

Agriculture and Agri-Food Canada / Agriculture et Agroalimentaire Canada

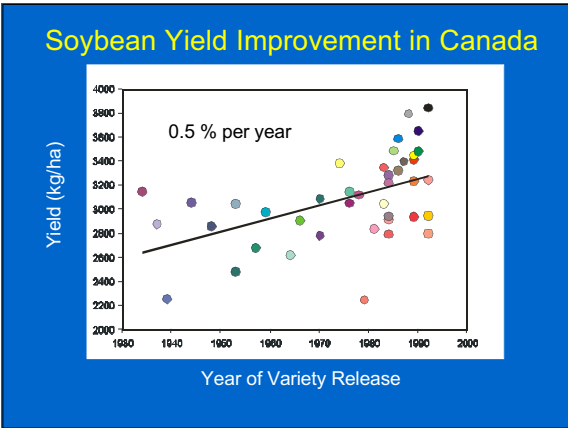
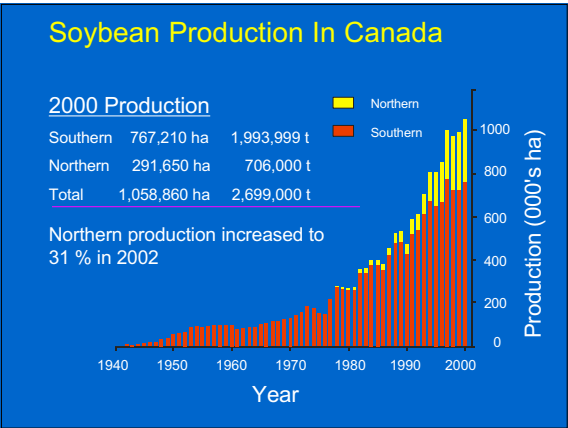
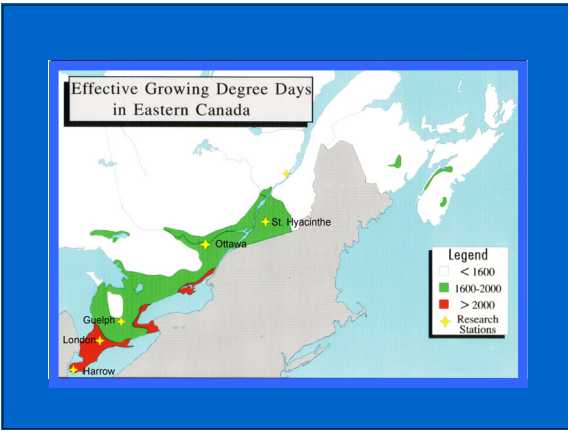
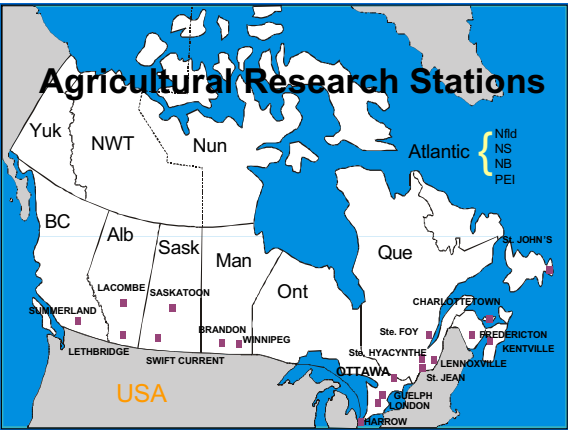
## Soybean for Food and Feed

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

Canada

### Comparative Statistics

Item	Canada	Australia	Units
Land	9.98	7.68	km <sup>2</sup>
Arable land	498,000	461,000	km <sup>2</sup>
Population	32	19	million
Sheep	<2	119	million
Cattle	13.0	27.7	million
Hog	13.3	2.8	million
Poultry	1,092	662	kt
Soybean	1,059	33	000 ha
	2.5	2.1	t/ha
	2,699	70.4	000 t



## AAFC Research Centre, Harrow, Ont Southern Adaptation

Soybean Breeding  
Pathology  
Soybean Cyst Nematode  
Seed Quality

Vaino Poysa  
Terry Anderson  
Tom Welacky  
Lorna Woodrow



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

## Performance of Recent Tofu Lines

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

## Soymilk and Tofu Yield of Recent Lines.

	Harovinton	AC Hime	AC X790P	AC Vin-Pro
<b>Soymilk</b>				
Yield (L/kg beans)	7.5	7.3	7.8	7.3
Solid content (%)	9.9	10.1	9.6	10.3
<b>Tofu (CaSO<sub>4</sub>)</b>				
Yield (kg kg <sup>-1</sup> )	6.3	6.0	6.5	6.1
Hardness (N)	1.6	1.3	1.7	1.4
Firmness (Newtons/mm)	0.3	0.2	0.3	0.3

## AAFC Research Centre, Ottawa, Northern Adaptation

- 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



Dr. E. Cober  
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## 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



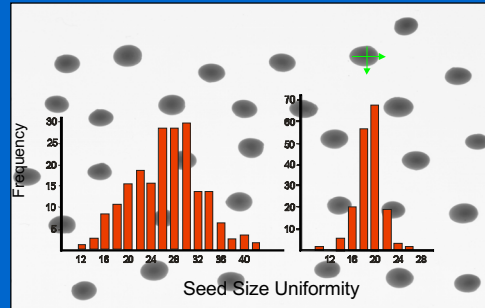
## Food-Grade Soybean Breeding

### Short-Season Tofu Breeding:

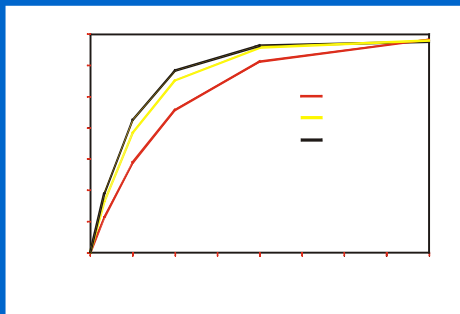
- Crosses with Japanese Tofu types and high protein short-season parents, 1995
- Backcrossing to improve adaptation and agronomy
- Selection for Tofu quality, and texture.
- Provide additional markets for soybean producers



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



## Water Uptake Rate 1999-2000

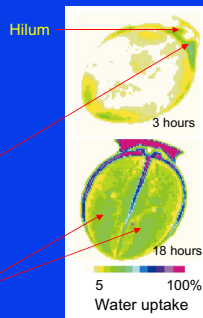


## Water Uptake Rate 1999-2000

Variety	Time to 50% uptake (Min)	%Hard Seed (24 hrs)
<i>Natto</i>		
AC COLIBRI	125	0.1
AC PINSON	130	0.0
MICRON	132	0.0
FAUCON	132	0.1
HERON	152	0.2
ELECTRON	158	0.6
CANATTO	192	23.7
X3555-B-B-15	129	0.0
X3604-B-B-11-5	148	0.0

## MRI Images of Water Uptake

- ⊙Magnetic Resonance Imaging (MRI) captures water movement into the seed through the micropile.
- ⊙Mucilage surrounding the rootlet rapidly expands
- ⊙Initially, water content is highest near the tip of the rootlet and the space between the cotyledon and the seed coat.
- ⊙Water moves from the rootlet through the vascular system of the cotyledon.



## Specialty Soybean Trial

Mean from 13 locations, 1999 and 2000.

Variety	Yield Kg/ha	Seed Wt g/100	Protein %	Oil %	Sucrose	Stach Raff (%)
<i>High Protein</i>						
AC HERCULE	2758	19.0	46.3	18.8	4.5	4.4
AC PROTEINA	2839	16.5	46.7	18.0	4.3	4.5
RD714	3103	20.3	48.8	17.2	4.6	3.9
<i>Natto</i>						
AC COLIBRI	2042	7.5	40.0	19.8	6.0	4.7
AC PINSON	2215	7.4	40.7	19.7	5.4	4.6
MICRON	2434	7.5	39.8	20.1	6.2	4.5
FAUCON	2134	7.2	41.8	19.0	5.9	4.5
HERON	2629	7.7	40.9	20.7	5.4	4.0
ELECTRON	2569	8.2	44.8	18.6	4.7	4.6
<i>Tofu</i>						
KAMICHIS	2946	19.7	46.8	18.0		
OHGATA	2931	26.0	43.7	19.8		

## Recent Varieties



## 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 soy-food 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  
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## Quality Traits & Tools: Seeds

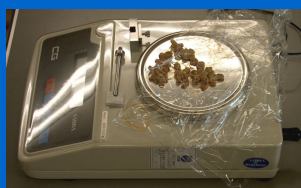
- Size fi Image Analysis
- Color fi Colorimeter (Hunter Lab)
- Protein content fi NIR whole grain
- Soluble sugar content fi Megazyme protocol
- Protein quality (specialty soybean) fi Electrophoresis (A<sub>4</sub> null) & lipoxigenase
- Water uptake fi Total uptake
- Rate of water uptake fi Uptake at T<sub>0.5</sub>
- Water Holding capacity fi 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).

	94-95	2000	Maximum Load in Newtons
Minnatto		161	
Ibaragi	147		
Hartz	125		
Micron	118	128	
Suzumaru	117		
Hokkaido	111		
AC Colibri	107	125	
AC Pinson		117	
Faucon		121	
Electron		114	
Heron		127	

The test is mechanized, standardized and repeatable.

## Protocol for Soymilk and Tofu

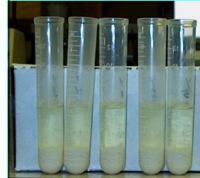
- Use of constant protein: water ratio of 18:1 to emphasize protein quality, not quantity.
- Tofu is silken.
- GDL, and  $\text{CaSO}_4$
- NIR Analyzer to evaluate soymilk composition.
- Colourimeter for soymilk and tofu colour.
- Instron Texture Measuring System for tofu firmness.

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



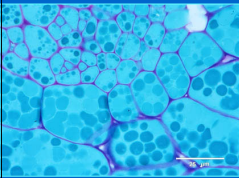
## Test Tube Tofu for Early Generation Selection

- 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  $\text{CaSO}_4$ ).



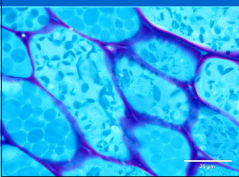
## Microscopy

Dr. S Miller



### OX951 – Normal seed

-protein bodies well developed and absorb stain.



### OX951 – Stone seed

-protein bodies in some cells fragmented and miss-shaped  
-variable staining of protein bodies

## Microscopy

### Miso Structure

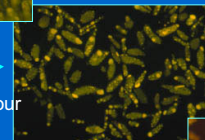


Dr. J. Mullin

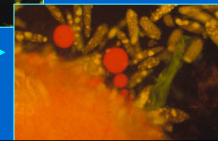


Experimental miso  
-granular texture  
-less complex flavour

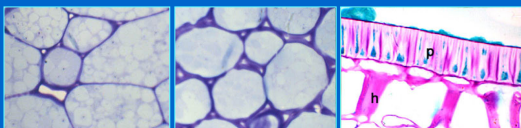
Commercial miso  
-smoother texture  
-more complex flavour



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



## Microscopy and Carbohydrate Analysis



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

Dr. F. W. Collins



### Separation Technology:

- Develop new methods to extract natural compounds from soybean.

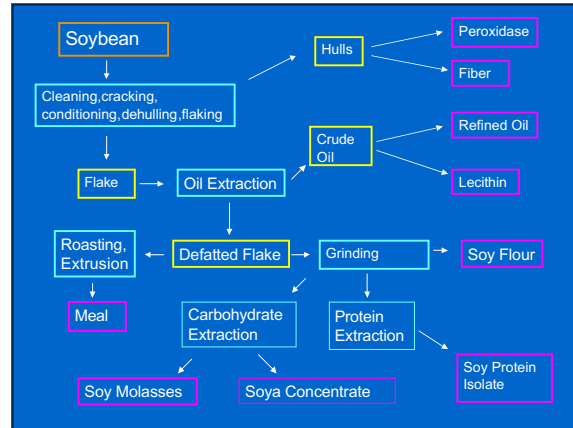
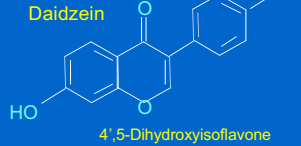
Use of "Designer Gels", organic solvents and patented extraction techniques for the purification of isoflavones and soyasaponins



## Isoflavones: Properties

- **USA FDA claim:** Diets low in fat that include 25 g of 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 -- antioxidants, free radical scavengers, LDL oxidants, anti-carcinogenic, plant estrogens: daidzein and genistein.
- Compounds responsible for flower and seed coat color, mitosis, nodulation.

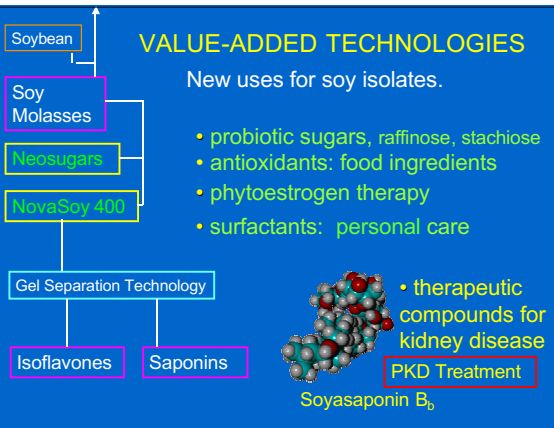
	U\$/g
Daidzein	71
Genistein	75
Soyasaponin B <sub>6</sub>	???



## VALUE-ADDED TECHNOLOGIES

New uses for soy isolates.

- probiotic sugars, raffinose, stachiose
- antioxidants: food ingredients
- phytoestrogen therapy
- surfactants: personal care



## Physiology, Ottawa

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

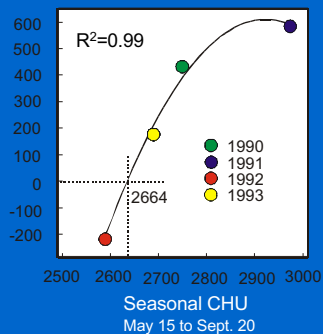


## Grey – Tawny Yield (kg/ha) Differential

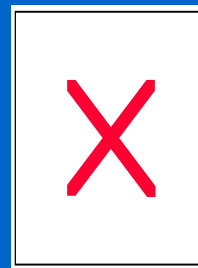
8 sets of F2-derived isolines with either tawny (T) or grey (t) pubescence.

Grey lines yield more than tawny lines in warm years (>2664). But in cold years Tawny yields more than grey. **WHY?**

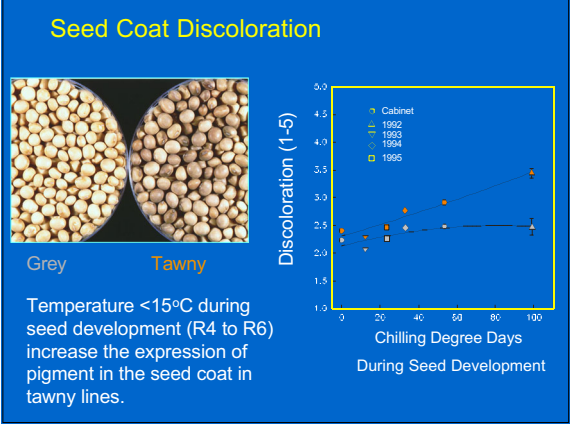
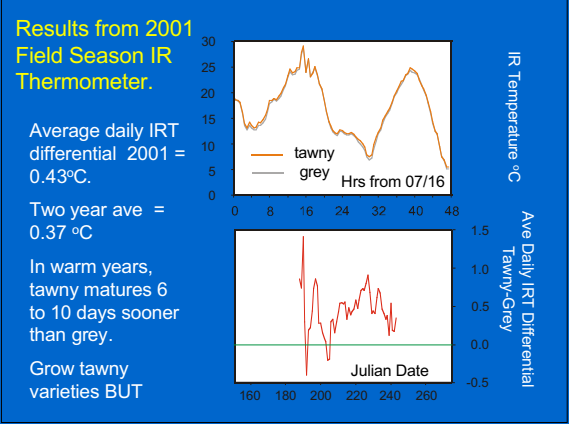
**Conclusion:** Grow Tawny lines with white hilum and seed coat.



## Canopy Temperature Differences Between Grey and Tawny Colored Pubescence



Infrared sensors  
Three replications  
Tawny and grey isolines  
Two years data.



### Pubescence Color and Seed Coat Discoloration

**Summary:**  
 Tawny colored lines perform better in cool regions (<2600 CHU) because of warmer canopies (0.37C)

**But,** Tawny colored lines with yellow seed coat and hila discolor with cool temperatures (<15C) 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 of seed pigment production.

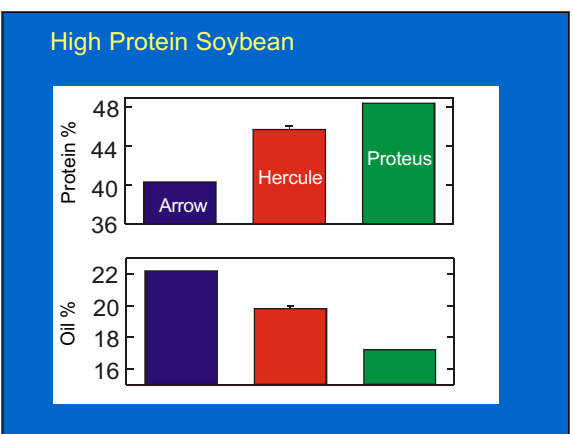
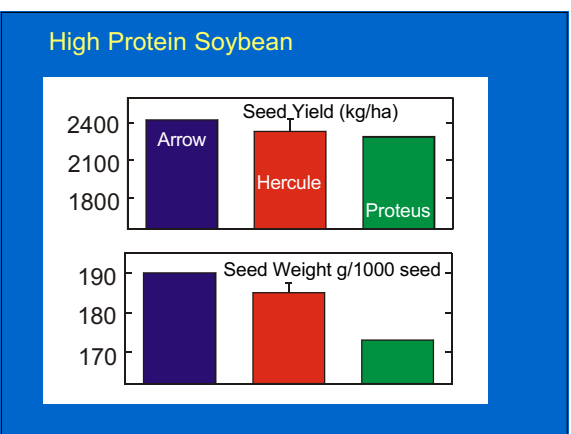
### High Protein Soybean

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

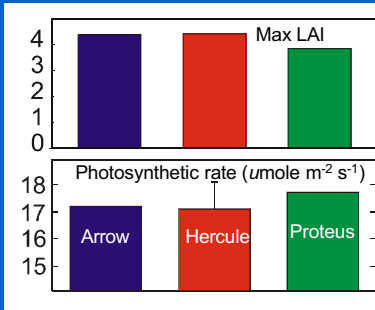
**Goal:** produce lines with high yield and protein.

- 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;

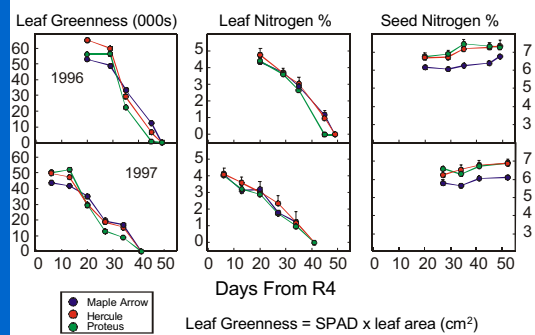


## High Protein Soybean



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

## High Protein Soybean



## High Protein Soybean: Summary

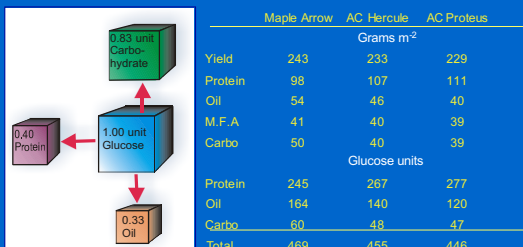
- High seed protein is associated with lower total seed yield. Physical reasons hard to find.
- In the high protein lines the demand for protein causes a rapid canopy senescence -- resulting in less photosynthate being produced towards the end of seed filling and lower yield.
- Protein occupies less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

## High Protein Soybean

### Yield Composition and Glucose units



Bahtai and Rabson, 1976, Science 19:1418.

Arrow significantly greater than Proteus

## 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.

**Why?** Fear of breast cancer and associated health risks.

- 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.

<http://www.nal.usda.gov/fnic/foodcomp/Data/isoflav/isoflav.html>

**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