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GRAIN RESEARCH LABORATORY
Annual Program Report
2019

Canadian Grain Commission
Commission canadienne des grains

Canada

Canadian Grain Commission **MANDATE**

The Canadian Grain Commission works in the interests of grain producers. Guided by the Canada Grain Act, the Canadian Grain Commission works to establish and maintain standards of quality for Canadian grain, regulate grain handling in Canada, and to ensure that grain is a dependable commodity for domestic and export markets.

Grain Research Laboratory **VISION**

Advancing science for better nutrition and lives through high-value, quality grain.

Grain Research Laboratory **MISSION**

- Be the pre-eminent provider of science to support Canada's grain quality assurance system
- Enhance the marketability of Canadian grains through scientific research, monitoring and analytical services
- Anticipate and respond to the needs of the grain value chain, through interaction with the grain sector

An electronic version of this publication is available online at www.grainscanada.gc.ca.
La présente publication est offerte français.

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Director's welcome

Dr. Esther Salvano
Director General
Grain Research Laboratory

It is an honour to submit my first Annual Program Report as Director General. After 73 editions, the format of this report has changed but its objective remains the same: to present the people, programs and activities of the Canadian Grain Commission's Grain Research Laboratory.

Our teams have much to be proud of this year. The Grain Biotechnology Research Program successfully completed a reassessment audit and is now accredited with the latest ISO standard, ISO/IEC 17025:2017. The Analytical Services Program prepared three methods for their own ISO initial accreditation assessment in early 2020, and the Milling and Malting / Research on Barley and Other Grains Program is preparing 12 methods for accreditation. The Bread Wheat and Durum Research Program is also pursuing accreditation by working towards implementing a new quality management system.

Our scientists and staff continue to lead the Harvest Sample Program, which has been running since 1927. We received and analyzed over 15,000 samples from the 2019 harvest. The data from this program provided valuable information to Canadian producers facing a challenging crop year. The Harvest Sample Program is also key to our participation to the annual New Crop Missions with Cereals Canada and the Canadian International Grains Institute (Cigi). Our scientists have presented the facts about the quality of Canadian grain to Asian, Latin American, North African and Italian grain buyers.

We also continued important activities that support the grain quality assurance system, such as providing plant breeder variety quality assessments and monitoring grain exports for variety, mycotoxins, GMOs, and other factors. We also completed a study of how the application of food-grade mineral oil to grain affects the grain's end-use functionality.

I would like to acknowledge the commitment of my predecessor Dr. Stefan Wagener, who retired in September 2019. Dr. Dave Hatcher also recently retired, after 35 years of helping to shape the Grain Research Laboratory into the world-class leader in grain science it is today. I'd also like to welcome Dr. Sean Walkowiak, who recently joined us as the new lead of the Microbiology Program.

As I've settled into this new role, I've had the privilege of getting to know our dedicated and well-respected scientists and staff. Their knowledge, experience and motivation are vital to our success in providing the scientific basis of Canada's grain quality assurance system. Although this report is just a glimpse of their work over the past year, I am proud to show you what they accomplished.

Canadian Grain Commission

Grain Research Laboratory

The research conducted by the Canadian Grain Commission's Grain Research Laboratory falls under two categories: crop research and technology research.

Research related to crops allows us to assess Canadian grain harvest quality and studies how grading factors affect end-use properties. Crop research also develops new uses for Canadian grain and evaluates new varieties as part of the variety registration process.

Research related to technology evaluates and develops methods used to assess the quality and safety of Canadian grain.

Crop research programs include:

- Bread and Durum Wheat Research
- Milling and Malting / Research on Barley and Other Grains
- Oilseeds
- Pulse Research
- Wheat Enzymes

Technology research programs include:

- Grain Biotechnology Research
- Microbiology
- Trace Organics and Trace Elements Analysis
- Variety Identification Research and Monitoring

Beyond each program's own testing and research, all of the programs support four key activities:

Cargo quality monitoring

Provides analytical testing of export grain shipments (e.g. mycotoxins, pesticides, variety composition) to ensure they meet Canada's grading and quality parameters.

Harvest Sample Program

Producers send in a voluntary sample of their harvest, and in return receive a personalized report on the quality of their crop.

Requests for service analysis

Provides analytical services of samples submitted by the industry for testing, at times for a fee.

Plant breeder line evaluation

Provides testing and recommendations for the advancement of breeder line seed.

Statistics and facts

Harvest Sample Program

We publish annual harvest and crop reports. We also publish an annual Fusarium survey report from samples we collect through the Harvest Sample Program.

We conducted **8487** Falling Number and DON tests on wheat

The Harvest Sample Program received **15,024** samples for the 2018-19 crop year

We conducted **607** tests for **service requests by external clients**, which included milling of **73** samples

The most popular requests were for **nitrogen/protein** by combustion and **fatty acid profile**

We tested **1517** cargo shipment samples

Currently, we use **86** different **test methods**

19 scientific articles were published by our scientists

46 scientific presentations were delivered by our scientists

Out of 20 grains regulated by the Canadian Grain Commission, we analyze 14 different types of grain:

- Peas
- Lentils
- Wheat
- Durum
- Barley
- Oats
- Buckwheat
- Chickpeas
- Beans
- Mustard
- Flaxseed
- Rye
- Soybeans
- Canola/ rapeseed

Bread Wheat and Durum Research

Dr. Bin Xiao Fu

Supporting Canada’s wheat quality assurance system

The overall goal of the Bread Wheat and Durum Research Program is to support the Canadian wheat quality assurance system. In addition to conducting research, we evaluate and monitor the quality of wheat and durum. Our work falls into six main areas of focus.

Researching grading factors

We research the effects of various degrading factors on wheat quality. For each factor, we determine the degree and frequency of its damage to end-use quality. Our results are the scientific basis for grading factor tolerances in wheat and durum.

Researching the physicochemical basis of quality

We identify and characterize biochemical components responsible for wheat quality. This research can lead to the development of new methods to measure quality more specifically. It’s also useful for wheat breeders developing new varieties with improved quality.

Quality evaluation for new wheat lines

We evaluate the quality of breeders’ new wheat lines to determine if they meet the requirements for registration. Registered varieties are then designated to a wheat class based on their quality profiles. The wheat class system provides a link between wheat breeders and marketplace quality requirements.

Cargo monitoring

We monitor the quality of wheat cargoes and investigate cargo complaints to ensure customers’ quality needs are met. We use cargo monitoring to make sure grades are assessed consistently from year-to-year. We also use the data from cargo monitoring to determine how accurately the Harvest Sample Program predicts the quality of that year’s export shipments.

Researching test methods

We develop new methods or modify existing ones to measure the functionality of wheat more quickly, accurately, specifically, or affordably.

Harvest Sample Program

Each year, we analyze producers' harvest samples to provide detailed information about the quality of Canadian wheat. We share this data so it can be used to

- market Canadian wheat around the world
- assess how future shipments will perform in grain buyers’ facilities
- support Canada’s grain quality assurance system
- study how the environment affects grain quality

Investigating kernel size distribution as a potential grading factor for durum

In the wheat trade, test weight (weight per hectoliter) is used worldwide as an indicator of milling potential. Dry growing conditions in 2017 and 2018 resulted in durum wheat with a wide range of test weight and kernel size distribution. Although most durum wheat harvested in those crop years met the test weight requirements for the top grades, we noticed that samples with smaller kernels had inferior milling performance compared to samples with larger kernels. Some Canadian durum customers expressed concerns about the milling quality of Western Amber Durum wheat, which is known for its superior milling quality and high semolina yield. The shipments in question graded as No. 1 or 2 but had small kernels.

Clearly, we couldn't rely on test weight alone to measure durum milling quality. We decided to reassess test weight and evaluate potential other alternatives for determining the milling quality of Canada Western Amber Durum wheat.

Our results indicated that kernel size distribution is a better indicator of milling quality in durum than test weight (Figures 1 and 2). As a result, we've proposed a new grading factor based on kernel size distribution to the Western Standards Committee. We proposed proportion of small kernels (small enough to pass through a No. 6 slotted sieve) replace shrunken kernels as a grading factor for Canada Western Amber Durum.

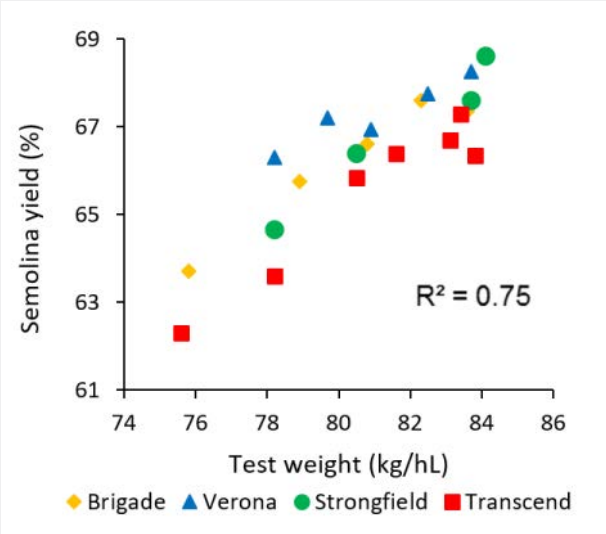


Figure 1 Relationship between semolina yield and test weight for samples from four popular durum varieties. Higher test weight is associated with higher semolina yield. However, the relationship is not as strong (R2=0.75) as the relationship shown in Figure 2.

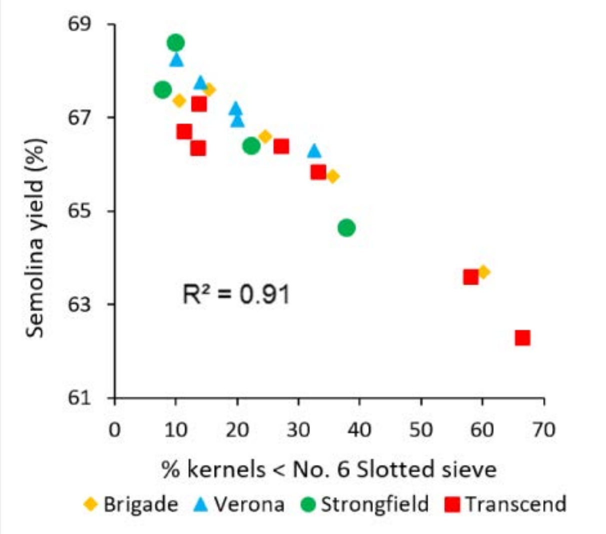


Figure 2 Relationship between semolina yield and proportion of small kernels for samples from four popular durum varieties. Samples with lower proportion of kernels passing through No. 6 sieve had higher semolina yield. The relationship is stronger (R2=0.91) than the relationship shown in Figure 1.

Other highlights

- We recently modified a rapid GlutoPeak protocol for use with wholemeal samples. The existing method requires careful control of milling conditions and is time consuming. For breeding programs or genetic mapping studies, wholemeal samples are much easier to prepare and require a much smaller sample. We can now quickly predict water absorption, dough mixing properties, and gluten viscoelastic properties using wholemeal samples.
- We investigated how pasta eating quality is affected by protein content, gluten strength, and their interaction. We found that gluten strength's impact on the firmness of cooked pasta depends on the wheat's protein content. This data helps set practical quality improvement targets for wheat breeders.
- We studied the biochemical basis of wheat quality by investigating how environment led to the unusual ranking of gluten strength in two wheat varieties. We found that increased gluten strength in some growing environments corresponded to higher production of a particular protein. This protein appears to be crucial for the formation of insoluble glutenin, which is directly related to dough strength.

Research team

- Research scientist/program manager
  - Dr. Bin Xiao Fu
- Chemists
  - Dr. Kun Wang
  - Carly Isaak
  - Brigitte Dupuis (retired as of October 2019)
- Technicians
  - Altash Yirdaw
  - Andrea Iverson
  - Dale Taylor
  - Jerry Suchy
  - Joseffus Santos
  - Li Tan
  - Ofelia Francisco-Pabalan
  - Yuming Chen

Milling and Malting / Research on Barley and Other Grains

Dr. Marta Izydorczyk

Reliable data for the Canadian barley value chain

Our program has three major components: grain and malt quality analysis; milling and processing technology; and research and innovation for barley and other grains.

Reporting on the quality of western Canadian malting barley

Each year, we collect barley samples from producers through the Harvest Sample Program and selected malting barley samples from grain handling and malting companies. We perform full barley and malt quality assessment on these samples and share our results with contributors. We use this data to publish and share up-to-date information about barley production and to inform our *Annual Harvest Report—Quality of Western Canadian Malting Barley*.

Exporters, buyers, and provincial crop commissions use our Annual Harvest Report as a main source of information about each year's crop. Exporters use it to market Canadian malting barley to potential buyers. Buyers use it to understand how Canadian malting barley may perform each year. Provincial commissions use it as a tool to develop a plan for sustainable, long-term barley production.

Collecting quality data every year (we've been publishing our Annual Harvest Report since 1989) puts us in the unique position of being able to provide historical quality data. We can also compare the quality of newly registered varieties to that of established varieties (Figure 1). The malting barley industry uses this information to inform their strategies for integrating new varieties into the marketplace.

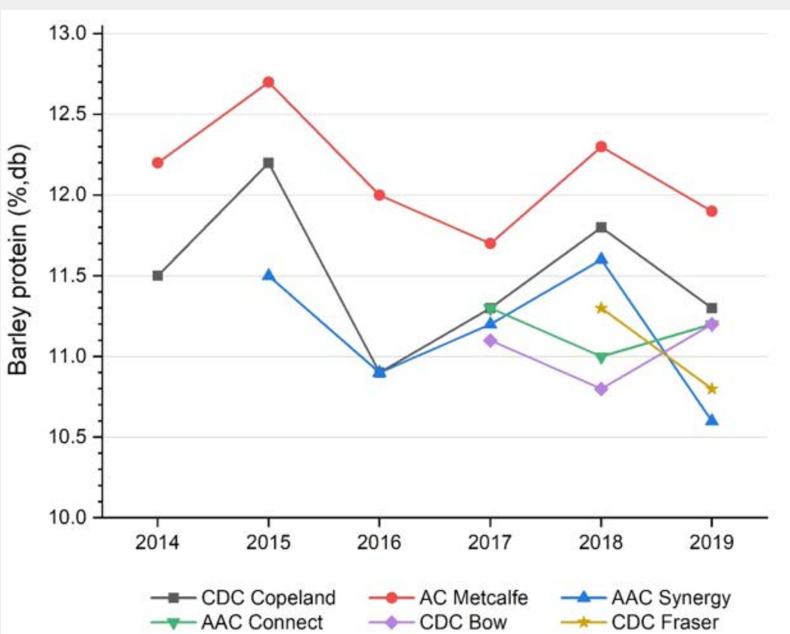


Figure 1 Weighted average protein content in barley selected for malting from 2014 to 2019, based on tonnage of composite samples received

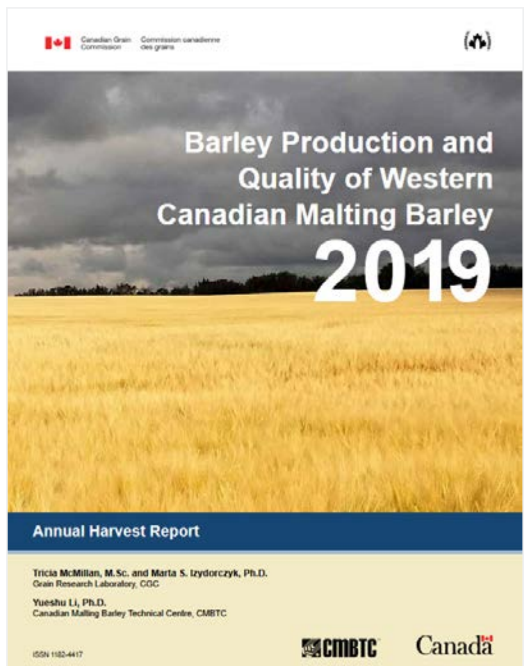


Figure 2 Annual Harvest Report—Quality of Western Canadian Malting Barley

Barley and oat varieties that work

We operate a pilot malting plant and two micro-malting units. We can malt samples ranging from just 125 grams to 5 kilograms (Figures 3, 4 and 5). Our wide range of analytical and processing capabilities makes us a unique partner for breeders, producers, grain companies, and processors. We also provide scientific expertise and data to help Canadian barley breeders develop new varieties with desirable quality traits.

Every year, we assess the quality of advanced breeder's lines tested in various registration trials. We also provide this data to the Prairie Grain Development Committee. The committee uses this data to assess candidate lines and decide whether to recommend them for registration.

Our laboratory tests the following:

- malting barley lines and food barley lines tested in the Western Cooperative Barley Registration Tests
- malting barley lines tested in the Western Collaborative Registration Tests
- milling oat lines tested in the Western Cooperative Oat Registration Tests
- barley lines tested in the Eastern Canada Quality Trials

Figure 3 Micromalting units

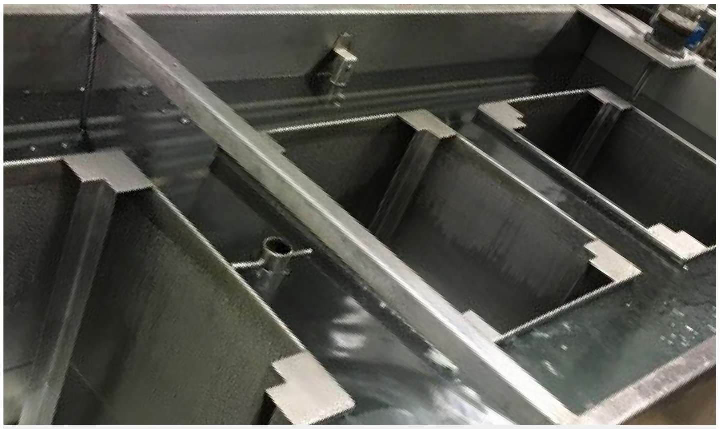


Figure 4 Pilot plant steep tanks

Figure 5 Pilot plant germination drums

Milling and processing technology

We mill samples from Canadian wheat export cargoes, annual harvest samples of certain Canadian wheat classes, and advanced wheat breeding lines. The milling performance data we collect is used by Canadian wheat breeders, marketers and customers.

Our milling lab also supports the Bread Wheat and Durum Research Program and the Trace Organics and Trace Elements Analysis Program by providing precise and accurate milling data for Canadian wheat. We supply the flour they use for further quality testing and to study how milling affects the presence of various contaminants in grain.

We've also taken our milling expertise to the global stage by collaborating with research institutions and scientific publications to develop mill flows for barley, oats and buckwheat. Some of our research focuses on developing new products and uses for Canadian grains.

Figure 6 Products made from black barley: **(A)** steel cut whole grain; **(B)** steel cut pearled grain; **(C)** instant flakes produced from steel cut whole grain; **(D)** instant flakes produced from pearled grain

Research and innovation

We pursue scientific research to quantify and characterize the parts that make up each grain and relate them to the grain's end-use quality. We share our results with collaborators, producers, plant breeders, grain handlers, and malting companies.

Our research projects are designed to

- help producers decide how to best grow specific crops
- address the concerns and problems faced by the industry during handling and processing of grain

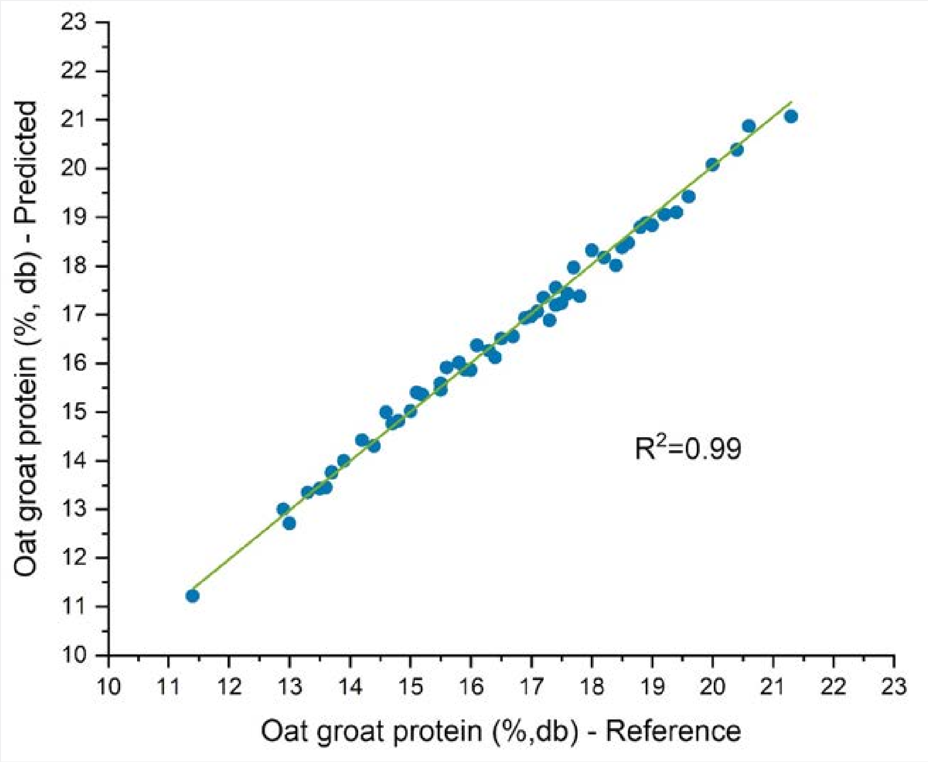


Figure 7 Oat groat protein as predicted by NIR versus reference values (Leco)

Other highlights

This year, we investigated

- developing near infrared spectroscopy (NIR) calibrations to predict proteins, oil, and vitamin E concentration in oats and barley (Figure 7)
- how malting barley quality and yield react to increasing nitrogen rates
- how seed treatments and foliar fungicides impact barley productivity and quality
- how well applying a post-harvest treatment to malt barley works to limit the impact of *Fusarium graminearum* during malting and brewing
- the effect of a plant growth regulator on yield and quality of malting barley

Research team

- Research scientist/program manager
  Dr. Marta Izydorczyk
- Chemists
  Tricia McMillan
  Arzoo Sharma
- Technicians
  Shin Nam
  Jerry Kletke
  Shawn Parsons
  Debby Kelly
  Anna Chepurna
  Dave Turnock

Oilseeds

Dr. Véronique Barthet

Developing new methods for analyzing oilseed quality

The Oilseeds Program researches factors that contribute to the quality of products made from Canadian oilseeds, including canola, rapeseed, flax, soybean and mustard. We analyze oilseeds for factors such as oil, protein, glucosinolate, fatty acid composition, free fatty acid and chlorophyll to give domestic and international customers an indication of each year's crop quality. We also study how variety and environment affect the composition and quality of oilseed crops and develop new and improved methods for analyzing minor and major components of oilseeds.

Using a handheld NIR spectrometer to predict key soybean quality traits

In 2019, we assessed whether a handheld Near-Infrared Reflectance (NIR) spectrometer could be used to predict oil and protein content in soybeans. While benchtop NIR spectroscopy is widely used to predict crop quality, these instruments are limited to use in the lab. We wanted to find out if a handheld tool, able to be used outside of the laboratory (such as in a processing plant or a grain elevator), could perform just as well.

Figure 1 Handheld NIR spectrometer and soybeans

Figure 2 Benchtop NIR spectrometer used for predicting oil and protein content in soybeans

Project design

- We used sets of calibration samples to develop four different models to associate the NIR scan data with the reference values of the compounds that we wanted to predict (oil and protein). We then analyzed sets of validation samples to find out if the models worked and could be used to accurately predict oil and protein content in soybeans.
- For each model, we averaged the NIR scan measurements of 5, 10, 15, and 25 individual scans to produce a representative average NIR scan of each sample.
- We determined that averaging the 15 individual scans for each sample provided better models and more accurate results than when only 5 individual scans were averaged to produce the representative sample scan.
- The optical window of the handheld NIR spectrometer is just 1.6 cm in diameter, while soybeans can vary from 0.5 to 1.1 cm in diameter. This meant that no more than 6 seeds could be scanned at a time. The small number of seeds per scan meant that one seed could have a large impact on the results while not being representative of the entire sample. To reduce how much sampling impacted the results, we used more scans per sample to create a more representative average for each sample.

Figure 3 Handheld NIR spectrometer used for predicting oil and protein content in soybeans

Conclusion

The more individual scans performed, the more accurate the results. Fifteen scans seemed to be a good balance between number of measurements and the model performance. This reduced the effect of sampling and made the results more robust.

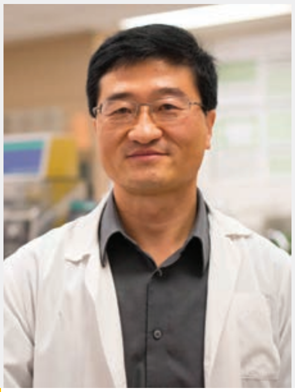
This project shows that handheld NIR spectrometers can be used to assess soybean quality when some parameters are controlled, such as using an increased number of scans to eliminate the sampling effect. Our findings show that the industry could bring handheld NIR devices into the processing plant or the grain elevator. Oil and protein content prediction no longer needs to be limited to the laboratory.

Other highlights

- We demonstrated that a handheld NIR spectrometer can be used to predict oil and protein content in canola seeds. A handheld NIR can be used to segregate canola seeds from rapeseed based on total glucosinolate content. It can also segregate conventional canola from high-stability canola based on fatty acid composition and iodine value. Unfortunately, we determined that a handheld NIR cannot be used to predict intact canola seed chlorophyll content.

Research team

- Research scientist/program manager
  Dr. Véronique Barthet
- Chemists
  Ann Puvirajah
  Bert Siemens
  Tao Fan
- Technicians
  Brad Speiss
  Hayeon Oh
  Katharine Schulz
  Marnie McLean



Pulse Research

Dr. Ning Wang

Developing new methods for measuring pulse quality and functionality

The Pulse Research Program investigates how the physical and chemical components of pulses affect the quality of the final product made from them. We study how grading, environmental factors, and genetic factors determine pulse quality and end-use functionality. We research methods for measuring and assessing pulse end-use quality and functionality. We also conduct the annual pulse and food-type soybean quality analysis for the Harvest Sample Program and take part in cargo monitoring to support the marketability of Canadian pulses.

Supporting Canadian pulse growers

In 2019, we worked closely with universities and other research centres on two projects to investigate the factors that determine how pulse ingredients perform in end-use products. The knowledge gained through these collaborative projects will support Canadian pulse growers and the industry.

Nutritional value, health benefits, and low cost are a few reasons why the food industry is excited about using plant-based protein ingredients, such as those made from pulses. However, food processors look for specific functional properties for use in food formulations. There are currently very few standard methods available for measuring the functional properties of pulse ingredients.

Measuring pulse quality

We're collaborating with researchers from Agriculture and Agri-Food Canada's Morden Research and Development Centre, the Canadian International Grains Institute (Cigi), the University of Manitoba and the University of Saskatchewan on a multi-year project. We helped to assess, modify and develop methods for measuring pulse quality attributes and functional properties.

We also studied how different processing and milling treatments affected certain chemical and functional properties in pulse flours. The functional properties we assessed included oil emulsifying capacity (using pulse proteins as an emulsifier to stabilize an emulsion) and oil absorption capacity (OAC).

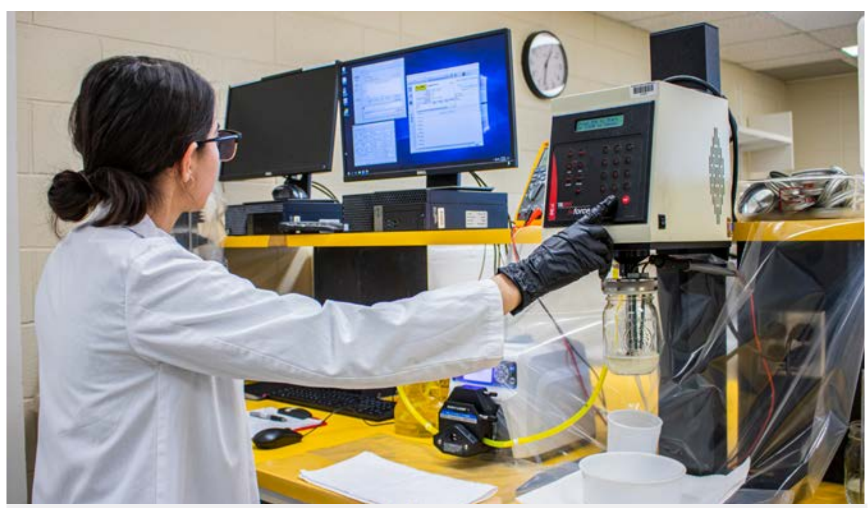


Figure 1 The apparatus we developed to measure oil emulsifying capacity in pulses

OAC is an important functional property for pulse ingredients. Pulse flours and proteins must be able to retain oil for use in certain food applications, such as doughnuts and baked goods. OAC is also important when adding pulse flours or proteins to ground meat formulations. The existing method for measuring OAC involves mixing a sample of pulse flour with oil, centrifuging the mixture, pouring off the excess oil, and then calculating how much oil the flour absorbed. However, we found that certain pulse ingredients tend to drain with the excess oil, while others reabsorbed part of the oil after being centrifuged. This causes measurement errors.

We're developing a new method for accurately measuring OAC. Results from this study will provide the pulse industry with consistent and objective measurements for pulse quality and functionlity. This information will help growers and the Canadian pulse industry compete in international markets.

Investigating faba bean functionality

We're also collaborating on a research project with Agriculture and Agri-Food Canada's Saskatoon Research and Development Centre. Our pulse research team is investigating how variety, growing location and growing year affect the chemical composition and functionality of fractions produced from faba beans using air-classification technology.

We determined what the best conditions are for separating faba bean flours into protein-rich and starch-rich fractions using a laboratory air classifier. Our team is now evaluating the functional properties of these fractions. The results of this study will support the increased use of pulse ingredients and the marketability of Canadian faba beans. In turn, increased demand for Canadian pulses will benefit the farmers who grow them.

Figure 2 Laboratory air classifier for separation of pea flour into protein-rich and starch-rich fractions

Heading into 2020

In collaboration with the Canadian Grain Commission's Industry Services division, we will investigate the effects of bleached and wrinkled seeds in red lentils on dehulling quality. This study will provide scientific support to the grain grading system by developing tolerances for both factors in the different grades of red lentils.

As always, the Pulse Research Program continues to provide information about the end-use quality of the latest harvest of Canadian pulses and food-type soybeans. The Canadian Grain Commission uses this data to monitor and support the quality assurance system. Producers across Canada can use our quality information to better market their crops. Abroad, this data is used to support the marketing of Canadian pulses.

Other highlights

- We investigated how the application of food grade mineral oil affects the end-use quality of peas, lentils and food-type soybeans. We found that applying mineral oil at a level of 0.02% by weight (w/w) had no significant effect on specific quality attributes.
- We assessed the existing methods for determining foaming capacity, foaming stability, and pasting properties of pulses. Preliminary results indicate that the methods need to be modified to improve their accuracy and precision.

Research team

- Research scientist/program manager
  Dr. Ning Wang
- Chemists
  Dora Fenn
- Technicians
  Lisa Maximiuk
  Monica Cabral

Wheat Enzymes

Ray Bacala, MSc

Explaining the biochemical basis of grain quality

The goal of the Wheat Enzymes Program is to apply new and existing technology to better understand quality traits in Canadian grain. We investigate how variety, growing conditions and damage due to disease impact grain quality at the molecular level.

Currently, the Wheat Enzymes Program is using state-of-the-art mass spectrometry to analyze cereal grain proteins. We also examine enzyme activity in wheat caused by fusarium or sprout damage.

Profiling gluten protein subunits

In the past year, we have developed a method to look at the individual gluten protein components with a very high level of detail. Gluten proteins are a key contributor to wheat quality. The composition of gluten proteins determines the balance between elasticity and extensibility of dough, which in turn determines processing properties and end-product quality.

Gluten is a complex mixture of similar proteins of different molecular mass and charge, which makes gluten very difficult to characterize. Understanding wheat's complex gluten proteins, including being able to detect and study their components in detail, would help guide and monitor wheat quality improvement through breeding.

The method we developed should provide a useful set of tools to investigate wheat's genetics, and how genetics and the environment interact to affect wheat's protein composition. We plan to use this tool to evaluate proteins associated with these interactions, which can result in significant variation in gluten strength.

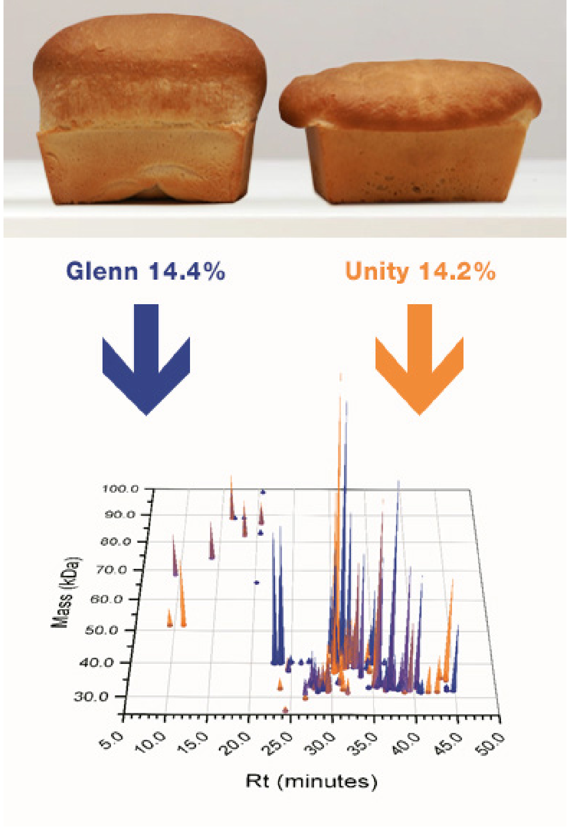


Figure 1 Comparison of the type and amounts of gluten proteins for two wheat flour samples with the same total protein content. Differences in these patterns help us understand why not all samples with the same protein count have the same baking quality

Investigating the impact of Fusarium protease on gluten strength

Fusarium head blight is a fungus that can infect cereals. These fungi cause a severe reduction in grain yield, produce mycotoxins, and secrete proteases. Proteases are a type of enzyme that can degrade or weaken gluten proteins. Proteases are activated when flour is made into dough, resulting in weakened dough and reduced loaf volume in baked bread.

We're studying the nature of the Fusarium protease to improve our understanding of the relationship between Fusarium infection and quality loss. Better understanding at the molecular level will allow us to directly measure protease activity and its impact on gluten properties. Our results clearly showed the differences in the protease activity among kernels with different degrees of infection. Next, we are studying the detailed mechanisms through which proteases degrade gluten proteins and weaken gluten. Understanding the impact of the Fusarium protease on grain quality would indirectly support the wheat grading system.

Characterizing barley malt and wort

We are working with the Milling and Malting / Research on Barley and Other Grains Program to explore techniques for identifying and quantifying essential components of wort and beer. Studying the components of barley malt and wort will allow us to compare different malting, mashing, and brewing practices to better understand how to improve quality. We're working to verify proteins that are known to reduce the quality of malting barley. We're also trying to establish how the quantity of these proteins in malt samples relates to malt quality.

Barley germinates during the malting process, producing various enzymes. These enzymes break down starch and proteins, so yeast can feed on sugars and amino acids during brewing. Some barley components don't change during germination, but most are partially or completely digested. Mashing before brewing causes further changes.

There are many molecular components present in malt samples. The relative amounts of these components depend on barley variety, growing environment, malting and mashing techniques. Some of these components define taste and mouthfeel and support the formation of beer foam, while others can cause problems such as hazing and gushing during brewing. Although many problem proteins have been identified, we don't fully understand all their components and it's not clear how processing methods may reduce their presence.

Our research supports science-based grain grading and allows breeders and producers to make more informed varietal choices. Better understanding of these components will help the grain industry learn more about quality-related barley and malt components and discover new ones.

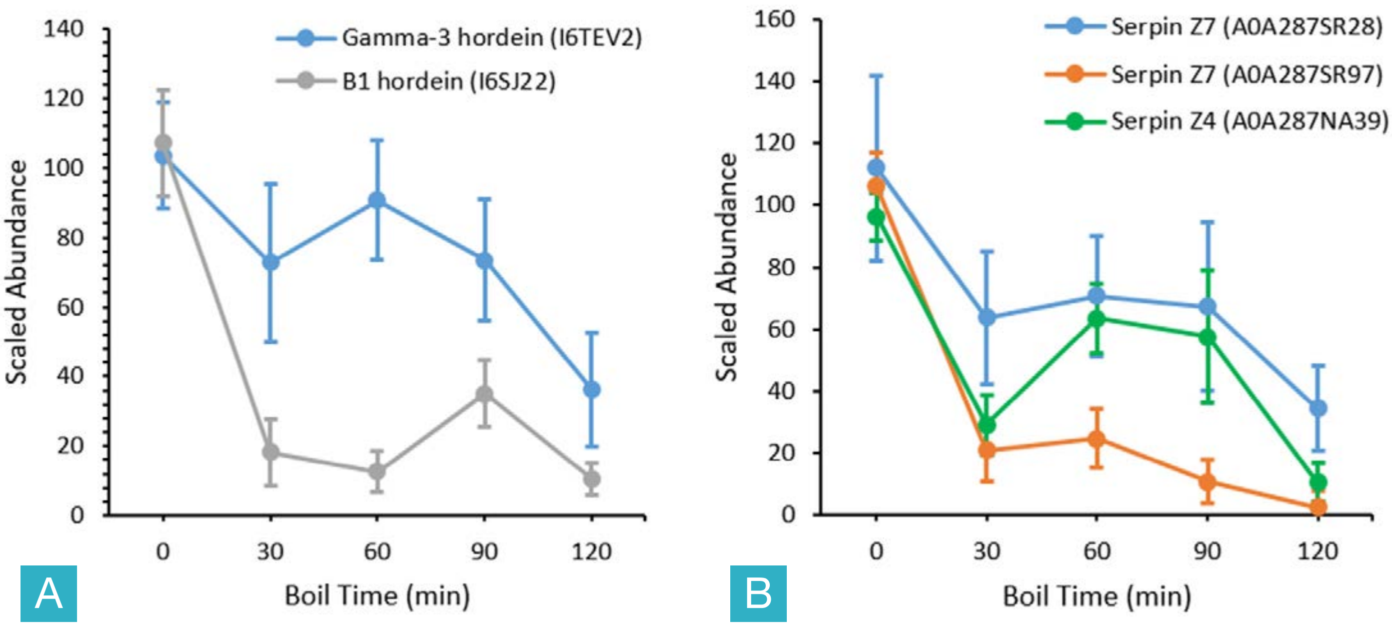


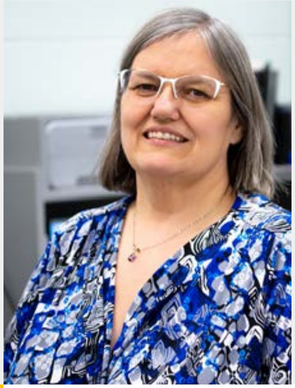
Figure 2 Boiling is a critical step to prepare wort prior to yeast addition during brewing. The relative amounts of two hordeins **(A)** and three serine protease inhibitors called serpins **(B)** changed throughout the boil. Hordeins are involved in hazing and serpins are involved in foaming, both of which are undesirable to brewers. The bars around the data points represent the known variance for these analyses

Other highlights

- We detected increased protease activity in sprouted durum, which suggests that it might affect quality when the environment is right for the protease to have a detrimental impact on gluten proteins during processing.
- We are developing proteomic methods for barley wort that identify and quantify peptides and proteins that affect brewing processes and beer quality.

Research team

- Research scientist/program manager
  Dr. Dave Hatcher (retired as of October 2019)
- Chemists
  Ray Bacala
- Technicians
  Katherine Cordova



Analytical Services

Twylla McKendry, MSc

Defining Canada's crop quality

The Analytical Services Program includes a diverse group of activities, providing many different types of analytical services for thousands of clients each year. We also oversee and maintain the Harvest Sample Program and provide the protein reference method the Canadian Grain Commission uses in important monitoring activities.

Harvest Sample Program

Canadian grain producers can submit samples of their crop to the Harvest Sample Program for analysis. In exchange for their samples, they receive the following results at no cost.

- Unofficial grade
- Dockage assessment on canola
- Protein content on barley, beans, chick peas, lentils, oats, peas and wheat
- Oil, protein and chlorophyll content for canola
- Oil and protein content and iodine value for flaxseed
- Oil and protein for mustard seed and soybeans
- Falling number (FN) for wheat
- Deoxynivalenol (DON) levels for wheat and corn

We added FN and DON to our testing protocol for wheat and durum in 2018. Both FN and DON can affect the quality of end products made from wheat or durum. In 2018, good growing and harvesting conditions meant that almost all the 8870 samples we tested received good FN and DON results.

In 2019, however, wet weather and harvest delays caused sprouting to become a serious challenge for certain crops in the prairies. This was reflected in the samples we received from producers. Producers who participated in the program can use their FN results when deciding how to market their crop.

Figure 1 A Foss Infratec™ 1241 Grain Analyzer used to analyze protein content in whole kernels of wheat and other cereals

Figure 2 A grain producer's Harvest Sample Program contribution being added to a Foss Infratec™ 1241 Grain Analyzer

Accuracy in protein testing

In the protein lab, we perform more than 25,000 combustion nitrogen analyses (CNA) on cereals, oilseeds and pulses each year. Our protein lab provides the reference method for protein testing at the Canadian Grain Commission's facilities. These facilities use our CNA results to calibrate their near-infrared (NIR) instruments. The Canadian Grain Commission relies on NIR instruments for monitoring grain segregation and cargos, analyzing Harvest Sample Program samples, and analyzing protein content.

Protein content is especially important to buyers of Canadian grain. When the Canadian Grain Commission certifies an export vessel, protein data is provided for that shipment. Our CNA results are used to verify that the Canadian Grain Commission, as part of the Government of Canada, generates accurate and reproducible results at the port. This is particularly important in years when challenging weather and growing conditions cause crop quality issues.

Protein premiums represent much-needed additional income for wheat growers. Producers who deliver the top two milling grades of Canada Western Red Spring (CWRS) are paid a premium for wheat that is high in protein. The premium increases based on each additional 0.1% protein content. Every other month, we provide protein "check" samples with a known protein value. We measure the samples several times by CAN or NIR. The industry can then use these samples to make sure their own instruments are accurate.

Canada sells over 30 million tonnes of grain and flour each year, worth between $4 and $6 billion. Our results must be accurate and reproducible to support the Canadian grain industry's quality assurance system.

Figure 3 Leco FP-628 used for combustion nitrogen analysis (CNA) to measure protein in ground grain, pulses and oilseeds

Figure 4 A sample being weighed for combustion nitrogen analysis

Other highlights

- In 2019, we received and analyzed over 15,000 crop samples from Canadian farmers, and 9030 emails were sent out with results.
- We've performed DON and FN analyses for over 8500 producer wheat samples so far this crop year. In November alone, we analyzed 2716 wheat samples, in duplicate, for FN. We increased the capacity of our team in order to perform these tests in a timely manner. In today's wheat trade, these results are of increasing importance to Canadian wheat producers.
- The Harvest Sample Program set a new record for number of samples received in one day. On November 4, 2019, we received 567 samples (all commodities). The previous record was November 2, 2018 with 532 samples.

Research team

- Program manager/chemist
  - Twylla McKendry
- Harvest Sample Program supervisor
  - Cherianne McClure
- Falling Number team lead
  - Evelyn Barnett
- Technicians
  - Rich McKinley
  - Gary Dion
  - Debbie Salazar
  - Bruno Klassen
  - Hong Yue
- Harvest Sample Program technicians
  - Gabby Nowakowski
  - Courtney Freeth
  - Igor Karnaoukh
  - Krystin Polden
  - Janelle Gelvosa
  - Ariel Barlintangco
  - Mohanad Zraik
  - Siobhan Boughen
  - Jennifer Nguyen
  - Pamela Lavallee
  - Paul Navidad
  - Aaron-John Gartner
  - Matthew Martin

Grain Biotechnology Research

Dr. Tigst Demeke

Protecting market access by refining genetically modified (GM) detection methods

The Grain Biotechnology Research Program develops and evaluates DNA-based methods for identifying and quantifying genetically modified organisms (GMOs) in grains and oilseeds. We also verify protein-based methods to determine if they are suitable for detecting GMOs.

Developing and validating GM detection methods

In 2019, we continued to develop and validate methods for detecting GM events in grain samples.

Occasionally, a GM event that is approved in one or more countries may be detected in food imports into a country that has not approved it. This is called a low-level presence. The European Union has a zero-tolerance policy for unapproved GM events. The sampling and testing protocol we helped develop for bulk shipments of flaxseed exported to the European Union is still in force today.

If a GM event hasn't been approved in any country, it's considered an adventitious presence if detected.

Recognized detection methodology

Our detection methods must be accurate and precise to maintain access to critical markets for Canadian grains. Our lab is ISO/IEC 17025-accredited to test for the presence of GM events in grain samples. ISO accreditation means that our technical expertise is recognized internationally. This expertise has helped Canada maintain market access to the European Union, Japan and other countries.

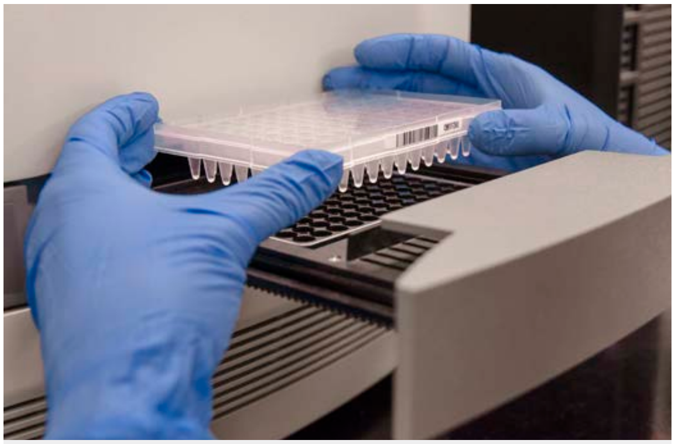


Figure 1 Polymerase chain reaction (PCR) assay ready to be placed in real-time PCR instrument

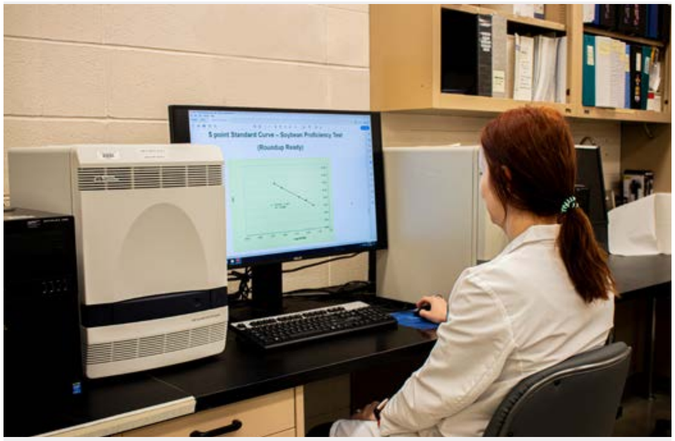


Figure 2 Analysis of PCR result

Refining GM detection techniques

In addition to ongoing monitoring work, our lab carries out research to improve detection methods. In the future, crops containing new and multiple GM events will be grown and we must be able to detect them quickly and accurately. This year, we validated methods using digital and real-time PCR to detect GM events in two important Canadian crops: canola and soybeans.

Digital PCR is a relatively new technique for detecting and quantifying GM events (Figure 1). In digital PCR, a DNA solution can be divided into thousands to millions of individual droplets or partitions. When digital PCR is carried out, some of the partitions contain the target molecule (positive) while others do not. The percentage of GM material present in the sample is calculated from the ratio between positive partitions and the total number of partitions.

Real-time PCR is routinely used for testing grains for the presence of GM events at Canadian Grain Commission. Real-time PCR techniques require certified reference materials, which aren't always available. On the other hand, digital PCR does not require reference materials. In the future, digital PCR is expected to replace real-time PCR for testing of grain samples for the presence of GM events. Our lab will continue optimizing PCR methods for the detection of GM events so that Canada's access to grain markets around the world is protected.

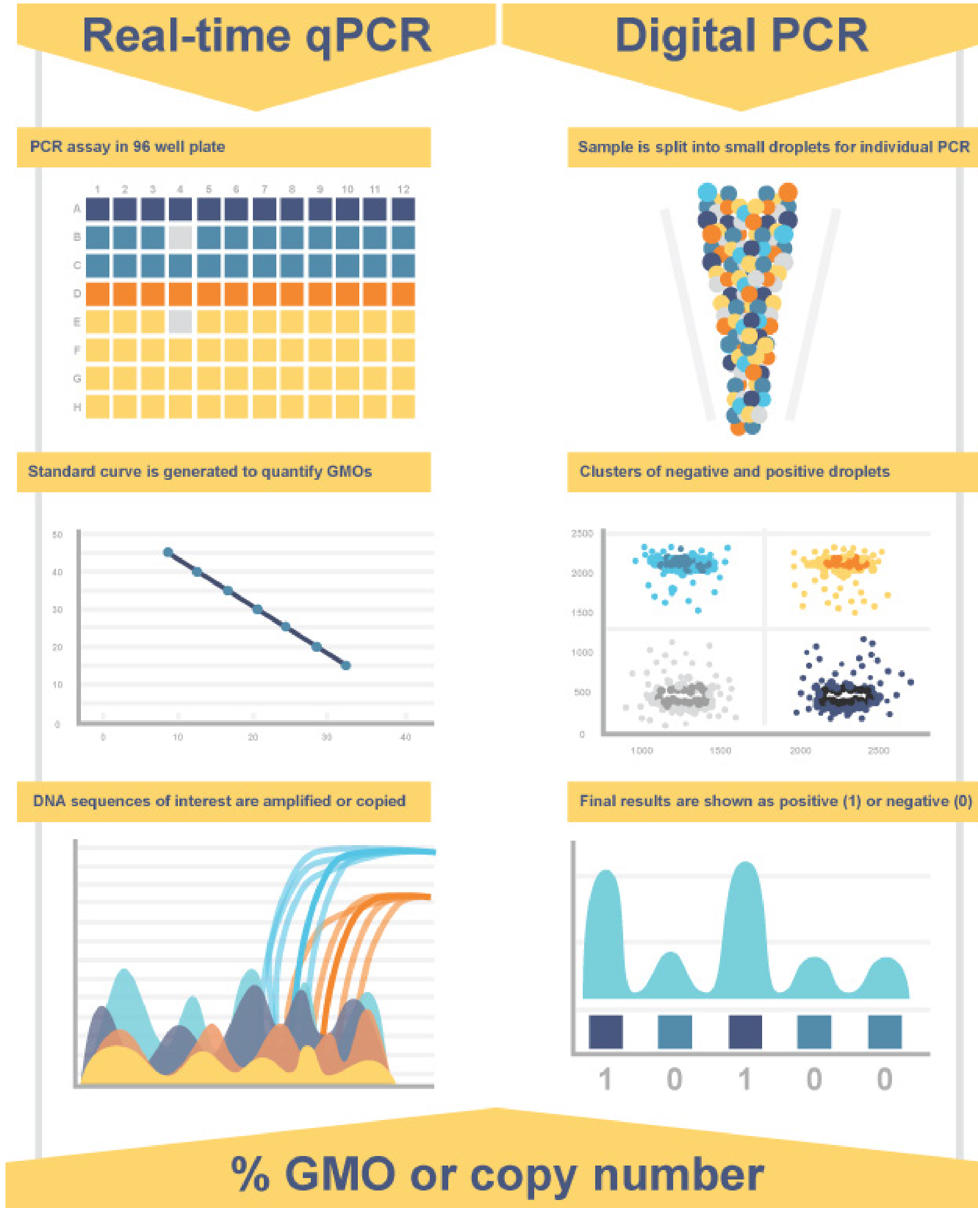


Figure 3 Graphic comparing the process of GM detection using real-time PCR and digital PCR techniques

Other highlights

- We successfully passed a Standards Council of Canada (SCC) ISO/IEC 17025:2017 audit carried out in September.
- From June 2018 to December 2019, we tested 1315 wheat cargo samples for the presence of the MON71200 GM wheat event discovered in Alberta in 2017. We have never detected this event in a wheat vessel leaving Canada, demonstrating that it is non-existent in the Canadian wheat supply. However, some countries still demand test results for the MON71200 GM wheat event, which we can provide thanks to our ongoing monitoring programs.

Research team

- Research scientist/program manager
  Dr. Tigst Demeke
- Biologist
  Michelle Holigroski
- Grain Research Laboratory ISO Coordinator
  Melissa Lindsay
- Technician
  Monika Eng

Microbiology

Dr. Sean Walkowiak

Staying one step ahead of potential threats to food safety

The Microbiology Program's objective is to research and monitor pathogenic, quarantine, and toxigenic microorganisms, such as fungi and bacteria, naturally associated with grain. We develop, validate, and implement new methods to identify and characterize these microorganisms. We also study how agronomics, environmental conditions, and processing affect microbial communities.

Through our work and collaborations with the Canadian Food Inspection Agency, the National Microbiology Laboratory, Agriculture and Agri-food Canada, and Génome Québec, we help the Canadian grain industry stay one step ahead of potential threats to grain production and food safety.

Detecting microbes on grain

We safely identify and characterize bacteria and fungi in our biological containment facility. There, we process grain samples using a pipeline designed to detect microbial contamination. Some microbial damage, such as ergot or Fusarium head blight, can be seen with the naked eye and can be processed directly. Other microbial contaminants are present in very low levels and cannot be identified by physical inspection. In order to study these microbes in more detail, we enrich them in our incubation chambers so they can grow in larger numbers. Once the samples get inspected and processed, we profile them using the latest DNA-based detection technologies.

Identifying and cataloguing microbes

We catalogue the microbes we identify. We keep a physical sample that is preserved in a culture collection in our cryogenic freezers, and we have digital records of the DNA tests and sequencing data. Our catalogue allows us to track differences in microbes found in different places in Canada. We can also track how microbial populations might change over time. If microbes were to be found in Canadian grain or grain products, we could use our microbial detection pipeline to help trace the contamination back to its source.

Figure 1 Incubator used for growing microbes in a temperature controlled environment

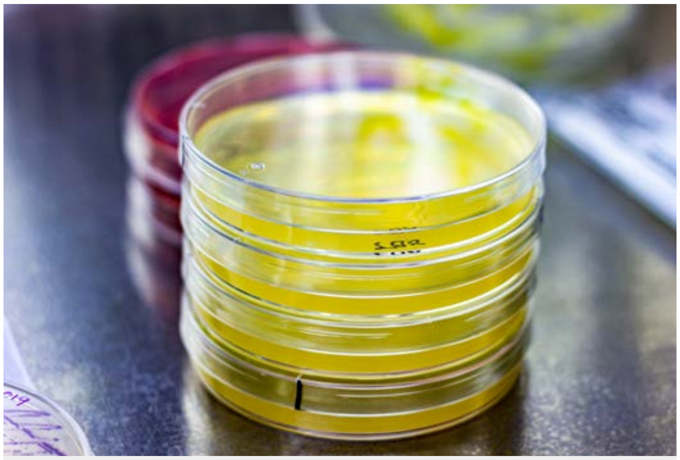


Figure 2 Dishes containing a nutrient- and energy-rich medium that allows microbes to grow and multiply. Different growth medium recipes are used to promote growth of particular microbes of interest

Microbial detection pipeline

1. Process the grain samples and enrich for the microbes using incubation chambers and standardized culturing methods
2. Preserve some of the microbes in our cryogenic freezers for future reference
3. Isolate microbial DNA from the samples using molecular biology tools and equipment
4. Use robotics and high-throughput DNA-based methods to test samples for microbes that can produce harmful toxins or cause disease
5. Determine the microbe's characteristics using whole genome sequencing and comparative genomics

Classifying microbes using the latest genomics technologies

We have developed data analysis pipelines that we use to assemble and compare microbial genomes, allowing us to capture information about the microbes at a level of detail that is more comprehensive than ever before. These analyses can classify the microbes into different populations (Figure 1), identify genes that are involved in causing plant or human diseases, and determine the toxins that the microbes may be producing. This information allows us to make more informed decisions on the risk certain microbes may pose to crop production or human and animal health. We can also assess how quickly the microbial communities may be changing, which allows us to be proactive and address emerging microbial threats early, thereby protecting the industry and its clients.

Figure 3 Examples of different microbe samples prepared for cataloguing

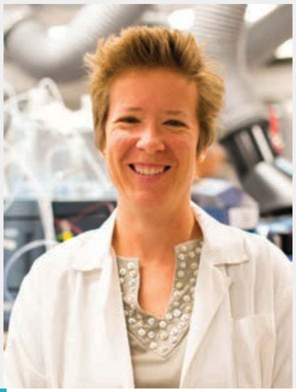
Figure 4 Wheat grain samples that will be processed for the presence of microbes

Other highlights

- We're developing new methods to profile microbes on Canadian grain based on their biochemical profile. We're building a database of these biochemical profiles using mass spectrometry. Each microbe has a unique profile that can be used to identify them and confirm the toxins they produce.

Research team

- Research scientist/program manager
  Dr. Sean Walkowiak
- Biologist
  Niradha Withana Gamage
- Technicians
  Janice Bamforth
  Tehreem Ashfaq



Trace Organics and Trace Elements Analysis

Dr. Sheryl Tittlemier

Bringing grain safety science from the lab to stakeholders

The overall mission of the Trace Organics and Trace Elements Analysis Program is to understand the factors affecting the presence of mycotoxins, pesticide residues, and trace elements in grain. We assess their occurrence, study how best to analyze grain for their presence, and investigate how processing affects them.

Monitoring the safety of Canadian grain

The Trace Organics and Trace Elements Analysis Program team conducts monitoring, surveillance and research on factors that affect the occurrence of pesticide residues, mycotoxins, and trace elements in grain. We also perform research to develop the best methods for analyzing grain for these substances. Our monitoring activities, such as the Cargo Monitoring Program, have been continuously run since the 1950s.

Figure 1 Our program uses this inductively-coupled mass spectrometer with robotic autosampler to analyze trace elements, including heavy metals such as lead and cadmium, in grain

Supporting producer access to safe, high-quality new durum varieties

We've been testing breeder samples to confirm that new varieties are low accumulators of cadmium since 1993. Plants, including durum, can absorb cadmium from soil. Testing new durum varieties for cadmium before they're registered helps ensure that Canadian durum continues to contain low levels of this heavy metal.

In 2019, we started using a new, inductively-coupled plasma-mass spectrometer to perform heavy metal analyses. The new instrumentation is more efficient and produces more precise results.

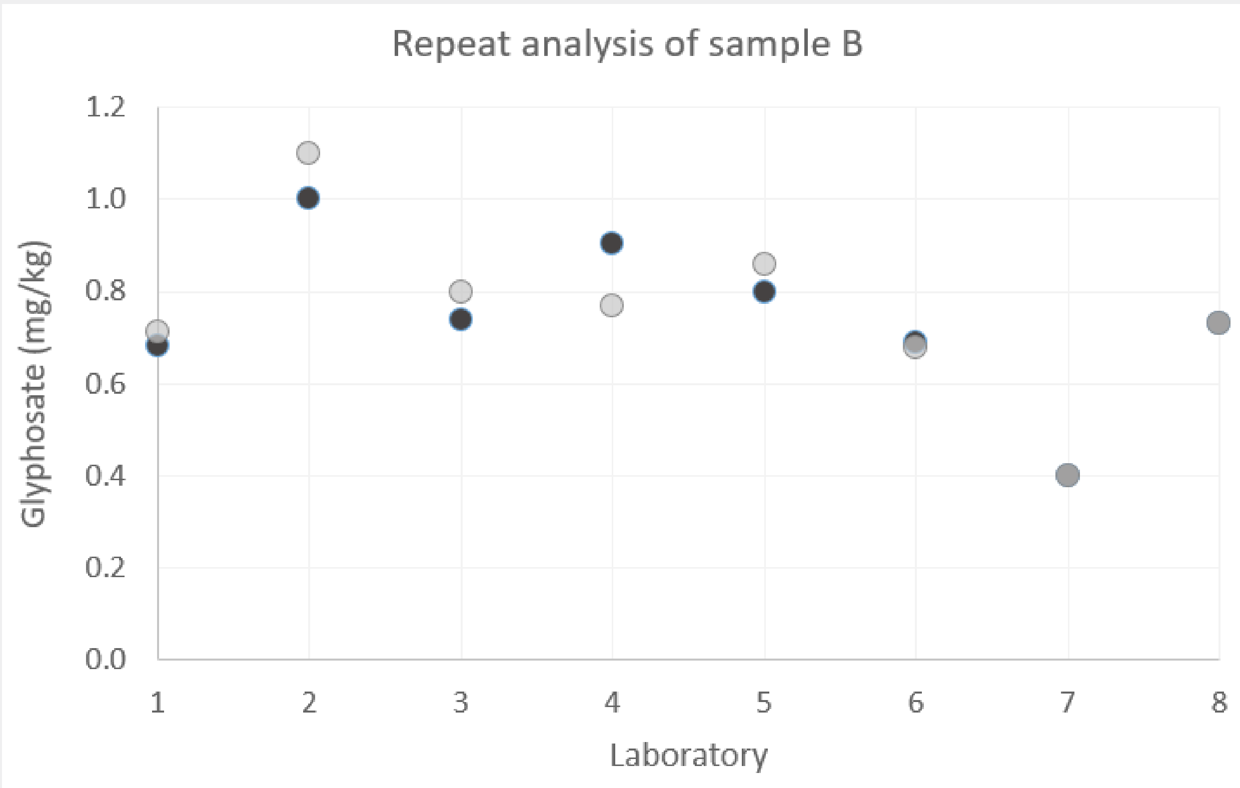


Figure 2 Repeat analysis of lentils by different laboratories

Helping the industry with increasing food safety scrutiny

We provided technical support and expertise for a ring test trial to characterize results obtained by different laboratories analyzing a set of lentil samples. The trial was a collaboration with Pulse Canada.

Our team prepared the test samples. Eight commercial laboratories in North America and in countries that import Canadian pulses analyzed them for glyphosate residues. Figure 2 shows how the results obtained by different laboratories differed. For example, Laboratory 7's results were the same for both analyses but were lower than the results obtained by the other laboratories. Laboratory 2's results varied slightly between analyses and were generally higher than the results obtained by the other laboratories. By comparing the results, we determined how much testing results could be expected to vary if shipments are tested at both import and export.

Providing concrete evidence that Canadian grain is safe

We issued over 4300 Statements of Assurance with results from our analysis of pesticides, mycotoxins, and heavy metals in grain exports during the 2018-19 crop year. Statements of Assurance are official Canadian Grain Commission documents that are used by many grain importers operating within a food safety quality management system. They need evidence that their processes effectively control food safety risks of their products, starting at where they source grain. Grain buyers use our Statements of Assurance as evidence that Canadian grain meets their specifications.

Figure 3 We use a liquid chromatograph high-resolution mass spectrometer to analyze pesticides in grain

Giving the industry a first-hand look at our food safety laboratories

Every year, we host multiple groups of Canadian and international processors, international buyers and government officials in our laboratory. These tours give us an opportunity to educate people from all areas of the value chain about how our work demonstrates the safety of Canadian grain.

Figure 4 Cereal grain samples being processed for the analysis of pesticides. The pesticides are in the top layer with water. The ground grain sample is the middle layer. A solvent that removes other grain components and prevents them from interfering with the analysis is the bottom layer

Figure 5 We use this liquid chromatograph tandem mass spectrometer to analyze mycotoxins in grain. This technology allows us to measure concentrations in the parts per billion range.

Other highlights

- We evaluated various equipment for preparing oats for mycotoxin analysis. We found that rotor beater-type grinders ground oats to smaller particle sizes, which reduces variance due to sub-sampling.
- We investigated the fate of mycotoxins during oat processing. Dehulling removed 60 to 100% of various *Fusarium- and Alternaria-* produced mycotoxins, as well as the fungal biomarker ergosterol, which can contaminate whole oats in the field. In groats, steaming appeared to increase ergosterol but decrease deoxynivalenol (DON) and deoxynivalenol-3-glucoside.
- We found that because DON can be distributed unevenly in wheat, sampling accounted for two-thirds of the total variation when measuring DON in bulk wheat lots close to the international regulatory limit with our procedure. Preparing a larger sample size for analysis can minimize this variation.
- We demonstrated that milling removes approximately 84% of ergot alkaloids present in whole grain durum. No additional losses were observed in the production and cooking of spaghetti. However, boiling changed the form of the ergot alkaloids present so cooked spaghetti contained a higher proportion of the less-hazardous forms of the ergot alkaloids than semolina and raw spaghetti.

Research team

- Research scientist/program manager
  - Dr. Sheryl Tittlemier
- Chemists
  - Jules Carlson
  - Kerri Pleskach
  - Anja Richter
- Technicians
  - Lianna Bestvater
  - Richard Blagden
  - Daniel Bockru
  - Jason Chan
  - Dainna Drul
  - Andy Peng
  - Valentina Timofeiev
  - Robert Trelka
  - Tanya Zirdum

Variety Identification Research and Monitoring

Dr. Daniel Perry

Ushering in changes to Canada's wheat classes

The Variety Identification Research and Monitoring Program plays a key role in ushering in major changes to Canada's wheat classes. Our monitoring has demonstrated that efforts by the grain industry, from producers to handlers, have succeeded in moving specific varieties out of the Canada Western Red Spring wheat class. These efforts have addressed class quality concerns, ensuring that buyers of Canadian wheat will continue to receive the quality they rely on.

Figure 1 Samples of four different varieties from the Canada Western Red Spring wheat class. Clockwise from top left: Glenn, AAC Elie, AAC Brandon, and AAC Redberry

Variety control in Canada's wheat quality

Control of varieties is an important part of Canada's wheat quality assurance system. The varieties designated to each milling class of wheat share specific properties so that each class will perform consistently and meet customer needs. We monitor wheat export shipments for wheats of other classes (including non-registered varieties), which could undermine quality and create problems for customers.

In 2015, the Canadian Grain Commission announced that it was addressing customer concerns about inconsistent gluten strength in the Canada Western Red Spring (CWRS) and Canada Prairie Spring Red (CPSR) wheat classes. To protect the reputation and performance of these classes, the Canadian Grain Commission tightened their quality parameters. Twenty-nine varieties that didn't meet the new parameters would be moved out of these classes and designated to a new class, Canada Northern Hard Red (CNHR), in 2018.

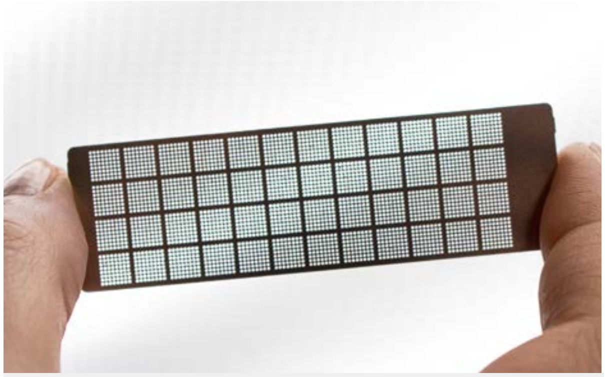


Figure 2 An OpenArray plate used for variety identification analysis. DNA extracted from wheat kernels is transferred onto the plate

Monitoring the progress

In preparation for these changes, we shifted to exclusively using our OpenArray DNA method to monitor varieties in wheat exports. This method, developed at the Grain Research Laboratory, gave us the precision and high throughput we needed to monitor the transitioning varieties. With it, we were able to keep a close eye on the affected varieties to see if the transition went according to plan.

Under the plan, producers could continue to deliver the transitioning varieties as CPSR or CWRS until July 31, 2018. Grain handlers then had until December 31, 2018 to clear those varieties from their stocks. From August 1 to December 31, 2019, the Canadian Grain Commission would help grain handlers manage the change by notifying them if we found the affected varieties in excess of grade tolerances. After December 31, 2019, the affected varieties would formally count as wheats of other classes if found in shipments other than CNHR.

A successful transition

Before the changes took effect, many producers switched to growing other varieties. At the time of the 2015 announcement, Harvest, Lillian and Unity were the most popular of the 25 affected CWRS varieties. However, their popularity, and the popularity of the other transitioning varieties, had already peaked and begun to decline. This is part of the normal cycle of variety turnover. After the 2015 announcement, the pace of that decline sped up (Figure 3). In 2015, about 20% of total CWRS acres in the prairies were planted with affected varieties. By 2018, less than 1% were.

Our monitoring program found that transitioning varieties made up about 22% of exported CWRS in the 2015-16 crop year and fell each year after that (Figure 4). In the 2018-19 crop year, these varieties all but disappeared from CWRS exports. They made up just over 7% of shipments in August, dropped to less than 2% by November, and have generally remained at about 1% since. We expect this number to shrink further as the current year's crop moves through the grain handling system.

Looking ahead

On August 1, 2021, five more varieties will transition out of the CWRS class. When this was announced in 2018 these varieties made up less than 7.5% of the CWRS acres planted in the prairies, so the magnitude of this final change will be smaller than that of the round just completed. Nonetheless, we will be busy monitoring its progress as it unfolds.

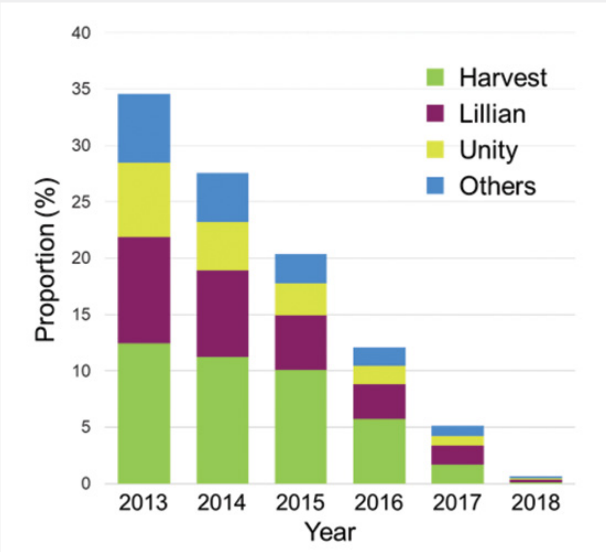


Figure 3 Acres planted with varieties transitioning from CWRS to CNHR, as a proportion of total insured acreage planted with CWRS in Manitoba, Saskatchewan, and Alberta.

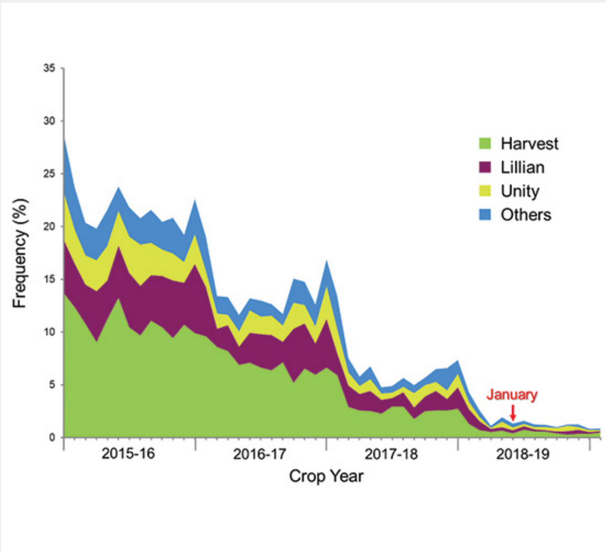


Figure 4 The percentage of transitioning varieties we detected in CWRS export shipments after the 2015 announcement. The red arrow marks January 1, 2019, the end of the transition period.

Other highlights

- During the 2018-19 crop year, we performed DNA-based variety identification analysis on over 132,000 individual kernels of wheat.
- We continuously update our reference databases of wheat and barley DNA profiles. Last crop year we added 42 varieties.

Research team

- Research scientist/program manager
  Dr. Daniel Perry
- Biologist
  Sung-Jong Lee
- Technicians
  Mathieu Dusabenyagasani
  Danny Saydak
  James Singer