1.5% protein. The β-Glucan content (0.3%) in the oat drinks prepared from whole oat flours are comparable to that of commercial products currently available in the market (typically 0.4% or less). Using oat fraction flours as the feedstock significantly enhanced the β-Glucan content (0.81%) in the final oat drink sample. According to FDA, the recommended level of β-glucan in a functional drink should be 0.75 g per serving. Thus the oat milk beverage prototype prepared from the oat fractions is qualified for β-Glucan health claim.

Our data shows that using oat fraction flours as the feedstock did not significantly enhanced the protein content of the final oat drink. Further research to better understand the processing properties of oat fraction flours is suggested in the future. The generated knowledge may help us to optimize the processing, leading to new oat drink products with further increased protein content comparable to real milk products (3.5-4% protein).

Table 2. The chemical composition and physical properties of the oat drink prototypes

Sample	Oat drink prepared from whole oat flours	Oat drink prepared from oat fraction flours
Protein Content (%)	2.20±0.3	2.18±0.5
β-Glucan (%)	0.30±0.05	0.81±0.03
Starch (%)	7.79±0.6	5.75±0.4
Solid Content (%)	12.76±0.7	12.10±0.5
Color	Beige	Beige
pH	6.2±0.2	6.3±0.1
smell	good	good
Texture	Creamy rich, smooth	Creamy smooth
Viscosity (c.p.)	54.6	458

The drink viscosity was measured by a rheometer (HR-3, TA instrument, Delaware, USA) and pH monitored by a lab pH meter. The two drink prototypes showed similar pH values (6.2-6.3) and both smell good. Due to difference in β-Glucan content, the oat drink prepared from whole oat flours demonstrated a creamy rich and smooth texture, whereas that prepared from oat fraction flours possessed a creamy smooth texture.

High β-Glucan content also resulted in significantly increased viscosity of the oat drink prototypes. But both prototypes possess viscosity acceptable for plant based beverages. For example, oat milk products possess viscosity of ~50 c.p. and coconut beverages typically show viscosity of ~350-400 c.p. The positive results from physical characterizations have provided justification for sensory evaluation of the oat drink prototypes with trained panelists in the future.

Summary:

- Oat milk drink prototypes were developed from both whole oat flours and oat fraction flours concentrated with protein and β-glucan by air classification technique
- The storage stability tests suggest that the drink prototypes will have a shelf-life of 6-12 months over refrigerator storage
- The oat milk drink prototypes showed higher protein content than the commercial oat milk products currently available in the market
- Using oat fraction flours as the feedstock significantly enhanced the β-Glucan content (0.81%) in the final oat drink prototype, which is qualified for β-Glucan health claim
- The drink prototypes possess acceptable smell, viscosity and texture

4.3. Enhance the beverage with nutrients known to be deficient in cancer patients and study the acceptability of the beverage with the cancer patients

Inadequate nutrient intake among patients with cancer is common and has been associated with worsened prognosis and treatment outcomes. Energy intake at optimal levels and anabolic nutrients such as protein, specific amino acids, fish oil, particularly eicosapentaenoic acid (EPA), and vitamins and minerals such as vitamin D have been investigated as potential nutrition interventions for low muscle mass with different evidence levels of benefits. Specific required levels have are still unknown due to lack of strong evidence, however fortification of food products could increase the intake of recommended nutrients. In the literature, only a few food products have been developed for people with cancer, including protein fortified and unfortified ice creams and a jelly-like product.

Oats stand out among other cereals for their high content of highly digestible quality protein, unsaturated fatty acids, minerals, vitamins and phenolic compounds. Health benefits associated with oats include glucose lowering effects and soluble dietary fiber content of beta-glucan (Government of Canada 2010; European Food Safety Authority 2011; Food and Drug Administration 2018). Oat-based beverages are a nutritious alternative as a vehicle for fortification to add nutrients of interest for oncology patients. As alternatives to increase nutrient intake among cancer patients, this study used oat-based product, which is a dry mix of skim milk, gluten-free whole oat flour and sugar, with three different flavors (vanilla, cinnamon and chocolate). The dry product is designed to be mixed with hot or cold water or milk. When mixed with milk, the protein and vitamin D contents are increased.

Nutrition facts of the product and fortified versions are presented in Table 3. Three studies were performed to achieve the study aim; 1) confirm acceptance of the product in the clinical setting by patients with cancer and healthy participants; 2) determine acceptance of a fortified formulation; 3) assess consumption and perceptions of oats among patients with cancer. All studies received ethical approval from the Health Research Ethics Board of Alberta (HREBA) Cancer Committee and/or University of Alberta, as appropriate.

Table 3. Ingredients, protein & fish oil content of the fortified oat-based beverages

	Regular formulation (R)	**High protein, fish oil product (HPFO)**	**Low protein, fish oil product (LPFO)**
Ingredients	Milk, whole oat flour, sugar, xanthan gum, cocoa powder.	R + skim milk (No Name®, Canada), whey protein (Boost®, Nestle Canada), faba bean powder (VITESSENCE™ Pulse CT 3602 Protein, Ingredion, USA), microencapsulated fish oil (Marinol® Omega-3 HS Powder, Stepan Lipid Nutrition, USA)	RF + skim milk (No Name®, Canada), faa bean powder (VITESSENCE™ Pulse CT 3602 Protein, Ingredion, USA), microencapsulated fish oil (Marinol® Omega-3 HS Powder, Stepan Lipid Nutrition, USA)
Fish oil content (g/serving*)	-	0.54	0.54
Protein content (g/serving)	9.77	17.68	13.74

Carbohydrates (g/serving)	26.53	31.69	32.22
Total fat (g/serving)	4.01	6.12	6.26
Dietary fiber (g/serving)	0.89	1.24	1.26
Energy content (kcal/serving)	177.75	247.62	235.18

*Serving size of 200mL of the beverage containing milk and the powdered product; size recommended by the product manufacturer.

4.3.a) Evaluation of the oat-based beverages among patients with cancer

The powdered product was mixed with hot or cold milk, kept in a thermal carafe and served to each participant right before tasting. The beverages were evaluated at the Cross Cancer Institute (Edmonton, AB, Canada) by patients with cancer (n=92) and their accompanying caregivers as well as staff and volunteers (n=136). Participants assessed liking of the product on a 9-point hedonic scale with Just About Right (JAR) evaluation of the sweetness, thickness and flavor intensity of the products using 5-point scales. Each flavor/ temperature combination was evaluated by at least 30 participants. Participants provided demographic and clinical information.

Table 4. Characteristics of participants evaluating an oat-based beverage in the clinical setting (n=228).

	Number of participants (%)
Sex	
Male	76 (33.3)
Female	152 (66.7)
Age range	
18 - 29 years	17 (7.5)
30 - 49 years	41 (18.0)
50 - 65 years	90 (39.5)
Greater than 65 years	80 (35.1)

Role	
Patient with cancer	92 (40.4)
Caregiver/ accompanying a patient	73 (32.0)
Other (healthcare professional, volunteers)	63 (27.6)
For patients with cancer:	
Tumour site	
Breast	25 (27.2)
Lymphoma / Leukemia	11 (12.0)
Prostate	9 (9.8)
Lung	9 (9.8)
Gastrointestinal	7 (7.6)
Myeloma	7 (7.6)
Head and Neck	6 (6.5)
Other	18 (19.6)
Treatment modality over past 3 months*	
Chemotherapy	46 (50.0)
Radiation therapy	24 (26.1)
No treatment	23 (25.0)
Surgery	10 (10.9)
Other	10 (10.9)

*Total percentage over 100 because some participants were undergoing more than one treatment.

Most patients were not experiencing a high symptom burden affecting their food intake (Table 4). There was no significant difference in the proportion of males/females between patients with cancer and healthy participants, but there was a significantly higher proportion of healthy participants under 65 years ($p<0.0001$). All products were “Liked moderately” on the 9-point hedonic scale, indicating products were highly acceptable (Table 5).

Table 5. Mean liking scores[a] of an oat-based beverage in the clinical setting.

Flavor	Temperature*	Mean liking ± Standard Deviation (n=number of participants)	
		Patients with cancer	**Healthy participants**
Chocolate	Cold	7.0 ± 1.3 (n=24)	7.5 ± 0.8 (n=22)
	Hot	7.7 ± 0.6 (n=13)	7.3 ± 1.1 (n=28)
Vanilla	Cold	7.7 ± 0.5 (n=11)	7.5 ± 1.2 (n=24)
	Hot	7.1 ± 1.9 (n=16)	7.2 ± 1.5 (n=17)
Cinnamon	Cold	7.5 ± 0.9 (n=15)	7.5 ± 1.2 (n=22)
	Hot	7.1 ± 1.7 (n=13)	7.5 ± 1.3 (n=23)

[a]9-point hedonic scale where 1=Dislike extremely, 9=Like extremely;
*Cold temperature =4°C; hot temperature =60°C.

However penalty analysis (Figure 6) revealed that "too sweet" perception significantly decreased liking of the cold cinnamon and cold vanilla products among healthy participants and of hot cinnamon among patients with cancer. Patients with cancer consistently rated beverage sweetness intensity as JAR or "Too sweet"; over 20% of healthy participants perceived the cold vanilla and cinnamon (Figure 6, d and e) products as "Too thin" while this was not observed among patients with cancer. The perception of thickness and sweetness was influenced by product serving temperature. At hot temperature, 23% of patients with cancer perceived the chocolate flavored beverage as "Too sweet".

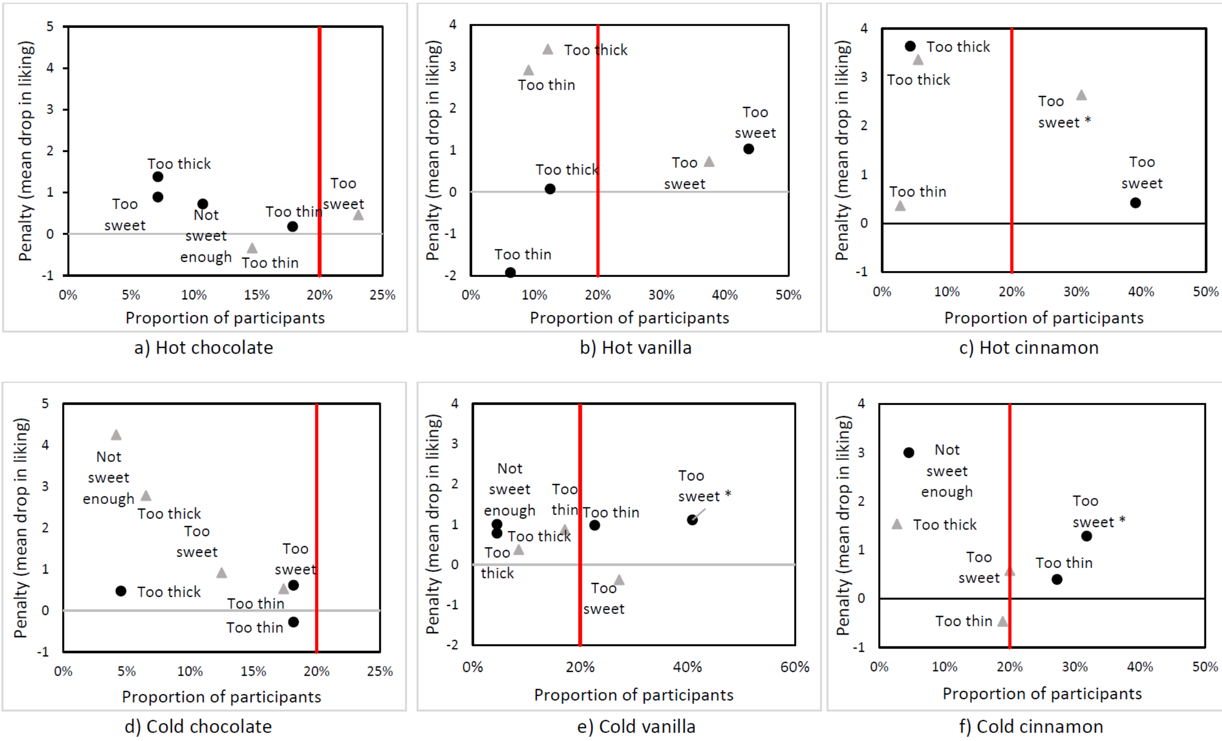


Figure 6. Penalty analysis plots for three flavors of oat beverages at hot (60°C) and cold (4°C) temperature evaluated in the clinical setting.
Grey triangles (▲) = evaluations by patients with cancer; Black circles (•) = evaluations by healthy participants. *=Significant non-JAR categories

4.3.b) Acceptance of fortified oat-based beverages by healthy participants

The cold chocolate product was fortified to increase the protein content and incorporate fish oil as a source of EPA. Ingredients, energy and nutrient content of the two fortified formulations one with higher protein and fish oil (HPFO), and one with lower protein and fish oil (LPFO), and the regular product are presented in Table 3. The three formulations were blended with cold milk and evaluated by 60 healthy participants at the University of Alberta. As beverage samples were fortified post-manufacture, evaluations among patients with cancer were not permitted by Health Canada. Participants evaluated overall liking on a 9-point hedonic scale and JAR evaluation of sweetness, thickness and flavor intensity of each product

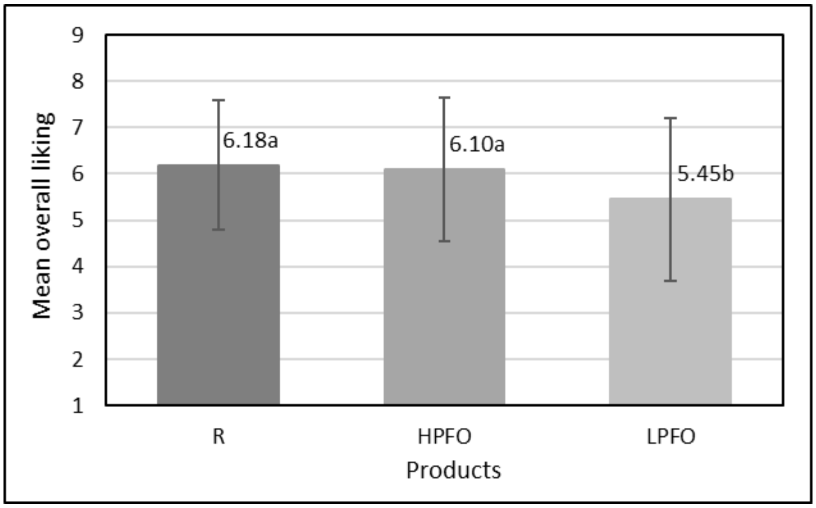
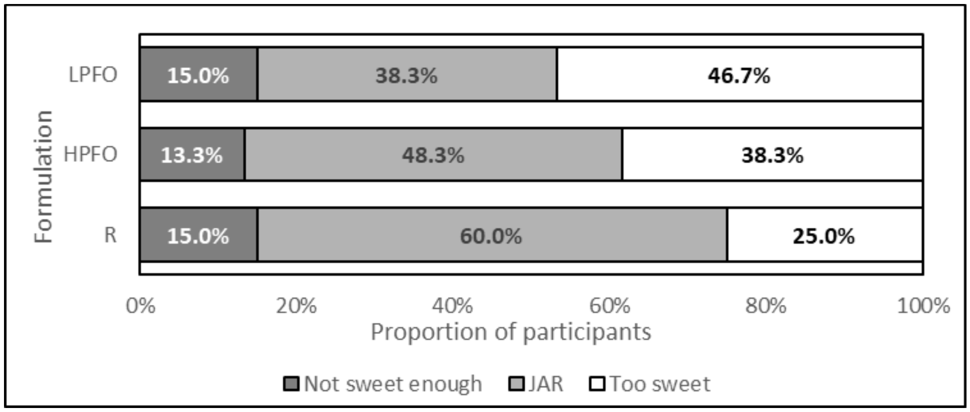
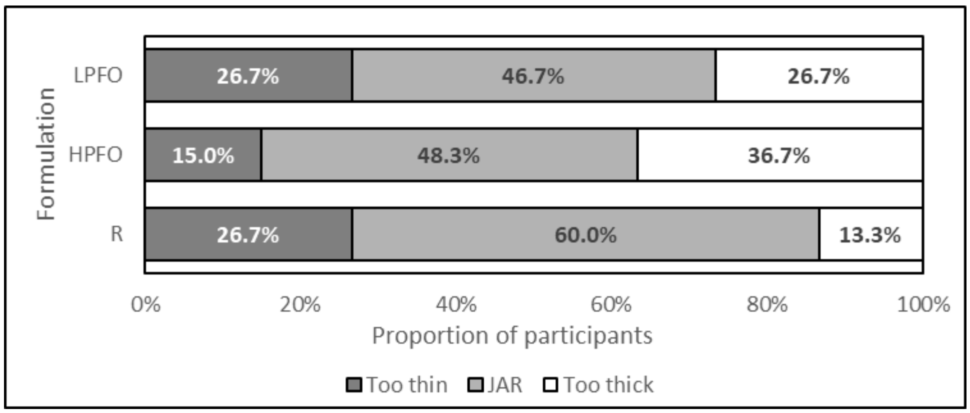


Figure 7. Overall liking on the 9-point hedonic scale for the fortified chocolate oat-beverage evaluated by healthy participants (n=60). Means with different letters are significantly different (p≤0.05). R= Regular Formulation; HPFO= High-Protein + fish oil; LPFO= Lower-protein + fish oil.

A majority of the participants were female (73%), 18 and 29 years (71%), and usual consumption of oats and of milk products was at least once a week for 70% and 73.3% of the participants, respectively. Overall liking of HPFO was not significantly different from the regular formulation; both with values close to "Like slightly" on the hedonic scale and greater than the LPFO formulation (Figure 7). Just-about-right results provided insight about product perception and the drivers of liking/disliking (Figure 8); attributes that could be modified to improve acceptance of the fortified products are the high sweetness of all products and the thickness of the low protein fortified product. The higher protein level through the inclusion of a higher level of whey protein in the HPFO product resulted in increased frequency of participants considering the product as "too thick", and a lower number of participants perceiving it as "too sweet", compared to LPFO.



a)



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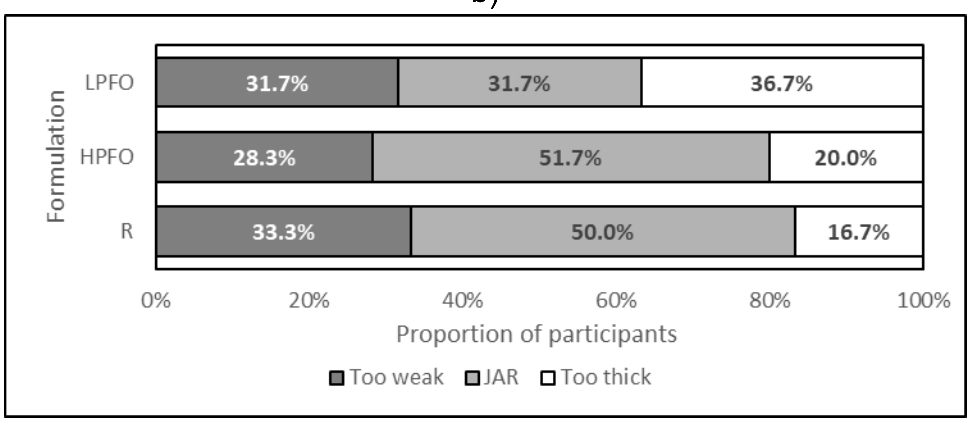

c)

Figure 8. Just-about-right (JAR) results for a) sweetness, b) thickness and c) flavor intensity for the fortified (HPFO, LPFO) and regular (R) products as evaluated by healthy participants (n=60).

4.3.c) Consumption and perceptions of oats among patients with cancer

A survey was used to assess frequency of consumption, identification of currently consumed oat food products, perception of oats through 'free word elicitation' and health benefits (responses to six questions on Likert scales from disagree very much (1) to agree very much (5). No product tasting was performed. Adult patients with any cancer (n=150) were recruited in the clinic waiting areas of the Cross Cancer Institute in Edmonton, Alberta.

Oat food products were consumed by 77% of the patients and 58% of them consumed oat products at least once per week. The most frequently eaten oat products were oatmeal, oat cereal, cookies and bars. Words or ideas describing oat perception were sorted into 19 categories across 6 dimensions (Table 6). Common words associated with oats were Health dimension terms, including nutrients in oats, satiety, and health benefits and detriments, and food products described foods made with or commonly eaten with oats. Sensory characteristics and hedonics were associated with taste, liking and texture. Oat products were also perceived within the context of agricultural and farming and eating challenges were identified such as high carbohydrate content and swallowing issues. With respect to agreement of specific health benefits of oats, over 90% agreed that oats are highly nutritious, and about 60% agreed that oats provide health benefits related to heart disease and acknowledged the benefits of oat fibers and beta-glucan. Most participants considered that it was easy to incorporate oats into their daily diets.

Table 6. Perceptions of oat products among patients with cancer obtained by Free Word Association (n=144).

Dimensions	Categories	Most common words/ terms in descending order of mention	Frequency of mention by patients*
Health			**92.4%**
	Nutrients	Fiber, nutritious, vitamins, protein, energy	25.7%
	Satiety	Filling, fullness, satisfying	19.4%
	General health	Healthy, unhealthy	16.7%
	Health benefits	Easy to digest or aids digestion, gluten-free, lowers cholesterol, heart health, regularity	16.0%
	Eating challenges	Carbohydrate content, hard to swallow, allergies, hard to eat	9.0%
	Health detriments	Pesticides or chemicals, genetically modified	5.6%

Food products			**74.3%**
	Foods from oats	Oatmeal or porridge, cookies, bars, cereal, baking, crisps, muffins	66.0%
	Complementary foods	Milk, maple syrup or flavor, fruits, brown sugar, yogurt	8.3%
Sensory characteristics and hedonics			**67.4%**
	Taste	Tasty, taste, bland, taste good, flavor, little or no taste, plain	20.8%
	Liking	Good, like, love, yummy	18.1%
	Texture	Dry, texture, chewy, crunchy, mushy	13.2%
	Temperature	Warm, hot	8.3%
	Dislike	Not good, yucky, unattractive	6.9%
Consumption details			**23.6%**
	Time of consumption	Breakfast, morning, snack	9.0%
	Ease of use	Easy to eat, easy, easy to cook/ prepare	8.3%
	Other benefits / reasons for consumption	Comfort food, easy to swallow, long lasting, no side effects, sugar-free	6.3%
Agriculture and farming			**11.8%**
	Agriculture	Field, harvest, sunshine fields, farm	6.3%
	Feed	Horses, cows, piglets	5.6%
Memories			**6.9%**
	Memories	Family member, childhood memories	6.9%

* Some percentages higher than 100% as patients could provide up to four responses.

Summary and Discussion:

Overall, the three flavors of the oat-based beverage were liked by patients at both cold and hot temperatures, but some indicated that the products were perceived as “Too sweet”. Patients were aware of positive health benefits of oats and consumed them in some form frequently. We assessed the potential of oat-based beverages for fortification with protein and EPA, both nutrients recommended by European Society for

Clinical Nutrition and Metabolism (ESPEN) oncology nutrition guidelines and studied as potential interventions to prevent muscle loss in this population. The addition of those nutrients into the chocolate flavored product did not change liking compared to the unfortified product. Liking of the oat-based beverage was not significantly different between patients with cancer and healthy participants. The penalty analyses of JAR evaluations of the oat-based beverage in the clinical setting showed an effect of increased sweetness and thickness perception with higher serving temperatures. No differences were observed in the perceived flavor intensities. These positive results suggest that oat-based products may be appropriate for nutrient fortification among patients with cancer and could guide future product development in this area.

Studies to assess factors that affect consumption of food products among patients with cancer are limited. Overall, the majority of patients consumed oats regularly and oats were considered nutritious and healthy products, high in fiber and related to satiety. The most frequently mentioned, considered most relevant for consumer conceptualization of the product and with higher influence in their decisions, were specific oat-based food products and health dimensions of filling, fiber, healthy, nutritious and good. Two of the eating challenges associated with oats (i.e. hard to swallow and hard to eat) were likely associated with oatmeal, a hot cereal, and could be solved by the beverage presentation format. As early satiety experienced by some patients with cancer reduces food intake, successful new oat-based food products for cancer patients should consider perceived satiety and serving size.

A limitation of the initial beverage assessment in the clinical setting was the small number of participants for each combination of flavor/temperature among patients with cancer and healthy participants. Sensory assessment studies of food products among older people and those with chronic diseases may routinely have smaller participant numbers (less than 50 subjects) than similar assessments in the healthy population. To decrease patient burden and provide the context of the usual eating environment on consumption and perception of food products, home use tests could be used in the oncology setting to generate ecologically valid results. We have designed a home use study protocol for the 'long term' assessment of an oat beverage in a future study to evaluate its long term acceptance and contribution to daily nutrient intake. The protocol was approved by a human ethics research committee and received treatment centre site approval. Future studies could target a specific tumor group or stage which may reduce variability in responses.

Together, the positive sensory acceptance of flavored oat beverages and their perceived and established health benefits, reveal the potential for oats to be included in fortified and unfortified products targeted to patients with cancer. Future developed products must be evaluated by consumer panels of patients with cancer to confirm product and sensory attribute acceptance, which may differ from the healthy population. Furthermore, the evaluated oat-based beverages may be accepted by older adults and other populations with similar nutrient needs and eating challenges.

4.4. An on-line survey to determine the desirable food product form to deliver oats and their nutrients to cancer patients

Reduced food intake and malnutrition are frequent among patients with cancer. Inadequate nutrient intake among patients with cancer has been associated with malnutrition and decreased quality of life, reduced response to treatment and decreased survival. The European Society for Clinical Nutrition and Metabolism (ESPEN) guidelines for oncology patients state that “the best way to maintain or increase energy and protein intake is with normal food”. Snacks, defined as food and beverages consumed in-between main meals have been associated with increased energy and nutrient intake among older adults, hospitalized patients and patients with cancer. Fortification of regular foods with recommended nutrients is a simple alternative to increase intake in this population. Current commercially available food products to increase nutrient intake among people with cancer are mainly liquids (soups and milk-, yogurt- or juice-based shakes) and puréed foods. While these products target some nutrient requirements, they fail to consistently address patient preferences and factors that contribute to the enjoyment of eating.

The aim of this study was to identify snack foods preferred for fortification among patients with cancer and to determine the influence of experienced symptoms on snack food selection. Specific nutrients of interest to patients, current snack consumption, preferences for snack food products and perception of oral nutritional supplements (ONS) were also evaluated. These results could be used to guide new oat based food product development of fortified snacks that appeal to patients with cancer.

This study used a self-administered survey specifically designed to assess current preferences for snacks and preferred fortified snacks, as well as nutrition impact symptoms that influence dietary intake and food preferences in the following sections:

- Demographics, cancer-related information, and presence and interference with eating of 17 symptoms using the Head and Neck Patient Symptom Checklist (HNSC©).
- Current food intake compared to usual using Question 2 from the Patient Generated - Subjective Global Assessment (PG-SGA Short Form©); number of meals in a day, preferred food characteristics and food aversions.

- Satisfaction with Food-Related Life (SWFL) using a five-item questionnaire validated among older people.

- Agreement with a list of 33 suggested snack products as suitable vehicles for fortification, assessed on a 5-point Likert scale (1 = “Strongly disagree” to 5 = “Strongly agree”. Patients were asked to imagine the products were available with added nutrients and at the same price as the unfortified product. Open space was available to suggest other snacks. The list of snacks included at least one item from each of the categories of commonly consumed snacks in the United States, excluding alcohol and soft drinks. Additionally, patients indicated product characteristics and nutrients or ingredients desired in a fortified snack using Check-All-That-Apply type questions.

A convenience sample of 150 patients was recruited in the chemotherapy and radiotherapy clinic waiting areas of the Cross Cancer Institute (Edmonton, Canada), the oncology treatment center for northern Alberta. The study received appropriate ethics and site approval. A total of 139 valid survey responses were analyzed. Agglomerative hierarchical clustering (AHC) was conducted to cluster patients based on similarity of reported symptom presence. Numerical survey responses were analyzed by the appropriate non-parametric data analysis technique. A p-value <0.05 was used for statistical significance.

Table 7. Demographic characteristics of all patients and 3 patient clusters of symptom presence*.

	All patients (n=139)	Low symptom presence (n=92)	High symptom presence (n=28)	Moderate symptom presence (n=19)
Sex				
Female	81 (58.3)	54 (58.7)	15 (53.6)	12 (63.2)
Male	58 (41.7)	38 (41.3)	13 (46.4)	7 (36.8)
Age				
30-49	24 (17.3)	13 (14.1)	5 (17.9)	6 (31.6)
50-65	56 (40.3)	37 (40.2)	12 (42.9)	7 (36.8)
Over 65	59 (42.4)	42 (45.7)	11 (39.3)	6 (31.6)
Cancer types				
Breast	32 (23)	24 (26.1)	5 (17.9)	3 (15.8)
Gastrointestinal	19 (13.7)	10 (10.9)	6 (21.4)	3 (15.8)

Colorectal	12 (8.6)	7 (7.6)	1 (3.6)	4 (21.1)
Lung	12 (8.6)	9 (9.8)	3 (10.7)	-
Non-Hodgkin lymphoma	11 (7.9)	7 (7.6)	3 (10.7)	1 (5.3)
Head and neck	7 (5%)	2 (2.2)	5 (17.9)	-
Other type[a]	53 (38.1)	33 (35.9)	5 (17.9)	8 (42.1)
Treatment(s) received in last three months				
No medical treatment	26 (18.7)	18 (19.6)	5 (17.9)	3 (15.8)
CT	48 (34.5)	34 (37	8 (28.6)	6 (31.6)
CRT	13 (9.4)	6 (6.5)	5 (17.9)	2 (10.5)
Immunotherapy	13 (9.4)	9 (9.8)	3 (10.7)	1 (5.3)
Surgery	2 (1.4)	1 (1.1)	-	1 (5.3)
Surgery + CT	12 (8.6)	8 (8.7)	2 (7.1)	2 (10.5)
Surgery + CRT	4 (2.9)	2 (2.2)	-	1 (5.3)
Surgery + RT	2 (1.4)	1 (1.1)	-	1 (5.3)
RT	6 (4.3)	3 (3.3)	3 (10.7)	-
Immunotherapy + other treatment modality	9 (3.6)	6 (4.3)	1 (3.6)	2 (10.5)
Other (experimental drug, drug trial, hormonal therapy)	4 (2.9)	2 (2.2)	1 (3.6)	1 (5.3)

[a] Tumor types with less than 10 patients: Bone, brain, gynecological, head and neck, Hodgkin lymphoma, leukaemia, liver, melanoma, multiple myeloma, prostate, thyroid, metastasized to more than one site.
* Clusters determined by agglomerative hierarchical clustering.

Results are presented for all 139 patients and by cluster. Most patients were female (58.3%), over 50 years of age (82.7%) and represented a variety of tumor types (Table 7). Patients were undergoing treatment, with 92 (66%) undergoing more than one treatment modality. Over 56% of the patients reported consuming the same food intake or higher compared to their normal intake. Among patients with reduced food intake, most (48 out of 60) were consuming "normal" food.

"Low", "High" and "Moderate" patient clusters were identified according to their reported number of symptom present (Table 8). Lack of energy and feeling full were the only symptom reported by over 50% of patients in the Low symptom presence cluster. In contrast, patients in the High symptom cluster had 12 of 17 symptoms reported by over 60% of the patients, and were more likely to experience difficulty chewing and swallowing, vomiting, and sore mouth. Patients in the Moderate symptom cluster experienced mainly presence of appetite loss, feeling full, diarrhea, lack of energy, nausea and taste changes.

Table 8. Number and frequency (%) of patients indicating the presence[a] of each symptom for the whole population and categorized by clusters[b].

	All patients	Low symptom presence (n=92)	High symptom presence (n=28)	Moderate symptom presence (n=19)	Association between cluster and variable
Symptom					
Pain	**70 (50.4)**[C]	43 (46.7)	**23 (82.1)**	4 (21.1)	*
Anxiety	63 (45.3)	33 (35.9)	**21 (75.0)**	9 (47.4)	*
Dry mouth	61 (43.9)	37 (40.2)	**20 (71.4)**	4 (21.1)	*
Loss of appetite	**71 (51.8)**	31 (33.7)	**25 (89.3)**	**16 (84.2)**	*
Constipation	53 (38.1)	27 (29.3)	**21 (75.0)**	5 (26.3)	*
Feeling full	**86 (61.9)**	**46 (50.0)**	**26 (92.9)**	**14 (73.4)**	*
Depression	43 (30.9)	19 (20.7)	**17 (60.7)**	7 (36.8)	*
Thick saliva	35 (25.2)	15 (16.3)	**18 (64.3)**	2 (10.5)	*
Diarrhea	51 (36.7)	26 (28.3)	13 (46.4)	**12 (63.2)**	*
Sore mouth	30 (21.6)	14 (15.2)	13 (46.4)	3 (15.8)	*
Lack of energy	**94 (67.6)**	**48 (52.2)**	**27 (96.4)**	**19 (100)**	*
Nausea	44 (31.7)	13 (14.1)	**16 (57.1)**	**15 (78.9)**	*
Difficulty chewing	17 (12.2)	10 (10.9)	6 (21.4)	1 (5.3)	NS
Smells bother you	49 (35.3)	22 (23.9)	**19 (67.9)**	8 (42.1)	*
Vomiting	11 (7.9)	4 (4.3)	5 (17.9)	2 (10.5)	NS
Difficulty swallowing	23 (16.5)	11 (12.0)	10 (35.7)	2 (10.5)	*
Taste changes	69 (49.6)	33 (35.9)	**26 (92.9)**	**10 (52.6)**	*
Food intake compared to normal[d]					
More than usual	13 (9.4)	6 (6.5)	6 (21.4)	1 (5.3)	*
Unchanged	66 (47.5)	54 (58.7)	5 (17.9)	7 (36.8)	*
Less than usual	60 (43.2)	32 (34.8)	17 (60.7)	11 (57.9)	*

[a] Score of 2 to 5 (“A little bit” to “A lot”) selected in the symptom presence section of the Head and Neck Symptom Checklist©.
[b] Clusters determined by agglomerative hierarchical clustering according to reported symptom presence.
[c] Symptoms present for 50% or more patients within each cluster are bolded.
*p<0.05.
NS: Not significant difference between groups

4.4 a) Food intake, snack consumption and satisfaction with food-related life

Patients in High and Moderate symptom presence clusters were more likely to have reduced food intake compared to usual, while patients in the Low symptom presence cluster more commonly reported food intake as unchanged (Table 6). No other differences were found when comparing the demographics of the three clusters. The number of meals consumed throughout the day among all patients varied from 1 to 6; most patients consumed 4 meals. Breakfast, lunch, dinner and afternoon snacks were consumed by 82, 78, 76 and 96% of patients, respectively.

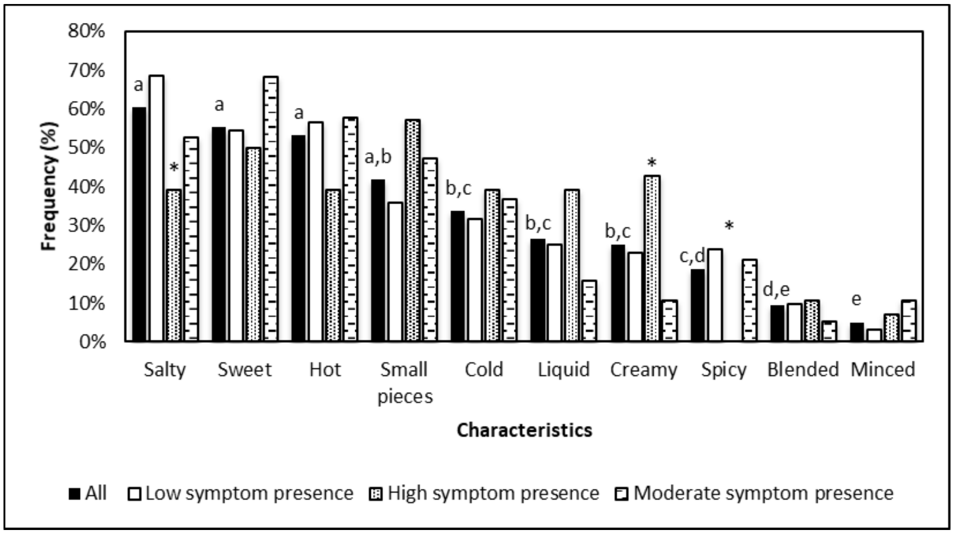

Figure 9. Characteristics of food products preferred by patients with cancer (n=139). Different letter superscripts indicate significant differences in the frequency of selection among all participants ($p<0.05$). * indicates differences in frequency of selection among the clusters.

The frequencies of selected characteristics of preferred food products are presented in Figure 9. Over 50% of patients indicated preference for salty, sweet or hot food products. Patients in Low and Moderate symptom presence clusters were more likely to select “salty”. Patients in the High symptom presence cluster were more likely to select “creamy” compared to the other patients, and none of the patients in this cluster selected “spicy”. Patients in the Low symptom presence cluster had significantly higher SWFL mean scores (28.5) compared to the High symptom presence cluster (24.5) ($p<=0.05$). Mean SWFL scores for the Moderate symptom cluster (26.4) were not different compared to the other clusters.

4.4.b) Preferred snacks for fortification

The agreement with each suggested fortified snack differed among the patients (data not shown). Products with agreement by 60% or more of the patients were soup, yogurt, cheese, fruit juice, egg product and protein bar. Over 30% of patients disagreed that burritos, flavored milk, candies, pretzels, nacho and potato chips, cake, pastries and cookies were suitable.

Nutritious, flavorful, convenient, ready to eat, easy to chew or easy to swallow were selected significantly more frequently as desired fortified snack attributes than other characteristics like plain aroma or flavor and coarse, liquid and soft texture (Figure 10). Patients in the High symptom presence cluster more frequently selected the attributes easy to swallow, liquid, soft texture and warm compared to the other clusters.

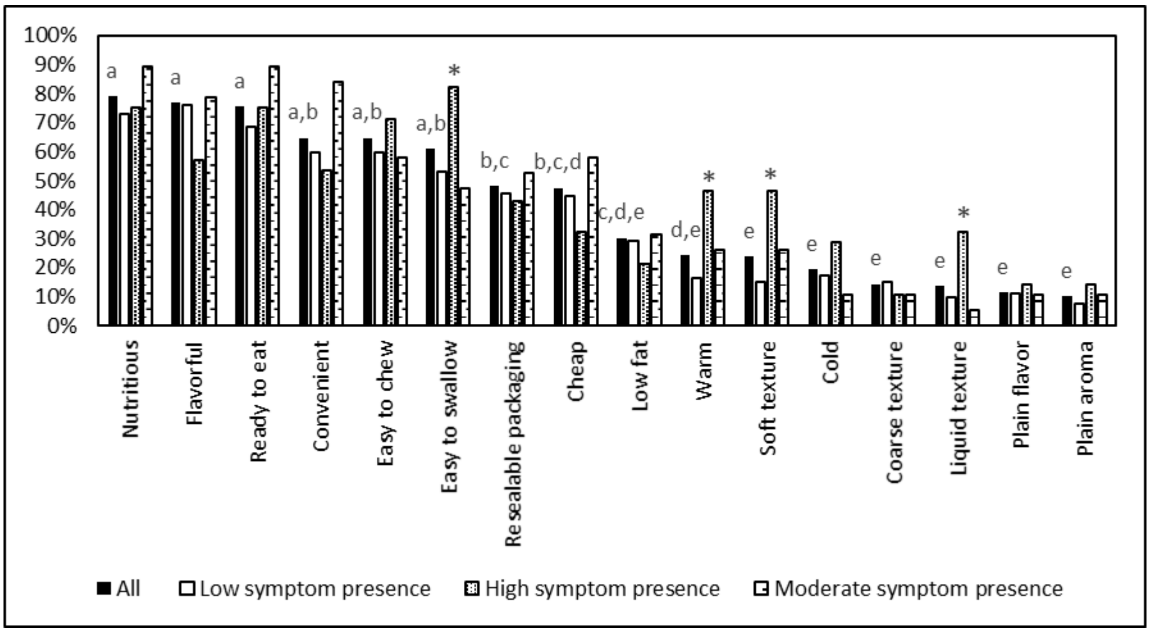

Figure 10. Frequencies of selection for characteristics patients would like to have in a nutrient-enhanced snack (n=139).

Different letter superscripts indicate significant differences in the frequency of selection for all participants ($p<0.001$). * indicates differences in frequency of selection among the clusters.

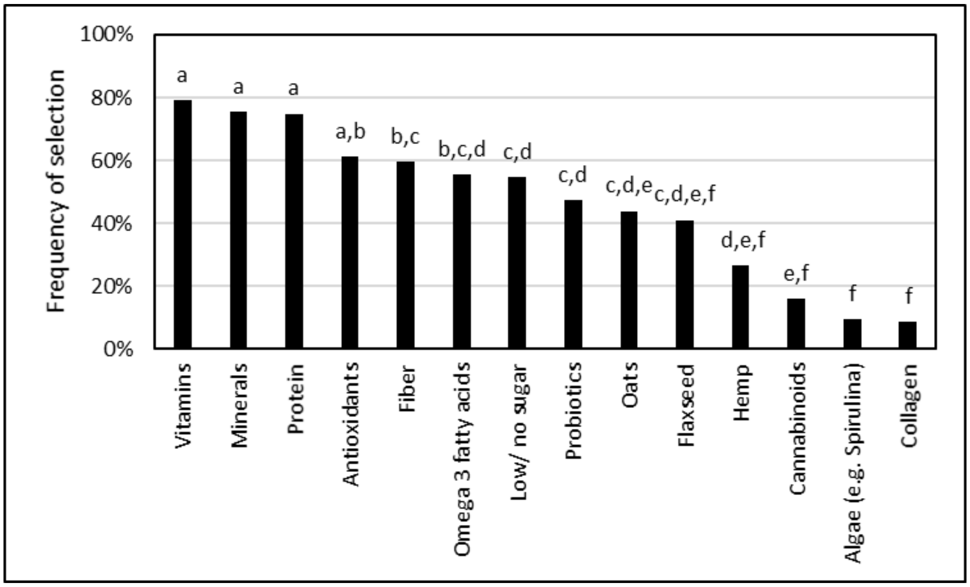

Figure 11. Frequencies of selection of nutrients patients would like to have in a nutrient-enhanced snack (n=139).

Different letter superscripts indicate significant differences in the frequency of selection for all participants ($p<0.001$).

Over 54% of patients (n≥76) indicated interest in vitamins (all), minerals, protein, antioxidants, fiber, omega-3 fatty acids and a low or null sugar content in a fortified product (Figure 11). The more commonly selected desirable protein sources were plant, egg, meat and dairy ($p<0.05$). Calcium, iron, potassium or “All minerals” were more frequently selected compared to the other minerals.

Table 9 identifies symptoms associated with significantly decreased or increased agreement of the suitability of a food product as a snack across all patients. The presence of appetite loss, feeling full, or thick saliva influenced a greater number of products compared to other symptoms. Patients experiencing thick saliva were more likely to agree that viscous products are suitable as fortified snacks. The presence of appetite loss associated with increased agreement of yogurt drink and milk, and the presence of feeling full decreased the agreement of five products as snack formats.

Table 9. Associations* between symptom presence and agreement scores of snack products (n=139).

Symptom	Products with increased agreement	Products with decreased agreement
Anxiety	Chocolate	
Appetite loss	Yogurt drink, milk	Soy, almond or rice beverage
Depression	Yogurt drink	
Difficulty chewing	Flavoured milk	
Difficulty swallowing	Flavoured milk	
Dry mouth		Meat product
Feeling full		Fruit juice, vegetable juice, cookies, pretzel, burritos
Lack of energy	Pudding or custard, yogurt drink	
Nausea	Flavoured milk	
Pain	Iced coffee or tea	Protein bar, fish product
Taste changes	Oral nutritional supplements	
Thick saliva	Oral nutritional supplements, porridge, mashed potatoes, yogurt drink	

* Associations obtained through penalty analysis of symptom presence scores and Likert scale responses.

Summary and Discussion

This is the first study to identify snack foods that patients with cancer consider suitable for fortification and to evaluate the presence of nutrition impact symptom on snack product choice. Soup, yogurt and cheese, fruit juice, egg products, and protein bars were selected by 60% or more of the patients as suitable fortified snacks.

Soup was considered a suitable fortified snack by the majority of patients. In a survey among 1199 patients with cancer, soup was among the five preferred foods. Soup has many of the most frequently selected preferred food characteristics (salty, hot), desired snack characteristics identified by patients (easy to chew and swallow and can be flavorful and nutritious) and is a comfort food. Our results identify fruits, cheese and yogurt as currently preferred snacks suitable for fortification. Bread, pastries and baked goods, cookies, crackers and some salty snacks were identified as current snack choices but showed lower agreement as suitable nutrient fortification vehicles.

The high frequency of selection of nutritious, flavorful, convenient and ready to eat as desired attributes in fortified snacks reported by the survey respondents have also been identified as motivators for snack consumption among healthy US adults. The frequency of selection of easy to chew and easy to swallow highlights the importance of texture on food preferences and could have been influenced by the age group of the participants in which dysphagia and xerostomia can be common.

Protein or specific amino acids, omega-3 polyunsaturated fatty acids and micronutrients (e.g. vitamin D) provide recognized benefits among patients with cancer. Our research identifies vitamins, minerals and protein as nutrients of interested to patients. It is unknown if patients selected those nutrients due to their familiarity or their perceived nutritional benefits.

Patients in the High symptom cluster had lower food intake, interest in creamy, easy to swallow, liquid, soft and warm foods, and had low preference for salty and spicy foods. The presence of lack of energy, taste changes, appetite loss, difficulty chewing and dry mouth has been associated with reduced food intake. The presence of multiple prevalent symptoms could complicate the identification of desired fortified products. Future studies could assess in detail the effect of symptom presence, frequency and severity on preferences of patients with cancer for fortified foods as it is so clearly linked to food choice.

CONCLUSION

Overall, the results obtained from “Development of an oat based beverage rich in dietary fiber and protein project” are extremely valuable in showcasing the applications of Canadian oats and oat fractions in the development of oat milk products that are popular in the global market. Protein from gluten-free oats offers a sustainable source of plant based protein which is convenient and low allergenic, while the fibre fraction offers significant amount of dietary fibre, especially β-glucan. These fractions are increasingly valued by consumers globally. Using the results obtained from this oat milk beverage research will help to provide value-added opportunities of oat crops and support the sustainability of the Western Canadian enterprises along oat value-added chains. Furthermore, this research results demonstrate the potential of oat based beverage as a vehicle to delivery healthy ingredients such as protein, dietary fiber, vitamin D and unsaturated fatty acids to improve nutritional status of cancer patients.

RESEARCH RESULT DISSEMINATION

Thesis:

Blanca Enriquez Fernandez (2020) Use of Sensory Nutrition to Optimize and Evaluate Food Products for Patients with Cancer, PhD thesis supervised by Dr. Wendy Wismer, Department of Agricultural, Food and Nutritional Science, University of Alberta

Scientific publications:

Blanca Estela Enriquez-Fernandez, Lingyun Chen, Pamela Klassen, Sunita Gosh, Vera Mazurak, Wendy Victoria Wismer, Fortified snack preferences among patients with cancer, 2020, to be submitted to Nutrition and Cancer.

International scientific conference:

Chen, L. (2019) Road Map for Plant Proteins: the Oat Example, The Plant Protein Summit, May 29-30, Saskatoon, SK, Canada (invited oral presentation, targeting global protein industries

Industry workshops:

Chen, L. (2018) Oat protein value-added processing and applications, Prairie Oat Grower Association Annul General Meeting, January 29, Westin, Edmonton

Chen, L. (2018) Challenges and opportunities in oat protein processing and applications, invited by Roquette, June 4, 2018

Chen, L. (2018) Structure function properties of plant proteins and their value added applications, Nov. 19-22, Protein Mission to Japan and China, invited by Protein Industries Canada.

Media articles:

Lingyun Chen (December 21, 2017) Oats may join $8 billion plant protein market, The Western Producer, https://www.producer.com/2017/12/oats-may-join-8-billion-plant-protein-market/

Lingyun Chen (January 31, 2019) Consumer Demands Driving Value-Added Oat Research, Grainews, https://www.grainews.ca/features/consumer-demands-driving-oat-research/

Potential benefits to oat industry

A key strategy in meeting Canada's growth targets is to focus research and development on crops that form the core strength of agricultural production. Oat is the third most widely grown cereal crop in Canada, behind wheat and barley with an annual production of 3.8 million tons (statistics Canada, 2017). In spit of high quality, most of Canadian oats are still used as animal feed. The new knowledge generated from this research will help industry to develop value-added opportunities from Canadian oats to catch the fast-growing oat milk market that is expected to reach a value of $490 Million in 2026. Development oat based beverages will be a significant step towards the value-added utilizations of oat nutritive components for human consumptions. This will assist with stabilizing or increasing oat acreages, potentially help oat growers to gain higher value industry or company supply contracts, thus generate increased revenue return to benefit oat producers.

The knowledge generated from this research will also help technology innovation of Canadian food industry to make full use of Canadian oats for development of healthy drink products. This will expand the market reach of Canadian food industry to capture health conscious consumers, thus strengthen their competitiveness and leadership in the global markets.

The research outcomes will also benefit heathy consumers and patients with cancer in Canada and around the world by providing more choices of high quality food products.

This research has also trained two highly qualified personnel in Food Science and Nutrition, including one Postdoctoral Fellow (Dr. Ewelina Eckert) and one PhD student (Dr. Blanca Enriquez Fernandez) to meet the workforce shortfall in fast-growing functional food industry.

Technology transfer plan

This project team will engage oat producers and processing companies to seek their interest in building a supply chain to covert oats into healthy beverages containing both protein and dietary fiber to target the fast-growing oat milk global market and as an option for patients with cancer. Scientists from U of A will be available to help industry set up and optimize their production processing.

The team will also seek additional funding from provincial and federal government to support pilot food product development in collaboration with industry partners that are interested in this work, and conduct sensory evaluations of the pilot samples among health population and patients with cancer. In addition, the clinical trials need to be conducted to demonstrate the capacity of the beverage to improve health status among cancer patients for daily use. These studies will provide the scientific and consumer support to convince industry players to invest in oat milk product development.

Moreover, POGA will help knowledge dissemination of project results through various communication tools including industry meetings and newsletters, and help build oat value-added chains through established networks with oat producers, processers, buyers and end users.

Financial Report:

Total Revenues
Alberta Crop Industry Development Fund & Prairie Oat Growers Association: $220,000
Total revenues: $220,000

Expenditure:
Salaries and benefits: $ 16,1641.58
Materials and supplies: $51,127.29
Travel: $7,231.13
Total expenditures: 220,000

Balance: $0