The Three-Sisters Project: products' characteristics and potentials

Martin Mondor, Marie Thérèse Charles & Sébastien Villeneuve

Laval University – Tuesday, May 10, 2016
Overview

- AAFC’s research centres
- The Three Sisters
  - Commercially available ancestral seeds
  - Bioactive compound content
  - Valorization of maize, beans and squash
- Future work
- Conclusion
A National Team

Access 19 AAFC’s research centres
Saint-Hyacinthe Research and Development Centre in Brief

- Established in 1987
- 80 indeterminate employees
- 19 research teams
Saint-Hyacinthe RDC Strategic Direction

Development of knowledge and technologies for improving production systems and processing practices

- Studying the composition and functionality of raw materials and ingredients of food matrices
- Increasing the nutritive value of processed foods and facilitating the development of functional foods
- Finding new opportunities and increase the competitiveness through innovation
- Control pathogenic organisms in food systems
Four Ways of Supporting Industry

- Information
- Infrastructure
- Expertise
- Business incubators

Since 1987…

- Over 1,950 research projects
- More than 1,000 client businesses
- More than 75,000 hours of pilot plant use
The most complete collection in regards with food processing in Canada. Access given to industry and public.

Seminars and scientific & technologic workshops on specific issues (by INITIA).

Since 2001, 157 events that attracted more than 11,800 clients took place at Saint-Hyacinthe RDC.
Infrastructure

- The SHRDC Industrial Program allows R&D projects to be conducted in a confidential setting with a fee for services
- 3,500 m² for food processing pilot plants
- Full range of processing equipment
  - Experienced technologists
- Four industrial incubators for start-ups or market trials.
Expertise Available at Saint-Hyacinthe Research and Development Centre
Food Engineering Research

- Develop or adapt new manufacturing processes (ohmic heating, aseptic packaging, ultrafiltration, membrane technologies, and more…).
- Better control energy costs.
- Control formulation for enhanced quality or safety.
- Find value for underused by-products.
Food for Health Research

- Protect the activity of probiotic bacteria in processed foods by encapsulation.

- Resolve the technical challenges caused by incorporation of bioactives into processed food formulations.

- Document the physiological activity of bioactive ingredients in sophisticated in vitro models.

- Elucidate the influence of manufacturing processes and formulations on the release of bioactive ingredients in the human gut.

- Use all the above information to design efficient functional foods.
Food Safety Research

- Detection of biological (pathogenic bacteria and viruses) and chemical (allergens, biogenic amines and nanoparticles) threats in food.

- Study of the effects of process and formulation on the inactivation of the pathogens during food processing.

- Development of mitigation strategies.

- Evaluation/adaptation of novel processes for safety.

- Building the scientific evidence in support of process regulatory approval.

- Investigating disinfection of food processing environments.
An Integrated, Common-Sense Approach to Agri-Food

- Extraction
- Formulation
- Processing – Unit operations
- Packaging and shelf stability
- Domestic processing
- Oral processing
- Release (digestion)
- Absorption

- Extraction → Encapsulation → Oral processing → Release (digestion) → Absorption
- Formulation → Encapsulation → Oral processing → Release (digestion) → Absorption
- Processing → Encapsulation → Oral processing → Release (digestion) → Absorption
- Packaging and shelf stability → Encapsulation → Oral processing → Release (digestion) → Absorption
- Domestic processing → Encapsulation → Oral processing → Release (digestion) → Absorption
Saint-Jean-sur-Richelieu Research and Development Centre in Brief

- Established in 1912
- 93 employees
- 12 research teams
- Over 63 students and trainees
Infrastructure

- **At St-Jean-sur-Richelieu**
  - 62 offices, 3 meeting rooms, one library
  - 26 well-equipped laboratories including a service lab
  - an in-vitro culture lab
  - A complex of 17 greenhouses, 25 growth chambers
  - 7 freezers (-80°C), 10 incubators
  - 8 insect breeding rooms, One in vitro culture

- **Two experimental farms (112 ha)**
  - At l’Acadie (mineral soil)
  - At Sainte Clotilde (muck soil)
Saint-Jean-sur-Richelieu RDC
Strategic Direction

12 scientists working on the departmental priority: « Generate new knowledge, foster innovation and increase adoption and commercialization of agricultural, agri-food and agri-based products, processes or practices »

4 STB Strategic Objectives:
1. Increasing agricultural productivity;
2. Improving environmental sustainability;
3. Improving attributes for food and non-food uses;
4. Addressing threats to the agriculture and agri-food value chain.
Areas of research at St-Jean

- Plant protection
  - Entomology, Nematology, Phytopathology (fungi, bacteria and virus), Malherbology
- Bioclimatology and modeling
- Precision horticulture
- Crop nutrition and management
- Postharvest physiology
Two novel scientific platforms

**Biovigilance**
- Approach aiming at maintaining crop health
- Study the evolution of pests and risk factors
  - Detection of significant spatio-temporal trends linked to agricultural practices, new plant protection products, changes in farming practices, cultivars, climate changes, or new pests.

**Precision Horticulture**
- Management strategy for optimal crop production
- Use of information technologies
  - Georeferenced data
  - Tools and Infrastructures
    - drones, multispectral imagery, aerial dispersion modeling

- 3 new scientists are been hired in support of these 2 platforms
Bioactive contents of the three sisters
Why do plants need antioxidants

- Respiration
- Photosynthesis
- Senescence
- Biotic stress
  - Micro-organisms (pathogenic vs non-pathogenic)
  - Insects
  - Herbivores
- Abiotic stress
  - Environmental factors (Heat, T°C, UV, Ozone, drought, wind)
  - Chemical agents

- Generation of reactive oxygen species and free radicals from a reduced to oxidized state
- Fight back on site/no escape
# Antioxidants of horticultural crops

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<th>Vitamins</th>
<th>Carotenoids</th>
<th>Phenolics</th>
<th>Others</th>
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<td>Ascorbic Acid</td>
<td>Carotenes Xanthophylls</td>
<td>Phenolic acids</td>
<td>Sulfur Nitrogen</td>
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<td>Tocopherols</td>
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<td>• Cinnamic acids</td>
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Vicente et al., 2009
Factors affecting antioxidant levels

Genetic
- Species
- Variety

Environmental
- Preharvest
  - Radiation
  - Cultural practices
    - Biotic
    - Abiotic
- Harvest
  - Maturity
  - Handling
- Postharvest
  - Storage
  - Postharvest treatments
  - Processing

Vicente et al., 2009
Damages by ROS and Human health

- Lipids
- Proteins
- Carbohydrates
- DNA, RNA
- Membranes

- Brain –cognitive function
- Eye
- Heart and cardiovascular system
- Kidney
- Gastro-intestinal tract
- Cancer
- Inflammatory-immune injury
- Lung
- Red blood cell
- Etc…
Assessment methods

- **Total antioxidant capacity**
  - *Hydrogen atom transfer*
  - ORAC=Oxygen radical absorbance capacity
  - TRAP=Total radical trapping antioxidant parameter
    - *Electron transfer*
  - TEAC=Trolox equivalent antioxidant capacity
  - FRAP=Ferric ion reducing antioxidant parameter
  - DPPH=Diphenyl-picrylhydrazyl copper reduction capacity
  - TP=Folin-Ciocalteu, total phenol

- **LC (HPLC-DAD, MS)**
- **GC (GC-FID, MS)**
- **PAGE (enzymes)**
- **Microscopy**
  - Cytochemistry
  - Histochemistry
- **Non destructive method-spectral analysis**
  - Fluorescence
  - Reflectance
Commercially available ancestral maize

- Algonquin White
- Red Mohawk
- Gaspé Flint
Commerially available ancestral beans

Hopi black; Early Mohawk; Amish Nuttle and GaGa Hut Pinto
Commercially available ancestral squash

Algonquin

Canada Crookneck
LC- Carotenoids profile of squash

Crookneck

Algonquin
Carotenoids contents of squash heirloom varieties

Algonquin

Crookneck
Antioxidant capacity of heirloom squash varieties

Ferric ion reducing antioxidant parameter

µmol/g FW

Algonquin
Crookneck

Folin-Ciocalteu

µg/g FW

Algonquin
Crookneck
LC-Phenolic profile of bean heirloom varieties

Amish nuttle

Early Mohawk

Gaga H pinto

Hopi black
Phenolic content of bean heirloom varieties

- Anthocyanins
- Flavonols

<table>
<thead>
<tr>
<th>Variety</th>
<th>Content mg/g FW</th>
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<td>Hopi black</td>
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<tr>
<td>Amish Nudle</td>
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<tr>
<td>Early Mohawk</td>
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<tr>
<td>Gaea H Plano</td>
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</table>
Antioxidant capacity of bean heirloom varieties

Ferric ion reducing antioxidant parameter

0 5 10 15 20
µmol/g FW

Hopi Black Early Mohawk Amish Nuttle GaGa Hut Pinto

Oxygen radical absorbance capacity

0 5 10 15 20
mmol TE/100g

Hopi Black Early Mohawk Amish Nuttle GaGa Hut Pinto

Folin Ciocalteu

0 500 1000 1500
µg/g FW

Hopi Black Early Mohawk Amish Nuttle GaGa Hut Pinto
Valorization of maize, beans and squash
Objectives - valorization

- Production of ingredients from ancestral varieties of maize, beans and squash.

- Evaluation of the functionality and attributes of derived ingredients, and comparison with commercial alternatives.

- Make recommendations to the First Nations on the commercial potential of their ancestral varieties in terms of new ingredients and new food products.
Bread-making potential of maize, beans and squash flours

- Commercial wheat flour is substituted at a level of 10%
- Bread characterization: specific volume
Bread-making potential of maize, beans and squash flours

- **KEYNOTE 80**
- **GARA HUT PINTO**
- **AMISH NUTTLE**
- **HOPI BLACK**
- **EARLY MOHAWK**
- **GASPÉ FLINT**
Bread-making potential of maize, beans and squash flours

ALGONQUIN WITH PEEL

ALGONQUIN WITHOUT PEEL

CROOKNECK WITH PEEL

CROOKNECK WITHOUT PEEL
Bread-making potential of maize and beans flours
Bread-making potential of squash flours

Keynote 80
Algonquin with peel
Crookneck with peel
Algonquin w/o peel
Crookneck w/o peel
Maize and beans valorization: other approaches
Maize and beans valorization: other approaches

Nixtamalization

Bannick bread
Squash valorization: other approaches
Flesh
Flesh

- **Liquid extract (juice)**
  Can be used as is or processed in vinegar

- **Solids (pomace)**
  Can be processed into flours
  Hypoglycemic.

- **Peel**
  Rich in pectins and carotenoids.
Seeds
Seeds

- **Oil**
  
  Can be extracted.
  
  Rich in phytosterols, good fatty acids profile.

- **Meal**
  
  Proteins can be isolated.
  
  Functional ingredient in processed food.

- **Fiber**
  
  Potential has to be explored.
Leaves
Leaves

- **Edible**

  Can be consumed similarly as spinach. Beyond vitamins A and C, they are rich in calcium, vitamin B2, iron and proteins.
Stem
Stem

- **Water extraction**

  Contains anti-inflammation substances.
Example of squash products on the market
Seeds

Proteins isolated

Whole seeds

Oil
Not only of interest for the food industry
Future work – year 2

- Assess the processing attributes of commercial ancestral lineages of maize, beans and squash beyond their bread-making potential.

- Study the characteristics of non-commercial ancestral lineages, and of derived ingredients.
Conclusions

- The ancestral lineages under study demonstrate interesting antioxidant capacity. Highest bioactive content was found in Hopi Black and Early Mohawk for beans and in Crookneck for squash.

- Some commercial ancestral lineages of maize, beans and squash have demonstrated potential to be processed into ingredients that could be used in food products formulation.
Contacts:
Sébastien Villeneuve, Sebastian.Villeneuve@agr.gc.ca
Martin Mondor, Martin.Mondor@agr.gc.ca
Marie-Thérèse Charles, MarieTherese.Charles@agr.gc.ca
Michel Gros-Louis, Michel.Gros-Louis@agr.gc.ca