

ORIGINAL ARTICLE OPEN ACCESS

Physico-Chemical, Microstructural, and Cooking Characteristics of Faba Bean (*Vicia faba*) Varieties From New Zealand

Navneet¹ | Jaspreet Singh^{1,2} | Nneka I. Ajomiwe¹ | Lovedeep Kaur^{1,2} ¹School of Food Technology and Natural Sciences, Massey University, Palmerston North, New Zealand | ²Riddet Institute, Massey University, Palmerston North, New Zealand**Correspondence:** Lovedeep Kaur (l.kaur@massey.ac.nz)**Received:** 2 April 2025 | **Revised:** 31 July 2025 | **Accepted:** 1 August 2025**Funding:** The authors thank the New Zealand Ministry of Business, Innovation and Employment (MBIE) Endeavour Fund (Smart Idea, contract no. MAU2443) for their support.**Keywords:** cooking characteristics | faba beans | microstructure | physical properties

ABSTRACT

This research examines the physical and microstructural properties of New Zealand faba beans (*Vicia faba*), with a focus on their influence on swelling, hydration, and cooking characteristics. Four native varieties (Early Long Pod, Evergreen, Coles Dwarf, and Janet) were studied. No statistically significant differences were found in the seed physical characteristics, including sphericity, equivalent diameter, thousand kernel weight, seed volume, and surface area, among the varieties. The faba bean seeds showed high levels of protein (24%–27%) and starch content (35%–39%), with Coles Dwarf exhibiting a significantly higher protein content. Cooking times varied among the varieties and were decreased by at least 30 min for all varieties when seeds were soaked before cooking. Evergreen seeds took the least time to cook, while those from Janet required the longest time, which was significantly higher than the other varieties, especially when soaked faba beans were used for cooking. These results were in accordance with the scanning electron microscopy (SEM) results, which revealed significant differences in cotyledon cell wall thickness and surface ridge morphology. Despite a relatively high hydration capacity, Janet required the longest cooking time, suggesting that its thicker cotyledon cell walls and folded surface topography may limit thermal softening despite adequate water uptake. The rapid visco analyzer (RVA) results also showed that the Janet flour exhibited significantly higher peak viscosity, indicating strong water-holding and gelation potential during heating. The Coles Dwarf variety, which exhibited the highest protein content, displayed pronounced surface ridges but showed a significantly lower hydration index, highlighting how macronutrient composition and microstructure jointly influence water uptake and pasting behavior. These results highlight the varying suitability of each variety for different food applications, considering their distinct physico-chemical and cooking properties.

1 | Introduction

Plant-based foods are gaining popularity as more people adopt vegetarian and plant-based diets because of various adverse health and environmental responses associated with meat diets. Legume crops are a sustainable source of high-protein food grown worldwide. Among them, the faba bean (*Vicia faba* L.), also known as

broad faba bean, is an annual legume belonging to the family Fabaceae (Singh et al. 2013; Penchalaraju and Don Bosco 2022).

The mature seeds of the faba bean are high in dietary fiber (25.0%), proteins (26.1%), and carbs (58.3%), in addition to other bioactive compounds (Dhull, Kidwai, Siddiq, and Sidhu 2022). As faba beans contain a high percentage of starch, other

This is an open access article under the terms of the [Creative Commons Attribution](https://creativecommons.org/licenses/by/4.0/) License, which permits use, distribution and reproduction in any medium, provided the original work is properly cited.

© 2025 The Author(s). *Legume Science* published by Wiley Periodicals LLC.

researchers investigated characteristics of starch, such as granule size, shape, and chemical makeup and how it may significantly impact the functional behavior of faba bean flours. High gelatinisation temperatures, limited swelling, and minimal breakdown viscosity values are the outcomes of high amylose concentration of the faba bean starch (Romero and Zhang 2019). Prior studies have found a positive, linear relationship between physical properties (such as seed dimensions, surface area, and seed volume) and moisture content (Matouk et al. 2018). Jeganathan et al. (2022) examined the topography of the faba bean's abaxial, adaxial, and cross-sectional surfaces, verifying varietal differences linked to their micromorphological traits.

To the best of the authors' knowledge, there is no published information on New Zealand grown varieties of faba beans, and there is limited knowledge on the inter-relationship of physical and microstructural parameters with the cooking quality of faba beans as a potential plant-based food source. Examining the microstructure can also assist in explaining the relatively long cooking time and provide insight into the cell makeup that affects cooking quality. It would be possible to assess the cooking properties of the varieties and select one that is appropriate for its specific use by looking at variations in cell wall thickness and surface topography. Considering the above, this study aimed to understand mainly the relationship between the physical and microstructural properties of four faba bean seed varieties and the cooking time required for suitable tenderness associated with palatability. The experimental design for this study involved studying the (a) dimensional characteristics, color, and weight of the faba beans, as well as their proximate composition; (b) swelling, hydration, and cooking characteristics; and (c) the microstructural parameters to observe seed topography and faba bean cotyledon structures using a scanning electron microscope. The second objective was to examine the pasting properties of the faba bean flour suspensions from these varieties to understand the differences in their response to heating, cooling, and shear. This study will assist in identifying the best variety out of the four, which may be helpful for the food industry to proceed further to create a plant-based product that would benefit from these faba beans' high-protein content. In this article, the terms broad faba bean and faba bean have been used interchangeably.

2 | Material and Methods

2.1 | Materials

Four locally grown whole dry broad faba bean seed varieties—Early Long Pod, Evergreen, Coles Dwarf, and Janet (Figure 1)—were obtained from a certified supplier (Morton Smith-Dawe

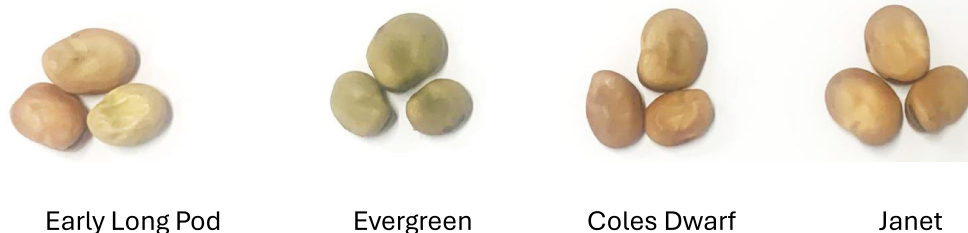


FIGURE 1 | Four broad bean varieties used in the study.

Ltd., Christchurch, New Zealand). Each dry broad faba bean seed variety was stored in a separate bag in a dry location at ambient temperature (approximately 21°C) for further studies. All four varieties were grown in Canterbury (New Zealand). Early Long Pod was sown in autumn/winter and reached maturity at 11–13 weeks; Evergreen was sown in autumn-spring and reached maturity at 11–13 weeks, Coles Dwarf was sown in autumn/winter and reached maturity at 11–13 weeks, and Janet was sown in winter-spring and reached maturity at 10–12 weeks.

2.2 | Physical Properties

Different seed properties, including sphericity, equivalent diameter, seed volume, and surface area, were assessed using eight randomly selected seeds per replicate.

The whole dried seeds were randomly selected from each variety and measured for length (L), width (W), and thickness (T) using a digital calliper (Product Code: 11787105, Fisherbrand Traceable Digital Carbon Fiber Callipers, Thermo Fisher Scientific, Massachusetts, United States) with a 0.1-mm resolution and ± 0.2 mm accuracy. These dimensions were used to measure the equivalent diameter (D_m), sphericity (Φ), seed volume (V), and surface area (A_s) of the seeds, which were determined based on the following relationship (Matouk et al. 2018; Wani et al. 2016):

$$D_m \text{ (mm)} = (\text{LWT})^{1/3} \quad (1)$$

$$\Phi = D_m / L \quad (2)$$

$$V \text{ (mm}^3\text{)} = \pi b^2 L^2 / 6(2L - 3), \text{ where } b = (\text{WT})^{1/2} \quad (3)$$

$$A_s \text{ (mm}^2\text{)} = \pi b L^2 / 2L - b \quad (4)$$

For the thousand kernel weight (TKW), a digital electronic balance with 0.001 g precision was used to calculate the weight of the thousand kernels. Ten seeds of each variety were weighed at a time in a preweighed beaker. The measurements were made using 10 sample replicates, and the average of one faba bean was obtained. The weight of one faba bean was used to determine the weight of 1000 kernels (weight of one seed \times 1000) (Matouk et al. 2018).

2.3 | Colorimetry

Using a colorimeter (Chroma Meter CR-400, Konica Minolta Inc., Tokyo, Japan), the whole faba beans of each variety were analyzed to examine color differences, using a colorimeter

(Chroma Meter CR-400, Konica Minolta Inc., Tokyo, Japan). The instrumental color measurements are based on the L^* , a^* , and b^* coordinates. A random single faba bean from each variety was placed on the measuring head with a white background. A total of eight replicates on a different faba bean were performed for each variety for precision in the measurements. The L^* , a^* , and b^* coordinates were selected on the data processor and on a zero to 100 scale. L^* denoted lightness from black to white, whereas a^* and b^* denoted chromaticity without numerical bounds. It is known that negative a^* is associated with green, positive a^* with red, negative b^* with blue, and positive b^* with yellow (Konica Minolta 2006–2023). The white calibration plate was used to calibrate the system to obtain accurate results. According to these values, the total color was calculated as a range of dark to light, more green or red and more blue or yellow.

2.4 | Cooking Characteristics

Cooking characteristics were analyzed using the methods established by Wani et al. (2016) but with 50g of faba beans.

2.4.1 | Swelling Capacity and Swelling Index

About 50g of faba beans of each variety was added to a graduated cylinder, and the volume was noted. The faba beans were counted and then transferred into a 100mL beaker. The faba beans were submerged in water, covered with aluminum foil, and soaked overnight at room temperature. The water was drained, and the faba beans were gently pressed between paper towels to remove any remaining moisture from their surface. The faba beans were then transferred back into a measuring cylinder, and the volume was measured after soaking. The swelling capacity and index of faba beans of each variety were measured using (Adebowale et al. 2004; Wani et al. 2016).

$$\text{Swelling Capacity, (SC)} = (\text{Volume after soaking} - \text{Volume before soaking}) / \text{No. of seeds} \quad (5)$$

$$\text{Swelling Index (SI)} = \text{Swelling Capacity} / \text{Volume of 1 Seed} \quad (6)$$

$$\text{Where Volume of 1 seed} = \text{Volume before soaking} / \text{No. of seeds} \quad (7)$$

2.4.2 | Hydration Capacity and Hydration Index

Like swelling capacity, faba beans of each variety were added to a preweighed measuring cylinder and weighed to measure around 50g of each. The number of faba beans making 50g was noted for further calculations. The faba beans were similarly submerged in water overnight at room temperature. The water was drained, and the faba beans were patted dry and weighed again to note the increase in weight after swelling. The hydration capacity and hydration index of faba beans of each variety were measured using (Adebowale et al. 2004; Wani et al. 2016):

$$\text{Hydration Capacity, (HC)} = (\text{Weight after soaking} - \text{Weight before soaking}) / \text{No. of seeds} \quad (8)$$

$$\text{Hydration Index, (HI)} = \text{Hydration Capacity} / \text{Weight of 1 Seed} \quad (9)$$

$$\text{Where, Weight of 1 seed} = \text{Weight before soaking} / \text{No. of seeds} \quad (10)$$

2.4.3 | Cooking Time

Four 400mL of glass beakers were filled with distilled water and placed on a hot plate. The water was boiled, and around 20g of faba beans of each variety was added to a marked beaker and made to cook. The timer was started as soon as the faba beans were added. A faba bean was taken from the boiling water at various times, starting from 10, 20, 30, and 40min and so on. It was then gently pressed between two glass slides until the appropriate softness of each variety was achieved, where the seed coat broke easily, and the faba beans were tender all the way through without being mushy (Lange 2020). The time at which each variety was cooked sufficiently, till the center of the faba bean, was noted as the cooking time for the variety (Adebowale et al. 2004; Wani et al. 2016). A similar method was followed for faba beans that had undergone prior soaking for 8h at 25°C in beakers containing 20g of faba beans with 400mL of distilled water, and the time was also noted for them to compare the difference in cooking time for raw and soaked faba beans. All the above procedures were done in triplicates for each variety to obtain a more accurate recording.

2.5 | Microstructure Analysis

Using methods employed in previous studies by Ajala et al. (2023), the microstructure of protein and starch granules in whole faba beans of each variety was characterized using a scanning electron microscopy (SEM). Using a sharp blade, faba beans from each type were carefully sliced into flatter pieces to maximize the surface area for imaging. The faba beans were then fixed, dried, and gold-coated at the Manawatu Microscopy and Imaging Centre (MMIC), Massey University, Palmerston North, New Zealand. Each variety's sliced pieces were fixed for 48h using an electron microscope fixative that contained 3% glutaraldehyde and 2% formaldehyde in 0.1M of phosphate buffer. Following a 20-min dehydration period with standard

ethanol, the surplus fixative was rinsed with distilled water. After being cleaned three times in 100% ethanol for 30min, the samples were dried using a critical point drier (Polaron E3000 series II, Quorum Technologies, England) (Ajala et al. 2023). To maximize the surfaces available for efficient findings, each type was positioned on a stub facing upward or downward.

The gold coating was applied to the dried and fixed samples using a gold sputter coater (Baltec SCD 050 sputter coater, New York, USA). The samples were examined using an SEM (SU3800 Scanning Electron Microscope, Hitachi High-Tech Corporation, Tokyo, Japan) at the Robinson Research Institute, Victoria

University of Wellington, for imaging purposes. The top surface of each faba bean sample was imaged at three separate sites using 400× and 1000× magnifications. To observe the starch granules and protein globules in the faba bean cotyledon, cross-sectional pictures of each faba bean sample were captured at a magnification of 800×. The number of starch granules, cotyledon cell diameter, thickness of cell wall, diameter of starch granules, and the length of surface ridges were calculated using ImageJ software. The SEM images were loaded onto the software and calculated under the “Analyse Particl” setting, which provided data for length measurements used for diameter, thickness, and surface length, as well as counting particles, which helped to quantify the number of starch granules. A series of nine measurements were taken for each parameter using three cells of each variety. The mean of these measurements was taken using Minitab.

2.6 | Preparation of Faba Bean Flour

The broad faba beans were weighed, ground (Coffee Grinder Model BCG200, Breville, Pty Ltd., Sydney, Australia), and sieved through a fine-mesh sieve (B.S. 410/I.S.O. 3310-1:2016, Glenammer Sieves, Ayrshire, United Kingdom) to remove the bigger husk components and collect the faba bean flour. This flour was weighed and stored in a zip-lock bag, away from sunlight, at 21°C until further processing.

2.7 | Protein, Total Starch, and Dietary Fiber

The crude protein content of the faba bean flours was estimated using the Kjeldahl method (Kjeltec 2100 System, Tecator, Sweden), with a nitrogen-to-protein conversion factor of 6.25 (Vogelsang-O’Dwyer et al. 2020).

Total starch and total dietary fiber were analyzed using the Megazyme kits, following the AOAC 996.11 and AOAC 991.43 methods, respectively.

2.8 | Pasting Properties

The pasting properties of the broad faba bean flours were determined using a rapid visco analyzer (RVA) (Rapid Visco Analyzer 4500, Perten Instruments, New South Wales, Australia), following the methods described by Romero and Zhang (2019). To obtain a 3.5-g sample of faba bean flour, each flour sample was precisely weighed using a digital electronic scale with a precision of 0.001 g. The flour was added and combined with 25 g of water in the canister to create a suspension. The paddle was inserted into the canister and assembled in the instrument. The dispersions were allowed to acclimate to 50°C for 1 min. They were then heated to 95°C at a rate of 6°C per minute and maintained at this temperature for 5 min. Lastly, they were cooled back to 50°C at a rate of 6°C per minute and maintained at this temperature for 2 min. A spindle speed of 160 rpm was selected. The total time of a test run was 21 min. Each variety was run in the RVA thrice for a more accurate recording.

2.9 | Statistical Analysis

The physical and cooking measurements for each variety were performed in triplicate, and the colorimetric measurements were performed on eight faba beans of each variety. Using Minitab 21 statistical software (Minitab LLC, Chicago, USA), all the data for average mean and standard deviation were statistically analyzed by one-way analysis of variance (ANOVA) at $p \leq 0.05$. The microstructural images obtained in triplicate for each parameter from the SEM were precisely measured using ImageJ software (ImageJ 0.5.8, National Institutes of Health and the Laboratory for Optical and Computational Instrumentation, University of Wisconsin, USA). ANOVA was used to analyze and obtain the mean of these measurements from ImageJ. Pearson’s correlation coefficients (MS Excel, Microsoft 365, Version 2202) were calculated to study the correlation among various factors.

3 | Results and Discussion

3.1 | Physical Traits of Faba Bean Seeds

Variations in seed variants that result in distinct plant growth patterns could be the origin of the physical differences between the faba bean varieties. Various factors, including growing conditions such as temperature, soil type, and harvest timing, may influence these differences. However, the physical properties of faba bean seeds, including sphericity, equivalent diameter, seed volume, surface area, and thousand-kernel weight, did not show statistically significant differences among the four varieties (Table 1). This similarity in physical traits may be due to the fact that all varieties were grown under uniform agronomic conditions during the 2022–2023 season in Canterbury, New Zealand. Similar ranges for seed length, width, thickness, sphericity, and volume have also been reported for Turkish faba bean varieties, including Sakiz and Tokat (Haciseferoğullari et al. 2003; Altuntaş and Yıldız 2007).

3.2 | Colorimetry

In food systems, color measurement is an important technique for researching consumer acceptability of products, market performance and statistics, and postharvest losses resulting from quality degradation that causes color variations (Dutta and Nath 2024). The faba bean varieties did not differ significantly in L^* and b^* values (Table 2). However, the Evergreen variety showed a significantly lower a^* value than the other varieties, indicating that it retained its green color even upon complete maturity and drying, unlike the other three varieties. This property could help explain some other important characteristics mentioned later in this paper. Despite having a similar overall appearance, faba beans range widely in their flavor and aroma profiles, which gives each variety a distinct place in the food industry. A sample’s average of several colorimeter readings provides enough information to evaluate difficult samples in a meaningful manner, allowing for natural variation without compromising the quality of the result (Phillips 2024).

TABLE 1 | Physical characteristics of whole dried faba bean seeds from four varieties.

Parameter	Early Long Pod	Evergreen	Coles Dwarf	Janet
Length L (mm)	19.88 ± 1.20 ^a	18.18 ± 0.90 ^a	20.74 ± 1.90 ^a	19.42 ± 1.50 ^a
Width W (mm)	14.88 ± 1.00 ^a	13.72 ± 0.80 ^a	15.84 ± 1.70 ^a	14.84 ± 0.80 ^a
Thickness T (mm)	6.02 ± 0.90 ^a	6.66 ± 0.80 ^a	6.26 ± 1.30 ^a	7.74 ± 1.20 ^a
Equivalent dia. Dm (mm)	12.08 ± 1.40 ^a	11.61 ± 0.60 ^a	12.44 ± 1.10 ^a	12.55 ± 0.80 ^a
Sphericity Φ	59.71 ± 2.70 ^a	63.85 ± 1.70 ^a	59.46 ± 2.50 ^a	66.17 ± 4.10 ^a
Seed vol. V (mm ³)	514 ± 186 ^a	449.6 ± 74 ^a	551.8 ± 135.6 ^a	568 ± 121.1 ^a
Surface area A _s (mm ²)	390 ± 94.6 ^a	356.7 ± 39.9 ^a	412 ± 71.9 ^a	418.4 ± 60 ^a
1000 kernel weight (g)	1456 ± 213.6 ^a	1188.8 ± 223.1 ^a	1457.3 ± 293.1 ^a	1552 ± 319 ^a

Note: All values are reported as the mean ± SD, where $N=8$. Values within a row not having a common superscript differ significantly ($p < 0.05$).

TABLE 2 | Colorimetry results for whole faba bean seeds.

Parameter	Early Long Pod	Evergreen	Coles Dwarf	Janet
L*	51.55 ± 9.58 ^a	50.09 ± 2.67 ^a	51.28 ± 3.01 ^a	52.35 ± 4.13 ^a
a*	8.11 ± 3.35 ^a	1.82 ± 2.16 ^b	11.88 ± 3.05 ^a	9.60 ± 2.55 ^a
b*	26.12 ± 4.59 ^a	28.19 ± 1.65 ^a	28.68 ± 1.14 ^a	28.55 ± 1.67 ^a

Note: All values are reported as the mean ± SD, where $N=3$. Values within a row not having a common superscript differ significantly ($p < 0.05$).

TABLE 3 | Swelling and hydration capacities of the four varieties of faba beans.

Parameter	Early Long Pod	Evergreen	Cole Dwarf	Janet
Swelling capacity (mL/seed)	2.67 ± 0.03 ^a	2.12 ± 0.11 ^b	2.19 ± 0.04 ^b	2.51 ± 0.04 ^c
Swelling index	0.51 ± 0.04 ^a	0.52 ± 0.03 ^a	0.49 ± 0.03 ^a	0.49 ± 0.03 ^a
Hydration capacity (g/seed)	1.52 ± 0.02 ^a	1.17 ± 0.05 ^b	1.11 ± 0.02 ^b	1.43 ± 0.01 ^c
Hydration index	0.51 ± 0.03 ^a	0.50 ± 0.01 ^a	0.45 ± 0.01 ^b	0.49 ± 0.007 ^a

Note: All values are reported as the mean ± SD, where $N=3$. Values within a row not having a common superscript differ significantly ($p < 0.05$).

3.3 | Hydration and Cooking Characteristics

By investigating their hydration capacity, we can gain a deeper understanding of how much water faba beans can absorb, how much they swell, and how their size and texture change when they are soaked. Because it can affect the final texture, flavor, and appearance of foods developed from these faba beans, this knowledge is helpful for food processing and cooking (Wood et al. 2016). According to the data presented in Table 3, Early Long Pod had the highest swelling capacity (2.67 mL/seed), which differed significantly from Evergreen, Coles Dwarf, and Janet. Evergreen and Coles Dwarf did not vary significantly. This demonstrates that Early Long Pod can absorb large amounts of water and grow considerably in volume when submerged. This trait can be advantageous in food processing, as it can result in foods of this variety having a better mouthfeel, greater volume, and improved texture. The rise in volume and weight of some faba beans after soaking and water absorption can be attributed to their hydration and swelling capacities. Wood et al. (2016) found that the swelling capacity of chickpeas ranged from 1.33 to 1.60 mL/seed, significantly less than the swelling capacity of all four of the faba bean varieties

investigated in this study (2.12 to 2.67 mL/seed). This might be because, compared to chickpeas, faba beans can swell more when exposed to water due to their larger size and cellular structure, resulting in fewer seeds required to uptake the same volume. When employing these distinct faba bean varieties, the variations in their tendency to swell can impact the outcome of various meal preparations and finished products. In this study, swelling and hydration capacities were reflected in postsoak changes in volume and weight, as well as the number of faba beans that amount to the same weight.

Determining the optimal cooking time for the varieties helps ensure that the faba beans are cooked to the desired texture and taste. By understanding these characteristics, one can achieve optimal results in their dishes and avoid overcooking or undercooking the faba beans. Janet required the longest cooking time (approximately 75 min) to reach a favorable softness (Table 4), which was significantly higher than that of the other varieties, especially when soaked faba beans were used. A high swelling index in faba beans indicates that each faba bean absorbs more water, resulting in softer, tender faba

beans that cook more quickly. Soaking the faba beans overnight before cooking has been shown to significantly reduce cooking time (by at least 30 min), thereby decreasing energy consumption. A noticeable swelling of the faba beans and softening of the seed coat was observed upon prior soaking, resulting in a marked decrease in cooking times (Tables 3 and 4). Evergreen took the least amount of time to cook, and this time was reduced even further when using presoaked seeds. It was observed that seeds from the Early Long Pod variety took significantly longer to soften than those from Coles Dwarf and about the same time as Janet after unsoaked conditions but cooked significantly faster than Janet after soaking, likely due to Early Long Pod's significantly higher swelling capacity and water absorption (Tables 3–5). Cooking is known to result in permanent modifications to proteins and middle lamella pectin, which gives food a mushy texture. Intrinsic characteristics, such as seed size, seed coat thickness, cotyledon composition, hilum and micropyle size, as well as temperature, pH level, and the presence of particles in the soaking media, affect the hydration of faba beans (Perera et al. 2023).

It has been determined that the disintegration of the central lamella in some faba bean varieties results in simple cell separation, which softens the faba beans during cooking. This explains why some faba bean varieties require shorter cooking times than others due to inherited morphological traits (Perera et al. 2023; Wani et al. 2016).

3.4 | Seed Microstructure

Faba bean seeds were imaged cross-sectionally using a scanning electron microscope. Regardless of variety, the starch granules in the faba beans were comparatively large and spherical to oval in shape, with diameters ranging from 16.02 to 35.48 μm (Table 6). These granules were embedded in a protein body matrix, encased within a cell wall of 0.64 to 2.06 μm in thickness. When studied under SEM, the four faba bean varieties showed no significant difference in the number of starch granules per cell (Figure 2 and Table 5). The diameter of a typical cotyledon cell ranged from 97.27 to 161.9 μm , with each variety containing approximately 6–10 starch granules. Only the cell wall thickness differed significantly between Early Long Pod and Evergreen. Janet was not significantly different from Early Long Pod, and Coles Dwarf did not differ significantly from any other variety. These differences in cotyledon microstructure may influence cooking time and water absorption. The integrity and hardness of faba beans are influenced by cell wall thickness; therefore, Janet faba beans may take longer to soften due to their thicker cell walls, which can hinder water penetration and texture development during cooking (Wani et al. 2016).

To investigate surface microstructure, the cotyledon surfaces of mature seeds were imaged. Figure 3 shows the top surface of each variety, revealing ridges, grooves, and wrinkles. The

TABLE 4 | Cooking time (min) of the four varieties of faba beans with and without presoaking.

Cooking method	Early Long Pod	Evergreen	Coles Dwarf	Janet
Cooking without presoaking	66.67 \pm 5.77 ^a	56.67 \pm 2.89 ^b	61.67 \pm 5.77 ^b	73.33 \pm 2.89 ^a
Cooking with presoaking	25.00 \pm 0.02 ^a	20.00 \pm 0.10 ^b	26.67 \pm 5.77 ^a	36.67 \pm 2.89 ^c

Note: All values are reported as the mean \pm SD, where $N=3$. Values within a row not having a common superscript differ significantly ($p < 0.05$).

TABLE 5 | Cross-sectional and surface properties of the four faba bean varieties observed through a scanning electron microscope.

	Early Long Pod	Evergreen	Coles Dwarf	Janet
Number of starch granules/cell (n)	6.33 \pm 1.52 ^a	7.00 \pm 2.65 ^a	7.33 \pm 2.31 ^a	8.00 \pm 1.00 ^a
Cotyledon cell diameter (μm)	107.74 \pm 16.97 ^a	101.24 \pm 3.97 ^a	121.51 \pm 8.56 ^a	125.60 \pm 36.30 ^a
Thickness of cell wall (μm)	1.47 \pm 0.12 ^a	0.99 \pm 0.13 ^b	1.07 \pm 0.37 ^{ab}	1.71 \pm 0.31 ^a
Average diameter of starch granule (μm)	25.97 \pm 3.03 ^a	26.15 \pm 4.16 ^a	22.72 \pm 6.96 ^a	28.79 \pm 5.12 ^a
Length of surface ridges (μm)	33.58 \pm 3.60 ^a	32.27 \pm 3.44 ^a	54.24 \pm 5.30 ^b	32.11 \pm 4.89 ^a

Note: All values are reported as the mean \pm SD, where $N=3$. Values within a row not having a common superscript differ significantly ($p < 0.05$).

TABLE 6 | Protein, starch, and dietary fiber content of flour from faba bean varieties.

Parameters	Early Long Pod	Evergreen	Coles Dwarf	Janet
Crude protein (%)	24.81 \pm 0.51 ^a	24.81 \pm 0.22 ^a	27.49 \pm 0.06 ^b	25.38 \pm 0.07 ^a
Starch (%) ^a	39.1	37.8	35.3	38.4
Total dietary fiber (%) ^a	10.2	9.7	10.3	10.2

Note: All values for crude protein % are reported as the mean \pm SD, where $N=3$. Values within a row not having a common superscript differ significantly ($p < 0.05$).

^aStarch and total dietary fiber values were not tested in replicates.

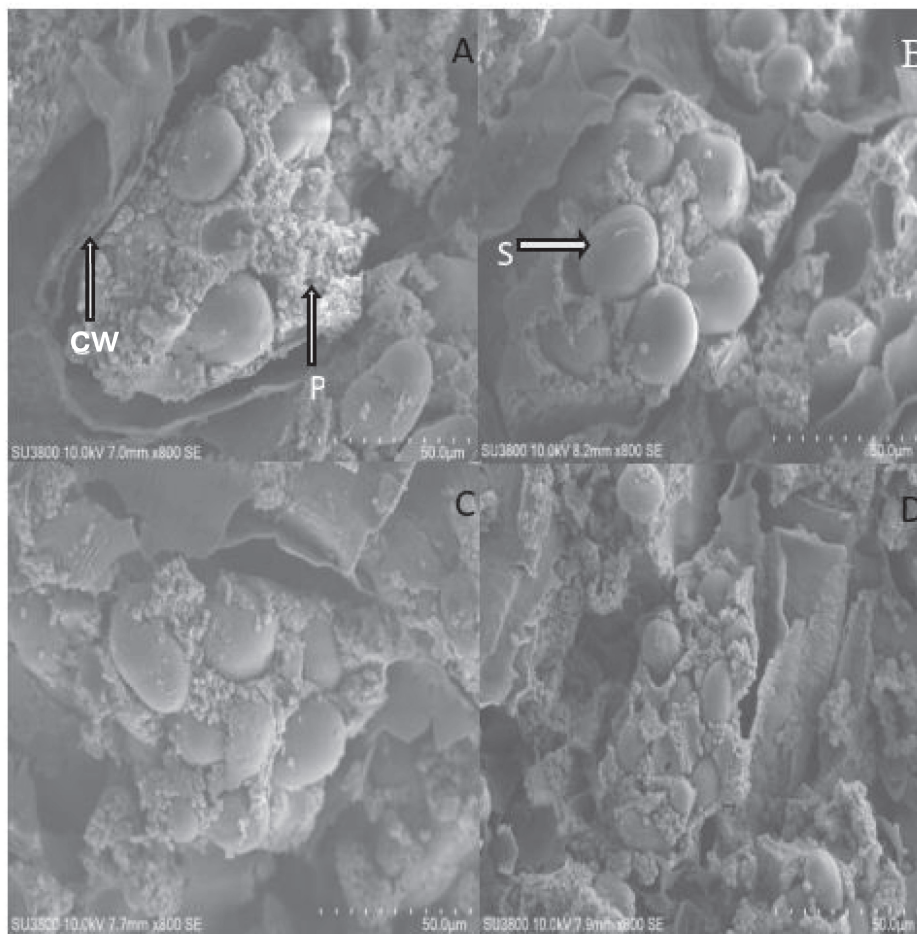


FIGURE 2 | Cross-section of the four faba bean seed varieties through SEM at $\times 800$ magnification. A, B, C, and D represent Early Long Pod, Evergreen, Coles Dwarf, and Janet varieties, respectively. CW, cell wall; P, protein bodies; S, starch granule.

length, structure, and arrangement of surface ridges varied by variety. These features may influence texture, water absorption, milling efficiency, and protein extraction (Wood et al. 2016). Early Long Pod exhibited broad, symmetrical rectangular ridges measuring $30\text{--}36\ \mu\text{m}$ (33.58 ± 3.60), suggesting a pronounced and persistent surface pattern that may affect water absorption and heat dispersion. Evergreen had thinner, irregular ridges with smoother troughs ($32.27 \pm 3.44\ \mu\text{m}$), indicating a smoother surface and potentially more uniform heat diffusion during cooking. Coles Dwarf exhibited narrow Y- or T-shaped ridges with uneven patterns and thin connections ($54.24 \pm 5.30\ \mu\text{m}$), which were significantly longer than those of the other varieties. Janet seed surface exhibited dense surface folding and polygonal ridges, suggesting higher compaction.

Wood et al. (2016) proposed that surface ridges correspond to underlying cell wall connections. Longer boiling durations may be required to soften faba beans with thicker ridges and cell walls, such as those observed in Early Long Pod and Janet, possibly due to higher cellulose content in these structural features. Cellulose resists breakdown during cooking because of its rigid structure. This may explain why, despite exhibiting high swelling and hydration capacities, Janet showed significantly delayed texture softening, as indicated by its prolonged cooking time (Table 4), highlighting the role of cell wall composition

and ridge topology in softening efficiency, independent of water uptake.

3.5 | Protein, Starch, and Dietary Fiber

The protein content of the four varieties was quantified as shown in Table 6; Cole Dwarf had the highest protein percentage (27.49%), which was significantly higher than Janet (25.38%), Early Long Pod (24.81%), and Evergreen (24.81%), all of which had no significant difference in protein content. These results for protein content were within the range reported by Dhull, Kidwai, Noor, et al. (2022). The morphological traits unique to a given species of broad faba bean may be connected to the variance in protein content among several varieties. The growth environment, including temperature, soil composition, and genetic diversity, can also influence the generation of protein in faba beans. Agronomic practices, such as fertilization and irrigation, may further affect protein levels (Walter et al. 2022; Martineau-Côté et al. 2022). It would be preferable to use a faba bean variety with a higher protein content as a source of plant-based protein. As the faba beans were ground manually and not traditionally dehulled, it was necessary to quantify the amount of starch and total dietary fiber in the flour. When tested for their carbohydrate content, the varieties showed a total dietary fiber range of 9.7%–10.3% and a starch range of 35.3%–39.1%, which falls

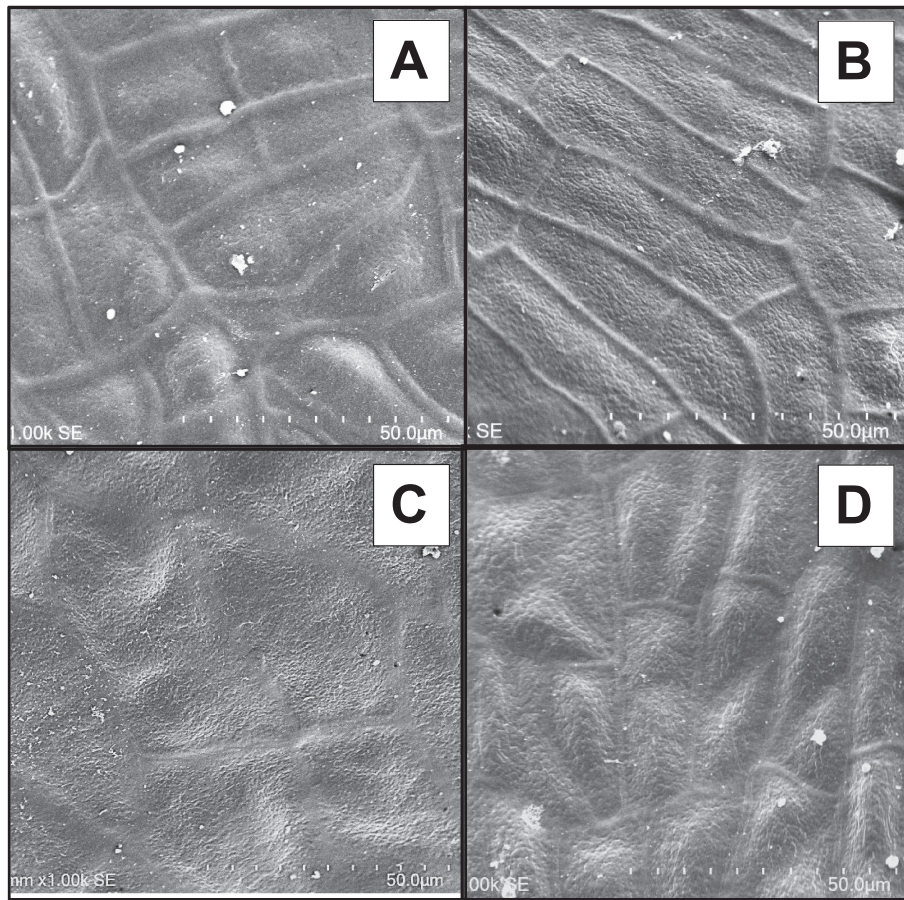


FIGURE 3 | Cotyledon surface topography of the four faba bean seed varieties. A, B, C, and D represent Early Long Pod, Evergreen, Coles Dwarf, and Janet varieties, using SEM at $\times 1000$.

within the range discussed by Badjona et al. (2023). The higher protein and lower starch content in Cole Dwarf, along with its unique seed topography, may partly explain its reduced swelling and hydration performance. Temperature, water availability, and soil fertility can all impact the amount of protein and starch in broad faba beans. While the protein level may decrease somewhat as the faba beans mature, the starch amount usually increases. A lower starch content can be advantageous for specific food processing applications, such as the production of flour or protein isolates. Because faba beans have a high starch content and provide livestock with energy, they have long been an essential component in animal feed. The seed coat of faba beans contains over half of the dietary fiber content, which is crucial for gut health and general well-being. It supports a healthy digestive system, lowers blood sugar levels and may also reduce the risk of developing certain chronic illnesses (Chaudhary et al. 2022). To conclude, further evaluation of functional characteristics may help determine the suitability of each variety for specific processing applications.

3.6 | Pasting Properties

Flour from the Janet variety had significantly higher peak viscosity (693 cP) at a pasting temperature of 77.11°C and peak time of 8.33 min (Table 7). Peak viscosity is a sign of the starch's high water-absorbing and holding capacity, which causes

the gel to become thick and viscous when heated and cooled. The temperature rises above the starch's gelatinisation point, causing the starch granules to swell and the viscosity to rise quickly (creating a peak). The term "pasting temperature" refers to the temperature at which viscosity begins to develop and paste forms as the amylose leaches out of the starch granules (Liang and King 2003; BeMiller 2011). The pasting temperature, roughly 76°C – 77°C for all varieties, is essential to understanding the behavior of starch gelatinisation and can shed light on the minimum temperature required to cook flour and the functional characteristics of starch in various applications. Janet's high peak viscosity and peak time corresponded with its higher swelling and hydration indices (Table 3), reflecting a strong water-holding capacity and slower starch gelatinization. Coles Dwarf, with lower peak and trough viscosities, exhibited reduced starch swelling, aligning with its lower starch content and hydration performance (Table 6), which may limit its functionality in thickening applications.

At the holding stage, a decrease in viscosity was observed as the melting of the crystalline regions of the starch granules enabled rapid water movement into the granules, resulting in a breakdown of viscosity. A reduced breakdown value was detected since the peak did not decline rapidly. This could mean that the sample's starch was resilient enough to endure the continuous high heat and shear stress, which decreased the rate of rupturing of starch granules (Balet et al. 2019). The uniformly low

TABLE 7 | Rapid visco analyzer (RVA) analysis results for flours from four faba bean varieties.

Parameter	Early Long Pod	Evergreen	Coles Dwarf	Janet
Peak 1 (cP)	620 ± 13.11 ^a	591 ± 15.72 ^b	584 ± 15 ^b	693 ± 28 ^c
Trough 1 (cP)	592 ± 18.3 ^a	573 ± 19.1 ^{ab}	546 ± 23.80 ^b	663 ± 43.7 ^c
Breakdown (cP)	28 ± 5.29 ^a	17.67 ± 7.57 ^a	38 ± 15.87 ^a	29.67 ± 16.80 ^a
Final viscosity (cP)	1079 ± 71.8 ^a	962 ± 51.2 ^a	1045 ± 39.8 ^a	1138 ± 109.5 ^a
Setback (cP)	487 ± 64.6 ^a	389 ± 32 ^b	499 ± 16.82 ^a	475 ± 65.8 ^a
Peak time (min)	7.82 ± 0.04 ^a	8.22 ± 0.08 ^b	8.02 ± 0.08 ^b	8.33 ± 0.26 ^b
Pasting temp (°C)	76.21 ± 0.03 ^a	76.83 ± 0.54 ^a	77.11 ± 0.03 ^a	77.11 ± 0.83 ^a

Note: All values are reported as the mean ± SD, where $N=3$. Values within a row not having a common superscript differ significantly ($p < 0.05$).

breakdown values across all varieties suggest the structural resistance of faba bean flours to shear-induced degradation, which may be advantageous in high-temperature processes such as re-torting and extrusion processing, where viscosity stability under shear is desirable (Martínez 2024; Nastasi et al. 2025).

The re-association of amylose with the cooled sample, as the starch granules cooled and retrogradation occurred, led to gel formation due to the recrystallization of amylose chains and a sharp rise in viscosity, resulting in the final viscosity. Flour from Early Long Pod had a significantly lower peak time, indicating a faster rate of thickening/pasting, and the thickest gel (1078 cP as final viscosity) at the end of the run compared to other varieties, which was caused by the disintegration of the granules. A higher setback value for flours from Early Long Pod, Cole Dwarf, and Janet indicated a higher tendency for the starch to retrograde, which may affect gel firmness during storage (Li et al. 2024).

The RVA tests conducted on the faba bean flour samples provided insight into the fact that the starch did not experience adequate breakdown or viscosity reduction throughout the holding period, which could have resulted in a greater final viscosity and affected the overall viscosity profile (Balet et al. 2019). In many industries, such as food processing, where the ideal viscosity level is critical to the quality of the finished product, this could impact the texture, consistency, and performance of the starch.

4 | Conclusions

The physical and microstructural properties of the four native faba bean varieties—Early Long Pod, Evergreen, Coles Dwarf, and Janet—were examined. It is essential to note that the findings presented in this paper reflect performance under the tested conditions and may vary across different seasons or environments. The Evergreen variety displayed a noticeable color difference (green) from the other types (brown); however, the physical dimensions of the various varieties did not differ significantly. When the faba beans were cooked, the Evergreen and Coles Dwarf varieties required far less cooking time than the Janet and Early Long Pod varieties. Soaking the faba beans ahead of time reduced cooking time by nearly a third. Positive Pearson correlation coefficient values were observed between seed weight, volume, cotyledon cell wall thickness, the number

of starch granules per cell, and cooking time. The Janet variety of faba beans exhibited thicker cell walls and dense surface folding with polygonal ridges, contrasting with the smoother topography of Evergreen and suggesting compaction-linked resistance to thermal softening. This structural characteristic may account for its considerably higher (though potentially slower) hydration rates and extended cooking times. Although the pasting temperatures of the faba bean flours did not show significant differences among the varieties, Janet demonstrated a notably higher peak viscosity. This behavior aligns with its strong water-holding capacity and slower gelatinisation profile, consistent with hydration traits and structural persistence. Coles Dwarf had the highest protein content and pronounced surface ridges and also showed lower swelling and viscosity, supporting the idea that macronutrient composition and surface morphology can jointly influence water uptake and functional starch behavior. These findings highlight distinct processing-relevant traits across varieties, supporting the selection of faba bean types based on cooking efficiency, hydration performance, and viscosity behavior for tailored food applications.

Acknowledgements

Open access publishing facilitated by Massey University, as part of the Wiley - Massey University agreement via the Council of Australian University Librarians.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

References

- Adebowale, Y., A. Adeyemi, and A. Oshodi. 2004. "Variability in the Physicochemical, Nutritional and Antinutritional Attributes of Six *Mucuna* Species." *Food Chemistry* 89, no. 1: 37–48. <https://doi.org/10.1016/j.foodchem.2004.01.084>.
- Ajala, A., L. Kaur, S. J. Lee, and J. Singh. 2023. "Native and Processed Legume Seed Microstructure and Its Influence on Starch Digestion and Glycaemic Features: A Review." *Trends in Food Science & Technology* 133: 65–74. <https://doi.org/10.1016/j.tifs.2023.01.011>.

- Altuntaş, E., and M. Yıldız. 2007. "Effect of Moisture Content on Some Physical and Mechanical Properties of Faba Bean (*Vicia faba* L.) Grains." *Journal of Food Engineering* 78: 174–183.
- Badjona, A., R. Bradshaw, C. Millman, M. Howarth, and B. Dubey. 2023. "Faba Bean Processing: Thermal and Non-Thermal Processing on Chemical, Antinutritional Factors, and Pharmacological Properties." *Molecules* 28, no. 14: 5431. <https://doi.org/10.3390/molecules28145431>.
- Balet, S., A. Guelpa, G. Fox, and M. Manley. 2019. "Rapid Visco Analyser (RVA) as a Tool for Measuring Starch-Related Physicochemical Properties in Cereals: A Review." *Food Analysis Methods* 12: 2344–2360. <https://doi.org/10.1007/s12161-019-01581-w>.
- BeMiller, J. N. 2011. "Pasting, Paste, and Gel Properties of Starch-Hydrocolloid Combinations." *Carbohydrate Polymers* 86, no. 2: 386–423. <https://doi.org/10.1016/j.carbpol.2011.05.064>.
- Chaudhary, V., P. Kajla, and Shobhit. 2022. "Chemistry, Nutrient Composition and Quality of Faba Beans." In *Faba Bean: Chemistry, Properties and Functionality*, edited by S. Punia Bangar and S. Bala Dhull. Springer. https://doi.org/10.1007/978-3-031-14587-2_4.
- Dhull, S. B., M. K. Kidwai, R. Noor, P. Chawla, and P. K. Rose. 2022. "A Review of Nutritional Profile and Processing of Faba Bean (*Vicia faba* L.)." *Legume Science* 4, no. 3: e129. <https://doi.org/10.1002/leg3.129>.
- Dhull, S. B., M. K. Kidwai, M. Siddiq, and J. S. Sidhu. 2022. "Faba (Broad) Bean Production, Processing, and Nutritional Profile." In *Dry Beans and Pulses*, edited by M. Siddiq and M. A. Uebersax. <https://doi.org/10.1002/9781119776802.ch14>.
- Dutta, K., and R. Nath. 2024. *Application of Colorimetry in Food Industries*. IntechOpen. <https://doi.org/10.5772/intechopen.112099>.
- Haciseferoğullari, H., I. Gezer, Y. Bahtiyarca, and H. O. Mengeş. 2003. "Determination of Some Chemical and Physical Properties of Sakiz Faba Bean (*Vicia faba* L. Var. Major)." *Journal of Food Engineering* 60, no. 4: 475–479. [https://doi.org/10.1016/S0260-8774\(03\)00075-X](https://doi.org/10.1016/S0260-8774(03)00075-X).
- Jeganathan, B., F. Temelli, and T. Vasanthan. 2022. "Micromorphological and Elemental Characteristics of Chickpea, Faba Bean, Field Pea, and Lentil Cotyledon Topographies." *Cereal Chemistry* 99, no. 2: 380–392. <https://doi.org/10.1002/cche.10499>.
- Lange, C. 2020. "Bon appetit. 7 Tips for Making Your Best Pot of Dried Beans, Even If It's Your First." <https://www.bonappetit.com/story/the-best-pot-of-beans-in-your-future#:~:text=In%20her%20book%20An%20Everlasting,That%20brothy%20black%20bean%20business>.
- Li, W., A. Xie, X. Li, Z. Jin, B. Svensson, and Y. Bai. 2024. "Effects of Large-Ring Cyclodextrin Produced by 4- α -Glucosyltransferase on Gelatinization and Retrogradation Behavior of Starches." *Food Hydrocolloids* 154: 110090. <https://doi.org/10.1016/j.foodhyd.2024.110090>.
- Liang, X., and J. M. King. 2003. "Pasting and Crystalline Property Differences of Commercial and Isolated Rice Starch With Added Amino Acids." *Journal of Food Science* 68: 832–838. <https://doi.org/10.1111/j.1365-2621.2003.tb08251.x>.
- Martineau-Côté, D., A. Achouri, S. Karboune, and L. L'Hocine. 2022. "Faba Bean: An Untapped Source of Quality Plant Proteins and Bioactives." *Nutrients* 14, no. 8: 1541.
- Martínez, M. M. 2024. "Applications of the Rapid Visco Analyser (RVA) in the Food Industry: A Broader View." PerkinElmer. Available Online: <https://www.perten.com/Publications/Articles/Applications-of-the-Rapid-Visco-Analyser-RVA-in-the-Food-Industry-a-broader-view/>.
- Matouk, A., M. EL-Kholy, A. Tharwat, S. El-Far, and S. El-Serey. 2018. "Determination of Physical Properties of Some Legume Crops." *Journal of Soil Sciences and Agricultural Engineering* 9, no. 11: 683691. <https://doi.org/10.21608/jssae.2018.36508>.
- Minolta K. 2006-2023. "Identifying Color Differences Using L*a*b* or L*C*H* Coordinates." <https://sensing.konicaminolta.us/us/blog/identifying-color-differences-using-l-a-b-or-l-c-h-coordinates/>.
- Nastasi, J. R., S. Alagappan, and D. Cozzolino. 2025. "The Combination of Machine Learning Tools With the Rapid Visco Analyser (RVA) to Enhance the Analysis of Starchy Food Ingredients and Products." *Applied Sciences* 15, no. 6: 3376. <https://doi.org/10.3390/app15063376>.
- Penchalaraju, M., and S. J. Don Bosco. 2022. "Legume Protein Concentrates From Green Gram, Cowpea, and Horse Gram." *Journal of Food Processing and Preservation* 46: e16477. <https://doi.org/10.1111/jfpp.16477>.
- Perera, D., L. Devkota, G. Garnier, J. Panozzo, and S. Dhital. 2023. "Hard-to-Cook Phenomenon in Common Legumes: Chemistry, Mechanisms and Utilisation." *Food Chemistry* 415: 135743. <https://doi.org/10.1016/j.foodchem.2023.135743>.
- Phillips, K. 2024. "Spectrophotometrically Measuring the Color of Beans Is Instrumental to Quality Assurance." HunterLab. <https://www.hunterlab.com/blog/spectrophotometrically-measuring-the-color-of-beans-is-instrumental-to-quality-assurance/>.
- Romero, H. M., and Y. Zhang. 2019. "Physicochemical Properties and Rheological Behavior of Flours and Starches From Four Bean Varieties for Gluten-Free Pasta Formulation." *Journal of Agriculture and Food Research* 1: 100001. <https://doi.org/10.1016/j.jafr.2019.100001>.
- Singh, A. K., R. C. Bharati, N. C. Manibhushan, and A. Pedpati. 2013. "An Assessment of Faba Bean (*Vicia faba* L.) Current Status and Future Prospect." *African Journal of Agricultural Research* 8, no. 50: 6634–6641. <https://doi.org/10.5897/AJAR2013.7335>.
- Vogelsang-O'Dwyer, M., I. L. Petersen, M. S. Joehnke, et al. 2020. "Comparison of Faba Bean Protein Ingredients Produced Using Dry Fractionation and Isoelectric Precipitation: Techno-Functional, Nutritional and Environmental Performance." *Food* 9, no. 3: 322. <https://doi.org/10.3390/foods9030322>.
- Walter, S., J. Zehring, K. Mink, U. Quendt, K. Zocher, and S. Rohn. 2022. "Protein Content of Peas (*Pisum sativum*) and Beans (*Vicia faba*)—Influence of Cultivation Conditions." *Journal of Food Composition and Analysis* 105: 104257. <https://doi.org/10.1016/j.jfca.2021.104257>.
- Wani, I. A., D. S. Sogi, A. A. Wani, and B. S. Gill. 2016. "Physical and Cooking Characteristics of Some Indian Kidney Bean (*Phaseolus vulgaris* L.) Cultivars." *Journal of the Saudi Society of Agricultural Sciences* 16, no. 1: 7–15. <https://doi.org/10.1016/j.jssas.2014.12.002>.
- Wood, J. A., E. J. Knights, and M. Choct. 2016. "Topography of the Cotyledon Surfaces and Adjoining Seed Coat of Chickpea (*Cicer arietinum* L.) Genotypes Differing in Milling Performance." *Cereal Chemistry* 94, no. 1: 104–109. <https://doi.org/10.1094/CCHEM-04-160110-FI>.