Variation in Soybean seed quality parameters: The Manitoba Advantage

Malcolm Morrison, Roger Burak, Nirmal Hari, James Lindal

Collaborators

Elroy Cober, Judith Fregeau-Reid, Ottawa RDC, AAFC
Anfu Hou, Morden RDC, AAFC
Philippe Seguin, Ste. Anne de Bellevue, McGill Uni.
Jeff Kostuik, PCDF Roblin, Manitoba Agriculture
Brian Beres, Lethbridge RDC, AAFC
Yvonne Lawley, Carman, Kelburn, University of Manitoba
Scott Chalmers, WADO Melita, Manitoba Agriculture
Josh Price, Brandon RDC, AAFC
Lorna Woodrow, Harrow RDC, AAFC

Background and Objectives

While Manitoba now grows primarily industrial soybean for crushing and meal, in the future farmers may want to take advantage of the lucrative food-type export market valued at nearly one billion dollars annually. Canadian food-type soybean for export are usually from non-GM varieties. Seeds that are bright yellow in colour, large and round are preferred. When seeds are dark in colour or stained they are not purchased at a premium price. Seed protein concentration should be at least 42 % while there are not criteria yet for oil concentration and the oil quality profile. Minerals such as iron and cadmium may also influence buyer preference. Seed components that can be considered beneficial for human health, such as isoflavones, lutein, and tocopherols, may receive a premium in the near future.

The objective of the project was to characterize the quality of food-type soybean grown in Manitoba to determine the potential to develop a food-type soybean export market in Manitoba. Seed quality characteristics were compared to the same varieties grown in Ottawa, an active food-type soybean producer. These results may show that there are specific qualities of Manitoba-grown soybean that will promote the Manitoba food-type soybean export market. They may also help plant breeders to improve characteristics that may be lacking from Manitoba varieties.

Materials and Methods

Six varieties of soybean were grown at several locations in Manitoba in 2015 and 2016. In addition, the test was grown in Eastern Ontario and Western Quebec in both years. Soil was sampled, and at harvest seed samples were taken to determine seed quality characteristics.

Six soybean varieties with appropriate maturity for Manitoba were grown in a randomized complete block design with four replications. Each location managed planting, land preparation, and weed control according to their established methods, and seeded at 65 seeds per

square meter. There were four locations in Manitoba in 2015 and six in 2016. Notes on phenological development (seeding, vegetative, flowering, and maturity stages) were taken. Plant height was measured before harvest. At maturity seeds were combine-harvested and a sample was sent to Ottawa for quality analysis. Grain moisture was determined at harvest.
The seed was examined for:

- Appearance: size, roundness, and brightness.
- Minerals: iron, zinc, sulfur, and cadmium concentration.
- Protein, oil and sugar concentration, and oil component profile.
- Seed human health components: isoflavones, lutein, and vitamin E (α-tocopherol). Lutein and vitamin E were only analysed in 2015 due to equipment failure.

Data was analysed using the Proc GLM model in SAS. Within each year, location data was combined and analyzed to examine the statistical differences among locations, with the error term being replication within location. Data was also analysed by location to examine the response of variety within each location. In order to determine the suitability of a location for producing food-type soybean, the Manitoba locations were compared to Ottawa by calculating a Dunnett's t-test to calculate the minimum significant difference (MSD) value. There were only three locations in Manitoba; Arborg, Morden, and Portage, and two in eastern Canada; Ottawa and Ste. Anne that repeated the experiment in 2015 and 2016.

Results

2015: Six short-season soybean varieties were grown at Roblin, Portage la Prairie, Morden, and Arborg in MB; Ottawa in ON; and Ste. Anne de Bellevue in QC. Seed was harvested and analysed for quality characteristics. Seed yield in Portage and Morden was similar to Ottawa and Ste. Anne (Table 1).

Seed from the east had higher protein. Manitoba seed had greater sugar concentration and, were rounder, smaller, and darker. Seeds from Morden did not differ from those grown in eastern Canada in yield, seed colour or shape. There was generally higher linolenic acid and linoleic acid, and lower oleic acid and palmitic acid in seed produced in Manitoba than Ottawa, although there was considerable variation across locations. Morden had the highest seed cadmium concentration of any location in the test, exceeding the 200 ppb export limitation. Portage and Ste. Anne had similar cadmium concentrations (~100 ppb) while Arborg, Roblin, and Ottawa were below 50 ppb. All locations had similar iron concentrations, while Manitoba seed was higher in zinc than eastern Canada seed. Earlier varieties are needed for Roblin because the selected varieties did not mature on time. Manitoba generally had higher total isoflavone concentration than in eastern Canada.

Table 1. Soybean varieties performance at different test sites during 2015.

	Roblin	Portage	Morden	Arborg	Ste Anne	Ottawa	LSD†	MSD‡
Yield (kg ha^{-1})	1641	3467	3481	1424	3497	3415	196	249
Days to Maturity	142	121	100	127	115	103	1	0.6
Protein (%)	37	43	39	40	43	43	0.8	1
Oil (%)	19	18	22	21	20	20	0.2	0.2
Sugar (%)	15	14	13	13	12	12	0.3	0.3
Linolenic acid (%)	13	9	8	9	7	8	0.4	0.4
Linoleic acid (%)	56	60	57	60	53	58	Ns	1.5
Oleic acid (%)	12	5	7	8	9	8	0.8	0.8
Palmitic acid (%)	15	24	26	19	28	24	ns	1
Stearic acid (%)	5	3	4	4	4	4	ns	0.3
Seed area (mm^2)	26	33	31	31	33	34	0.9	1.2
Seed roundness (%)	75	82	79	79	80	77	1	1
Seed brightness	58	60	62	59	59	61	1	0.9
Seed colour diff.	5	4	1	3	3	1	0.7	0.2
Seed cadmium (ppb)	48	90	353	25	78	22	19	0
Seed iron (ppm)	69	70	78	61	74	74	3.2	3.3
Seed sulfur (ppm)	2933	3356	3401	3360	2593	2739	112	58.3
Seed zinc (ppm)	38	33	46	43	32	28	3	1
Total isoflavone (µg g^{-1})	2982	2373	2121	2989	2252	1918	69	130
Vitamin E (µg g^{-1})	13	17	24	25	31	24	1.6	1.7
Lutein (µg g^{-1})	9	7	10	11	8	8	0.5	0.7

2016: The same six short-season soybean varieties were grown at Portage la Prairie, Morden, Arborg, Carman, Melita, and Kelburn in MN; Ottawa in ON, and Ste. Anne de Bellevue in QC. Seed was harvested and analysed for quality characteristics.

Compared to Ottawa, Morden and Arborg produced greater average seed yield while Portage and Carman produced similar yield, and Kelburn, Ste. Anne, and Melita lower yield (Table 2). Seed sugar concentration was significantly greater in seed produced at Manitoba locations than at Ottawa. Protein concentration was greater at Carman and Kelburn, similar at Morden, and lower at Portage, Arborg, and Melita than at Ottawa. Seed oil concentration was greater at Arborg and Melita than at Ottawa, but it was lower at the other Manitoba locations. Generally, Manitoba soybean seed was significantly greater in polyunsaturated (linoleic and linolenic) fatty acids, and significantly lower in unsaturated (oleic and palmitic) fatty acids. Seed cadmium was greater at the Manitoba locations that it was at Ottawa. At Morden, seed cadmium levels exceeded the 200 ppb export limitation.

Arborg results

The results from Arborg site are given in Table 3. During 2015, Soybean varieties Edward, Mandor and Prudence took less number of days to mature than other three varieties. In 2016, although Edward had less number of days to mature, but in comparison Mandor took more number of days to mature. Yield did not differ among soybean varieties in 2015. In 2016, soybean varieties Mandor, Jari and DH 863 produced significantly higher yield than all other varieties.

Table 1. Soybean varieties performance at different test sites during 2016.

	Portage	*Morden*	*Arborg*	*Melita*	*Carman*	*Kelburn*	*Ste.Anne*	*Ottawa*	*LSDł*	*MSDł*
Yield (kg ha^{-1})	*2981*	*4619*	*4049*	*1717*	*2731*	*2346*	*2119*	*2789*	*177*	*237*
Days to Maturity	*117*	*115*	*131*	*115*	*--*	*--*	*122*	*100*	*1*	*2*
Protein (%)	*38*	*41*	*37*	*30*	*44*	*44*	*41*	*42*	*1*	*2*
Oil (%)	*19*	*19*	*21*	*25*	*18*	*17*	*22*	*21*	*0.5*	*0.6*
Sugar (%)	*15*	*13*	*14*	*16*	*14*	*13*	*13*	*11*	*0.4*	*0.4*
Linoleic (%)	*59*	*59*	*54*	*56*	*57*	*61*	*57*	*51*	*1.5*	*0.4*
Linolenic (%)	*12*	*9*	*14*	*10*	*11*	*11*	*6*	*9*	*0.6*	*1.5*
Oleic acid (%)	*16*	*20*	*18*	*19*	*18*	*16*	*25*	*25*	*1.3*	*0.8*
Palmitic acid (%)	*8*	*7*	*12*	*12*	*9*	*7*	*9*	*13*	*1.2*	*1*
Stearic acid (%)	*4*	*3*	*4*	*5*	*4*	*3*	*4*	*4*	*0.3*	*0.3*
Seed area (mm^2)	*37*	*37*	*38*	*31*	*35*	*34*	*37*	*39*	*1*	*1*
Seed roundness	*84*	*86*	*84*	*85*	*85*	*85*	*80*	*80*	*2*	*2*
Seed brightness	*61*	*61*	*61*	*60*	*58*	*59*	*61*	*62*	*0.4*	*0.7*
Seed colour diff.	*4.7*	*3.5*	*2.8*	*3.5*	*5.8*	*6*	*3*	*2.3*	*0.5*	*0.7*
Seed cadmium (ppb)	*76*	*363*	*49*	*77*	*114*	*137*	*112*	*27*	*14*	*2.7*
Seed iron (ppm)	*71*	*78*	*69*	*104*	*80*	*74*	*80*	*71*	*2.3*	*5.9*
Seed sulfur (ppm)	*3278*	*3458*	*3122*	*3226*	*3435*	*3410*	*3112*	*3129*	*66*	*200*
Seed zinc (ppm)	*29*	*42*	*31*	*39*	*40*	*37*	*42*	*41*	*1.2*	*3.2*
Total isoflavone (µg g^{-1})	*3081*	*2862*	*2947*	*3069*	*2832*	*2707*	*1751*	*1352*	*135*	*154*

Table 3. Performance of different soybean varieties at Arborg site during 2015 and 2016.

Variety	*2015*			*2016*		
	Days to Maturity	*Yield (Kg/ha)*	*Protein (%)*	*Days to Maturity*	*Yield (Kg/ha)*	*Protein (%)*
Edward	*122*	*1398*	*38*	*128*	*3756*	*34*
Mandor	*125*	*1566*	*39*	*136*	*4408*	*36*
Prudence	*124*	*1544*	*41*	*133*	*3849*	*37*
OT1103	*129*	*1413*	*37*	*129*	*3711*	*35*
Jari	*130*	*1245*	*41*	*129*	*4292*	*40*
DH863	*130*	*1381*	*42*	*134*	*4285*	*41*
Mean	*127*	*1424*	*40*	*131*	*4050*	*37*
LSD†	*2*	*ns*	*0.9*	*5*	*406*	*1.4*

Project findings

- Seed yields are sufficiently high in Manitoba to support a thriving food-type soybean industry.
- Producers should be encouraged to grow varieties recommended for their Crop Heat Unit region. Pre-harvest desiccation alters the protein and oil concentration in the seed and should be discouraged.
- Seed protein concentration is sufficiently high at some locations in Manitoba (42 % target) but overall is too low for export. There are differences among varieties for protein

concentration and plant breeding effort should concentrate on developing high protein lines. Additional research should resolve the climatic factors resulting in low protein concentration.

- Long days in spring and cool nights during seed development result in a longer time to maturity. Photoperiod sensitivity should be an area of future plant breeding emphasis in order to increase the time for seed development.
- Cool night temperatures (<15^{o}C) during seed development increase the seed coat discoloration resulting in a darker appearance. Soybean for food-type market should be grey pubescence in colour, which has less of a tendency to darken with cool night temperatures.
- Manitoba seed was smaller in size. Future plant breeding and agronomy research may need to focus on methods to improve seed size.
- Natto soybean, which requires a smaller seed size may be another potential target market for Manitoba soybean as the export target demands higher sugar concentration, higher linolenic acid concentration and smaller, rounder seed. Natto seed production may be a very good fit for Manitoba food-type soybean. A new research project should investigate the potential for establishing a small and medium-small seeded market for export.
- Seeds from Manitoba are rounder in shape, which is an export advantage.
- The higher concentration of polyunsaturated fats (Omega-3 linolenic acid) may be an export advantage for Manitoba. The high sugar concentrations (>7 %) may be an export advantage for Manitoba food-type.
- Cadmium concentration in the seed greater than 200 ppb will be detrimental to soybean export. Cadmium is a problem in the Morden and Carmen areas. Varieties can be selected that accumulate lower concentration of cadmium in the seed. There are two types of cadmium accumulation; high and normal. Two out of the six varieties in this experiment were normal. Unfortunately, in regions of high soil cadmium, even normal accumulating soybean varieties can have seed concentrations exceeding or approaching the 200 ppb limit. These areas may not be suitable for food-type production. All food-type soybeans should be tested for cadmium accumulation prior to being recommended for growing.

Advantages

- Manitoba produced food-type soybeans that is high yielding in most location as eastern Canadian seed.
- The seed is rounder in appearance than eastern Canadian seed.
- The seed is low to medium oil concentration, which can be an advantage for some soy foods, like soymilk.

- The seed is higher in polyunsaturated fats and lower in unsaturated fats than eastern Canadian soybean.
- The seed is higher in sugar concentration than eastern Canadian produced soybean seed.
- The seed is higher in total isoflavone concentration, lutein and Vitamin E.

Disadvantages

- The seed is smaller in size and darker in appearance at most locations than eastern Canadian produced seed.
- The seed grown at many locations in Manitoba is lower in protein than seed produced in eastern Canada. Often it does not meet the 42 % target.
- The seed produced in some areas has excessively high concentration of cadmium which will limit its export.