2022 Pulse Quality Evaluation

Pea

Saskatchewan Food Industry Development Centre Inc.
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Pulse Quality Program—*Mission*

The Pulse Quality Program launched in spring 2022 with a partnership between Saskatchewan Pulse Growers and the Saskatchewan Food Industry Development Centre with the mission to add in best management practices for pulses grown in Western Canada and to help the development of pulse-based ingredients/products in the food industry.

The program aims to develop a comprehensive database of composition, functionality, and nutrition for pulses that provides information to growers, agronomists, breeders, buyers, and end users to make more informed choices. This program implements a genotype by environment (G x E) evaluation of quality parameters of peas, faba beans, lentils, chickpeas, and dry beans.

Phase 1 of the program analyzes up to 3000 samples annually from regional variety trials. The main focus of parameters includes seed quality (i.e., 1000 seed weight, amount of damage, seed size, and seed hardness), nutritional composition (i.e., ash, moisture, and protein content), and physical properties (i.e., colour, particle size, and Hausner ratio). The generated data are compared across pulse varieties, locations, and years. Additional parameters will be considered in future years in Phase 2 and Phase 3.

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2022 Pea Quality Evaluation

A total number of **936** pea samples were harvested in **2022.** The samples were acquired from **thirteen locations** x **twenty-four varieties**, where three replicates per variety per location were included. The eighteen varieties consist of five varieties of green peas, eighteen varieties of yellow peas, and one variety of maple pea. Table A and Figure A provide the samples' information and locations in detail.

Table A. Description of pea samples harvested in 2022 for the Pulse Quality Program.

Crop	Type	Variety		Site	Number of samples
Pea	Green	CDC Forest	CDC Rider	Aberdeen	
		CDC Huskie	CDC Spruce	Avonlea	
		CDC Limerick		Codette	
	Yellow	AAC Beyond	CDC Citrine	Lucky Lake	
		AAC Julius	CDC Hickie	Moose Jaw	
		AAC Profit	CDC Inca	Outlook	
		CDC Boundless	CDC Lewochko	Redvers	936
		CDC 5791	CDC Spectrum	Rosthern	
		CDC 5845	CDC Tollefson	Saskatoon (Sutherland)	
		CDC Engage	PS Boost	Scott	
		CDC Amarillo	CS ProStar	St Brieux	
		CDC Canary	Caphorn	Swan River, MB	
	Maple	AAC Lorlie		Swift Current	

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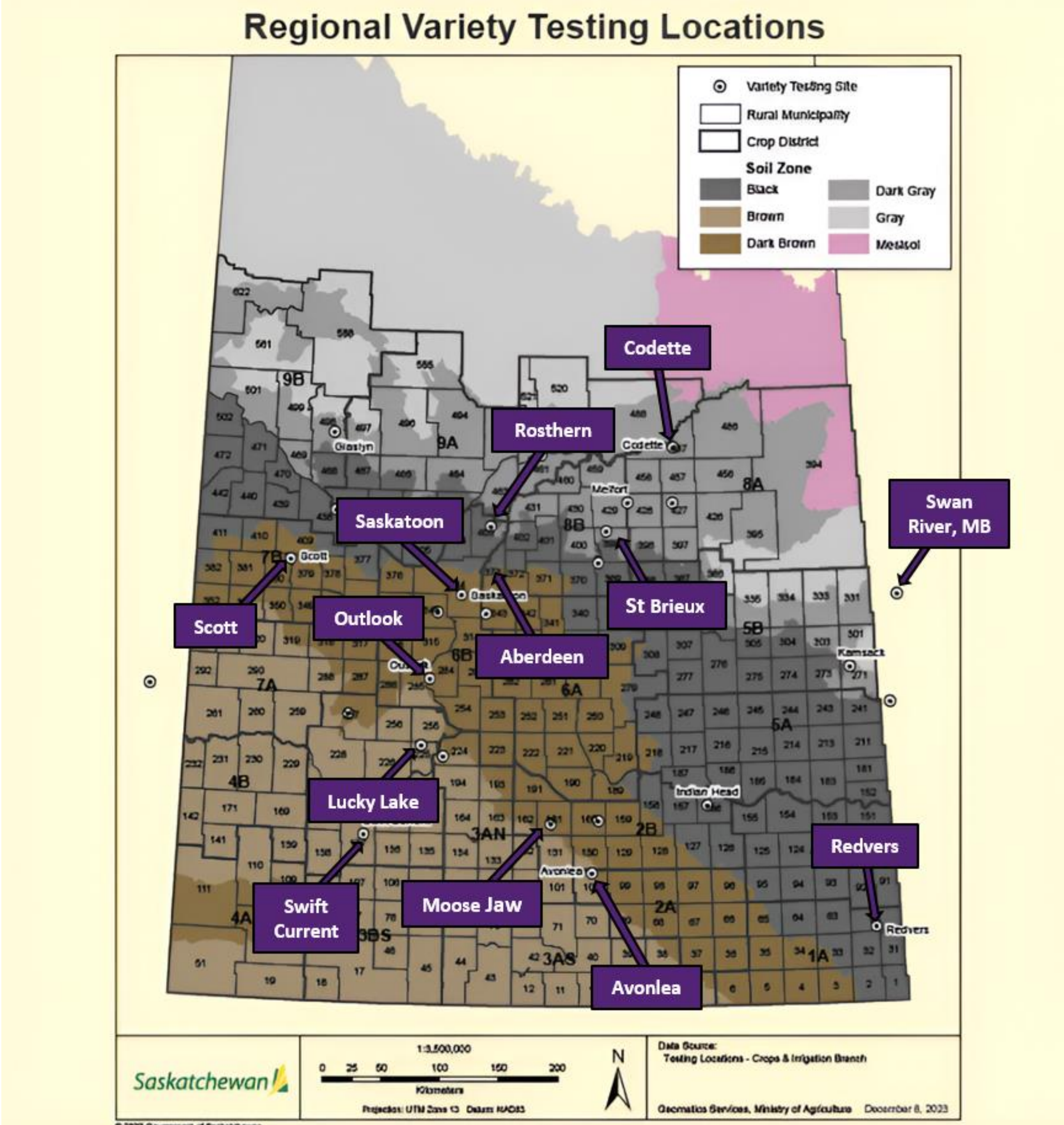

The cropland of Saskatchewan has been divided into four areas based roughly on agro-climatic conditions. Crop yields can vary from area to area. In choosing a variety, producers will want to consider the yield data in combination with marketing and agronomic factors.

Area 1: Drought is a definite hazard and high winds are common. Sawfly outbreaks often occur in this area. Cereal rust may be a problem in the southeastern section.

Area 2: Drought and sawfly may be problems in the western and central sections of the area. Cereal rust may be a problem in the southern section.

Area 3: Sawfly can also be a problem. Drought is not as likely to be a problem in this area, particularly in the east. Cereal rust may occur in the eastern portion. The frost-free period can be fairly short in the northern section.

Area 4: Rainfall is usually adequate for crop production. However, early fall frosts and wet harvest conditions are frequent problems.

Note About Dividing Lines:

The dividing lines do not represent distinct changes over a short distance. The change from one area to another is gradual.

Figure A. Locations for pea quality testing in 2022 and the corresponding soil zones. Figure was modified from material provided by the Saskatchewan Ministry of Agriculture.

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This report includes three sections: **1)** 2022 green pea varieties, **2)** yellow pea varieties, and **3)** maple pea variety. Each section includes ten subsections for the results of the following quality parameters:

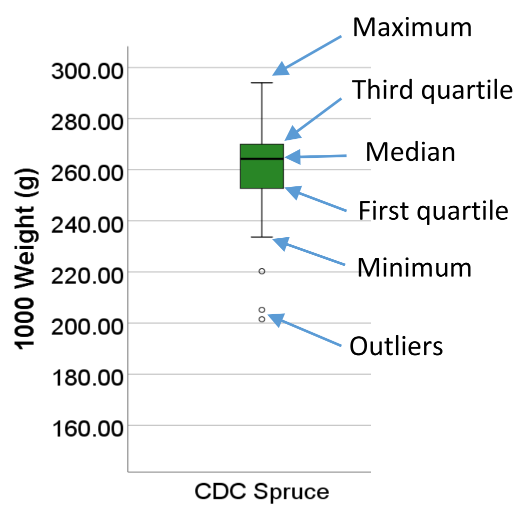
1. 1000 seed weight
2. Seed size distribution
3. Split amount
4. Other damage
5. Hardness of whole seed
6. Ash content
7. Protein content
8. Colour (*L*, a**, and *b**)
9. Hausner Ratio
10. Particle size

The **method** used to evaluate each quality parameter is provided at the beginning of each subsection.

For the **results**, a **Box and Whisker** plot is first provided to show the full dataset of each variety, where the minimum, median, maximum, first quartile (the median of the lower half of the dataset), and third quartile (the median of the upper half of the dataset).

In addition, a **Bar** graph is included to provide the mean value by variety to show the variety performance and by location to show how the locations differed.

Furthermore, the effects of variety, location, and variety x location on the characteristic are given in a **table**.



For **statistics**, a one-way analysis of variance (ANOVA) along with a post-hoc Tukey test (SPSS, Chicago, IL, USA) was performed to identify the differences in the quality parameters, including TKW, seed size, seed hardness, split + cracked seed coat, other damage, protein, ash, Hausner ratio, colour, and particle size, by variety and by location.

A two-way analysis of variance (ANOVA) was conducted to determine the effects of variety, location, and their interaction on each parameter. The Pearson Product Moment Correlation was performed to measure the correlation between quality parameters.

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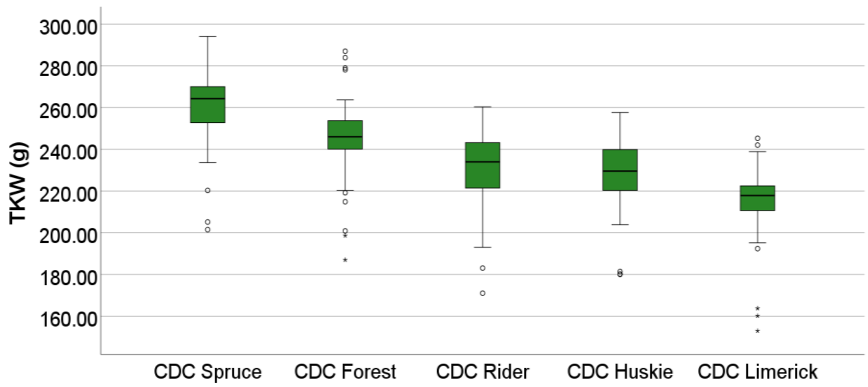
1) 2022 Green Pea Quality

1. 1000 Seed Weight

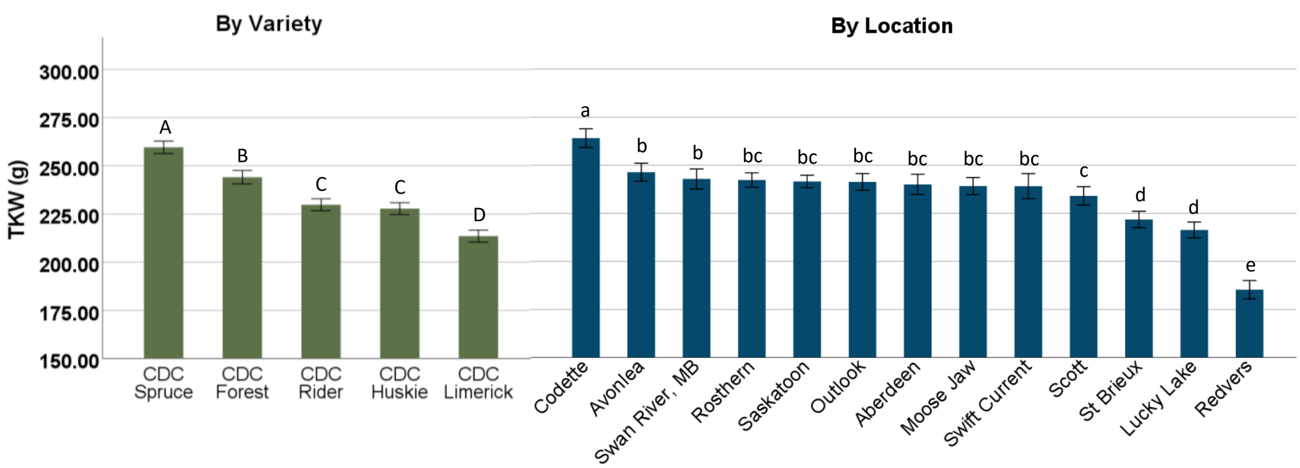
Method: Seed weight is important to indicate seed size and yield production. This test was conducted by weighing 300 seeds with duplicated measurements per sample. The 1000 seed weight (TKW) was reported.

Results: Figure 1.1.1. Box and Whisker plot of green peas for TKW resulting from 13 locations.



Overall, CDC Spruce had the largest TKW, while CDC Limerick had the smallest TKW.

Figure 1.1.2. Mean TKW by variety (left) and by location (right). Each bar represents mean ± one standard error.



Note: Capital letters indicated significant differences (p<0.05) by variety. Small letters indicated significant differences (p<0.05) by location.

- **By Variety:** A difference of 46 g was determined from the largest (CDC Spruce) to the smallest (CDC Limerick).
- **By Location:** Except for the extreme high of Codette and the lowest three locations, TKW for other locations were consistent, ranging from 234 g to 246 g.

Table 1.1. Effects of variety and location.

	Sig.
Variety	***
Location	***
Variety x Location	***

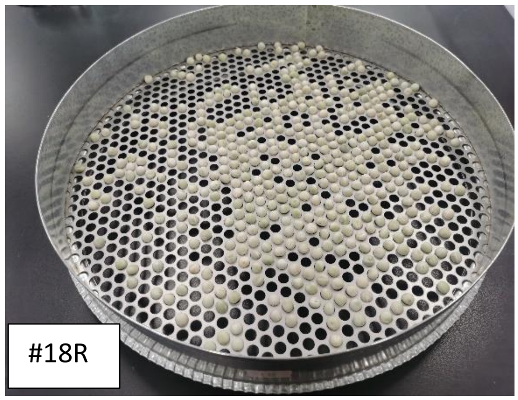
Note: ***p<0.001; ***p<0.01; *p<0.05; NS not significant.*

2. Seed Size Distribution

Method: 250 g of seeds were placed on a series of round-hole opening sieves. The weight of seeds retained on each sieve was determined and reported as % of seeds retained. Duplicated measurements were performed.

Sieves used for green pea varieties:

a. #20R: 7.94 mm
b. #18R: 7.14 mm
c. #16R: 6.35 mm
d. #14R: 5.56 mm



Results:

Table 1.2. TKW (g) and seed size distribution (%) of each green pea variety. Data represent mean ± one standard deviation.

Variety	TKW (g)	> # 20R (%)	> # 18R (%)	> # 16R (%)	> # 14R (%)	Below # 14R (%)
CDC Spruce	259.6 ± 20.2[a]	3.1 ± 1.9[a]	47.7 ± 16.6[a]	44.8 ± 13.4[e]	4.0 ± 5.3[c]	0.4 ± 0.6[c]
CDC Forest	244.1 ± 21.7[b]	2.2 ± 2.9[b]	39.5 ± 17.7[b]	52.3 ± 15.2[d]	5.6 ± 6.3[c]	0.4 ± 0.5[c]
CDC Rider	229.8 ± 19.3[c]	0.5 ± 0.7[cd]	26.0 ± 13.0[c]	62.9 ± 9.2[c]	9.7 ± 9.2[b]	0.9 ± 1.2[b]
CDC Huskie	227.8 ± 19.2[c]	0.8 ± 1.3[c]	21.3 ± 12.6[d]	66.8 ± 10.6[b]	10.3 ± 10.0[b]	0.8 ± 1.1[b]
CDC Limerick	213.6 ± 19.6[d]	0.1 ± 0.3[d]	8.5 ± 4.7[e]	73.7 ± 14.3[a]	16.3 ± 15.1[a]	1.3 ± 2.1[a]

Note: Means within a column followed by different lowercase letters are significantly different ($p<0.05$).

- The majority of green peas had a seed size between 6.4 mm to 7.9 mm.
- Seed size distribution results corresponded to TKW, where CDC Spruce had the highest weight and had the most seeds retained on the #20 and #18 sieves.
- In contrast, CDC Limerick had the lowest TKW and had the fewest seeds retained on the #20 and #18 sieves but more on the #16 and #14 sieves.

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3. Split + Cracked Seed Coat

Method: 100 grams of each sample was used for evaluation, and damaged seeds were selected by hand. Results included splits, cracks, seed coat damage, partially missing hull, and partially missing cotyledon.

Results: Figure 1.3.1. Box and Whisker plot of green peas for the split amount resulting from 13 locations.

CDC Limerick, Forest, and Spruce had similar split damage, but CDC Spruce had less variability. CDC Rider and Huskie were also similar.

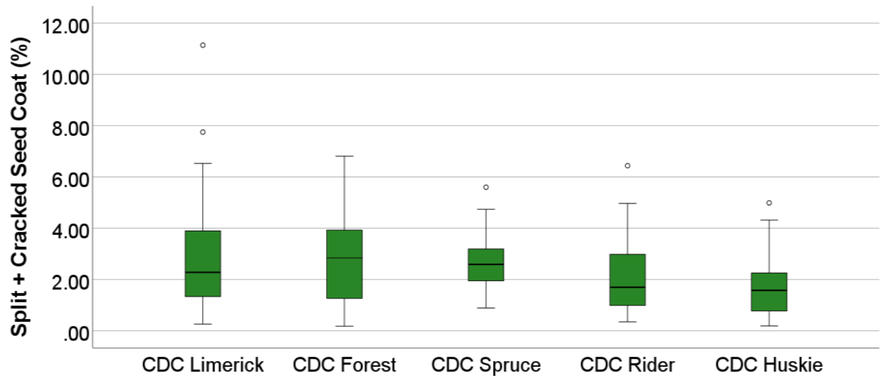
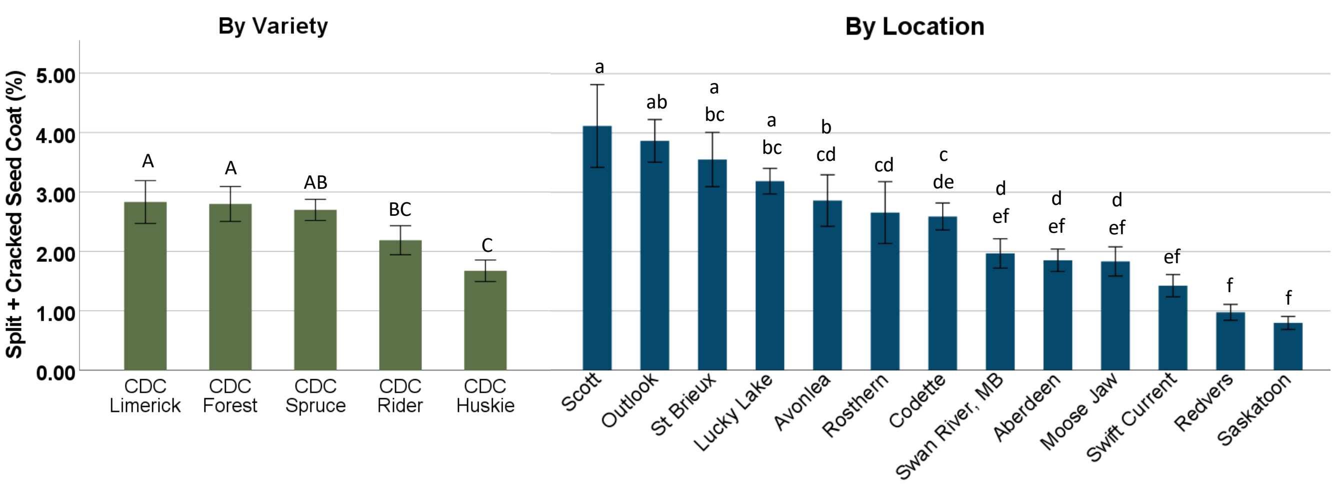


Figure 1.3.2. Mean split + cracked seed coat of green peas by variety (left) and by location (right). Each bar represents mean ± one standard error.



Note: Capital letters indicated significant differences (p<0.05) by variety. Small letters indicated significant differences (p<0.05) by location.

- **By Variety:** CDC Huskie had lower split + cracked seed coat (~1%) over CDC Limerick, Forest, and Spruce.
- **By Location:** The location effect also played a role. A 3.3% difference was observed from the highest (Scott: 4.1%) to the lowest (Saskatoon: 0.8%).

Table 1.3. Effects of variety and location.

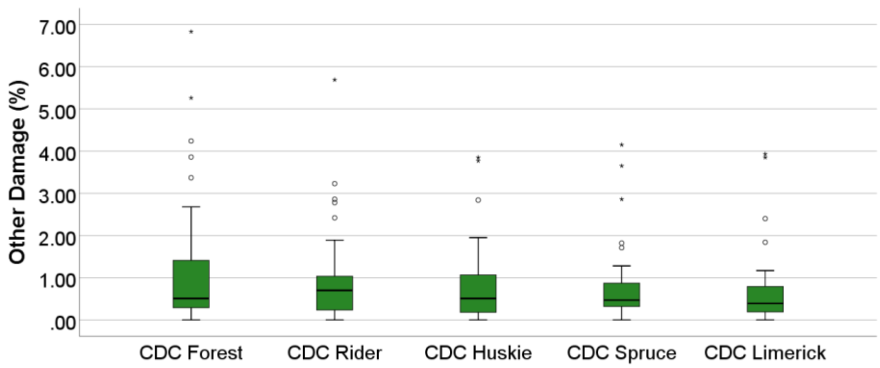
	Sig.
Variety	***
Location	***
Variety x Location	***

Note: ***p<0.001; ***p<0.01; *p<0.05; NS not significant.*

4. Other Damage

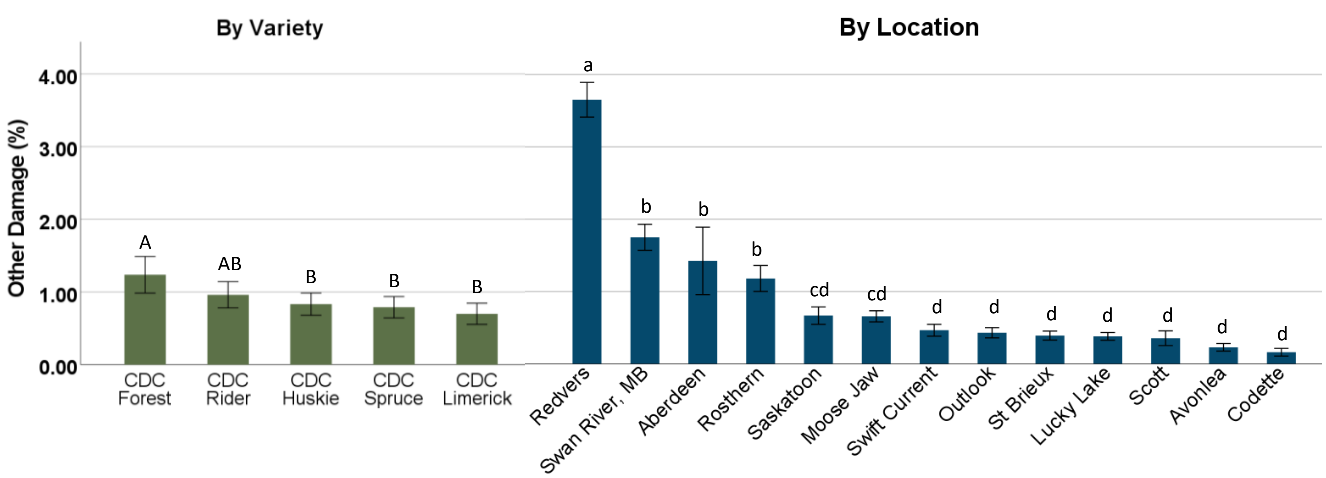
Method: 100 grams of each sample was used for evaluation, and damaged seeds were selected by hand. Other damage included bleaching, pink, sprouting, shrivelled, heated, frost, and insect damage.

Results: Figure 1.4.1. Box and Whisker plot of green peas for other damage resulting from 13 locations.



All varieties generally had a low level of other damage, but extreme outliers were observed.

Figure 1.4.2. Mean other damage of green peas by variety (left) and by location (right). Each bar represents mean ± one standard error.



Note: Capital letters indicated significant differences (p<0.05) by variety. Small letters indicated significant differences (p<0.05) by location.

- **By Variety:** CDC Forest had a higher amount of other damage. All other varieties are below 1%.
- **By Location:** Almost all the varieties harvested from Redvers were infected by the bacteria *Erwinia Rhapontici* and had a pink appearance.

Table 1.4. Effects of variety and location.

	Sig.
Variety	***
Location	***
Variety x Location	***

Note: ***p<0.001; ***p<0.01; *p<0.05; NS not significant.*

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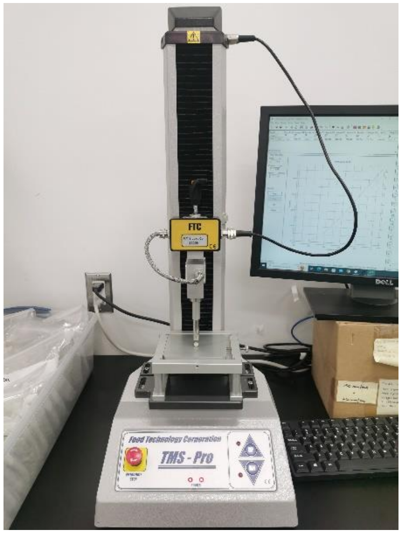
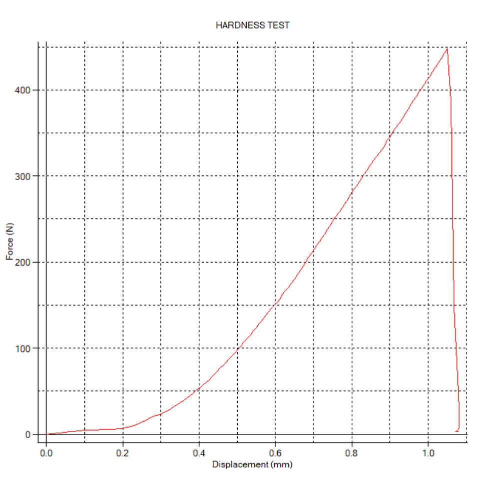
5. Hardness of Whole Seed

Seed hardness is an important parameter to indicate milling yield and cooking quality. Seed hardness is affected by seed size, shape, density, composition, etc.

Method:
Seed hardness was determined by measuring the force of breaking a seed using a texture analyzer (TMS-Pro, Food Technology Corporation, USA) equipped with a 2500 N load cell with a modified method from Karami et al. (2017) and Lovas-Kiss (2020)[1].

In brief, a seed was placed under the 10 mm cylinder probe that was lowered with a speed of 50 mm/min. The forces to lower the probe till a seed was broken were monitored. The mean peak force (N) of 10 seeds was reported.



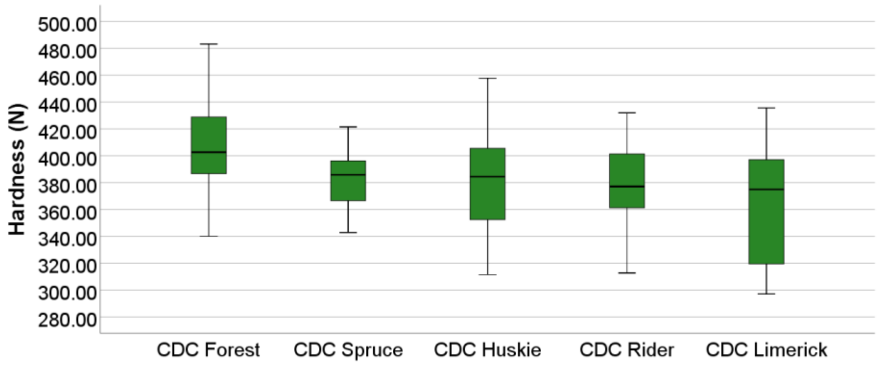


[1] Karami, S., Sabzalian, M. R., Rahimmalek, M., Saeidi, G., & Ghasemi, S. (2017). Interaction of seed coat color and seed hardness: An effective relationship which can be exploited to enhance resistance to the safflower fly (Acanthiophilus helianthi) in Carthamus spp. Crop Protection, 98, 267-275.

Lovas‐Kiss, Á., Vincze, O., Kleyheeg, E., Sramkó, G., Laczkó, L., Fekete, R., ... & Green, A. J. (2020). Seed mass, hardness, and phylogeny explain the potential for endozoochory by granivorous waterbirds. Ecology and Evolution, 10(3), 1413-1424.

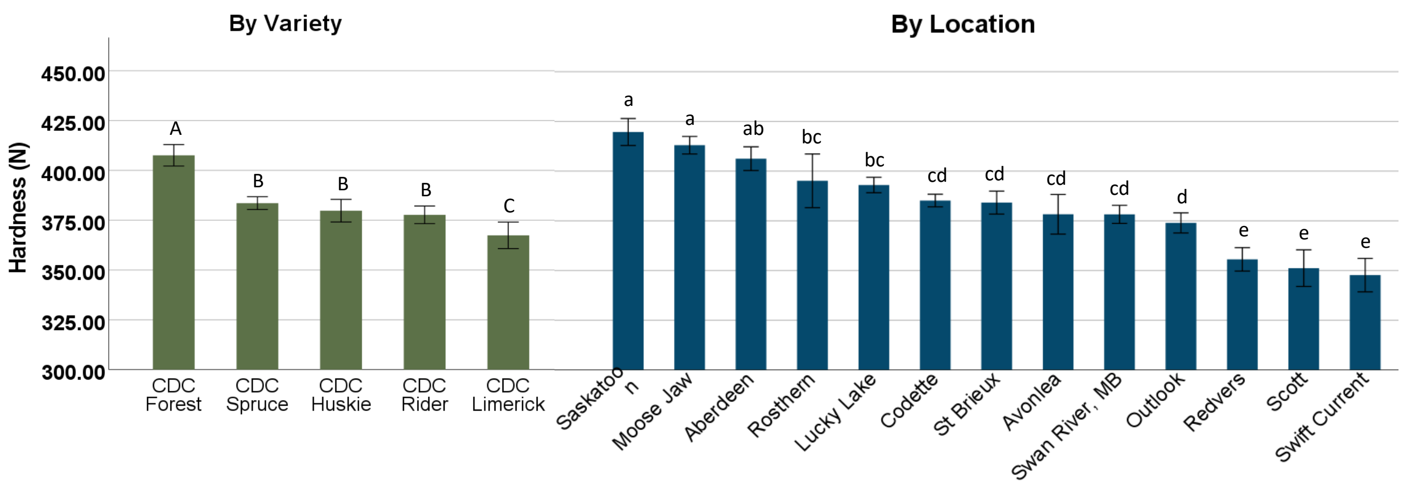
Results:

Figure 1.5.1. Box and Whisker plot of green pea hardness resulting from 13 locations.



CDC Forest was higher in hardness. CDC Spruce, Hiskie, Rider, and Limerick had similar median values, but Limerick had a larger variability.

Figure 1.5.2. Mean hardness of green peas by variety (left) and by location (right). Each bar represents mean ± one standard error.



Note: Capital letters indicated significant differences (p<0.05) by variety. Small letters indicated significant differences (p<0.05) by location.

By Variety:

- CDC Forest > CDC Sprice = CDC Huskie = CDC Rider > CDC Limerick.
- A positive trend was observed between the 2022 green pea hardness and seed weight (r=0.297, p<0.01).

By Location:

- A difference of 72 N was observed from highest (Saskatoon) to lowest (Swift Current).

Table 1.5. Effects of variety and location.

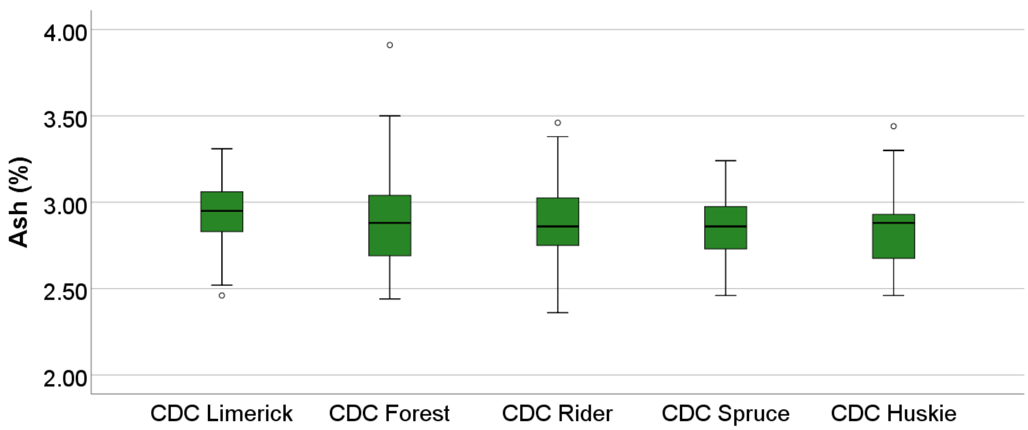
	Sig.
Variety	***
Location	***
Variety x Location	***

Note: ***p<0.001; ***p<0.01; *p<0.05; NS not significant.*

6. Ash Content

Method: Ash content (%) was determined using AACC 08-01.01[2] with modification. Samples were heated at 560°C till they turned white. Duplicated measurements were performed for each sample, and the average was reported on a dry basis (d.b.).

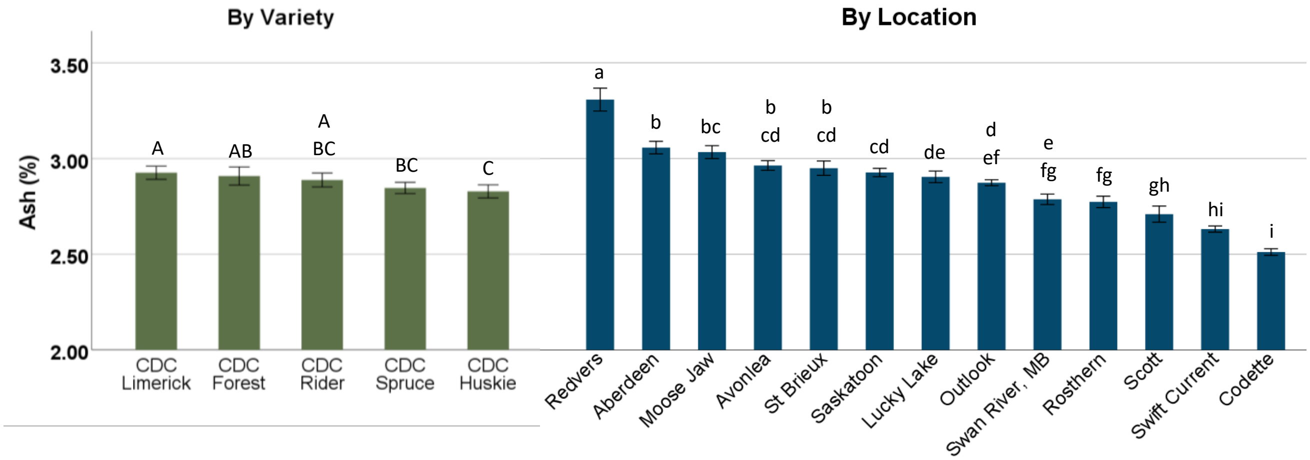
Results: Figure 1.6.1. Box and Whisker plot of green peas for ash content resulting from 13 locations.



Overall, ash content (d.b.) for all varieties were similar, ranging from 2.5% to 3.5%.

[2] AACC (1999). American Association of Cereal Chemists International. Approved methods of analysis (11th ed.). The Saint Pauls Association: Saint Paul, MN.

Figure 1.6.2. Mean ash content of green peas by variety (left) and by location (right). Each bar represents mean ± one standard error.



Note: Capital letters indicated significant differences (p<0.05) by variety. Small letters indicated significant differences (p<0.05) by location.

- **By Variety:** only a 0.1% difference from the highest to the lowest.

- **By Location:** Great differences were found with the highest ash level conducted in Redvers (p<0.05). A positive trend (r=0.485, p<0.01) was observed between ash and other damage.

Table 1.6. Effects of variety and location.

	Sig.
Variety	***
Location	***
Variety x Location	***

Note: ***p<0.001; ***p<0.01; *p<0.05; NS not significant.*

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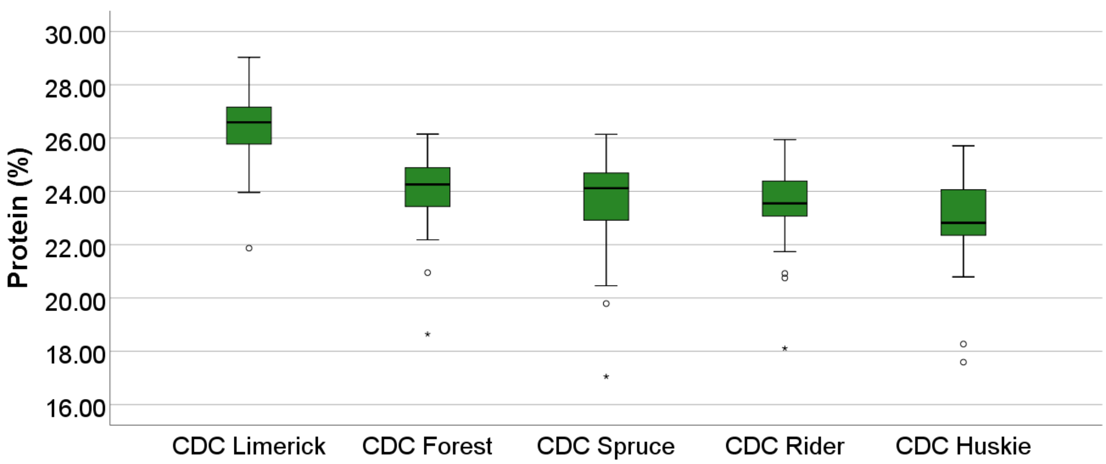
7. Protein Content

Method: The protein content (%) of each flour was determined through AACC 46-30[2] using the combustion method through a Rapid N Exceed (Elementar, USA). Duplicated measurements were performed for each sample, and the average was reported on a dry basis (d.b.).

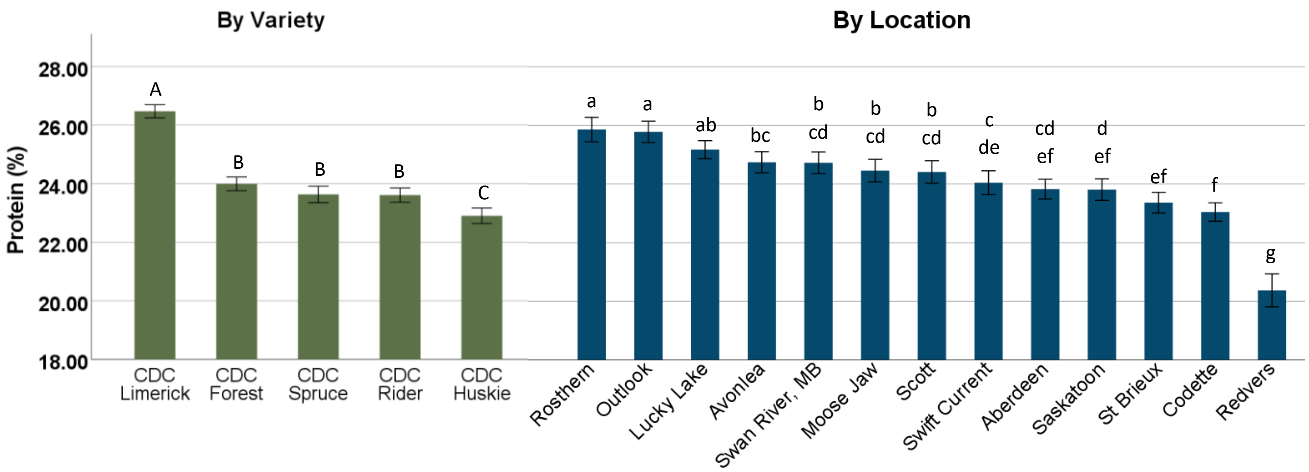
Results: Figure 1.7.1. Box and Whisker plot of green peas for protein content resulting from 13 locations.



CDC Limerick had a greater protein content. CDC Forest, Spruce, and Rider were similar. CDC Huskie had a slightly lower protein content.

[2] AACC (1999). American Association of Cereal Chemists International. Approved methods of analysis (11th ed.). The Saint Pauls Association: Saint Paul, MN.

Figure 1.7.2. Mean protein (%) of green peas by variety (left) and by location (right). Each bar represents mean ± one standard error.



Note: Capital letters indicated significant differences (p<0.05) by variety. Small letters indicated significant differences (p<0.05) by location.

- **By Variety:** Protein of CDC Limerick (highest) was 3.5% higher than CDC Huskie (lowest).

- **By Location:** Protein of Redvers was 2.7% lower than Codette (second lowest) and 5.5% lower than Rosthern (highest). A negative trend between protein and other damage levels was observed (r=-0.348, p<0.01).

Table 1.7. Effects of variety and location.

	Sig.
Variety	***
Location	***
Variety x Location	NS

Note: ***p<0.001; ***p<0.01; *p<0.05; NS not significant.*

8. Colour

Method: The absolute colour of each flour was determined using the Konica Minolta CR-400 Chroma meter, where *L*, a*,* and *b** values were reported.

- ***L* (lightness):*** white (100) to black (0)
- ***a*:*** red (+) to green (-)
- ***b*:*** yellow (+) to blue (-)

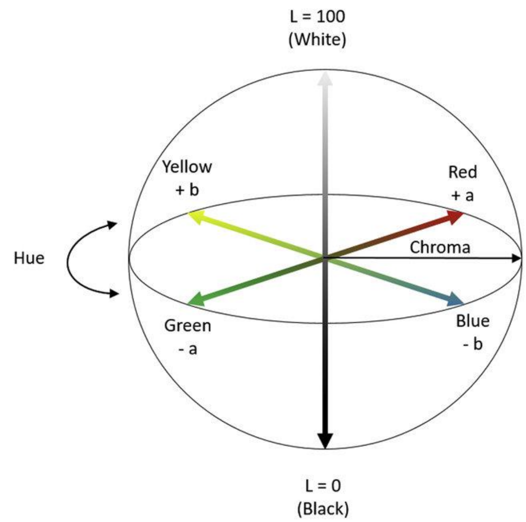
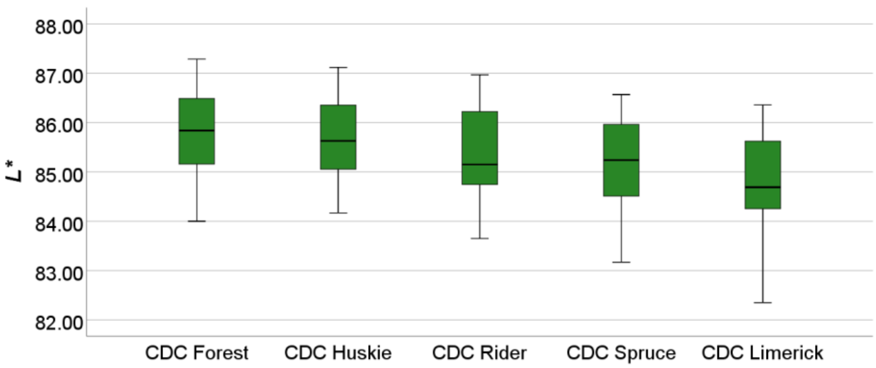


Figure 1.8.1. The CIELAB color spacediagram[3].

[3] Ly, B. C. K., Dyer, E. B., Feig, J. L., Chien, A. L., & Del Bino, S. (2020). Research techniques made simple: cutaneous colorimetry: a reliable technique for objective skin color measurement. *Journal of Investigative Dermatology*, *140*(1), 3-12.

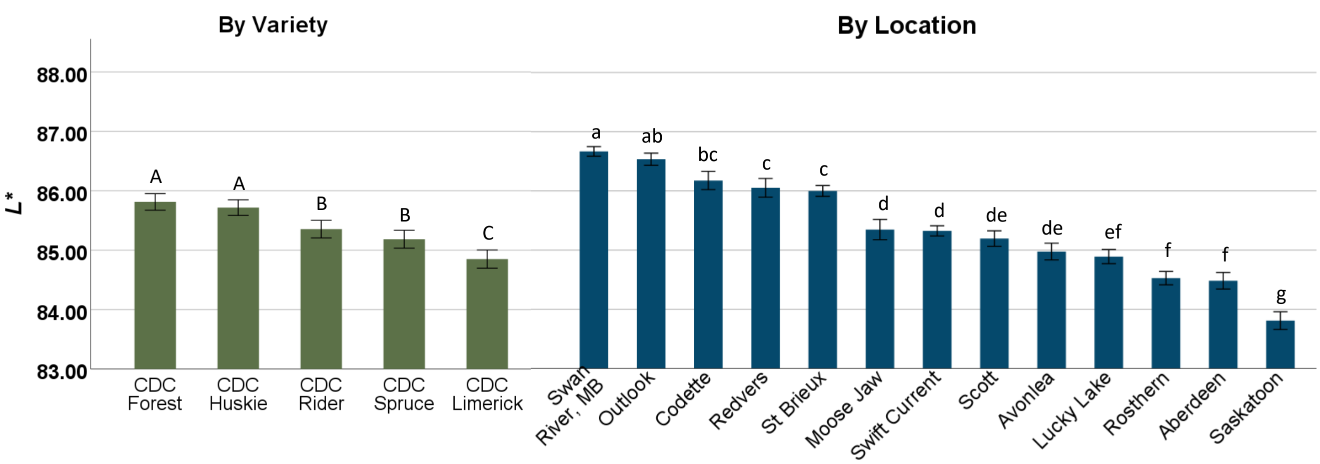
a) ***L* (lightness):*** white (100) to black (0)

Results: Figure 1.8.2. Box and Whisker plot of green peas for *L** values resulting from 13 locations.



CDC Forest and Huskie had a greater lightness. Limerick was lower in lightness with a greater variability.

Figure 1.8.3. Mean *L** value of green peas by variety (left) and by location (right). Each bar represents mean ± one standard error.



Note: Capital letters indicated significant differences (p<0.05) by variety. Small letters indicated significant differences (p<0.05) by location.

- **By Variety:** The difference from the highest to the lowest was 1 unit.
- **By Location:** Greater differences were conducted between locations, where flour lightness of Swan River (highest) was 2.9 units higher than Saskatoon (lowest).

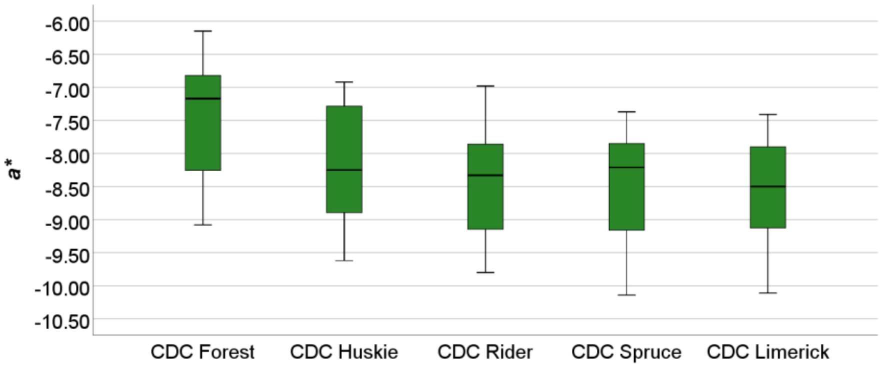
Table 1.8.1. Effects of variety and location.

	Sig.
Variety	***
Location	***
Variety x Location	NS

Note: ***p<0.001; ***p<0.01; *p<0.05; NS not significant.*

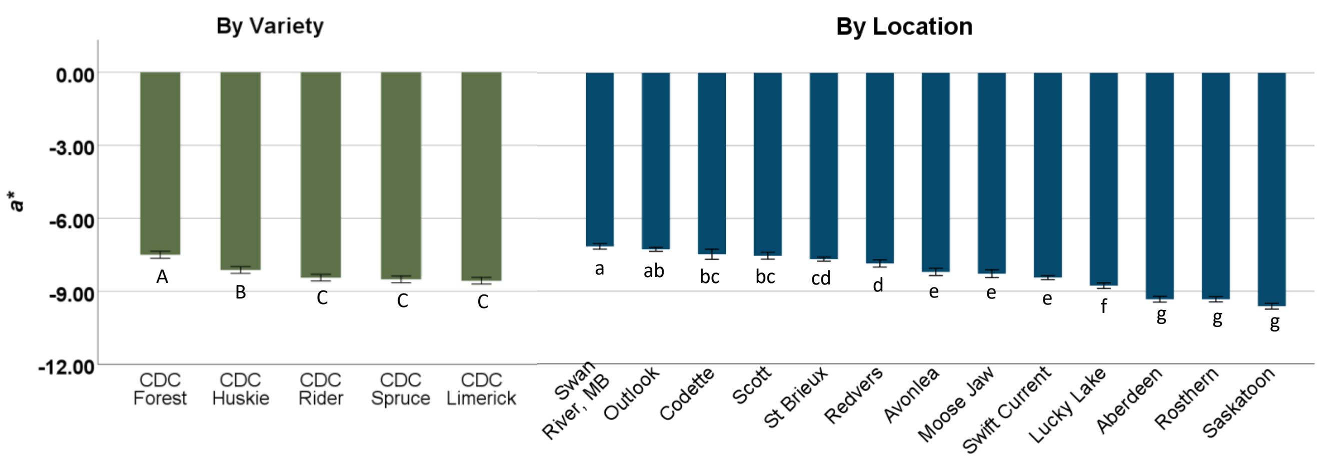
b) ***a*:*** red (+) to green (-)

Results: Figure 1.8.4. Box and Whisker plot of green peas for *a** values resulting from 13 locations.



Overall, CDC Forest had the least greenness. The median values of Huskie, Rider, Spruce, and Limerick were similar, but Huskie had a greater variability.

Figure 1.8.5. Mean *a** value of green peas by variety (left) and by location (right). Each bar represents mean ± one standard error.



Note: Capital letters indicated significant differences (p<0.05) by variety. Small letters indicated significant differences (p<0.05) by location.

- **By Variety:** CDC Forest had the least greenness. One reason may be that Forest is susceptible to bleaching.
- **By Location:** Greater differences were conducted between locations, where *a** of Swan River (least greenness) was 2.5-unit different from Saskatoon.

Table 1.8.2. Effects of variety and location.

	Sig.
Variety	***
Location	***
Variety x Location	***

Note: ***p<0.001; ***p<0.01; *p<0.05; NS not significant.*

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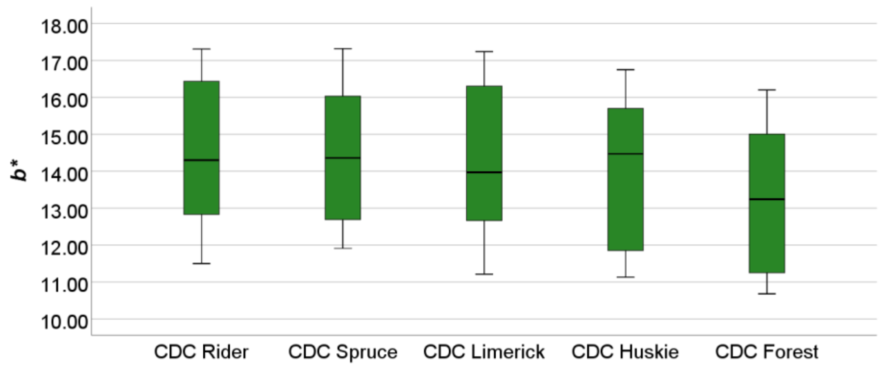
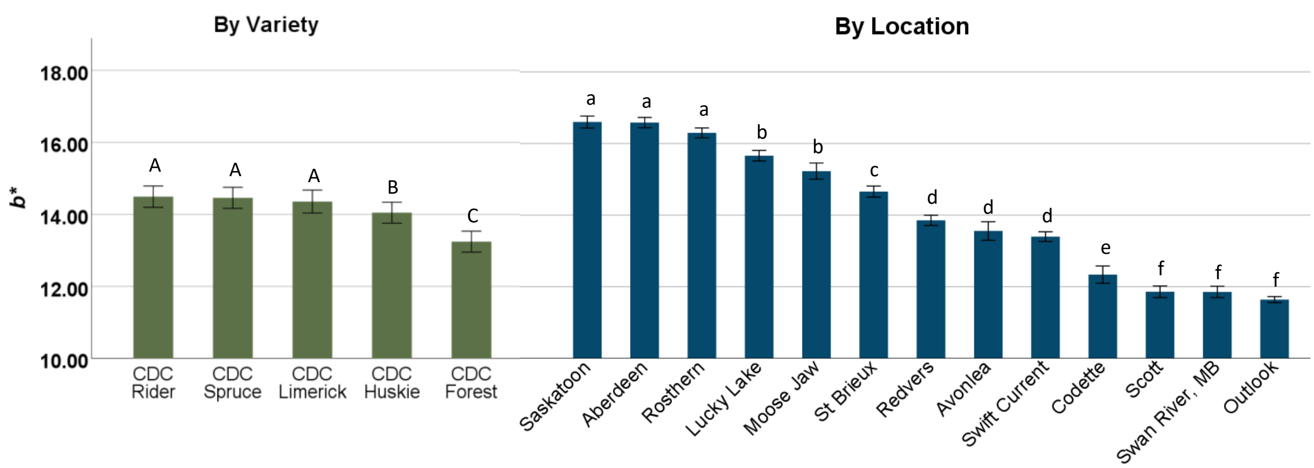
c) ***b*:*** yellow (+) to blue (-)

Results: Figure 1.8.6. Box and Whisker plot of green peas for *b** values resulting from 13 locations.



High variability was observed in all varieties.

Figure 1.8.7. Mean *b** value of green peas by variety (left) and by location (right). Each bar represents mean ± one standard error.



Note: Capital letters indicated significant differences (p<0.05) by variety. Small letters indicated significant differences (p<0.05) by location.

- **By Variety:** CDC Forest had the lowest *b** value.
- **By Location:** The *b** values varied between locations, where the *b** values of the highest three locations (Saskatoon, Aberdeen, and Rosthern) were 5 units higher than Outlook, Swan River, and Scott (lowest).

Table 1.8.3. Effects of variety and location.

	Sig.
Variety	***
Location	***
Variety x Location	***

Note: ***p<0.001; ***p<0.01; *p<0.05; NS not significant.*

9. Hausner Ratio

Hausner ratio measures the ratio of tapped density to loose bulk density, indicating the flow-ability and the compressibility of the flour after milling. Hausner ratio is an important parameter in food products handling, packaging, storage, processing, and distribution. It is useful in the specification of products derived from size reduction or drying processes. Usually, the lower the flow-ability a flour, the more compressible it becomes[4].

Method: The bulk and tapped volumes of 10 g of flour were determined using a 25 mL graduated cylinder. Duplicated measurements were made for each flour, and the Hausner ratio is calculated as:

Hausner ratio = $\frac{Tapped\ density}{Loose\ bulk\ density} = \frac{Bulk\ volume\ (mL)}{Tapped\ volume\ (mL)}$

Table 9. Relationship between powder flow-ability and Hausner ratio.

Type of flow	Hausner ratio
Excellent	1.00-1.11
Good	1.12-1.18
Fair	1.19-1.25
Passable	1.26-1.34
Poor	1.35-1.45
Very poor	1.46-1.59
Very, very poor	>1.59

[4] Buanz, A. (2021). Powder characterization. In *Remington* (pp. 295-305). Academic Press. https://doi.org/10.1016/B978-0-12-820007-0.00016-7

Amankwah, N. Y. A., Agbenorhevi, J. K., & Rockson, M. A. (2022). Physicochemical and functional properties of wheat-rain tree (Samanea saman) pod composite flours. *International Journal of Food Properties*, *25*(1), 1317-1327. https://doi.org/10.1080/10942912.2022.2077367

Aulton, M. E., & Taylor, K. M. G. (2013). *Powder flow* (pp. 189-200). Edinburgh, Scotland: Churchill Livingstone (Elsevier).

Maninder, K., Sandhu, K. S., & Singh, N. (2007). Comparative study of the functional, thermal and pasting properties of flours from different field pea (Pisum sativum L.) and pigeon pea (Cajanus cajan L.) cultivars. *Food chemistry*, *104*(1), 259-267. https://doi.org/10.1016/j.foodchem.2006.11.037

Ogunsina, B. S., Radha, C., & Govardhan Singh, R. S. (2010). *Physicochemical and functional properties of full-fat and defatted Moringa oleifera kernel flour. International Journal of Food Science & Technology, 45(11), 2433–2439.* https://doi.org/10.1111/j.1365-2621.2010.02423.x

Results: Figure 1.9.1. Box and Whisker plot of green peas for Hausner ratio resulting from 13 locations.

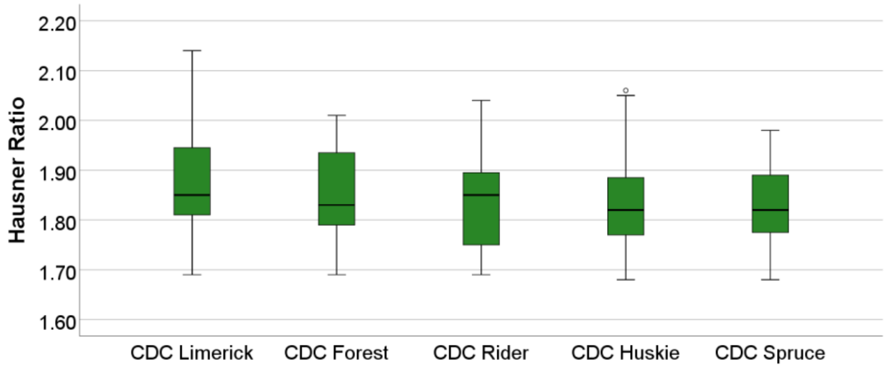
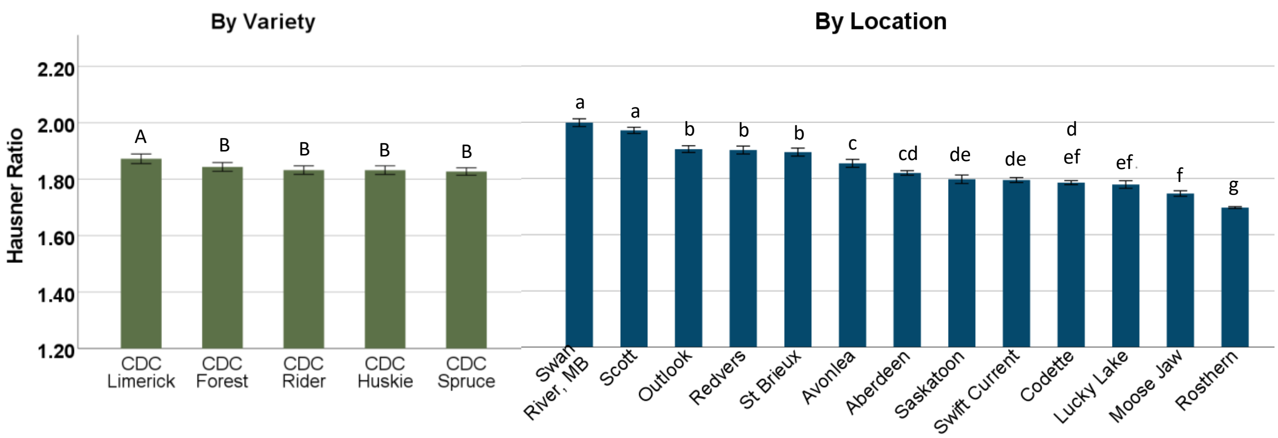


Figure 1.9.2. Mean Hausner ratio of green peas by variety (left) and by location (right). Each bar represents mean ± one standard error.



Note: Capital letters indicated significant differences (p<0.05) by variety. Small letters indicated significant differences (p<0.05) by location.

- The results of Hausner ratio from five varieties and 13 locations were all greater than 1.6, suggesting all green pea flours are classified as very, very poor flow.

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10. Particle Size

Method: The particle size of each flour was measured using the Mastersizer 3000 with a dry sample cell (Malvern Instruments Ltd., Worcestershire, UK). Five measurements were made for each flour, and the average values of D_{90} (µm) and $D_{4,3}$ (µm) were reported.

- **D_{90} (µm):** describes the diameter where 90% of the flour distribution has a smaller particle size and indicates whether the milling process reached the expected fineness.

- **$D_{4,3}$ (µm):** describes the mean diameter over volume.

Results: Figure 1.10.1. Box and Whisker plot of green peas for D_{90} (µm, left) and $D_{4,3}$ (µm, right) resulting from 13 locations.

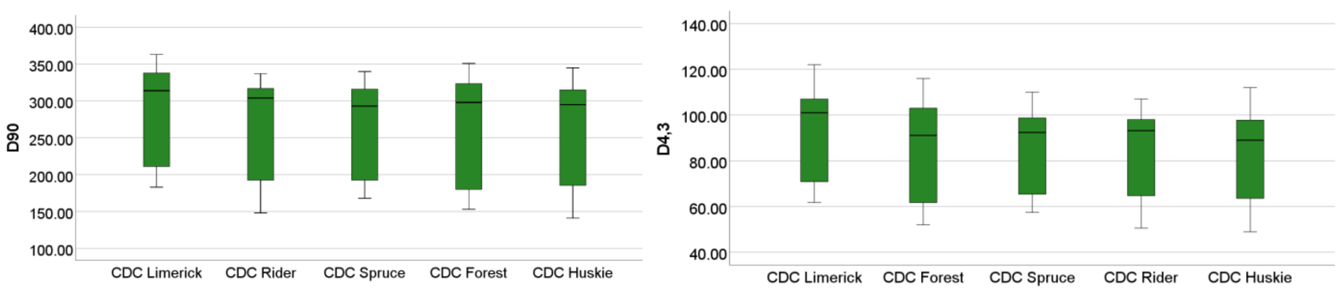
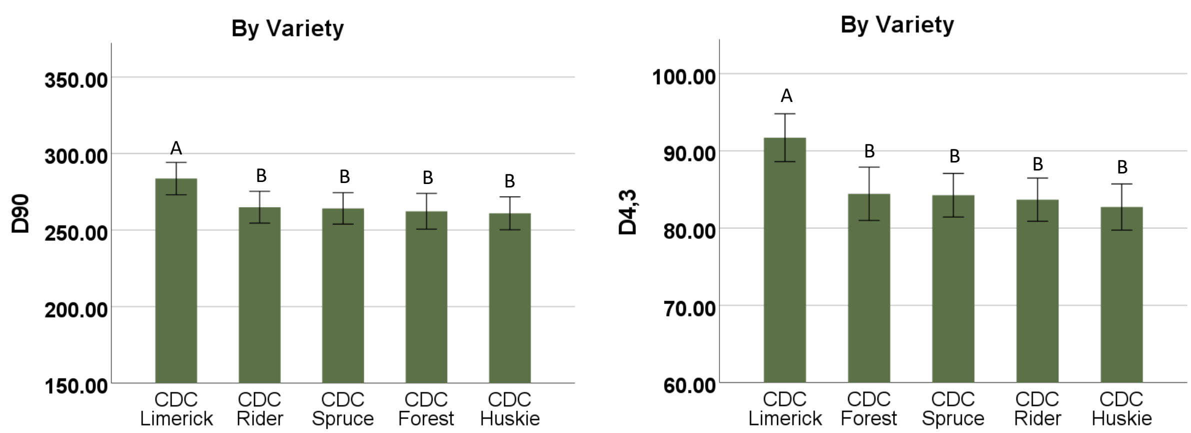


Figure 1.10.2. D_{90} (µm, left) and $D_{4,3}$ (µm, right) of green pea flours by variety. Each bar represents mean ± one standard error.



Note: Capital letters indicated significant differences ($p<0.05$) by variety.

- **D_{90}:** all flours were below 300 µm.
- **$D_{4,3}$:** The mean diameters of all flours were below 92 µm.

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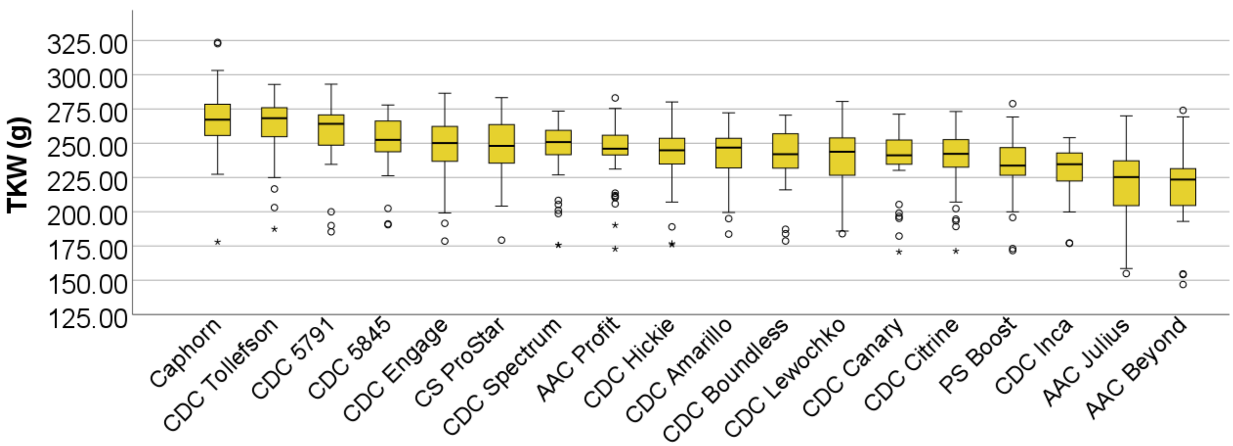
2) 2022 Yellow Pea Quality

1. 1000 Seed Weight

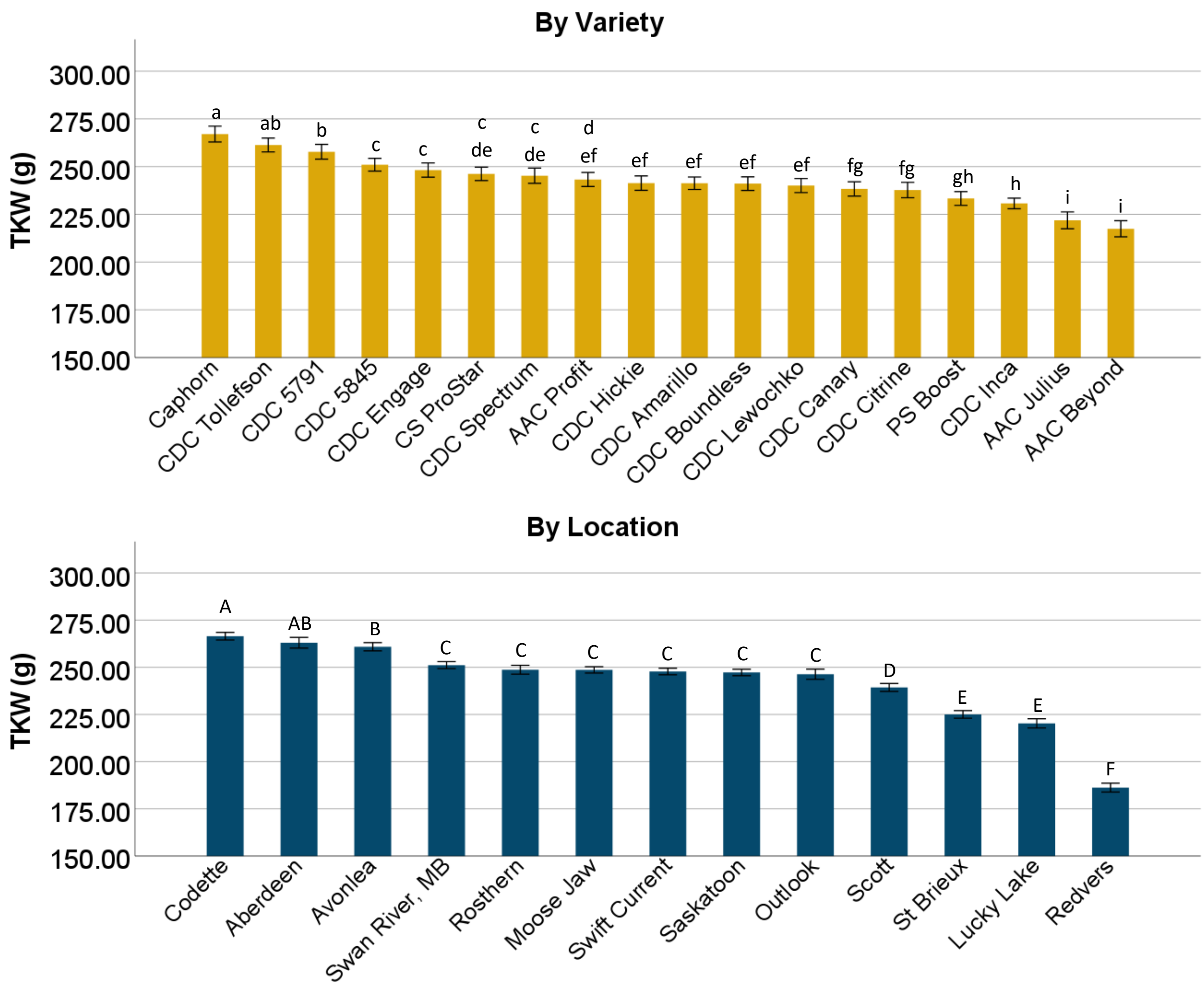
Method: This test was conducted by weighing 300 seeds with duplicated measurements per sample, and the 1000 seed weight (TKW) was reported.

Results: Figure 2.1.1. Box and Whisker plot of yellow peas for TKW resulting from 13 locations.



- Caphorn had the largest TKW, followed by CDC Tollefson.
- AAC Beyond and AAC Julius had the smallest TKW.

Figure 2.1.2. Mean TKW of yellow peas by variety (top) and by location (botton). Each bar represents mean ± one standard error.



Note: Small letters indicated significant differences (p<0.05) by variety. Capital letters indicated significant differences (p<0.05) by location.

- **By Variety:** A difference of 50 g was determined from the largest (Carphorn) to the smallest (AAC Beyond).

- **By Location:** Except for the three higher locations and the lower three locations, the means of the remaining seven locations are close to 250 g.

Table 2.1. Effects of variety and location.

	Sig.
Variety	***
Location	***
Variety x Location	***

Note: ***p<0.001; ***p<0.01; *p<0.05; NS not significant.*

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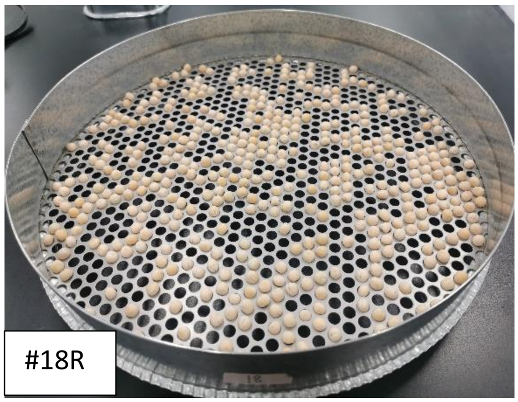
2. Seed Size Distribution

Method: 250 g of seeds were placed on a series of round-hole opening sieves. The weight of seeds retained on each sieve was determined and reported as % of seeds retained. Duplicated measurements were performed.

Sieves used for yellow pea varieties:

a. #20R: 7.94 mm
b. #18R: 7.14 mm
c. #16R: 6.35 mm
d. #14R: 5.56 mm


#18R

Results: Table 2.2. Seed size distribution (%) of each yellow pea variety. Data represent mean ± one standard deviation.

Variety	> # 20R (%)	> # 18R (%)	> # 16R (%)	> # 14R (%)	Below # 14R (%)
Caphorn	8.8 ± 10.5^{a}	54.6 ± 15.7^{a}	31.7 ± 14.5^{j}	3.6 ± 5.3^{i}	0.6 ± 0.9^{de}
CDC Tollefson	3.5 ± 3.2^{b}	50.4 ± 16.9^{b}	41.2 ± 13.7^{i}	4.4 ± 6.5^{hi}	0.5 ± 0.7^{e}
CDC 5791	2.8 ± 2.6^{bcd}	48.3 ± 17.9^{b}	43.3 ± 13.9^{i}	5.0 ± 7.6^{ghi}	0.5 ± 0.9^{de}
CDC 5845	2.5 ± 2.2^{cd}	42.6 ± 15.0^{c}	48.8 ± 11.5^{h}	5.6 ± 7.1^{fghi}	0.6 ± 0.8^{de}
CDC Engage	2.1 ± 3.0^{de}	35.4 ± 16.4^{de}	55.7 ± 14.8^{fg}	6.3 ± 7.8^{efgh}	0.6 ± 0.8^{de}
CS ProStar	3.1 ± 5.0^{bc}	38.7 ± 15.9^{d}	50.3 ± 13.2^{h}	7.0 ± 8.2^{defg}	0.8 ± 1.1^{cde}
CDC Spectrum	1.0 ± 1.3^{fgh}	30.3 ± 13.9^{gh}	58.8 ± 10.0^{def}	9.0 ± 11.8^{cd}	0.9 ± 1.6^{bcd}
AAC Profit	0.3 ± 0.6^{h}	24.9 ± 17.2^{h}	64.6 ± 13.6^{ab}	9.5 ± 12.1^{bc}	0.7 ± 1.1^{cde}
CDC Hickie	1.3 ± 1.0^{efg}	35.9 ± 16.8^{de}	54.0 ± 12.2^{g}	8.0 ± 9.6^{cde}	0.8 ± 1.2^{cde}
CDC Amarillo	1.0 ± 1.0^{fgh}	32.9 ± 16.6^{ef}	58.1 ± 12.4^{ef}	7.4 ± 8.4^{cdef}	0.6 ± 0.8^{de}
CDC Boundless	0.8 ± 1.2^{fgh}	27.9 ± 14.7^{gh}	62.3 ± 11.7^{bcd}	8.3 ± 8.9^{cde}	0.7 ± 1.0^{cde}
CDC Lewochko	1.6 ± 2.6^{ef}	30.2 ± 14.5^{fg}	58.0 ± 11.8^{ef}	9.3 ± 10.7^{c}	0.8 ± 1.1^{cde}
CDC Canary	1.4 ± 2.1^{efg}	28.4 ± 14.5^{gh}	59.6 ± 11.6^{cdef}	9.8 ± 11.3^{bc}	0.8 ± 1.2^{cde}
CDC Citrine	0.7 ± 1.5^{gh}	24.9 ± 16.4^{h}	62.1 ± 12.3^{bcde}	11.7 ± 13.9^{b}	0.7 ± 1.0^{cde}
PS Boost	2.0 ± 4.1^{de}	28.0 ± 13.2^{gh}	59.2 ± 13.0^{cdef}	9.7 ± 10.0^{bc}	1.1 ± 1.6^{abc}
CDC Inca	0.8 ± 1.2^{fgh}	20.7 ± 9.1^{i}	67.9 ± 8.9^{a}	9.8 ± 9.5^{bc}	0.8 ± 1.2^{cde}
AAC Julius	1.5 ± 3.8^{ef}	18.0 ± 15.8^{i}	62.9 ± 19.0^{bc}	16.3 ± 17.6^{a}	1.3 ± 2.2^{ab}
AAC Beyond	1.2 ± 3.3^{fgh}	13.5 ± 13.7^{j}	66.9 ± 19.5^{a}	17.1 ± 17.8^{a}	1.4 ± 2.2^{a}

Note: Means within a column followed by different lowercase letters are significantly different ($p<0.05$).

- The majority of yellow peas had a seed size between 6.4 mm to 7.9 mm.
- Caphorn had the largest TKW and the most seeds retained on the #20 and #18 sieves.
- In contrast, AAC Beyond had the lowest TKW and had the fewest seeds retained on the #20 and #18 sieves but more on the #16 and #14 sieves.

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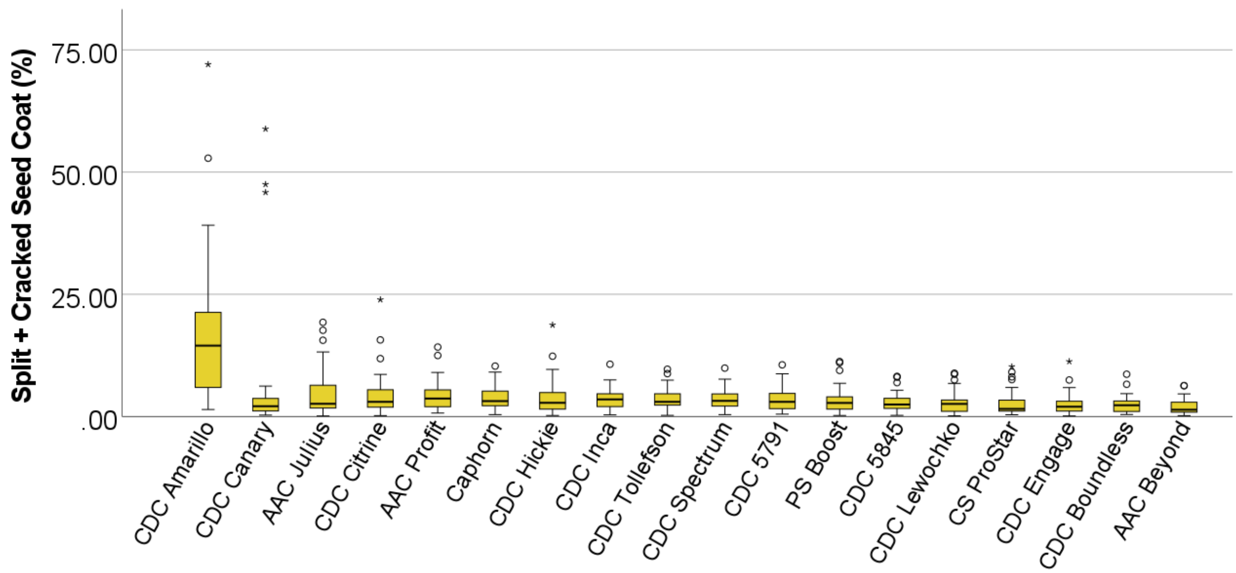
3. Split + Cracked Seed Coat

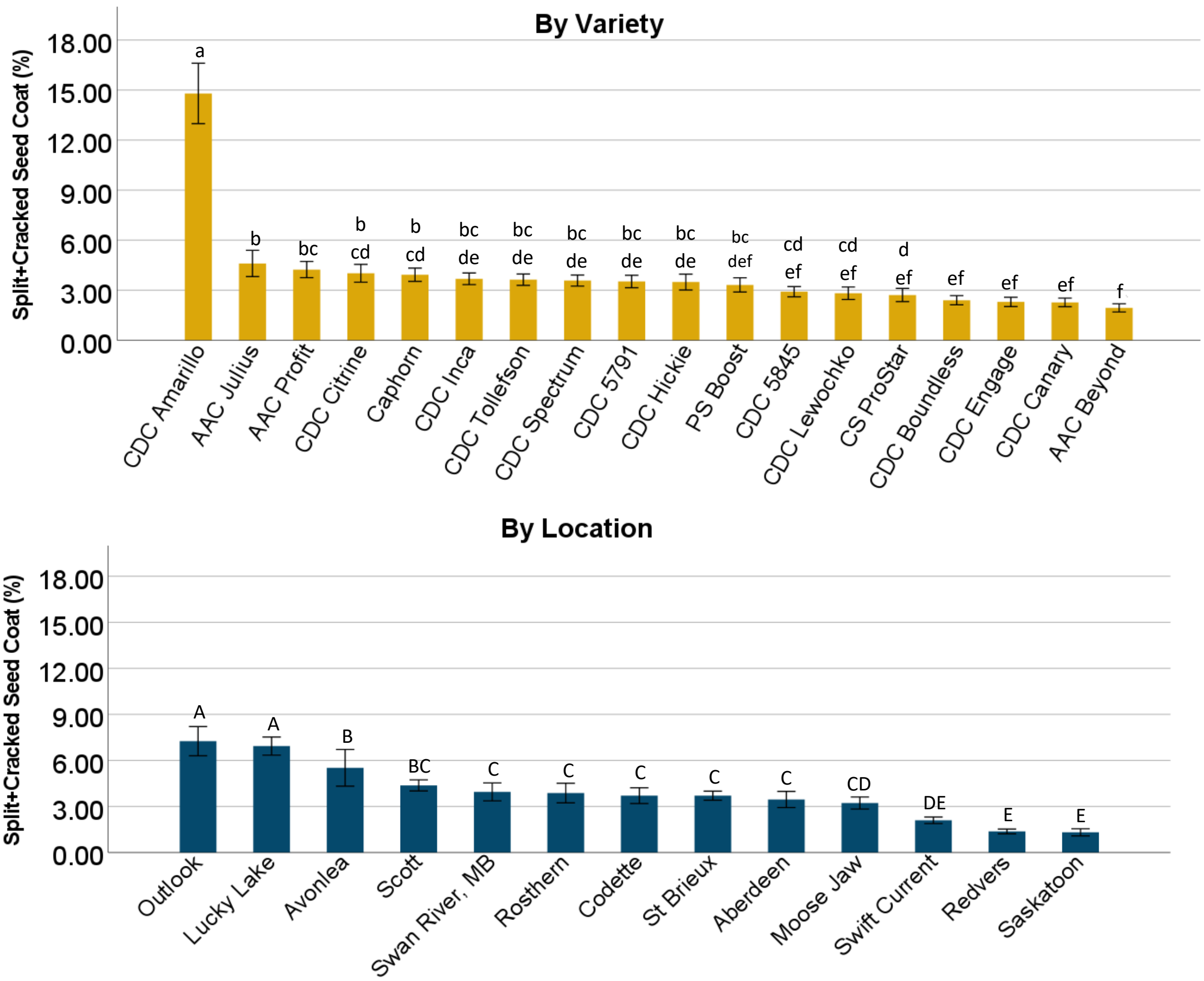
Method: 100 grams of each sample was used for evaluation, and damaged seeds were selected by hand. Results included splits, cracks, seed coat damage, partially missing hull, and partially missing cotyledon.

Results: Figure 2.3.1. Box and Whisker plot of yellow peas for the split amount resulting from 13 locations.



- CDC Amarillo was the most susceptible to seed coat breakage. Large variability was observed with some extreme outliers.

Figure 2.3.2. Mean split (%) of yellow peas by variety (top) and by location (bottom). Each bar represents mean ± one standard error.



Note: 1) Small letters indicated significant differences (p<0.05) by variety. Capital letters indicated significant differences (p<0.05) by location. 2) Results for CDC Amarillo and CDC Canary from Avonlea were extreme outliers (Figure 3.1) and were not reported.

- **By Variety:** The amount of split + cracked seed coat for CDC Amarillo was 14.8%. All other varieties were below 5%, with AAC Beyond below 2%.

- **By Location:** The location effect also played a role in yellow peas. The means split + cracked seed coat for Outlook, Lucky Lake, and Avonlea seeds were above 5%.

Table 2.3. Effects of variety and location.

	Sig.
Variety	***
Location	***
Variety x Location	***

Note: ***p<0.001; ***p<0.01; *p<0.05; NS not significant.*

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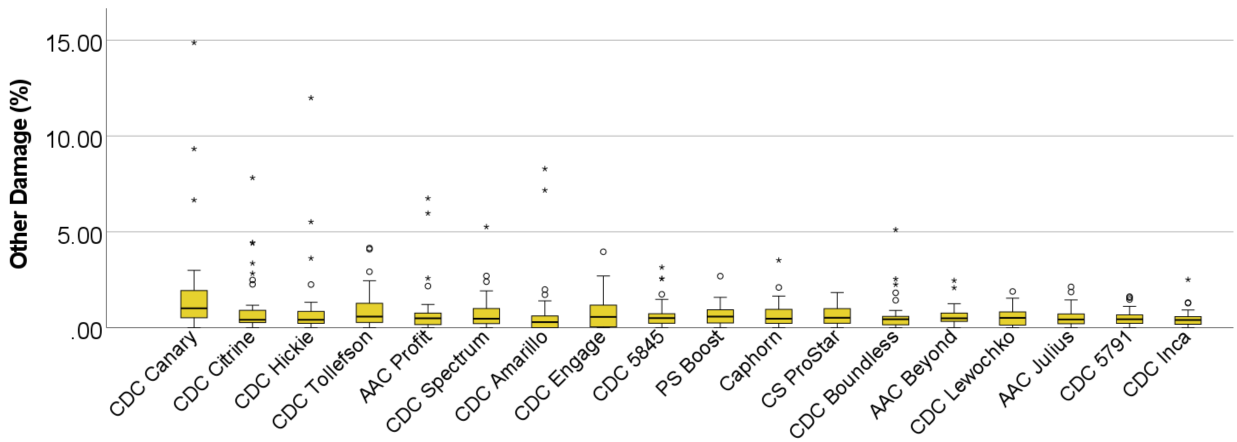
4. Other Damage

Method: 100 grams of each sample was used for evaluation, and damaged seeds were selected by hand. Other damage included pink, sprouted, shrivelled, heated, frost, and insect damage.

Results: Figure 2.4.1. Box and Whisker plot of yellow peas for other damage resulting from 13 locations.



- Overall, a low level of other damage was observed in all varieties, but some extreme outliers were observed.

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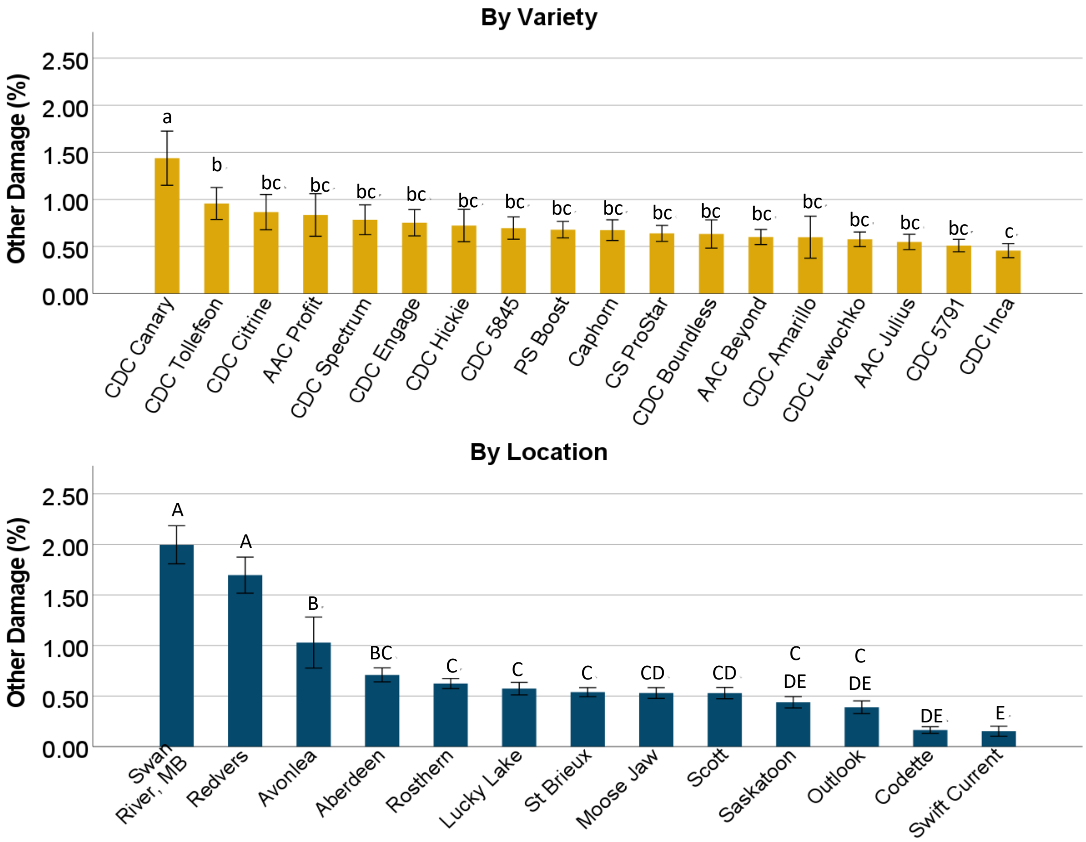
Figure 2.4.2. Mean other damage (%) of yellow peas by variety (top) and by location (bottom). Each bar represents mean ± one standard error.



Note: Small letters indicated significant differences (p<0.05) by variety. Capital letters indicated significant differences (p<0.05) by location.

- **By Variety:** CDC Canary had a higher amount (p<0.05) of other damage at 1.4%, while other varieties had other damage below 1%.

- **By Location:** Some yellow varieties harvested from Redvers were infected by the bacteria *Erwinia Rhapontici* and had a pink appearance (Figure 4.3).

Table 2.4. Effects of variety and location.

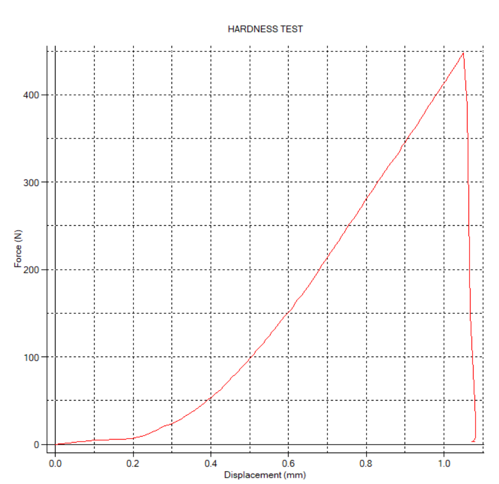
	Sig.
Variety	***
Location	***
Variety x Location	***

Note: ***p<0.001; ***p<0.01; *p<0.05; NS not significant.*

Figure 2.4.3. Infected seeds with pink appearance (CDC Amarillo from Redvers).

5. Hardness of Whole Seed

Seed hardness is an important parameter to indicate milling yield and cooking quality. Seed hardness is affected by seed size, shape, density, composition, etc.

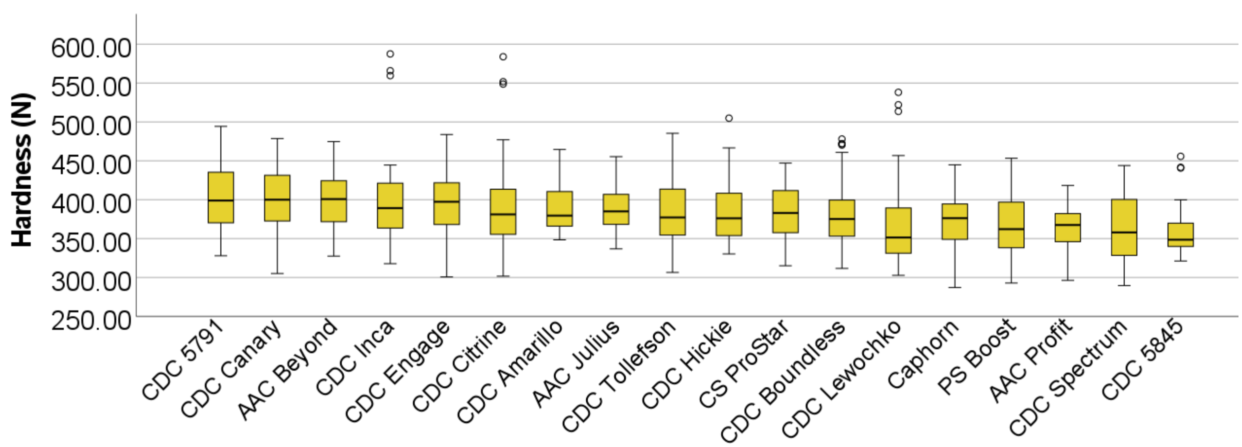


Method:

Seed hardness was determined by measuring the force of breaking a seed using a texture analyzer (TMS-Pro, Food Technology Corporation, USA) equipped with a 2500 N load cell with a modified method from Karami et al. (2017) and Lovas-Kiss (2020)[5].

In brief, a seed was placed under the 10 mm cylinder probe that was lowered with a speed of 50 mm/min. The forces to lower the probe till a seed was broken were monitored. The mean peak force (N) of 10 seeds was reported.

Results: Figure 2.5.1. Box and Whisker plot of yellow pea hardness resulting from 13 locations.

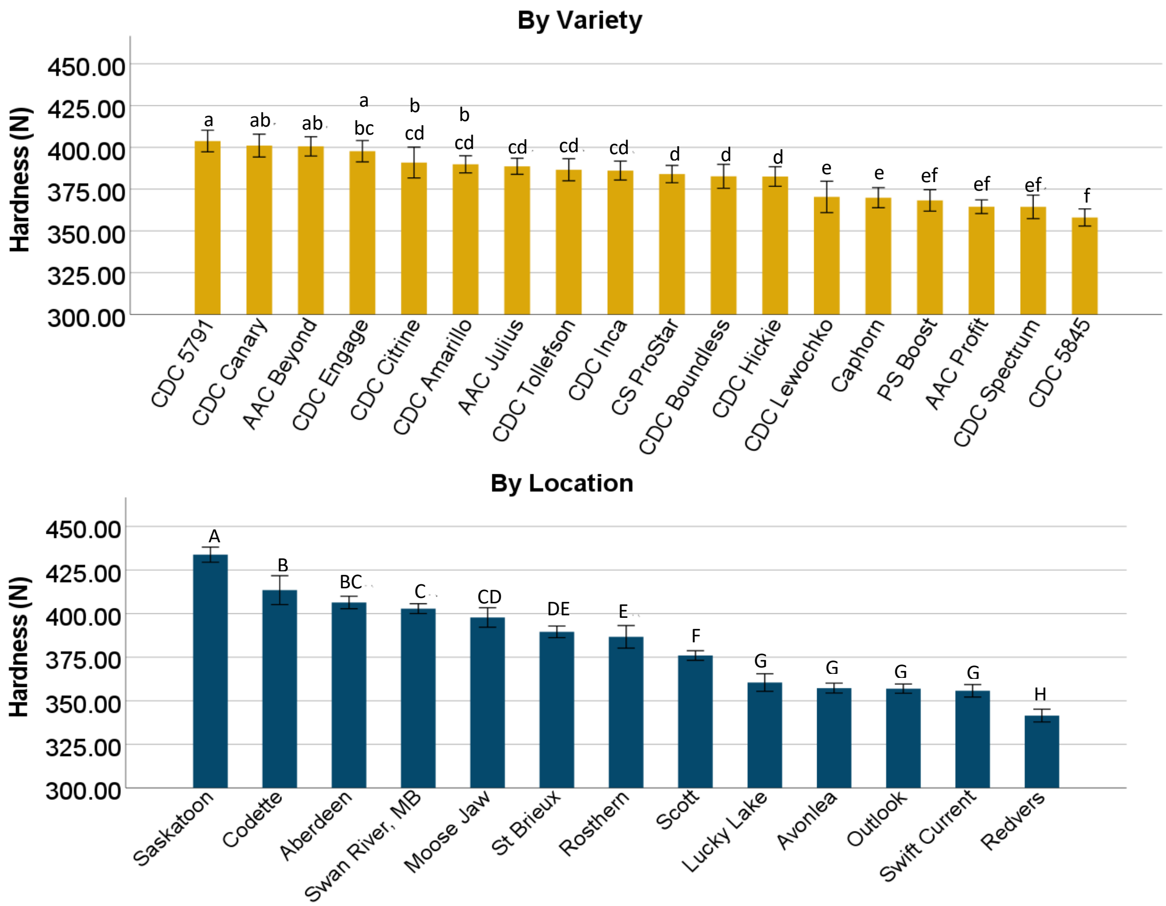


- The median hardness of each variety ranged from 350 N to 400 N.

[5] Karami, S., Sabzalian, M. R., Rahimmalek, M., Saeidi, G., & Ghasemi, S. (2017). Interaction of seed coat color and seed hardness: An effective relationship which can be exploited to enhance resistance to the safflower fly (Acanthiophilus helianthi) in Carthamus spp. Crop Protection, 98, 267-275.

Lovas‐Kiss, Á., Vincze, O., Kleyheeg, E., Sramkó, G., Laczkó, L., Fekete, R., ... & Green, A. J. (2020). Seed mass, hardness, and phylogeny explain the potential for endozoochory by granivorous waterbirds. Ecology and Evolution, 10(3), 1413-1424.

Figure 2.5.2. Mean hardness (N) of yellow peas by variety (top) and by location (bottom). Each bar represents mean ± one standard error.



Note: Small letters indicated significant differences (p<0.05) by variety. Capital letters indicated significant differences (p<0.05) by location.

By Variety:

- Mean hardness varied between varieties, where a 45 N difference was found from the highest (CDC 5791) to the lowest (CDC 5845).
- A positive trend between yellow pea hardness and the seed weight was observed (r=0.249, p<0.01).

By Location:

- Location also impacted the hardness of yellow peas. A high mean hardness of 434 N was observed for Saskatoon peas, while seed hardness was below 360 N for Lucky Lake, Avonlea, Outlook, Swift Current, and Redvers.

Table 2.5. Effects of variety and location.

	Sig.
Variety	***
Location	***
Variety x Location	***

Note: ***p<0.001; ***p<0.01; *p<0.05; NS not significant.*

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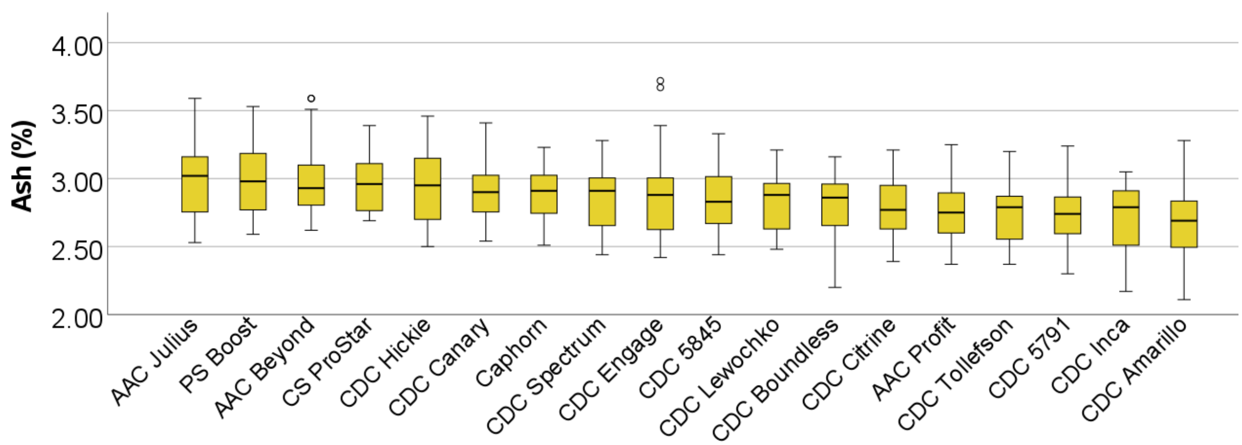
6. Ash Content

Method: Ash content (%) was determined using AACC 08-01.01[6] with modification. Samples were heated at 560°C till they turned white. Duplicated measurements were performed for each sample, and the average was reported on a dry basis (d.b.).

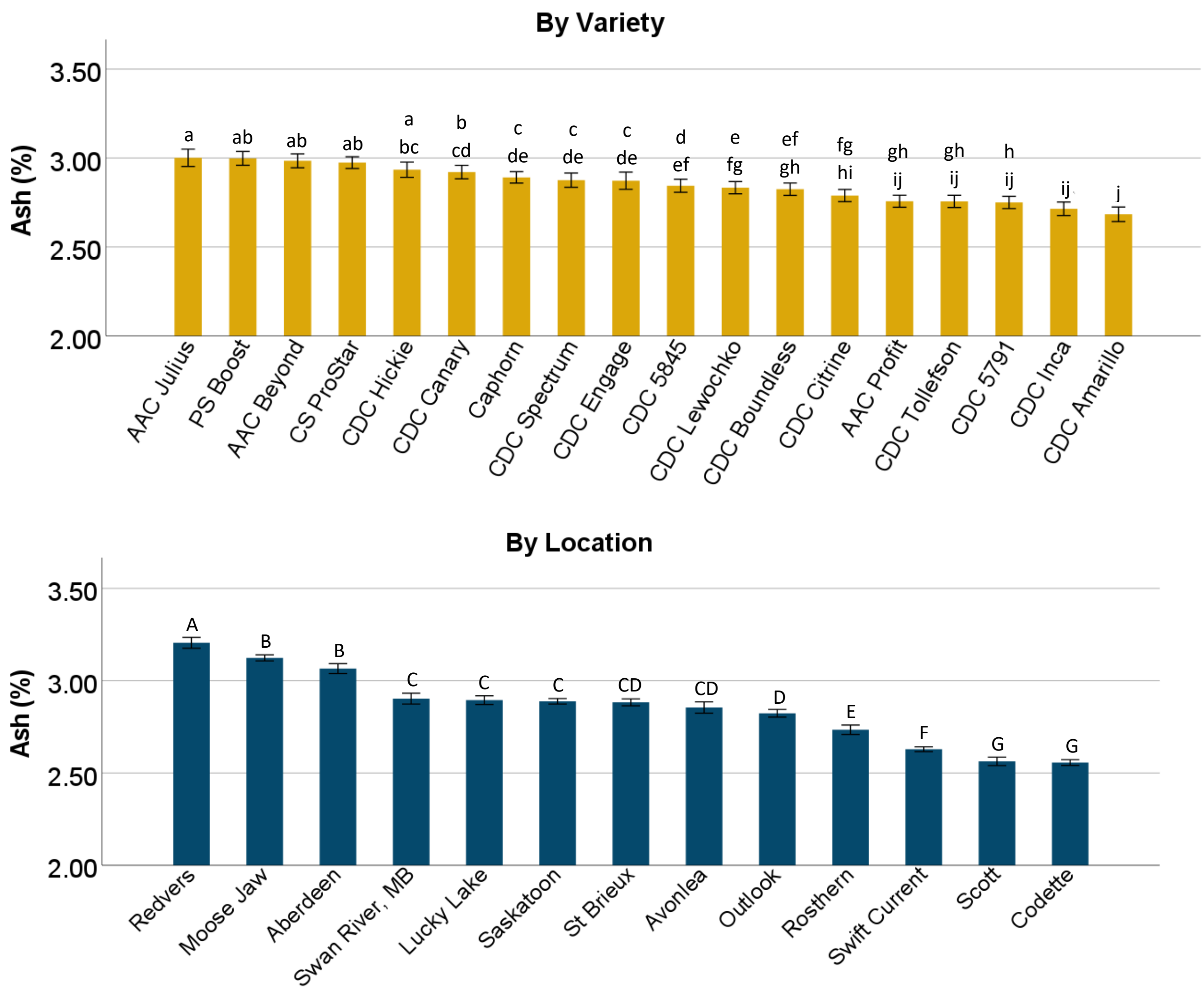
Results: Figure 2.6.1. Box and Whisker plot of yellow peas for ash content resulting from 13 location.



- CDC Amarillo and CDC Inca had lower ash contents.

[6] AACC (1999). American Association of Cereal Chemists International. Approved methods of analysis (11th ed.). The Saint Pauls Association: Saint Paul, MN.

Figure 2.6.2. Mean ash content (%) of yellow peas by variety (top) and by location (bottom). Each bar represents mean ± one standard error.



Note: Small letters indicated significant differences (p<0.05) by variety. Capital letters indicated significant differences (p<0.05) by location.

- **By Variety:** Means ranged from 2.7% to 3.0%.
- **By Location:** Ash contents were above 3% for Redvers, Moose Jaw, and Aberdeen. The lower three locations were around 2.6%.

Table 2.6. Effects of variety and location.

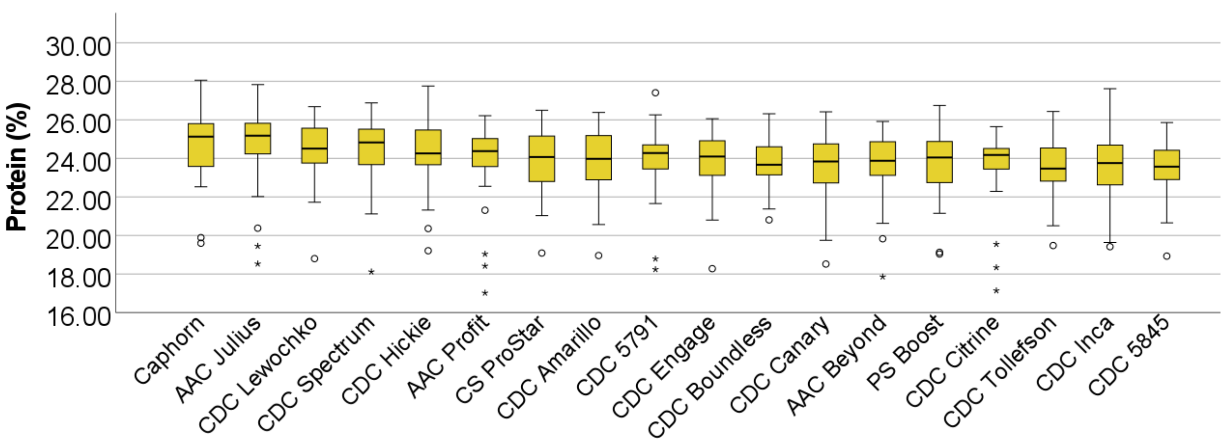
	Sig.
Variety	***
Location	***
Variety x Location	***

Note: ***p<0.001; ***p<0.01; *p<0.05; NS not significant.*

7. Protein Content

Method: The protein content (%) of each flour was determined through AACC 46-30[2] using the combustion method through a Rapid N Exceed (Elementar, USA). Duplicated measurements were performed for each sample, and the average was reported on a dry basis (d.b.).

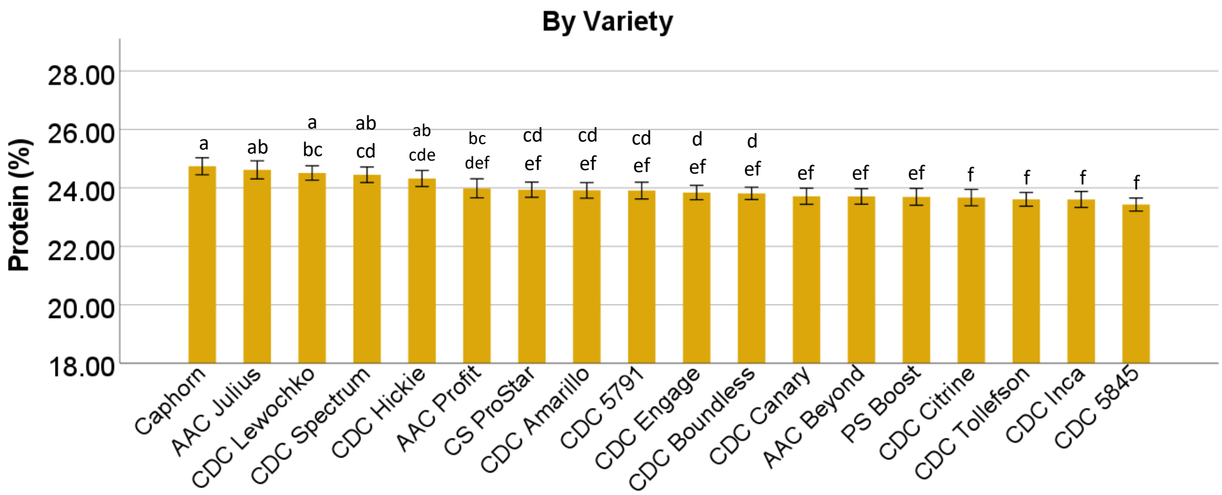
Results: Figure 2.7.1. Box and Whisker plot of yellow peas for protein content resulting from 13 locations.

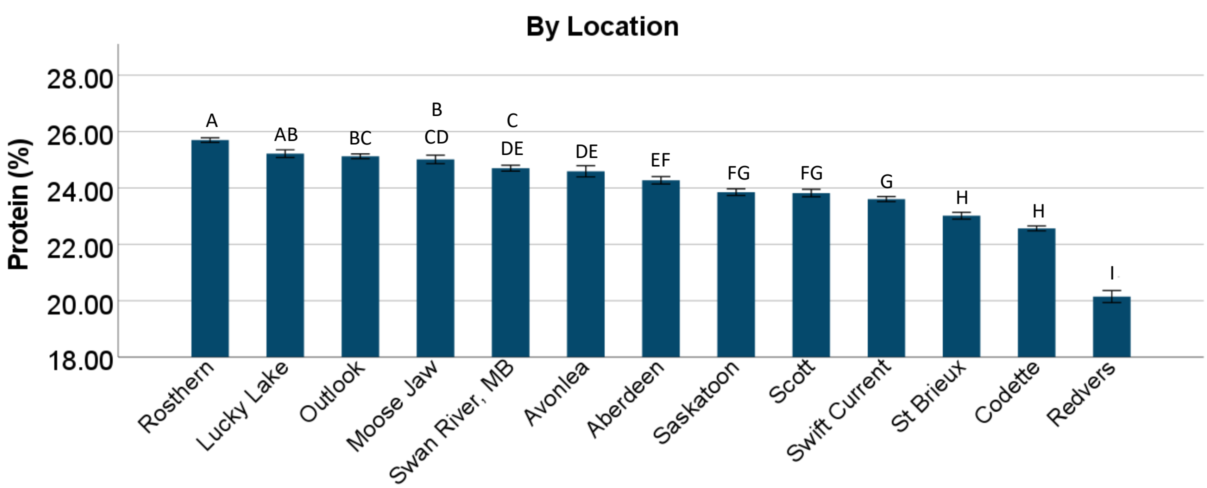


- The spread of the protein content for all varieties was similar. However, some lower outliers were observed.

[2] AACC (1999). American Association of Cereal Chemists International. Approved methods of analysis (11th ed.). The Saint Pauls Association: Saint Paul, MN.

Figure 2.7.2. Mean protein (%) of yellow peas by variety (top) and by location (bottom). Each bar represents mean ± one standard error.





Note: Small letters indicated significant differences (p<0.05) by variety. Capital letters indicated significant differences (p<0.05) by location.

- **By Variety:** Protein of Caphorn (highest) was only 1.3% higher than CDC 5845 (lowest).
- **By Location:** Protein of Redvers was 2.5% lower than Codette (second lowest) and 5.6% lower than Rosthern (highest). The inflection of the seeds (Figure 4.3, p. 28) from Redvers might cause the low protein content.

Table 2.7. Effects of variety and location.

	Sig.
Variety	***
Location	***
Variety x Location	***

Note: ***p<0.001; ***p<0.01; *p<0.05; NS not significant.*

8. Colour

Method: The absolute colour of each flour was determined using the Konica Minolta CR-400 Chroma meter, where *L*, a*,* and *b** values were reported.

- ***L* (lightness):*** white (100) to black (0)
- ***a*:*** red (+) to green (-)
- ***b*:*** yellow (+) to blue (-)

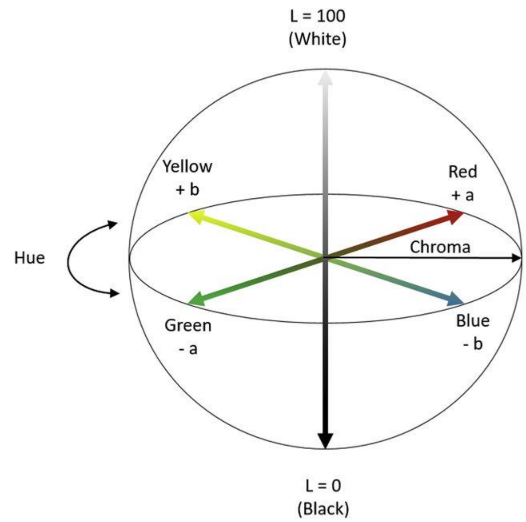
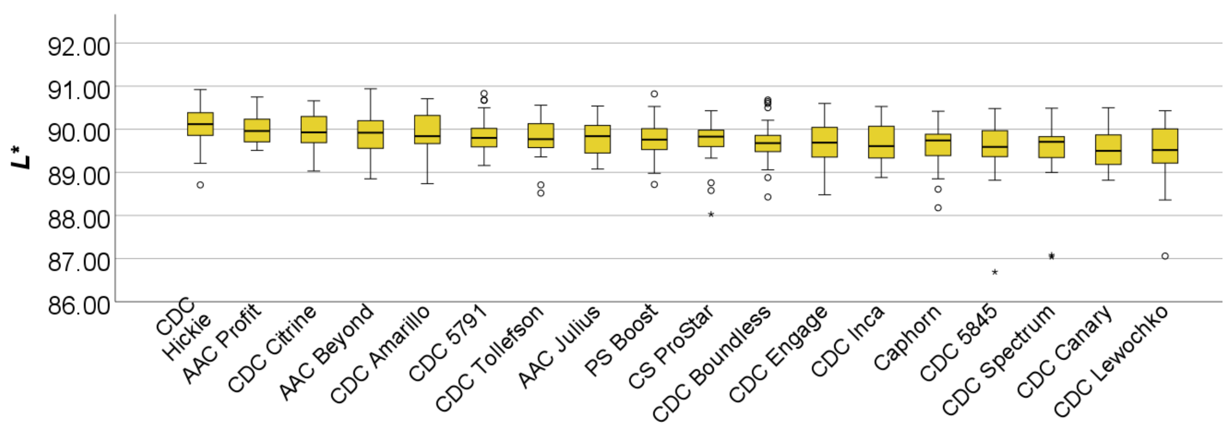


Figure 2.8.1. The CIELAB color spacediagram[7].

a) ***L* (lightness):*** white (100) to black (0)

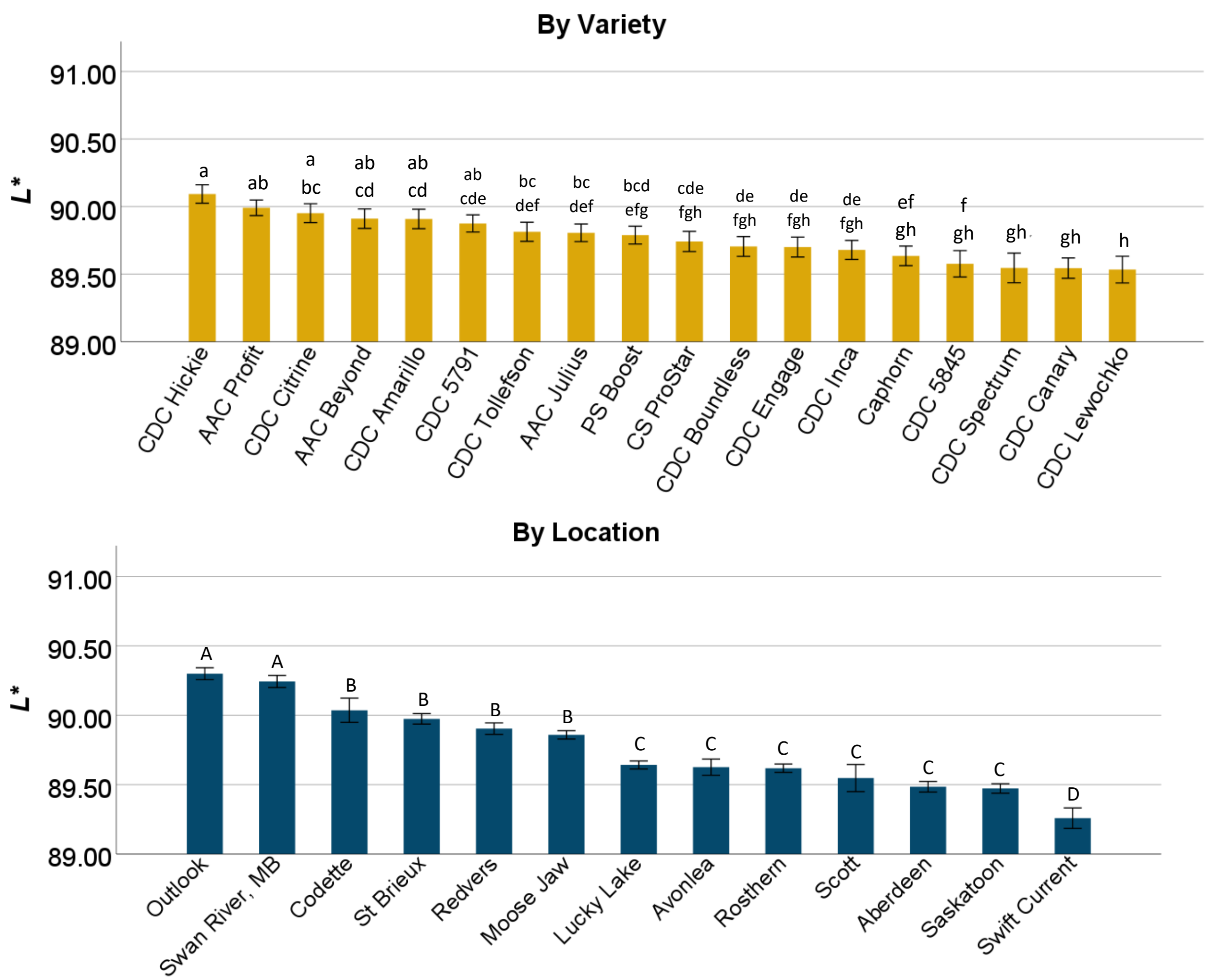
Results: Figure 2.8.2. Box and Whisker plot of yellow peas for *L** values resulting from 13 locations.



- Lightness for all yellow varieties was similar with small variability.

[7] Ly, B. C. K., Dyer, E. B., Feig, J. L., Chien, A. L., & Del Bino, S. (2020). Research techniques made simple: cutaneous colorimetry: a reliable technique for objective skin color measurement. *Journal of Investigative Dermatology*, *140*(1), 3-12.

Figure 2.8.3. Mean *L** value of yellow peas by variety (top) and by location (bottom). Each bar represents mean ± one standard error.



Note: Small letters indicated significant differences (p<0.05) by variety. Capital letters indicated significant differences (p<0.05) by location.

- **By Variety:** The mean difference of *L** values from highest to lowest was only 0.6 unit.
- **By Location:** The mean difference of *L** values from highest to lowest was 1 unit.

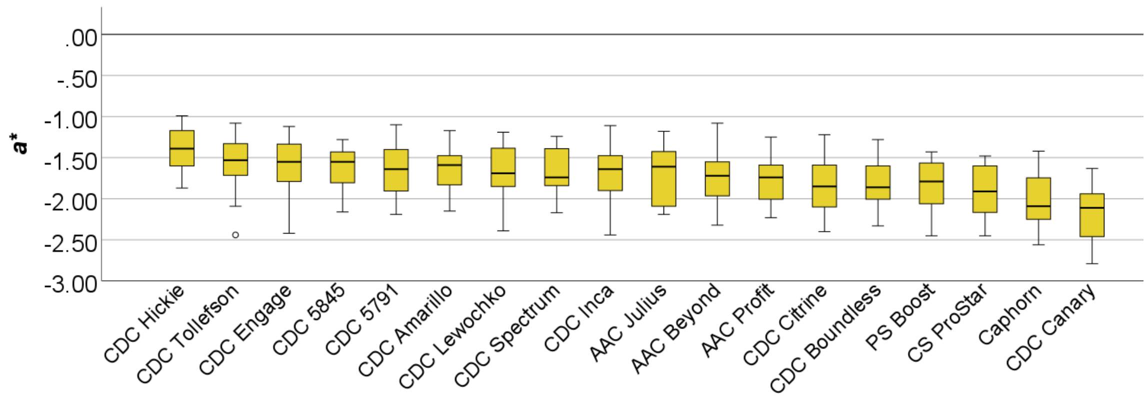
Table 2.8.1. Effects of variety and location.

	Sig.
Variety	***
Location	***
Variety x Location	***

Note: ***p<0.001; ***p<0.01; *p<0.05; NS not significant.*

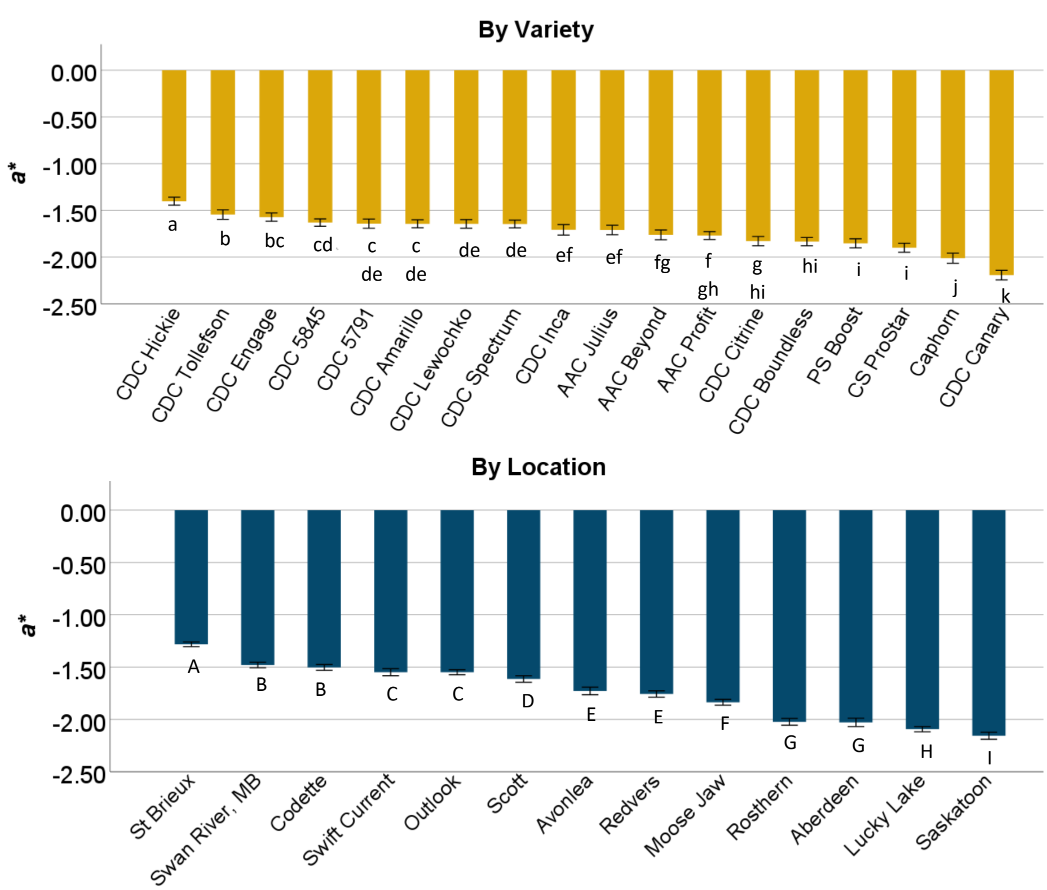
b) ***a*:*** red (+) to green (-)

Results: Figure 2.8.4. Box and Whisker plot of yellow peas for *a** values resulting from 13 locations.



- The *a** values of 18 varieties across 13 locations ranged from -3 to -1.

Figure 2.8.5. Mean *a** value of yellow peas by variety (top) and by location (bottom). Each bar represents mean ± one standard error.



Note: Small letters indicated significant differences (p<0.05) by variety. Capital letters indicated significant differences (p<0.05) by location.

- **By Variety:** Except for CDC Canary (most greenness, *a**=-2.2) and CDC Huckie (least greenness, *a**=-1.4), *a** values of all other varieties ranged from -1.5 to -2.

- **By Location:** Differences between locations were less than 1 unit.

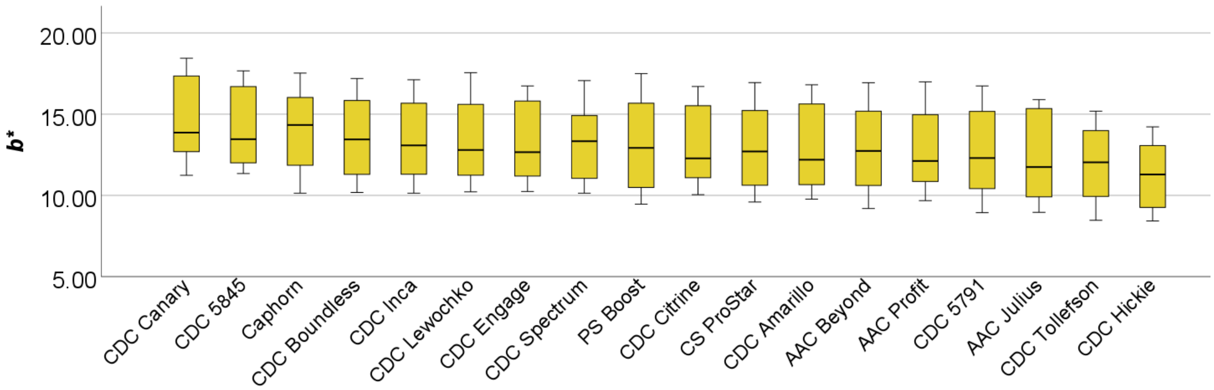
Table 2.8.2. Effects of variety and location.

	Sig.
Variety	***
Location	***
Variety x Location	***

Note: ***p<0.001; *****p<0.01; *p<0.05; NS not significant.*

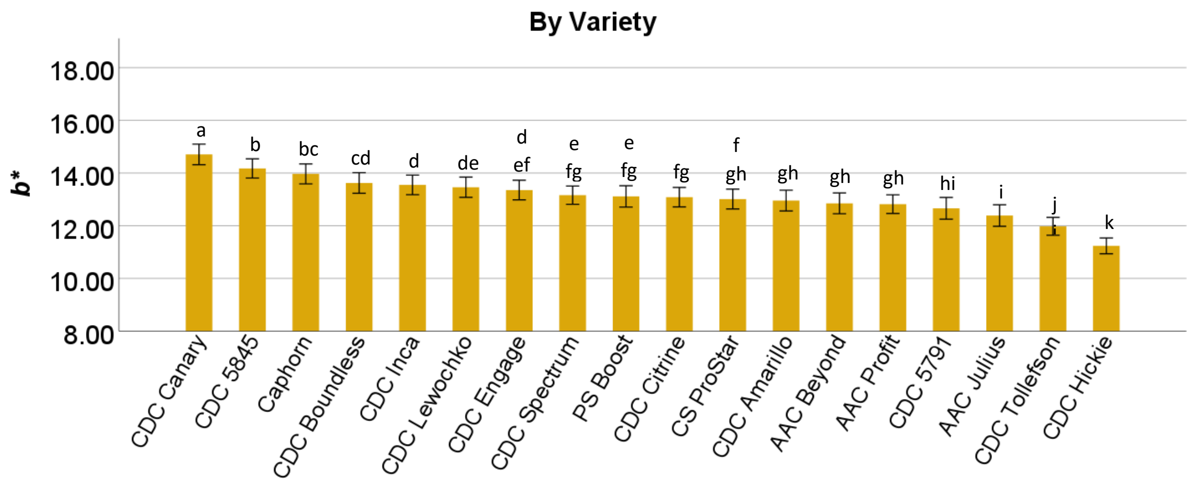
c) ***b*:*** yellow (+) to blue (-)

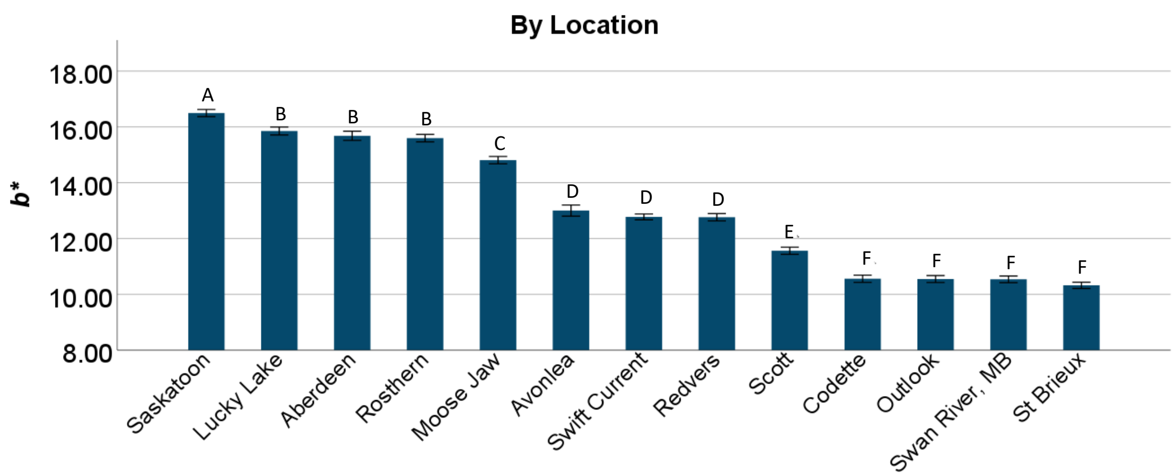
Results: Figure 2.8.6. Box and Whisker plot of yellow peas for *b** values resulting from 13 locations.



- High variability was observed in all varieties.

Figure 2.8.7. Mean *b** value of yellow peas by variety (top) and by location (bottom). Each bar represents mean ± one standard error.





Note: Small letters indicated significant differences (p<0.05) by variety. Capital letters indicated significant differences (p<0.05) by location.

- **By Variety:** Variety effect played a role in yellowness, where CDC Canary (highest) was 3.5 units higher than CDC Hickie (lowest).

- **By Location:** The *b** values varied between locations, where the *b** value of Saskatoon (highest) was 6 units higher than Codette, Outlook, Swan River, and St Brieux.

Table 2.8.3. Effects of variety and location.

	Sig.
Variety	***
Location	***
Variety x Location	***

Note: ***p<0.001; ***p<0.01; *p<0.05; NS not significant.*

9. Hausner Ratio

Hausner ratio measures the ratio of tapped density to loose bulk density, indicating the flow-ability and the compressibility of the flour after milling. Hausner ratio is an important parameter in food products handling, packaging, storage, processing, and distribution. It is useful in the specification of products derived from size reduction or drying processes. Usually, the lower the flow-ability a flour, the more compressible it becomes[8].

Method: The bulk and tapped volumes of 10 g of flour were determined using a 25 mL graduated cylinder. Duplicated measurements were made for each flour, and the Hausner ratio is calculated as:

Hausner ratio = $\frac{Tapped\ density}{Loose\ bulk\ density} = \frac{Bulk\ volume\ (mL)}{Tapped\ volume\ (mL)}$

Table 9. Relationship between powder flow-ability and Hausner ratio.

Type of flow	Hausner ratio
Excellent	1.00-1.11
Good	1.12-1.18
Fair	1.19-1.25
Passable	1.26-1.34
Poor	1.35-1.45
Very poor	1.46-1.59
Very, very poor	>1.59

[8] Buanz, A. (2021). Powder characterization. In *Remington* (pp. 295-305). Academic Press. https://doi.org/10.1016/B978-0-12-820007-0.00016-7

Amankwah, N. Y. A., Agbenorhevi, J. K., & Rockson, M. A. (2022). Physicochemical and functional properties of wheat-rain tree (Samanea saman) pod composite flours. *International Journal of Food Properties*, *25*(1), 1317-1327. https://doi.org/10.1080/10942912.2022.2077367

Aulton, M. E., & Taylor, K. M. G. (2013). *Powder flow* (pp. 189-200). Edinburgh, Scotland: Churchill Livingstone (Elsevier).

Maninder, K., Sandhu, K. S., & Singh, N. (2007). Comparative study of the functional, thermal and pasting properties of flours from different field pea (Pisum sativum L.) and pigeon pea (Cajanus cajan L.) cultivars. *Food chemistry*, *104*(1), 259-267. https://doi.org/10.1016/j.foodchem.2006.11.037

Ogunsina, B. S., Radha, C., & Govardhan Singh, R. S. (2010). *Physicochemical and functional properties of full-fat and defatted Moringa oleifera kernel flour. International Journal of Food Science & Technology, 45(11), 2433–2439.* https://doi.org/10.1111/j.1365-2621.2010.02423.x

Results: Figure 2.9.1. Box and Whisker plot of yellow peas for Hausner ratio resulting from 13 locations.

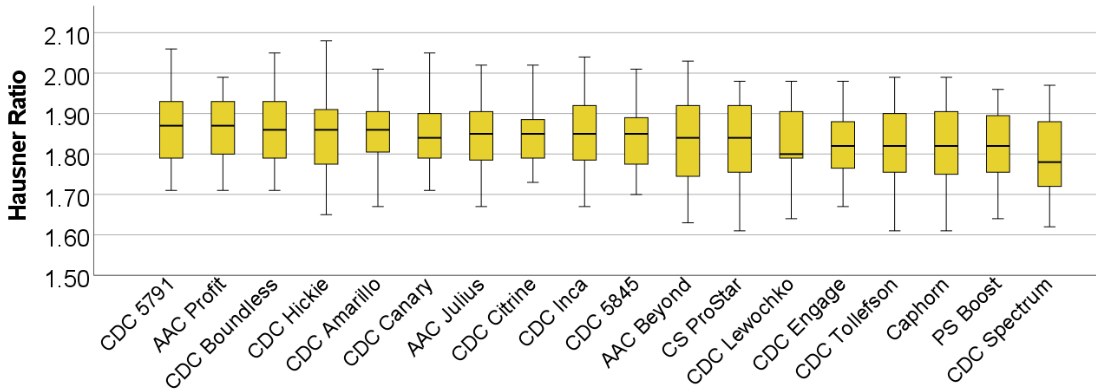
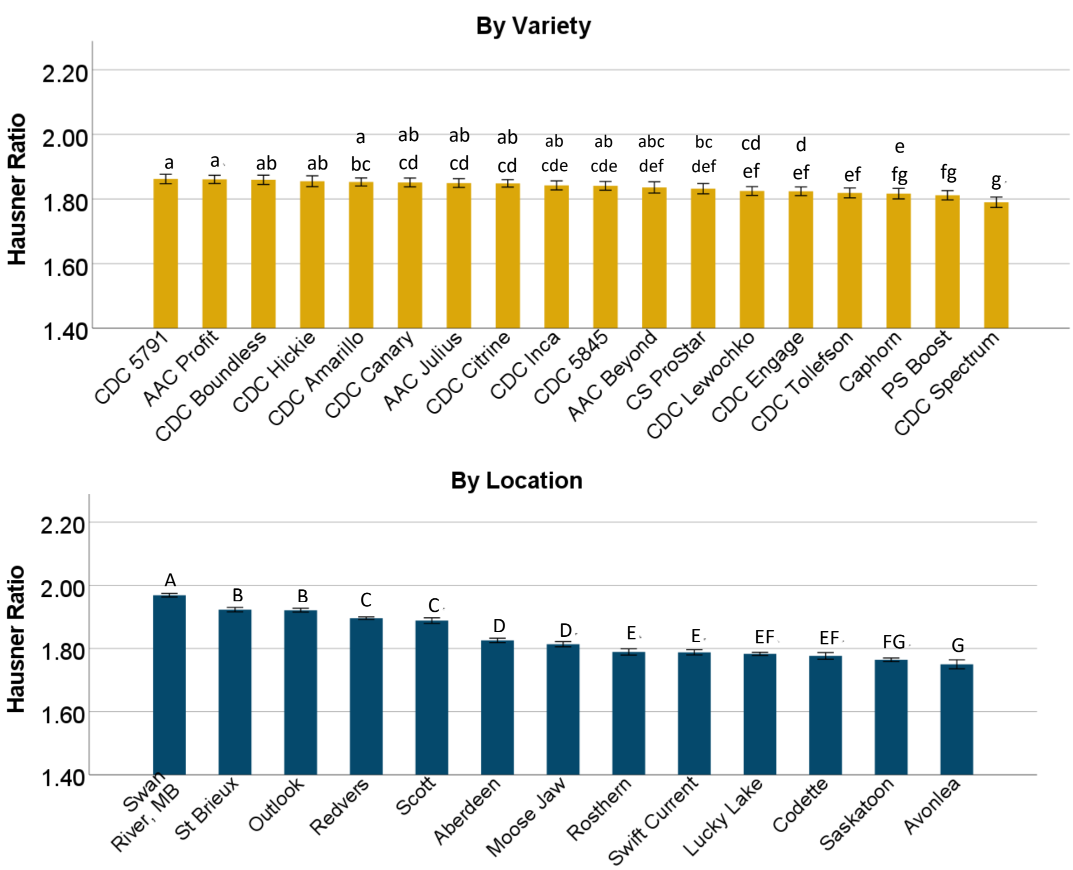


Figure 2.9.2. Mean Hausner ratio of yellow peas by variety (top) and by location (bottom). Each bar represents mean ± one standard error.



Note: Small letters indicated significant differences (p<0.05) by variety. Capital letters indicated significant differences (p<0.05) by location.

- The results of Hausner ratio for 18 varieties across 13 locations were all greater than 1.6, suggesting all yellow pea flours are classified as very, very poor flow.

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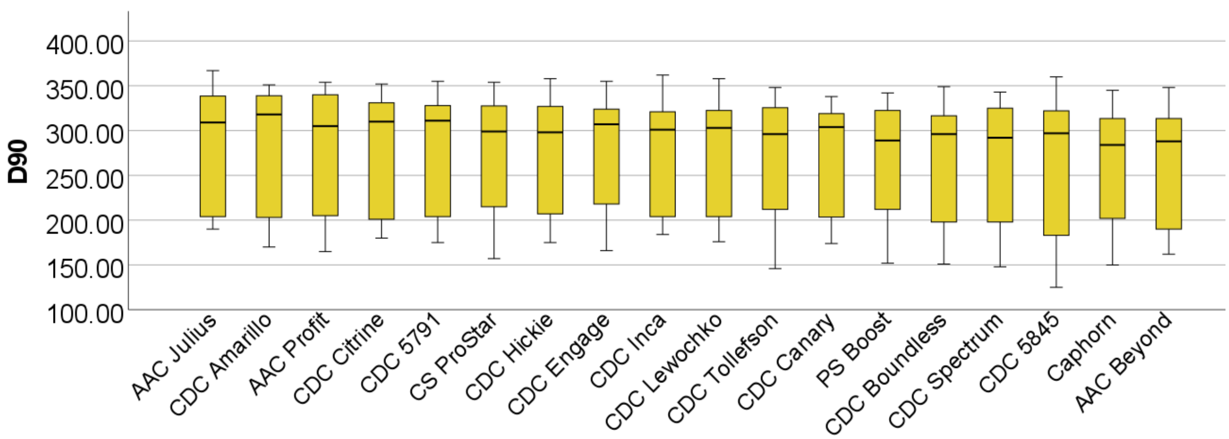
10. Particle Size

Method: The particle size of each flour was measured using the Mastersizer 3000 with a dry sample cell (Malvern Instruments Ltd., Worcestershire, UK). Five measurements were made for each flour, and the mean values of D_{90} (µm) and $D_{4,3}$ (µm) were reported.

- **D_{90} (µm):** describes the diameter where 90% of the flour distribution has a smaller particle size and indicates whether the milling process reached the expected fineness.

- **$D_{4,3}$ (µm):** describes the mean diameter over volume.

Results: Figure 2.10.1. Box and Whisker plot of yellow peas for D_{90} (µm, top) and $D_{4,3}$ (µm, bottom) resulting from 13 locations.



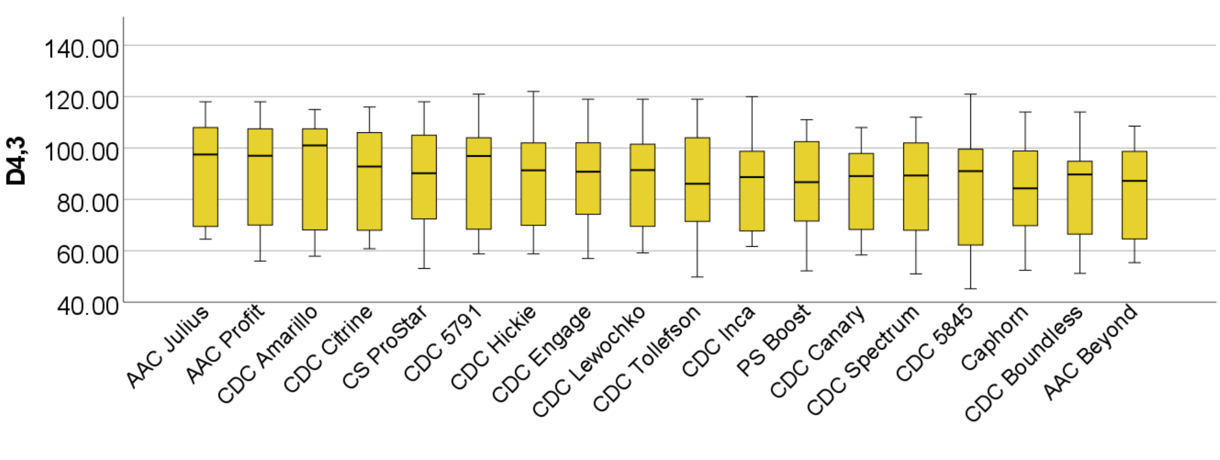
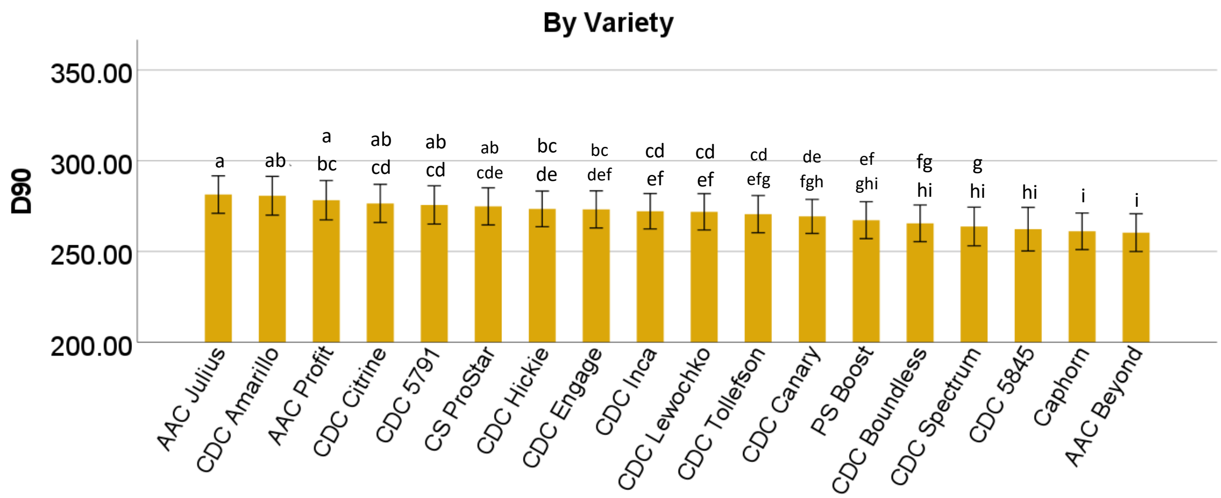
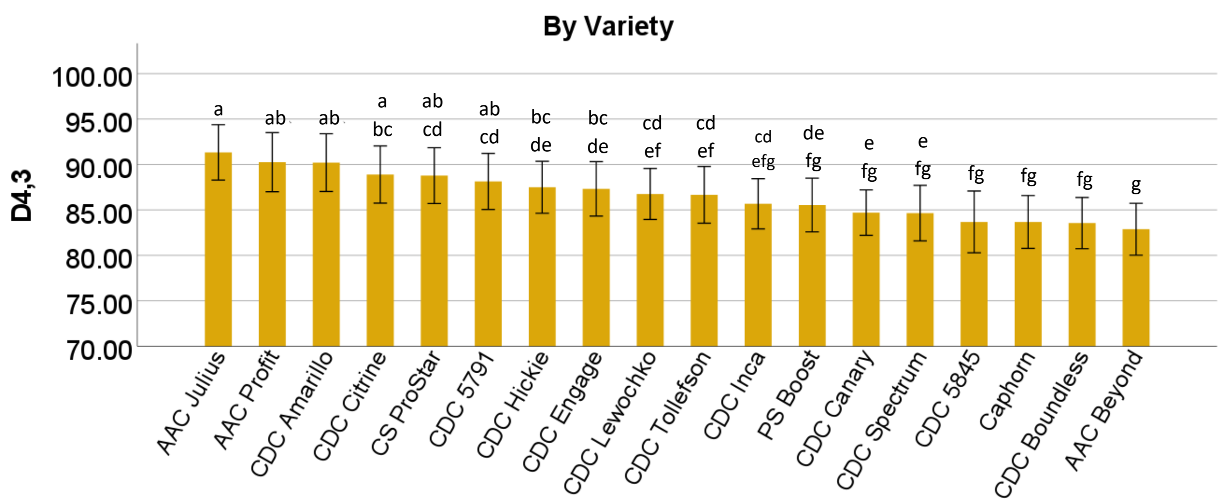


Figure 2.10.2. D_{90} (µm, top) and $D_{4,3}$ (µm, bottom) of yellow pea flours by variety. Each bar represents mean ± one standard error.





Note: Small letters indicated significant differences ($p<0.05$) by variety. Capital letters indicated significant differences ($p<0.05$) by location.

- **D_{90}:** all below 282 µm.
- **$D_{4,3}$:** The mean diameter of all flours was below 92 µm.

3) 2022 Maple Pea Quality

AAC Lorlie was the only maple pea variety in 2022. This variety was harvested from 13 locations (see Figure A), where three replicates in each location were cultivated, and a number of 39 samples were collected. The methods used for evaluation were the same as in previous sections. The quality results for each characteristic are provided in Table 3.1 and 3.2.

Table 3.1. TKW, seed size distribution, damage, and hardness for 2022 AAC Lorlie. Data represent mean ± one standard deviation.

Quality Attribute	AAC Lorlie
TKW (g)	247.5 ± 21.9
Size distribution	
> # 20R (%)	11.6 ± 9.7
> # 18R (%)	61.3 ± 14.0
> # 16R (%)	23.4 ± 14.8
> # 14R (%)	3.2 ± 3.3
Below # 14R (%)	0.4 ± 0.5
Split + Cracked seed coat (%)	2.3 ± 2.1
Other damage (%)	0.3 ± 0.5
Hardness (N)	404.2 ± 28.0

Table 3.2. Ash, protein, colour, Hausner ratio, and the flour particle size for 2022 AAC Lorlie. Data represent mean ± one standard deviation.

Quality Attribute	AAC Lorlie
Ash (d.b.; %)	2.8 ± 0.2
Protein (d.b.;%)	22.6 ± 1.8
Colour	
L*	87.7 ± 1.0
a*	-1.5 ± 0.2
b*	10.9 ± 1.6
Hausner Ratio	1.8 ± 0.1
D_{90} (µm)	272.7 ± 70.1
$D_{4,3}$ (µm)	86.0 ± 19.6

- TKW of AAC Lorlie was about 250 g.
- The majority of seeds were retained on sieves #18 and #16 (i.e., seed size between 6.35 and 7.94 mm).
- AAC Lorlie had a low level of split + cracked seed coat and other types of damage.
- AAC Lorlie had a high hardness value of above 400 N.
- Ash was similar to other green and yellow varieties.
- Protein was lower than the green and yellow verities.
- Color *(L*, a*, b*):*
    - *L** values: yellow > AAC Lorlie > green peas
    - *a** values (in terms of greenness): green > AAC Lorlie = yellow peas
    - *b** values (in terms of yellowness): yellow > green >> AAC Lorlie
- The Hausner ratio and particle size were similar to the green and yellow varieties.