**Soybean for Food and Feed**

Dr. Malcolm Morrison,
Eastern Cereal and Oilseed Research Centre
Agriculture and Agri-Food Canada

### Comparative Statistics

<table>
<thead>
<tr>
<th>Item</th>
<th>Canada</th>
<th>Australia</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land</td>
<td>9.98</td>
<td>7.68</td>
<td>km²</td>
</tr>
<tr>
<td>Arable land</td>
<td>498,000</td>
<td>461,000</td>
<td>km²</td>
</tr>
<tr>
<td>Population</td>
<td>32</td>
<td>19</td>
<td>million</td>
</tr>
<tr>
<td>Sheep</td>
<td>&lt;2</td>
<td>119</td>
<td>million</td>
</tr>
<tr>
<td>Cattle</td>
<td>13.0</td>
<td>27.7</td>
<td>million</td>
</tr>
<tr>
<td>Hog</td>
<td>13.3</td>
<td>2.8</td>
<td>million</td>
</tr>
<tr>
<td>Poultry</td>
<td>1,092</td>
<td>662</td>
<td>kt</td>
</tr>
<tr>
<td>Soybean</td>
<td>1,059</td>
<td>33</td>
<td>000 ha</td>
</tr>
<tr>
<td></td>
<td>2.5</td>
<td>2.1</td>
<td>t/ha</td>
</tr>
<tr>
<td></td>
<td>2,699</td>
<td>70.4</td>
<td>000 t</td>
</tr>
</tbody>
</table>

### Soybean Production In Canada

<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Production (000's ha)</td>
<td>0</td>
<td>200</td>
<td>400</td>
<td>600</td>
<td>800</td>
<td>1000</td>
<td>1200</td>
</tr>
</tbody>
</table>

**Northern**

2000 Production
Southern: 767,210 ha, 1,993,969 t
Northern: 291,650 ha, 706,000 t
Total: 1,058,860 ha, 2,699,000 t
Northern production increased to 31% in 2002

**Soybean Yield Improvement in Canada**

0.5% per year

**Effective Growing Degree Days in Eastern Canada**

**Agricultural Research Stations**

- BC
- AB
- SK
- MB
- ON
- QC
- NB
- NS
- PEI
- ATL
- NL
- NT
- NU

**Effective Growing Degree Days in Eastern Canada**

Legend:
- < 1000
- 1000-1500
- 1500-2000
- > 2000

**Year of Variety Release**

**Yield (kg/ha)**
AAFC Research Centre, Harrow, Ont
Southern Adaptation

Soybean Breeding: Vaino Poysa
Pathology: Terry Anderson
Soybean Cyst Nematode: Tom Welacky
Seed Quality: Lorna Woodrow

Breeding high yielding, white hilum, large seeded Tofu varieties.

Performance of Recent Tofu Lines

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Yield (t/ha)</th>
<th>Maturity (days)</th>
<th>Seed Weight (g 100^-1)</th>
<th>Protein %</th>
<th>Oil %</th>
<th>Sugar %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harovinton</td>
<td>3.67</td>
<td>114</td>
<td>27.6</td>
<td>47.6</td>
<td>18.5</td>
<td>10.3</td>
</tr>
<tr>
<td>AC Hime</td>
<td>3.87</td>
<td>114</td>
<td>26.7</td>
<td>46.1</td>
<td>18.4</td>
<td>10.7</td>
</tr>
<tr>
<td>AC X790P</td>
<td>3.77</td>
<td>115</td>
<td>27.6</td>
<td>48.6</td>
<td>18.4</td>
<td>10.2</td>
</tr>
<tr>
<td>AC Vin-Pro</td>
<td>3.84</td>
<td>113</td>
<td>26.4</td>
<td>46.4</td>
<td>19.5</td>
<td>10.7</td>
</tr>
</tbody>
</table>

Soymilk and Tofu Yield of Recent Lines.

<table>
<thead>
<tr>
<th></th>
<th>Harovinton</th>
<th>AC Hime</th>
<th>AC X790P</th>
<th>AC Vin-Pro</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soymlkie</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yield (L/kg beans)</td>
<td>7.5</td>
<td>7.3</td>
<td>7.8</td>
<td>7.3</td>
</tr>
<tr>
<td>Solid content (%)</td>
<td>9.9</td>
<td>10.1</td>
<td>9.6</td>
<td>10.3</td>
</tr>
<tr>
<td>Tofu (CaSO4)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yield (kg kg^-1)</td>
<td>6.3</td>
<td>6.0</td>
<td>6.5</td>
<td>6.1</td>
</tr>
<tr>
<td>Hardness (N)</td>
<td>1.6</td>
<td>1.3</td>
<td>1.7</td>
<td>1.4</td>
</tr>
<tr>
<td>Firmness (Newton:mm)</td>
<td>0.3</td>
<td>0.2</td>
<td>0.3</td>
<td>0.3</td>
</tr>
</tbody>
</table>

AAFC Research Centre, Ottawa, Northern Adaptation

Dr. E. Cober
CoberER@agr.gc.ca

Short Season Adaptation
- Disease and Stress Resistance
- Increasing the Zone of Adaptation

Breeding for Feed and Food:
- High Protein for food and feed: Natto,
- Short Season Tofu

Oilseed/Feed Soybean Breeding:

Short-season cultivars: (~2700 CHU)
- Develop cultivars with high yield, appropriate maturity, lodging resistance, and acceptable oil and protein.
- Develop cultivars with high seed protein content for on-farm feeding.
- Develop cultivars with white mold and phytophthora root rot tolerance and SCN resistance.
- Expand the range of cultivation and provide producers with an alternative livestock feed and cash crop.

Food-Grade Soybean Breeding

Natto Breeding:
- Early lines came from small seeded crosses with high protein wild types.
- Nattawa, 1981, first Canadian variety.
- Lines selected to eliminate stone seed; for seed size and shape; water uptake, natto texture.
- Provide additional markets for soybean producers.
Food-Grade Soybean Breeding

Short-Season Tofu Breeding:
- Crosses with Japanese Tofu types and high protein short-season parents, 1995
- Backcrossing to improve adaptation and agronomy
- Selection for Tofu quality, and texture.
- Provide additional markets for soybean producers

Image Analysis is used to Select for Seed Size Uniformity in Natto Breeding.

Water Uptake Rate 1999-2000

MRI Images of Water Uptake

Water Uptake Rate 1999-2000

Specialty Soybean Trial

Mean from 13 locations, 1999 and 2000.
Recent Varieties

Electron  Faucon  Heron

Future Soybean Breeding for Food Quality Traits, North and South

- High protein, yellow hilum.
- High sugar content.
- Low linolenic Acid content improved soymilk flavor and stability
- Lipoxigenase triple null lines for better soymilk taste
- A4 null lines Nigari tofu
- Edamame types

Soybean Quality

- Quantify seed quality characteristics for soyfood products (take the art out of soyfood making)
- Develop fast, reliable, and inexpensive screening tools for quality characteristics, ensuring variety suitability for end-users.

Dr. J. Frégeau-Reid
FregjeauJA@agr.gc.ca

Quality Traits & Tools: Seeds

- Size
- Color
- Protein content
- Soluble sugar content
- Protein quality (specialty soybean)
- Water uptake
- Rate of water uptake
- Water Holding capacity
- Image Analysis
- Colorimeter (Hunter Lab)
- NIR whole grain
- Megazyme protocol
- Electrophoresis (A4 null) & lipoxigenase
- Total uptake
- Uptake at T0.5
- Carver press

Taking the art out of Natto making

Natto soybean quality testing in Japan involves slicing 20 steamed and fermented natto soybean on a balance with a knife and recording the combined weight.

The results are dependent on the technicians skill and experience.

We have very little experience making or eating natto in Canada.

Natto Quality Characteristics

Potential natto lines tested for texture in the Instron Analyser following 30 minutes of steaming in an autoclave (120 psi).

<table>
<thead>
<tr>
<th>94-95</th>
<th>2000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Misnatto</td>
<td>161</td>
</tr>
<tr>
<td>Hozan</td>
<td>147</td>
</tr>
<tr>
<td>Haru</td>
<td>125</td>
</tr>
<tr>
<td>Micron</td>
<td>118</td>
</tr>
<tr>
<td>Suzumaru</td>
<td>117</td>
</tr>
<tr>
<td>Hokkaido</td>
<td>111</td>
</tr>
<tr>
<td>AC Colibri</td>
<td>107</td>
</tr>
<tr>
<td>AC Pinson</td>
<td>117</td>
</tr>
<tr>
<td>Faucon</td>
<td>121</td>
</tr>
<tr>
<td>Electron</td>
<td>114</td>
</tr>
<tr>
<td>Heron</td>
<td>127</td>
</tr>
</tbody>
</table>

The test is mechanized, standardized and repeatable.
Protocol for Soymilk and Tofu

- Use of constant protein: water ratio of 18:1 to emphasize protein quality, not quantity.
- Tofu is silken.
- GDL, and CaSO₄
- NIR Analyzer to evaluate soymilk composition.
- Colourimeter for soymilk and tofu colour.
- Instron Texture Measuring System for tofu firmness.
- Tofu is silken.
- GDL, and CaSO₄
- NIR Analyzer to evaluate soymilk composition.

Mullen, W.J and J.E. Frégeau-Reid et al. 2001
Food Research International 34:669-677

Test Tube Tofu for Early Generation Selection

- Protein content on whole seeds, NIR
- 10 to 20g of seeds soaked for 22hrs at 13°C
- Soymilk = 18:1 water to dry matter protein (soymilk protein conc. 4% to 5%).
- Tofu Yield measured on DW basis after centrifugation.
- 20 lines/day/tech; duplicate readings and 2 coagulants (GDL and CaSO₄).

Microscopy

Dr. S Miller

OX951 – Normal seed
- protein bodies well developed and absorb stain.

OX951 – Stone seed
- protein bodies in some cells fragmented and miss-shapened
- variable staining of protein bodies

Microscopy

Dr. J. Mullin

Experimental miso
- granular texture
- less complex flavour

Commercial miso
- smoother texture
- more complex flavour

Commercial miso
- aged longer
- more free and oxidised lipids (flavour development)

Microscopy and Carbohydrate Analysis

Dr. F. W. Collins

Ontario
Japanese
Seed Coat

- Survey of several Ontario and Japanese varieties showed differences in cell wall thickness.
- Japanese varieties have lower levels of xylan hemicellulose in the palisade layer of the seed coat, resulting in better water uptake.

VALUE-ADDED TECHNOLOGIES

Separation Technology:
- Develop new methods to extract natural compounds from soybean.

Use of “Designer Gels”, organic solvents and patented extraction techniques for the purification of isoflavones and soyasaponins.
Isoflavones: Properties
- USA FDA claim: Diets low in fat that include 25 g of soy protein per day may reduce the risk of heart disease.
- 1 cup of soymilk = 8 grams of soy protein = 100 to 200 mg of total isoflavones — antioxidants, free radical scavengers, LDL oxidants, anti-carcinogenic, plant estrogens, daidzein and genistein.
- Compounds responsible for flower and seed coat color, mitosis, nodulation.

<table>
<thead>
<tr>
<th>US/g</th>
<th>Daidzein</th>
<th>71</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Genistein</td>
<td>75</td>
</tr>
<tr>
<td></td>
<td>Soyasaponin Bb</td>
<td>???</td>
</tr>
</tbody>
</table>

VALUE-ADDED TECHNOLOGIES
New uses for soy isolates.
- probiotic sugars, raffinose, stachiose
- antioxidants: food ingredients
- phytoestrogen therapy
- surfactants: personal care

<table>
<thead>
<tr>
<th>Soybean</th>
<th>Peroxidase</th>
<th>Fiber</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multi</td>
<td>Crude Oil</td>
<td>Refined Oil</td>
</tr>
<tr>
<td>Flakes</td>
<td>Oil Extraction</td>
<td>Lecithin</td>
</tr>
<tr>
<td>Roasting, Extrusion</td>
<td>Defatted Flakes</td>
<td>Grinding</td>
</tr>
<tr>
<td>Meat</td>
<td>Carbohydrate Extraction</td>
<td>Soy Protein Isolate</td>
</tr>
<tr>
<td>Soy Molasses</td>
<td>Soya Concentrate</td>
<td>Soy Flour</td>
</tr>
</tbody>
</table>

Physiology, Ottawa
Plant characteristics that promote stress tolerance and ensure high yield, seed quality and marketability.

Grey - Tawny Yield (kg/ha) Differential
8 sets of F2-derived isolines with either tawny (T) or grey (t) pubescence.
Grey lines yield more then tawny lines in warm years (>2664). But in cold years Tawny yields more then grey. WHY?
Conclusion: Grow Tawny lines with white hilum and seed coat.

Canopy Temperature Differences Between Grey and Tawny Colored Pubescence
Infrared sensors
Three replications
Tawny and grey isolines
Two years data.
### Results from 2001 Field Season IR Thermometer

*Average daily IRT differential 2001 = 0.43°C.*

*Two year ave = 0.37 °C*

*In warm years, tawny matures 6 to 10 days sooner than grey.*

*Grow tawny varieties BUT...*

### Seed Coat Discoloration

*Temperature <15°C during seed development (R4 to R6) increase the expression of pigment in the seed coat in tawny lines.*

### Pubescence Color and Seed Coat Discoloration

**Summary:**

- Tawny colored lines perform better in cool regions (<2800 CHU) because of warmer canopies (0.37°C)

- But, Tawny colored lines with yellow seed coat and hilum discolor with cool temperatures (<15°C) during seed development.

**Solution:** ??? (i) Convince the buyers that discoloration does not matter. (ii) Grow grey lines and accept the yield loss. (iii) Find a new way to shut off seed pigment production.

### High Protein Soybean

**Objective:** determine the physiological differences among closely related lines differing in seed protein content.

**Goal:** produce lines with high yield and protein.

- Maple Arrow = normal protein (40%).
- Hercule = medium high protein (45%).
- AC Proteus = high protein (48%).

Lines grown for 4 years; 4 replications per year; standard growth analysis techniques, LAI, photosynthesis and SPAD, seed combine harvested and NIR used for protein and oil analysis.
High Protein Soybean

No significant differences among cultivars for max LAI or photosynthetic rates (ave of 3 readings: V3, R1 and R4 and two years).

ProteusHerculeArrow

Max LAI

Photosynthetic rate (umole m⁻² s⁻¹)

Arrow Hercule Proteus

High Protein Soybean: Summary

- High seed protein is associated with lower total seed yield. Physical reasons hard to find.
- In the high protein lines the demand for protein causes a rapid canopy senescence -- resulting in less photosynthate being produced towards the end of seed filling and lower yield.
- Protein occupies less storage space than oil, high protein seeds are smaller, with lower yield.

Soybean for Food and Feed: Summary

- Southern region concentrates on food-type soybeans for soymilk and tofu.
- Northern region breeds for Food, (natto and tofu), Feed (high protein) and oilseed types.
- Breeding is supported by Quality, Physiology, Pathology Genetics and Value Added Research Programs.
- Goal: to develop varieties and practices that result in a soybean product of consistent end-use quality for domestic use and export.

Isoflavones: Health claims

- USA FDA claim: Diets low in fat that include 25 g of soyprotein per day may reduce the risk of heart disease.
- 1 cup of soymilk = 8 grams of soyprotein ~ 100 to 200 mg of total isoflavones.
- In the US only 20% of post-menopausal women prescribed estrogen replacement therapy actively use it.
- There are two estrogen receptors in the body. ER alpha and ER beta. Genistein and Daidzein conform 80% to ER beta, 20% to ER alpha. Effectiveness of soyprotein depends on the estrogen receptor.
Isoflavones:
Summary of 30 years of study on the consumption of soyprotein isolate in primates
Dr. T.B. Clarkson, Wake Forest U.

**Brain Function:** improves cognition, memory.

**Hot Flashes:** only moderate decrease

**Cardiovascular:** indirect effect due to reduction in fat. Increase in Apo A1 and lipoprotein profile. Reduction in LDL cholesterol. Reduce risk of stroke.

**Cancer:** may decrease estrogen induced cell proliferation and reduce breast and endometrial cancer

**Osteoporosis:** No direct effect on humans