2022 Pulse Quality Evaluation

Faba Bean

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 Faba Bean Quality

A total of **147** faba bean samples harvested in **2022** were acquired from **seven locations**, including Glaslyn, Goodale, Melfort, Roblin (MB), Swan River (MB), St Brieux, and Prince Albert. Both **tannin-type** (three varieties) and **zero-tannin type** (four varieties) were harvested in each location, and three replicates of each variety were cultivated in each location. Table A and Figure A provide the samples' information and locations in detail.

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

Crop	Type	Variety	Location	Number of samples
Faba bean	Tannin	Allison Fabelle Victus	Glaslyn Goodale Melfort Prince Albert Roblin, MB St Brieux Swan River, MB	147
	Zero-Tannin	CDC 1089 CDC 1142 DL Nevado Navi		

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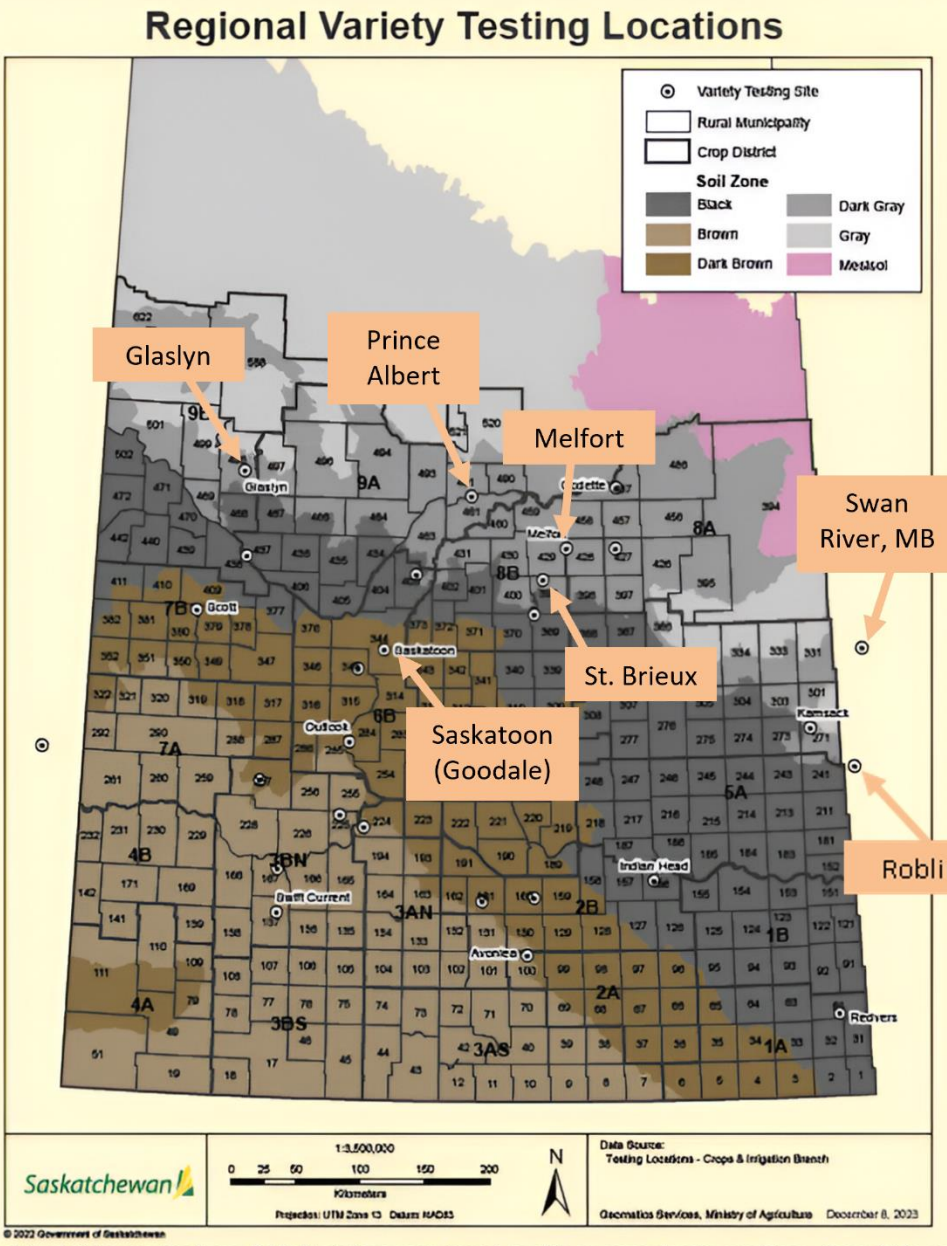

The cropland of Saskatchewan has been divided into four areas based roughly on agro-climatic conditions. Crop yields can vary from area to area. In choosing a variety, producers will want to consider the yield data in combination with marketing and agronomic factors.

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 faba bean 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 ten subsections for the results of the following quality parameters:

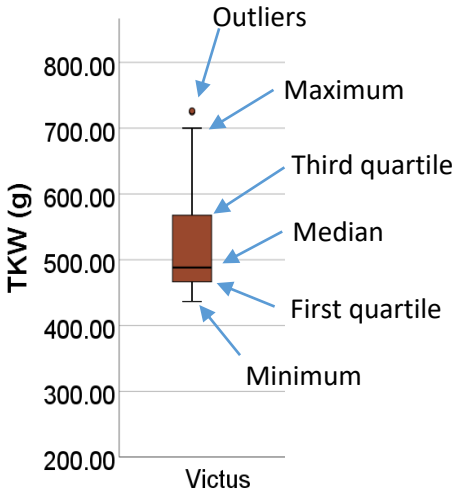
1. 1000 seed weight
2. Seed size distribution
3. Split amount
4. Other damage
5. Hardness of whole seed
6. Ash content
7. Protein content
8. Colour (*L**, *a**, and *b**)
9. Hausner Ratio
10. Particle size

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 values 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.

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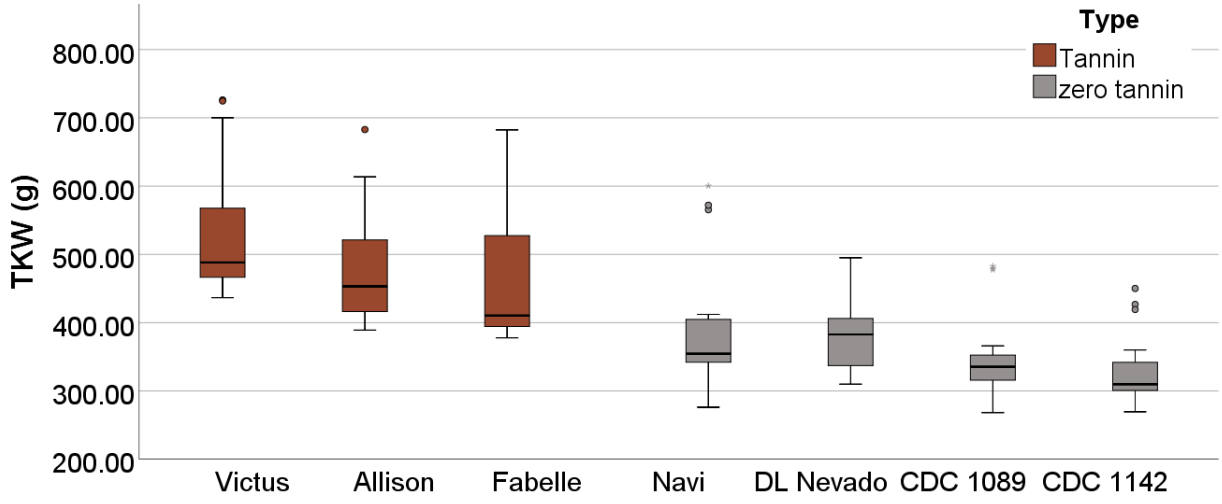
2022 Faba Bean Quality

1. 1000 Seed Weight

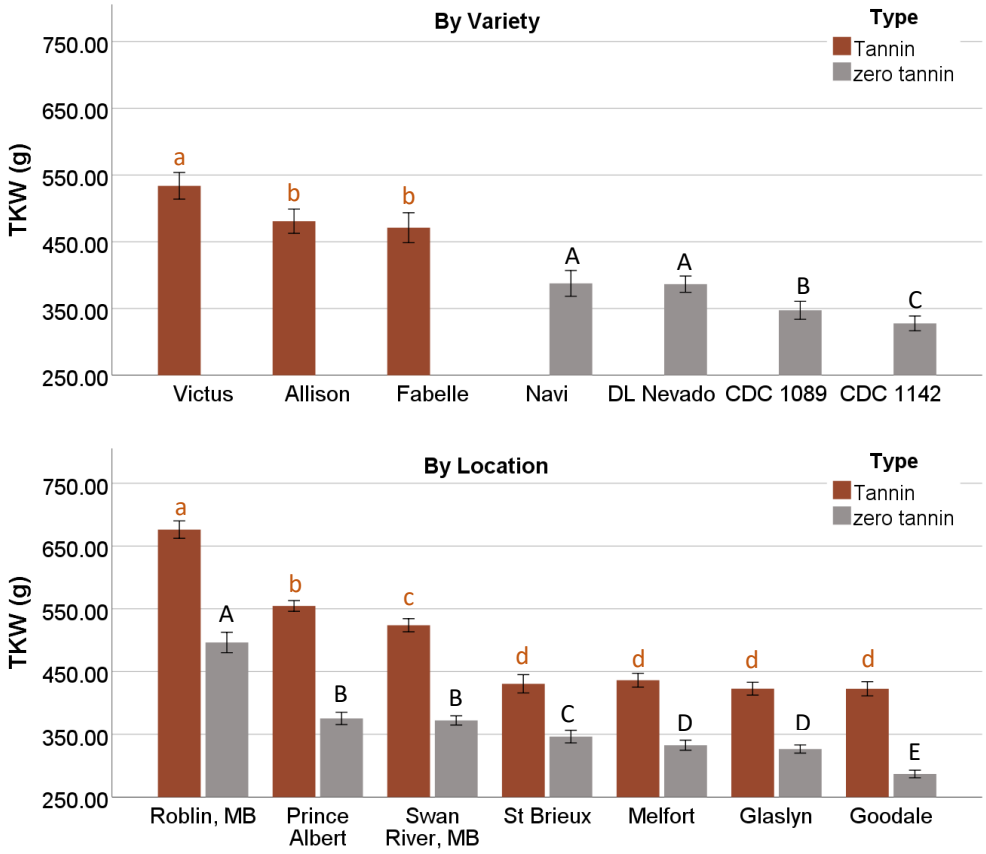
Method: Seed weight is an important parameter to indicate seed size and yield production. This test was conducted by weighing 300 seeds with duplicated measurements per sample, and the 1000 seed weight (TKW) was reported.

Results: Figure 1.1 Box and Whisker plot of faba beans for TKW resulting from 7 locations. Results by type (tannin and zero-tannin) were reported from highest to lowest.



- The tannin type had a higher TKW with larger variability, while the zero-tannin type had a lower TKW with less variability.
- Victus had the greatest TKW in three tannin varieties.
- For the zero-tannin type, Navi and DL Nevado were similar. CDC 1089 and CDC 1142 were similar.

Figure 1.2. Mean TKW of faba beans by variety (top) and by location (bottom). Each bar represents mean ± one standard error.



Note: Small letters indicated significant differences (p<0.05) between tannin varieties. Capital letters indicated significant differences (p<0.05) between zero-tannin varieties.

- **By Variety:**
  - **Tannin:** Mean TKW of Victus was 50 g higher (p<0.05) than Allison and Fabelle.
  - **Zero Tannin:** TKW of CDC 1142 was 60 g lower than Navi and DL Nevado and 20 g lower than CDC 1089.

- **By Location:** TKW was extremely high in Roblin, followed by Prince Albert and Swan River for both types.
  - **Tannin:** TKW was similar (p>0.05) for St Brieux, Melfort, Glaslyn, and Goodale.
  - **Zero Tannin:** The TKW of Goodale was the lowest.

Table 1. Effects of variety and location in 2022.

	Tannin	Zero-Tannin
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 faba beans:

a. #28R: 11. 11 mm
b. #26R: 10.32 mm
c. #24R: 9.52 mm
d. #22R: 8.73 mm
e. #20R: 7.94 mm
f. #18R: 7.14 mm
g. #16R: 6.35 mm
h. #14R: 5.56 mm

Results: Table 2. Seed size distribution (%) of each faba bean variety. Data represent mean ± one standard deviation.

Variety	> # 28R (%)	> # 26R (%)	> # 24R (%)	> # 22R (%)	> # 20R (%)	> # 18R (%)	> # 16R (%)	> # 14R (%)	Below # 14R (%)
Allison	0.4 ± 1.1^{a}	3.7 ± 6.4^{a}	16.8 ± 14.3^{a}	35.2 ± 7.9^{a}	30.0 ± 13.2^{a}	11.2 ± 8.3^{ab}	2.0 ± 1.6^{b}	0.4 ± 0.4^{a}	0.3 ± 0.5^{a}
Fabelle	0.5 ± 1.1^{a}	4.1 ± 8.1^{a}	13.3 ± 14.9^{a}	27.3 ± 10.4^{b}	32.5 ± 12.9^{a}	17.7 ± 12.0^{a}	3.8 ± 3.0^{a}	0.5 ± 0.4^{a}	0.3 ± 0.4^{a}
Victus	0.4 ± 1.0^{a}	4.1 ± 6.1^{a}	20.5 ± 15.5^{a}	36.1 ± 7.3^{a}	27.5 ± 13.2^{a}	9.2 ± 6.5^{b}	1.7 ± 1.4^{b}	0.3 ± 0.3^{a}	0.2 ± 0.3^{a}
CDC 1089	0.0 ± 0.0^{A}	0.1 ± 0.2^{B}	2.1 ± 4.8^{B}	11.2 ± 13.6^{AB}	33.6 ± 9.7^{A}	36.0 ± 12.8^{AB}	14.3 ± 9.2^{AB}	2.0 ± 2.0^{A}	0.7 ± 0.9^{A}
CDC 1142	0.0 ± 0.0^{A}	0.0 ± 0.2^{B}	0.8 ± 1.8^{B}	7.1 ± 10.8^{B}	29.4 ± 13.1^{A}	40.8 ± 12.1^{A}	19.0 ± 10.8^{A}	2.3 ± 2.1^{A}	0.6 ± 0.7^{A}
DL Nevado	0.0 ± 0.0^{A}	0.2 ± 0.5^{AB}	1.9 ± 2.8^{B}	13.6 ± 11.4^{AB}	36.1 ± 10.2^{A}	34.5 ± 12.0^{AB}	11.3 ± 7.9^{B}	1.6 ± 1.4^{A}	0.7 ± 0.9^{A}
Navi	0.2 ± 0.6^{A}	1.7 ± 3.9^{A}	7.1 ± 10.6^{A}	19.5 ± 11.8^{A}	33.4 ± 9.1^{A}	26.6 ± 12.5^{B}	9.0 ± 7.2^{B}	1.6 ± 1.7^{A}	0.8 ± 0.7^{A}

Note: Small letters indicated significant differences ($p<0.05$) between tannin varieties. Capital letters indicated significant differences ($p<0.05$) between zero-tannin varieties.

- The majority of tannin type retained onto sieves #24 to #18.
- The zero-tannin seeds tended to fall into #22 to #16 sieves.

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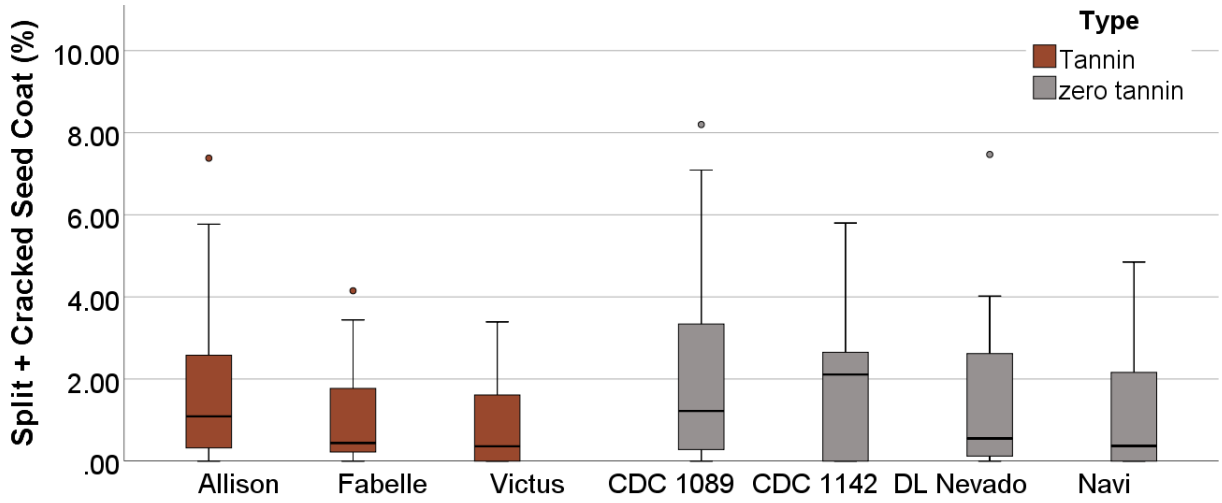
3. Split + Cracked Seed Coat

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 3.1. The Box and Whisker plot of faba beans for the split + cracked seed coat resulting from 7 locations. Results by type (tannin and zero-tannin) were reported from highest to lowest.



- Very large variability was observed in all zero-tannin faba beans.
- For the tannin types, Fabelle and Victus had lower split + cracked seed coat and less variability.

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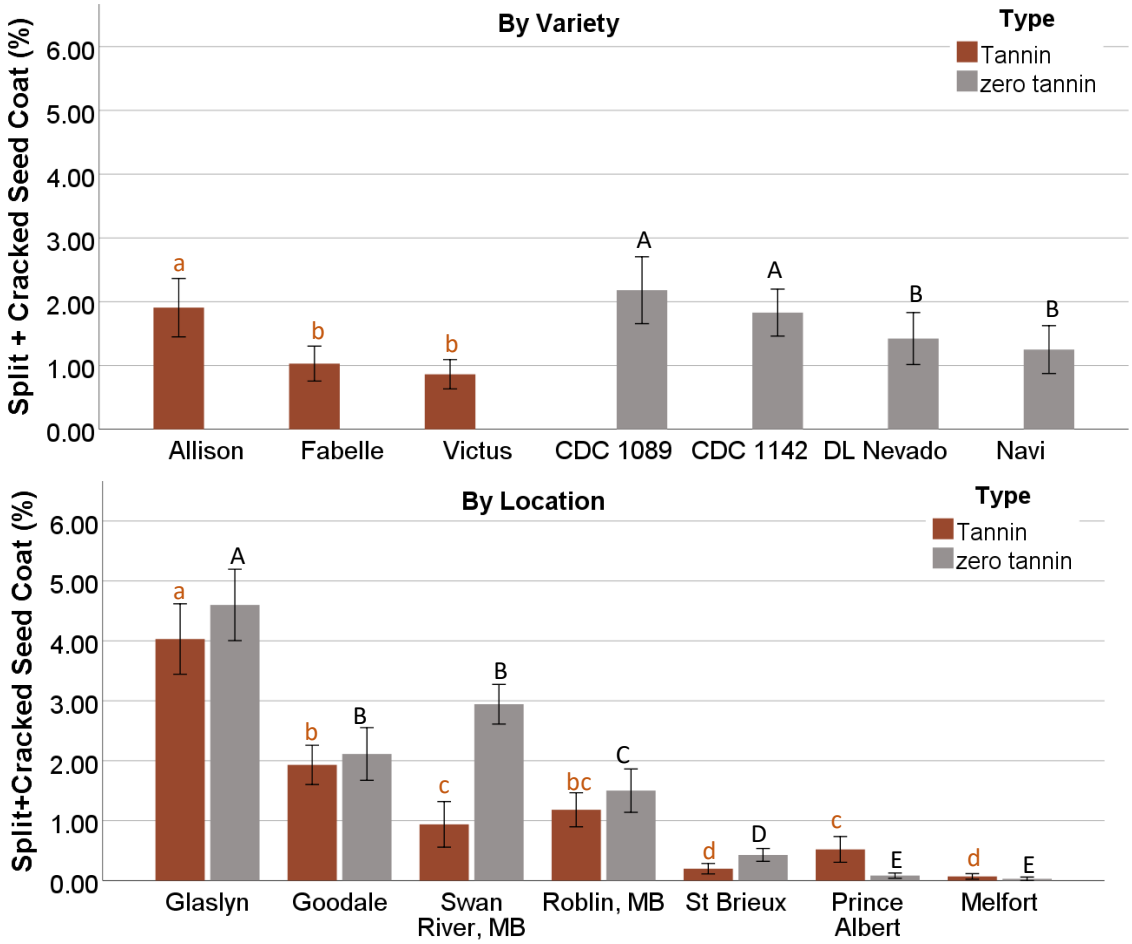
Figure 3.2. Mean split + cracked seed coat (%) of faba beans by variety (top) and by location (bottom). Each bar represents mean ± one standard error.



Note: Small letters indicated significant differences (p<0.05) between tannin varieties. Capital letters indicated significant differences (p<0.05) between zero-tannin varieties.

- **By Variety:**
  - **Tannin:** The amount of split + cracked seed coat for Allison was 1% higher than Fabelle and Victus.
  - **Zero Tannin:** CDC 1089 and CDC 1142 had higher split + cracked seed coats.

- **By Location:** The amount of split + cracked seed coat was extremely high in Glaslyn for both types, while very low damage was observed in the seeds harvested in Melfort, St Brieux, and Prince Albert, where post-harvest processing may play a role.

Table 3. Effects of variety and location.

	Tannin	Zero-Tannin
Variety	***	**
Location	***	***
Variety x Location	***	***

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

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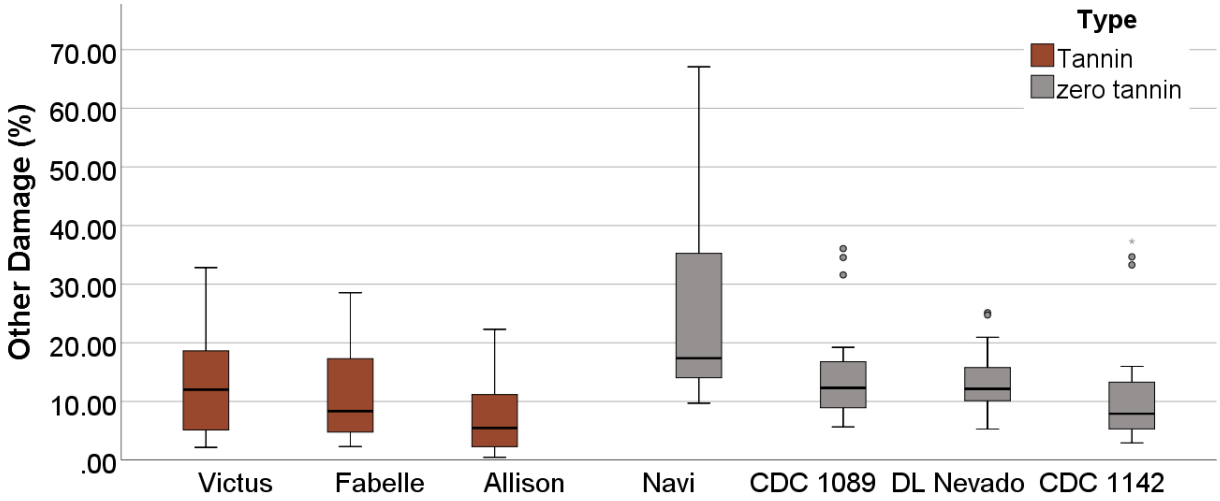
4. Other Damage

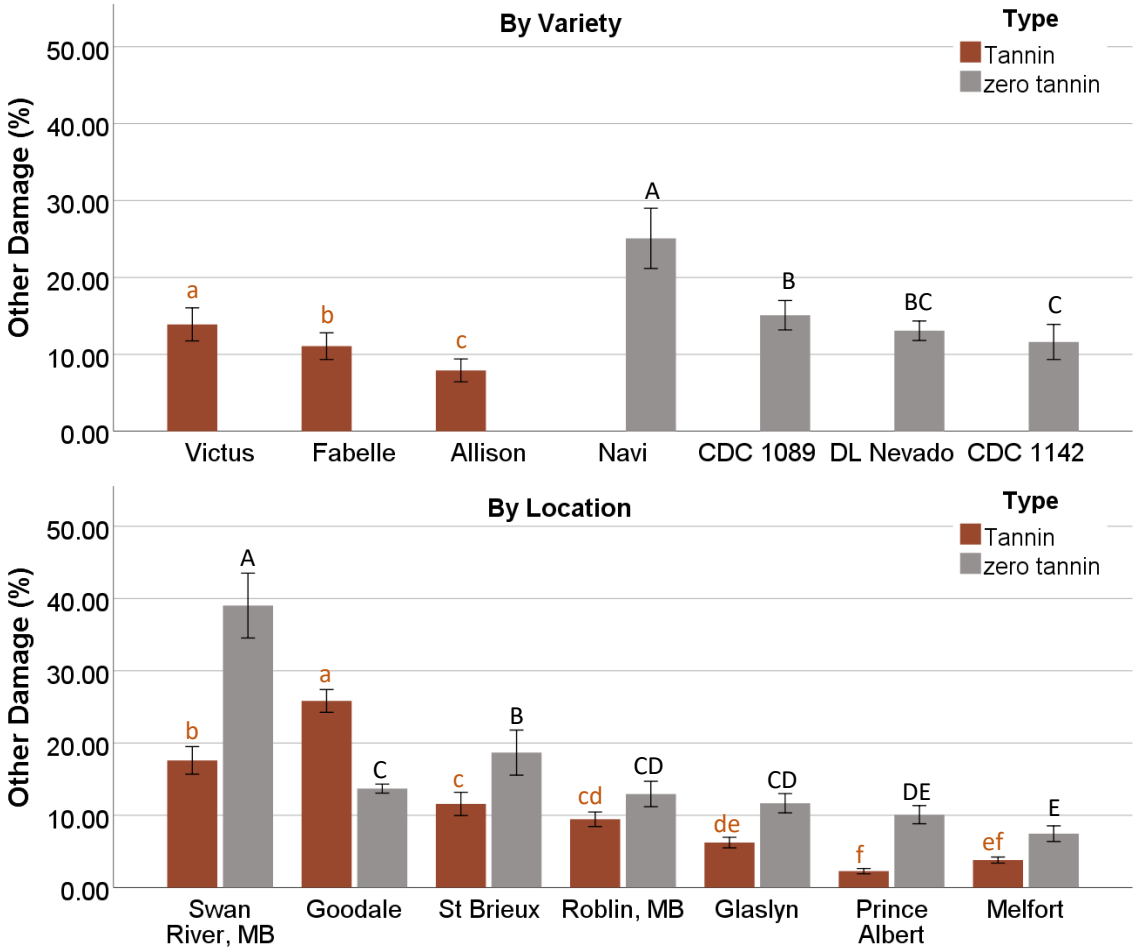
Method: 100 grams of each sample was used for evaluation, and damaged seeds were selected by hand. Other damage included sprouting, distinct immaturity, distinct deterioration or discolouration by weather or disease, insect damage, heat damage, and any other damage that affects appearance.

Results: Figure 4.1. Box and Whisker plot of faba beans for other damage resulting from 7 locations. Results by type (tannin and zero-tannin) were reported from highest to lowest.



- Navi had the highest other damage with very large variability. The other three zero-tannin types had much less variability, where line 1089-1-2 and DL Nevado were similar.
- For the tannin types, Victus and Fabelle were similar with larger variability than Allison.

Figure 4.2. Mean other damage of faba beans by variety (top) and by location (bottom). Each bar represents mean ± one standard error.



Note: Small letters indicated significant differences (p<0.05) between tannin varieties. Capital letters indicated significant differences (p<0.05) between zero-tannin varieties.

- **By Variety:** Zero tannin seeds in general had a higher other damage than tannin seeds.
  - **Tannin:** Allison had the lowest other damage of 8% (p<0.05).
  - **Zero Tannin:** Navi had the highest amount of other damage.

- **By Location:** Prince Albert and Melfort had the lowest other damage for both seed types.
  - **Tannin:** Goodale had a high other damage amount.
  - **Zero Tannin:** high in Swan River.

Table 4. Effects of variety and location.

	Tannin	Zero-Tannin
Variety	***	***
Location	***	***
Variety x Location	*	***

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

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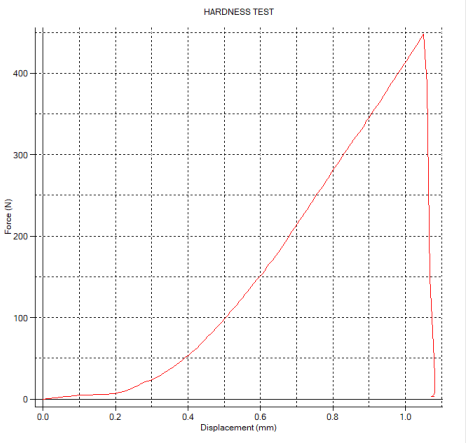
5. Hardness of Whole Seed

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

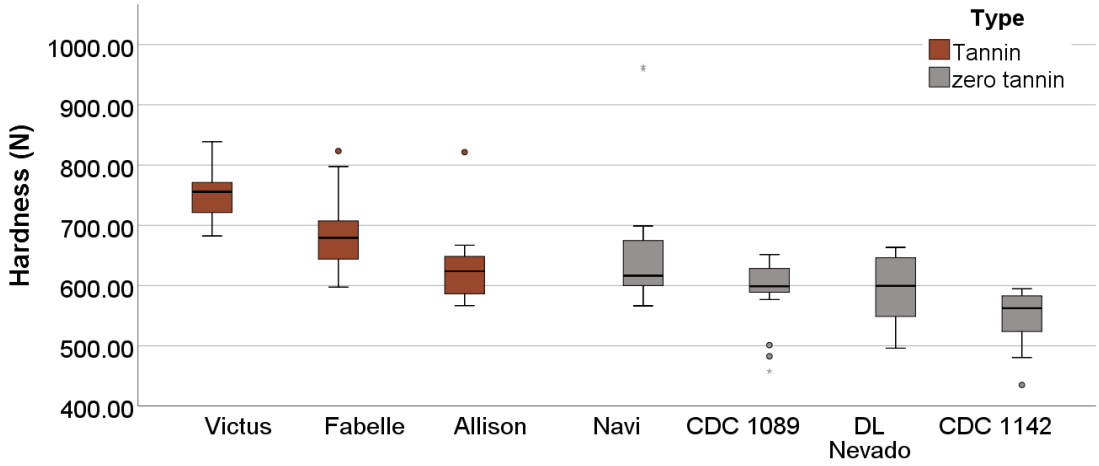


Method:

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.

Results: Figure 5.1. Box and Whisker plot of faba beans for seed hardness (N) resulting from 7 locations. Results by type (tannin and zero-tannin) were reported from highest to lowest.



- For tannin types, Victus > Fabelle > Allison.
- For zero-tannin types, CDC 1089 had the least variability, while DL Nevado had the largest variability.

[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.

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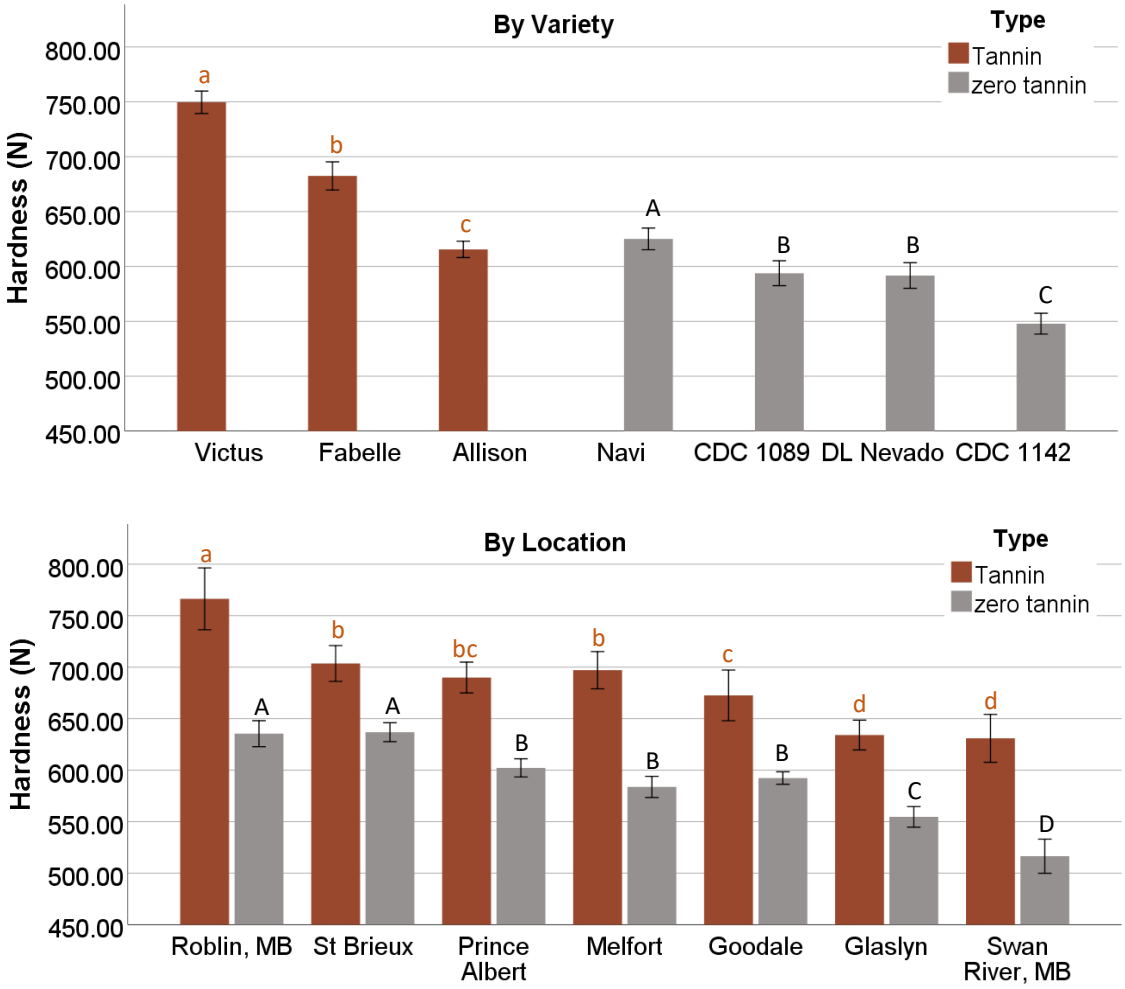
Figure 5.2. Mean seed hardness of faba beans by variety (top) and by location (bottom). Each bar represents mean ± one standard error.



Note: a) Small letters indicated significant differences (p<0.05) between tannin varieties. Capital letters indicated significant differences (p<0.05) between zero-tannin varieties; b) Hardness of Navi from Prince Albert Extreme was not reported as the results of two replicates were identified as extreme outliers.

By Variety:

- **Tannin:** Hardness of Victus was ~130 N higher than Allison.
- **Zero Tannin:** Navi had the largest hardness.

By Location: Location also impacted the hardness of faba beans. The tannin seed hardness in Roblin was ~130 N higher than those from Swan River.

Table 5. Effects of variety and location.

	Tannin	Zero-Tannin
Variety	***	***
Location	***	***
Variety x Location	***	***

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

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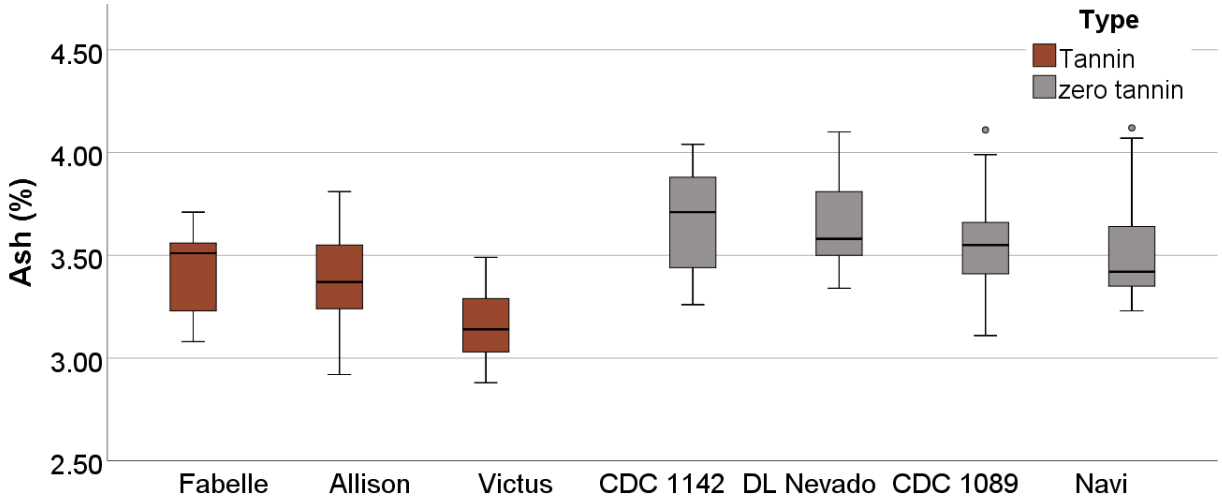
6. Ash Content

Method: Ash content (%) was determined using AACC 08-01.01[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 6.1. Box and Whisker plot of faba beans for ash content (%) resulting from 7 locations. Results by type (tannin and zero-tannin) were reported from highest to lowest.



- Overall, the zero-tannin types had a higher ash content than the tannin types.
- Victus had the lowest ash content.

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

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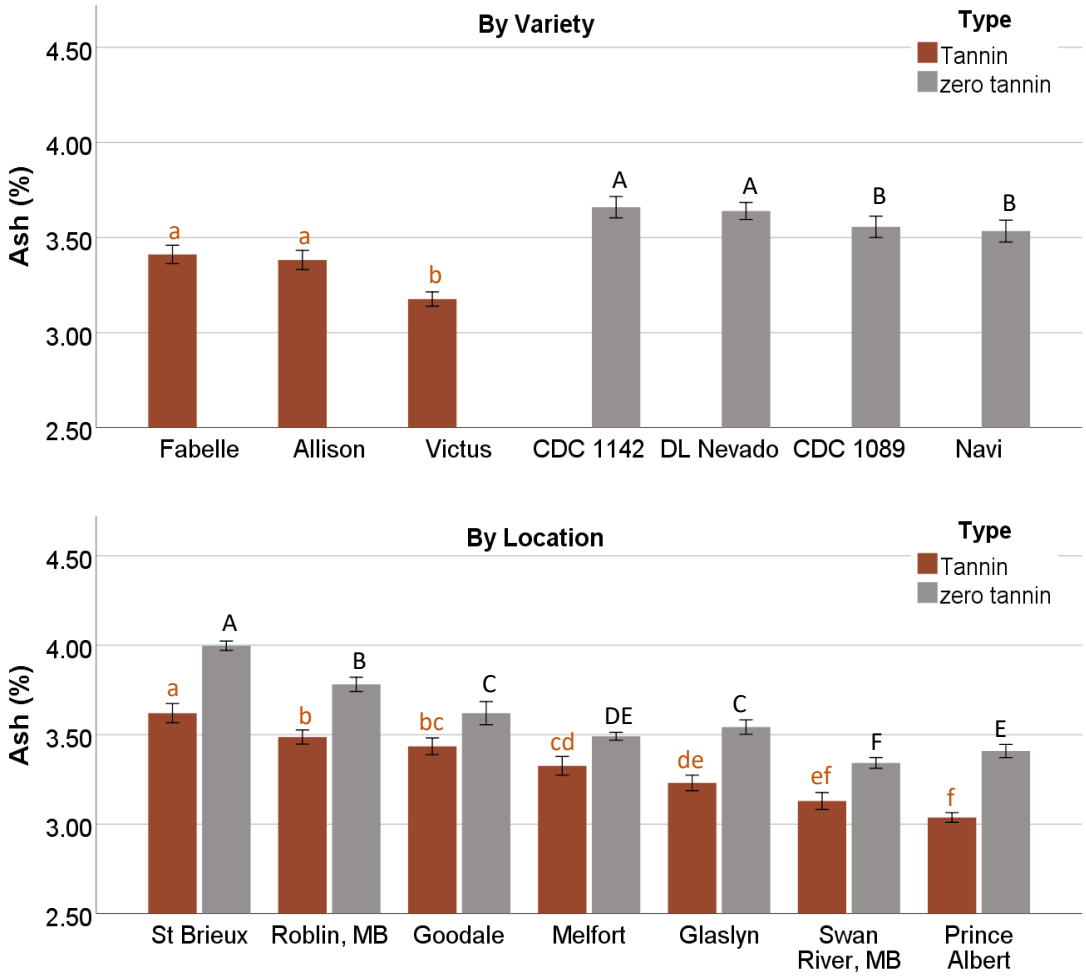
Figure 6.2. Mean ash of faba beans by variety (top) and by location (bottom). Each bar represents mean ± one standard error.



Note: Small letters indicated significant differences (p<0.05) between tannin varieties. Capital letters indicated significant differences (p<0.05) between zero-tannin varieties.

- **By Variety:**
  - **Tannin:** ranged from 3.2% to 3.4%.
  - **Zero Tannin:** ranged from 3.5% to 3.7%.

- **By Location:** Location effect played a role. Fabe beans from St Brieux had the highest ash content for both seed types, while seeds from Swan River and Prience Albert had the lowest ash level.

Table 6. Effects of variety and location.

	Tannin	Zero-Tannin
Variety	***	***
Location	***	***
Variety x Location	*NS*	***

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

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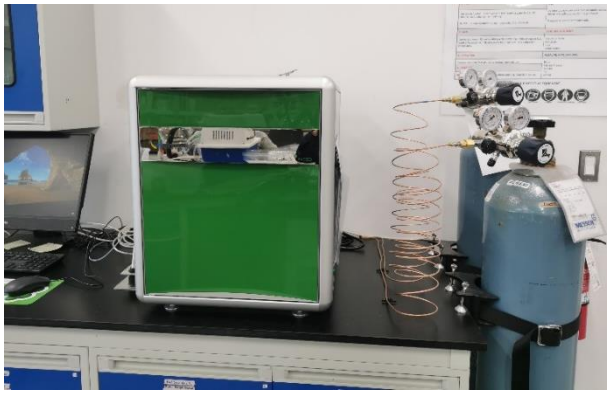
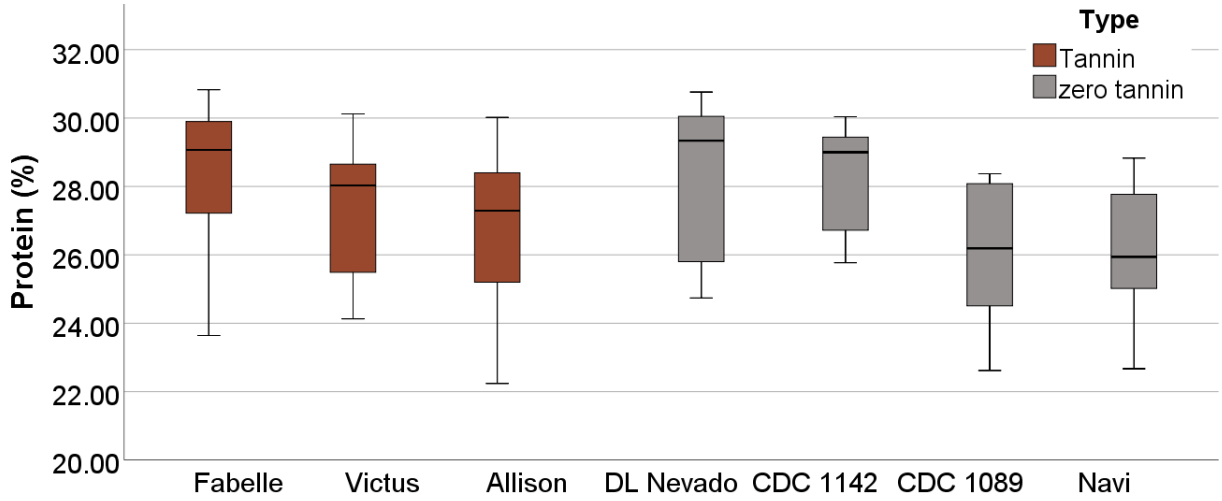
7. Protein Content

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.).



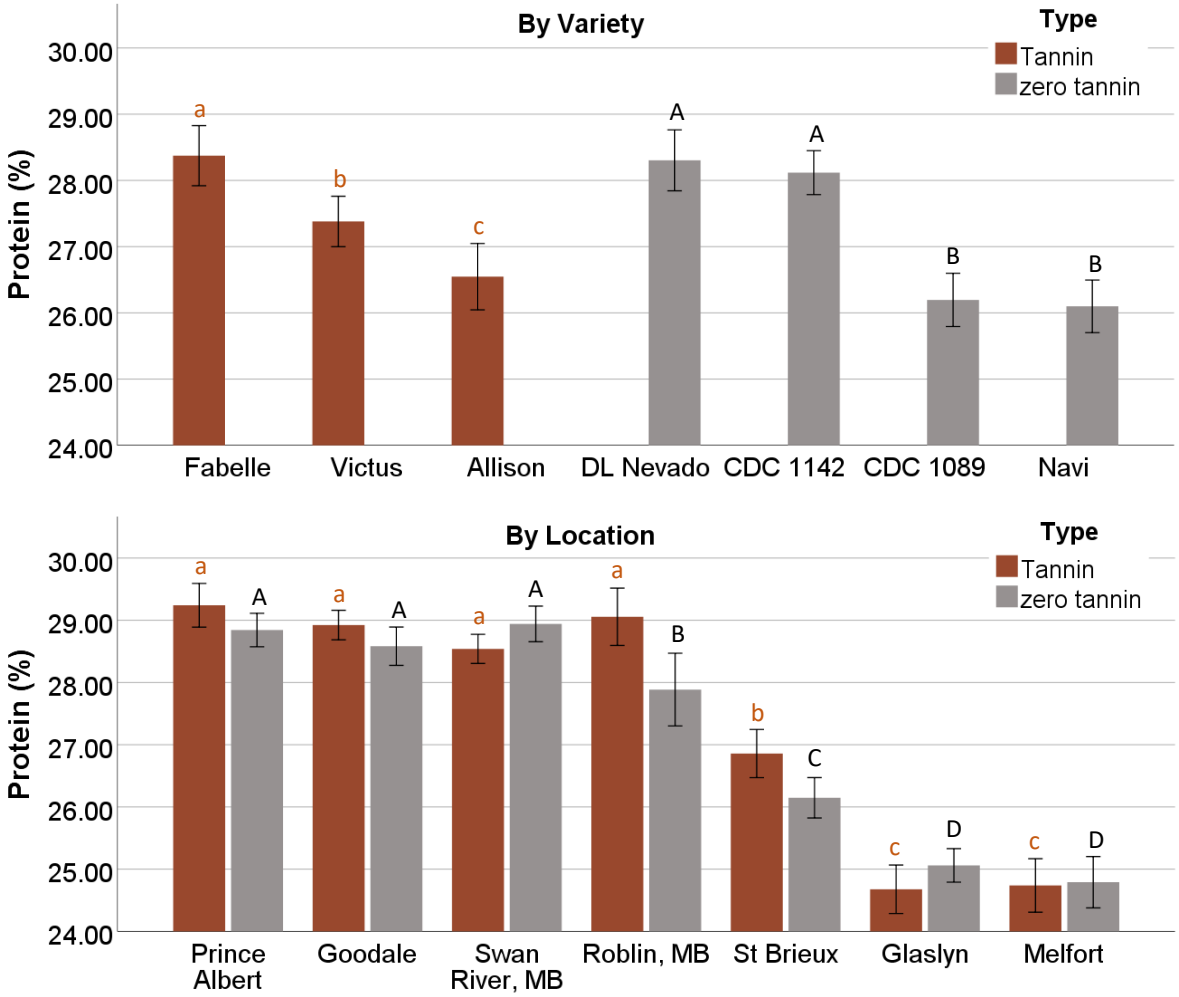
Results: Figure 7.1. Box and Whisker plot of faba beans for protein content (%) resulting from 7 locations. Results by type (tannin and zero-tannin) were reported from highest to lowest.



- Large variability of protein content was found in all 7 varieties.

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

Figure 7.2. Mean protein of faba beans by variety (top) and by location (bottom). Each bar represents mean ± one standard error.



Note: Small letters indicated significant differences (p<0.05) between tannin varieties. Capital letters indicated significant differences (p<0.05) between zero-tannin varieties.

- **By Variety:**
  - **Tannin:** Protein of Fabelle was 1.8% higher than Allison.
  - **Zero Tannin:** DL Nevado = CDC 1142 > CDC 1089 = Navi.

- **By Location:** Location effect played a significant role.
  - **Tannin:** A 4.6% difference was observed from the highest (Prince Albert) to the lowest (Glaslyn).
  - **Zero Tannin:** A 4.2% difference was observed from the highest (Swan River) to the lowest (Melfort).

Table 7. Effects of variety and location.

	Tannin	Zero-Tannin
Variety	***	***
Location	***	***
Variety x Location	*NS*	***

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

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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. Three measurements were made for each sample, and the mean value was reported.

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

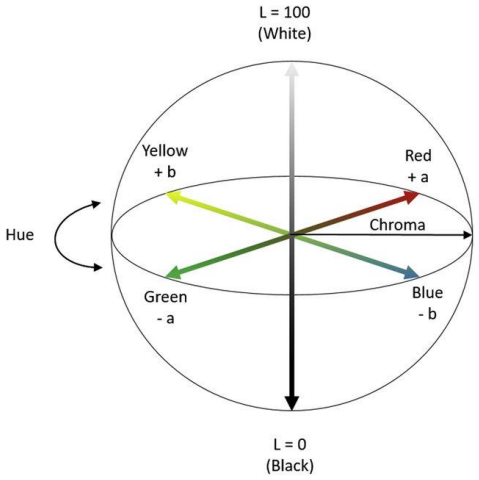
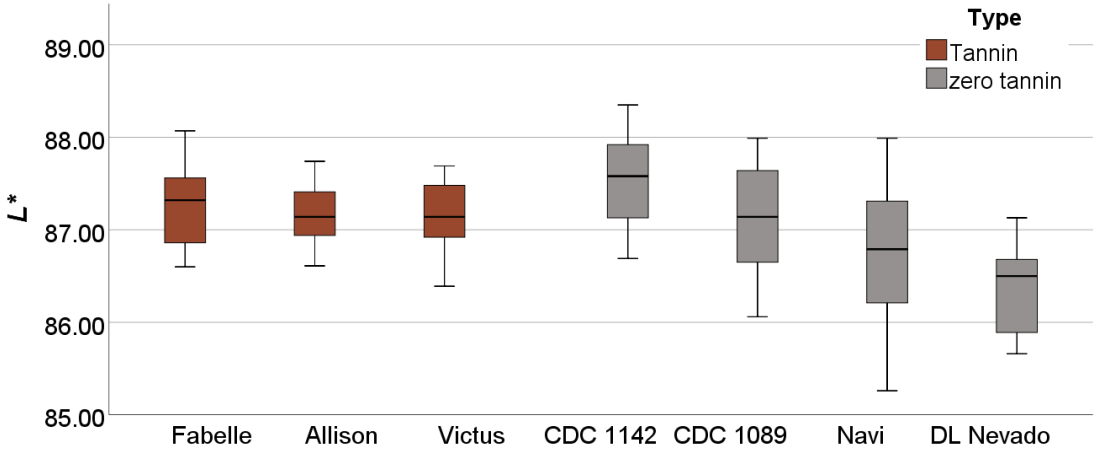


Figure 8.1. The CIELAB color spacediagram[3].

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

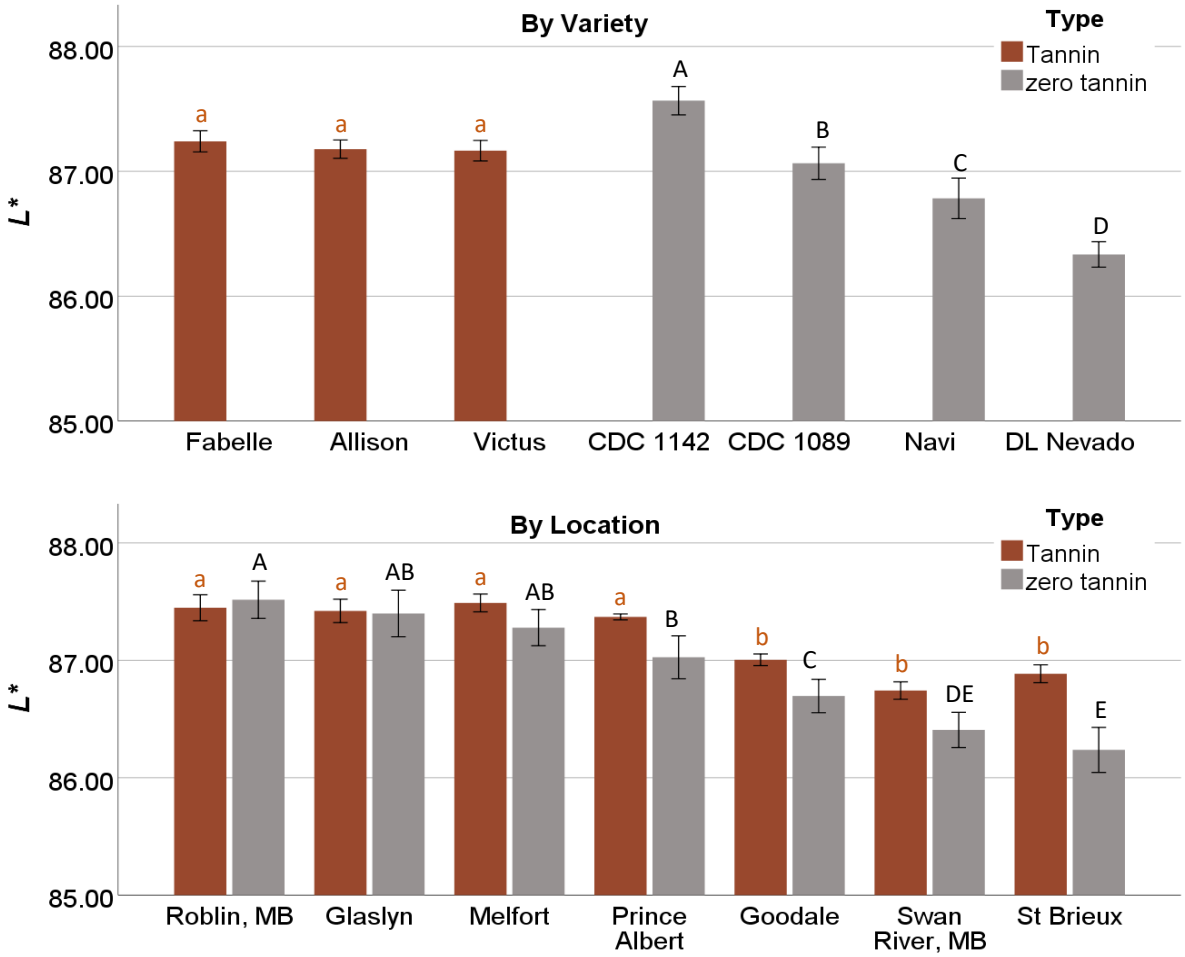
Results: Figure 8.2. Box and Whisker plot of faba beans for lightness resulting from 7 locations. Results by type (tannin and zero-tannin) were reported from highest to lowest.



- Lightness of tannin types had less variability than the zero-tannin types.

[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.

Figure 8.3.1. Mean lightness of faba beans by variety (top) and by location (bottom). Each bar represents mean ± one standard error.



Note: Small letters indicated significant differences (p<0.05) between tannin varieties. Capital letters indicated significant differences (p<0.05) between zero-tannin varieties.

- **By Variety:**
  - **Tannin:** no difference (p>0.05)
  - **Zero Tannin:** CDC 1142 > CDC 10898 > Navi> DL Nevado, which might be attributed to the seed coat color (see Figure 8.3.2).

- **By Location:** The mean differences of *L** values from highest to lowest were about 1 unit for both types.

Table 8.1. Effects of variety and location.

	Tannin	Zero-Tannin
Variety	*NS*	***
Location	***	***
Variety x Location	*NS*	*

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

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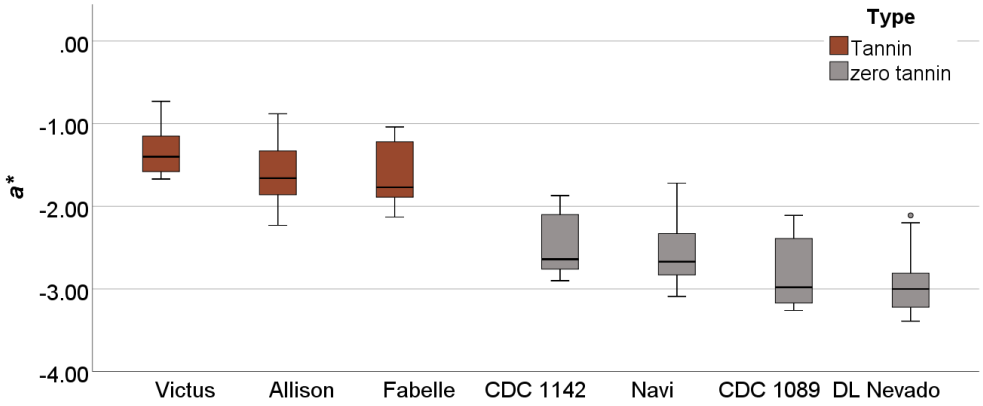
Figure 8.3.2. Images of 2022 zero-tannin faba beans harvested from Prince Alberta.

CDC 1142 ***CDC 1089*** ***Navi*** ***DL Nevado***

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

Results: Figure 8.4. Box and Whisker plot of faba beans for *a** resulting from 7 locations. Results by type (tannin and zero-tannin) were reported from highest to lowest.



- The zero-tannin showed stronger greenness than the tannin type.

Figure 8.5.1. Mean *a** of faba beans by variety. Each bar represents mean ± one standard error.

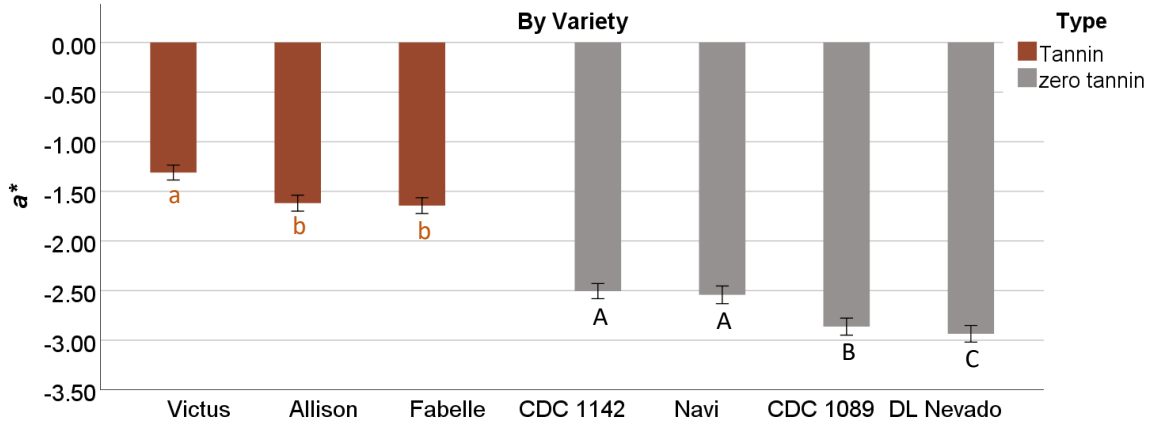
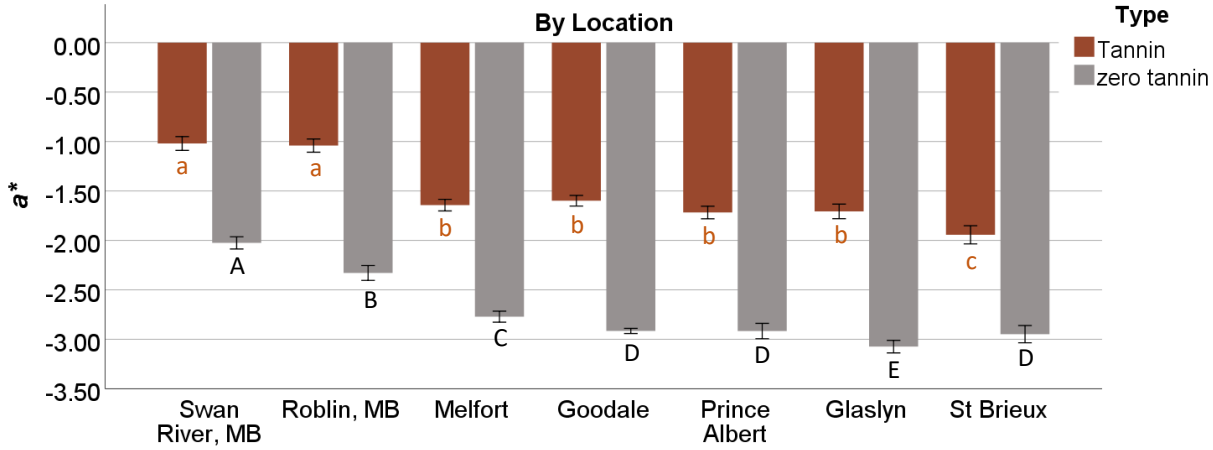


Figure 8.5.2. Mean *a** of faba beans by location. Each bar represents mean ± one standard error.



Note: Small letters indicated significant differences (p<0.05) between tannin varieties. Capital letters indicated significant differences (p<0.05) between zero-tannin varieties.

- **By Variety:**
  - **Tannin:** ranged from -1.6 to -1.3.
  - **Zero Tannin:** ranged from -2.9 to -2.5.
- **By Location:** played a role on both tannin and zero tannin types.

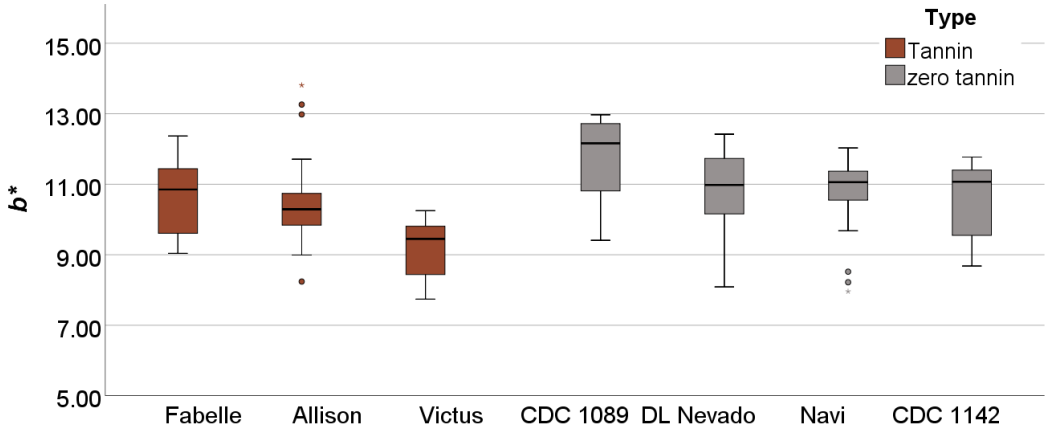
Table 8.2. Effects of variety and location.

	Tannin	Zero-Tannin
Variety	***	***
Location	***	***
Variety x Location	*NS*	***

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

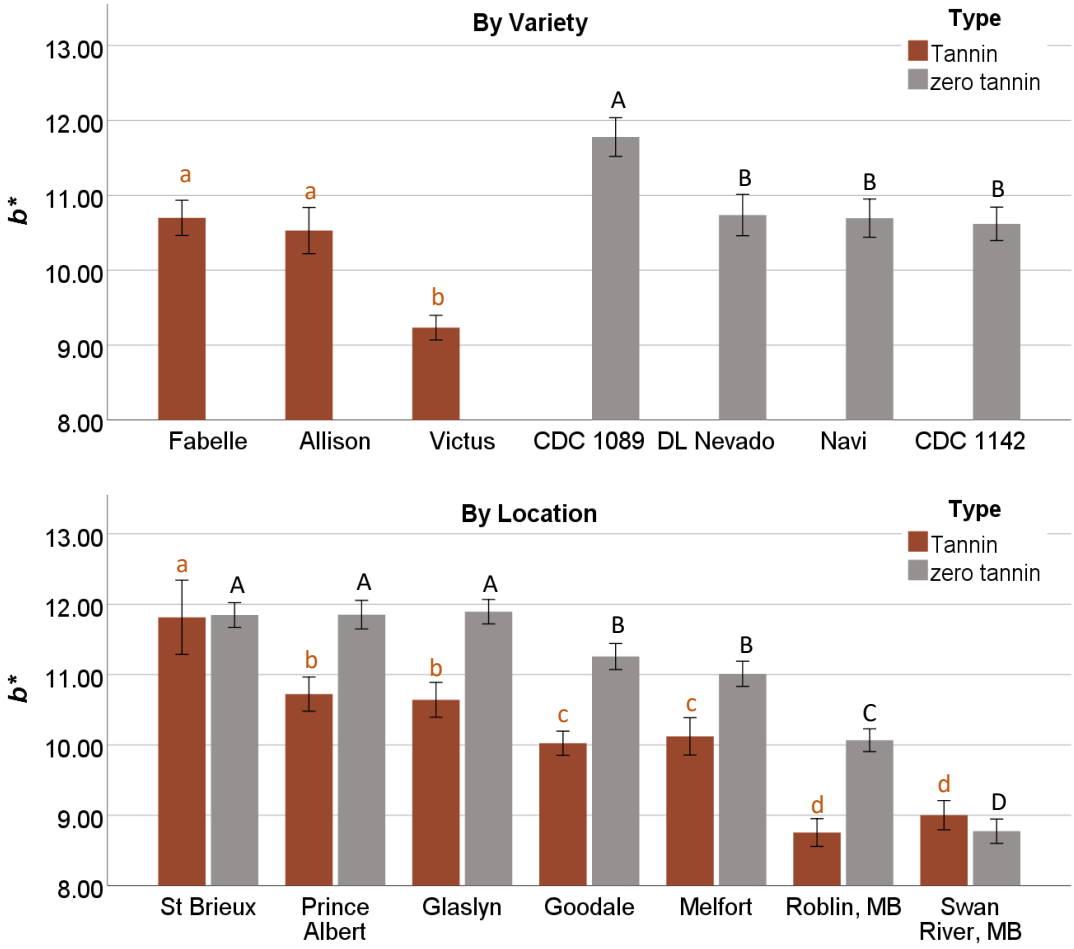
3) ***b*:*** yellow (+) to blue (-)

Results: Figure 8.6. Box and Whisker plot of faba beans for *b** resulting from 7 locations. Results by type (tannin and zero-tannin) were reported from highest to lowest.



- Overall, *b** values for zero-tannin types were higher than tannin types.

Figure 8.7. Mean *b** of faba beans by variety (top) and by location (bottom). Each bar represents mean ± one standard error.



Note: Small letters indicated significant differences (p<0.05) between tannin varieties. Capital letters indicated significant differences (p<0.05) between zero-tannin varieties.

- **By Variety:**
  - **Tannin:** Fabelle = Allison > Victus.
  - **Zero Tannin:** CDC 1089-1-2 had greater yellowness.

- **By Location:** played a role on both tannin and zero tannin types. Yellowness of both seed types from Swan River was about 3 units lower than St Brieux.

Table 8.3. Effects of variety and location.

	Tannin	Zero-Tannin
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:

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

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 9.1. Box and Whisker plot of faba beans for Hausner ratio resulting from 7 locations. Results by type (tannin and zero-tannin) were reported from highest to lowest.

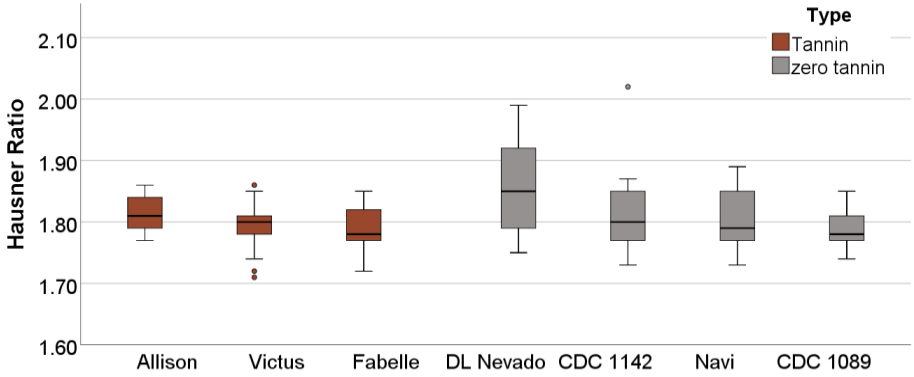
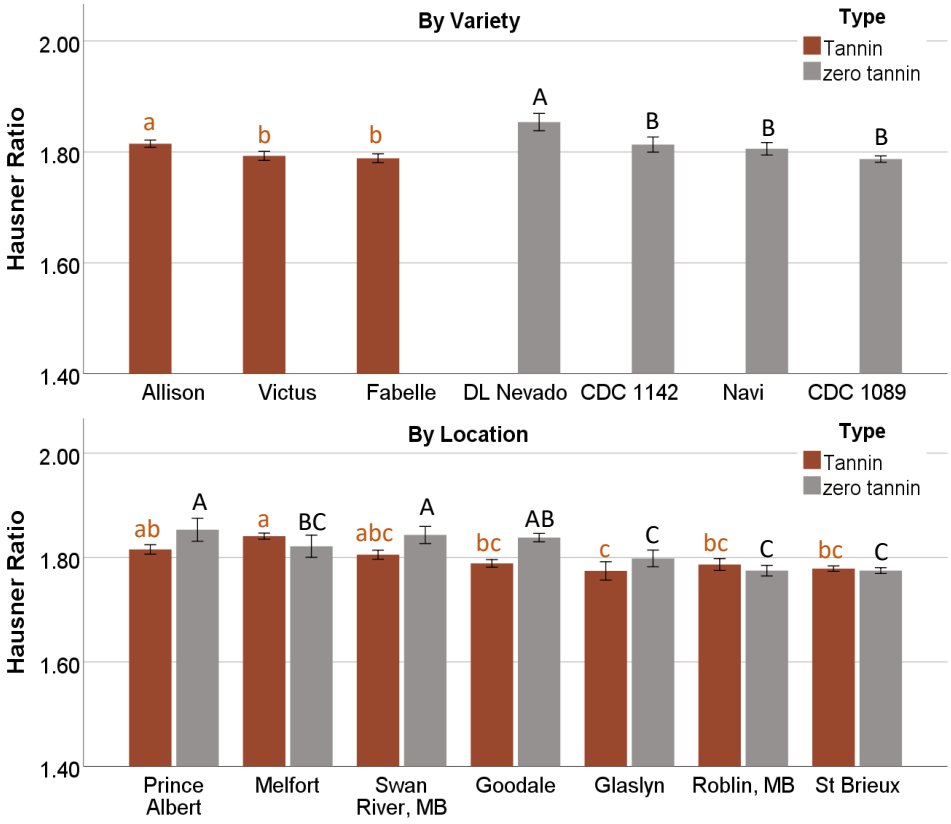


Figure 9.2. Mean Hausner ratio of faba beans by variety (top) and by location (bottom). Each bar represents mean ± one standard error.



Note: Small letters indicated significant differences (p<0.05) between tannin varieties. Capital letters indicated significant differences (p<0.05) between zero-tannin varieties.

- The results of Hausner ratio for 7 varieties across 7 locations were all greater than 1.6, suggesting all faba bean 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 averages 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 10.1. Box and Whisker plot of faba beans for D_{90} and $D_{4,3}$ values resulting from 7 locations. Results by type (tannin and zero-tannin) were reported from highest to lowest.

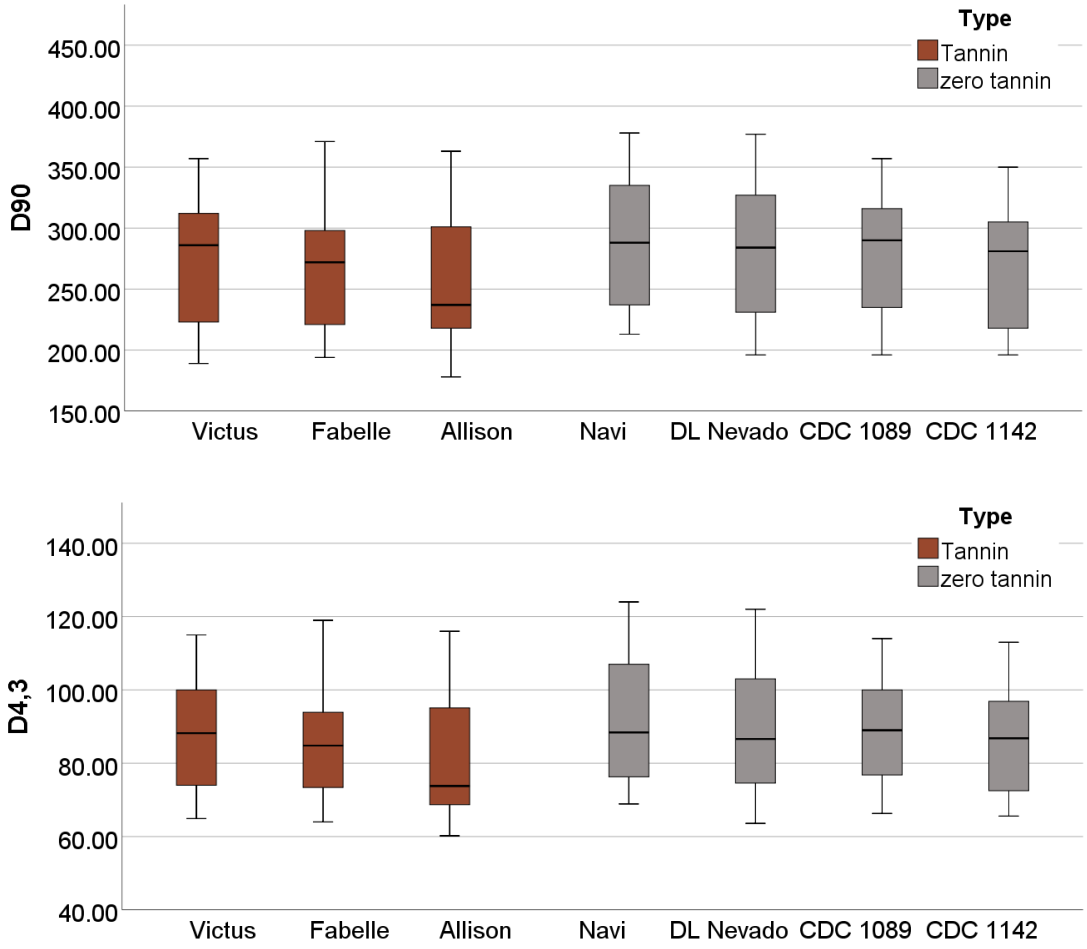
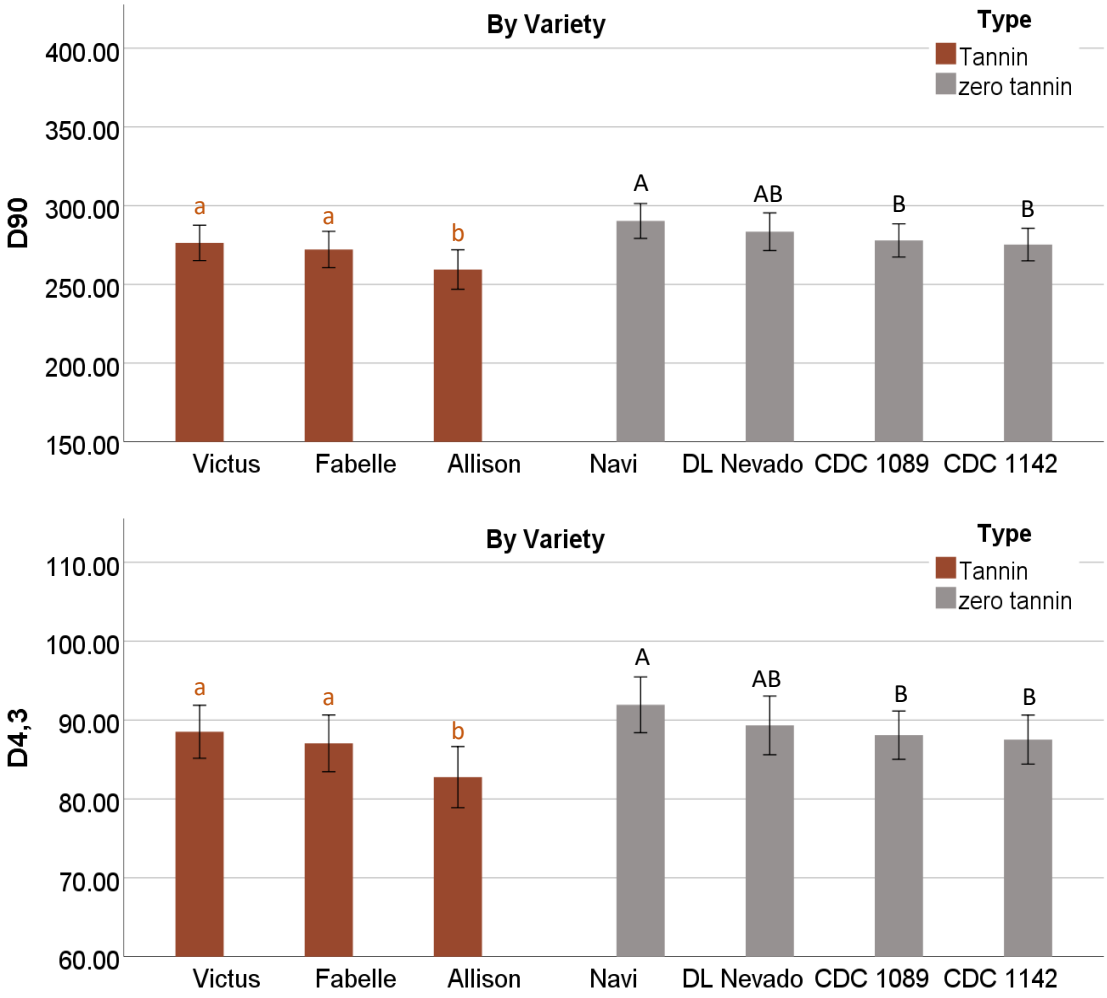


Figure 10.2. D_{90} (µm, top) and $D_{4,3}$ (µm, bottom) of faba bean flours by variety. Each bar represents mean ± one standard error.



Note: Small letters indicated significant differences (p<0.05) between tannin varieties. Capital letters indicated significant differences (p<0.05) between zero-tannin varieties.

- **D_{90}:** all below 300 µm.
- **$D_{4,3}$:** The mean diameters of all flours were below 100 µm.