

Characterization of Protein and Oil in Winter-Hardy Faba Bean (*Vicia faba* L.) Grown in Virginia (USA)

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Received: May 5, 2025

Accepted: June 3, 2025

Online Published: July 15, 2025

doi:10.5539/jas.v17n8p43

URL: <https://doi.org/10.5539/jas.v17n8p43>

Abstract

We had previously reported that faba bean (*Vicia faba* L.) has considerable potential as an alternate winter food legume crop in the eastern USA to supply green immature seeds. Current study was conducted to characterize protein quality of mature faba bean seed. We determined concentrations of protein and oil in mature seeds of two winter-hardy faba bean breeding lines. Two faba bean lines (VSX-BL and VSX-BH) were planted in the field in November 2022 and mature pods were harvested in July 2023. The mean values for protein and oil concentrations were 23.4 and 1.42 percent, respectively. The mean values for Alanine, Arginine, Aspartic acid, Glutamic acid, Cystine, Glycine, Histidine, Isoleucine, Lysine, Phenylalanine, Proline, Serine, Threonine, Total Lysine, Tyrosine, Valine, Methionine, and Tryptophan were 1.02, 2.00, 2.58, 3.92, 0.25, 1.04, 0.62, 0.98, 1.79, 1.03, 1.00, 1.17, 0.86, 1.64, 0.59, 1.11, 0.19, and 0.23 percent, respectively. The mean values for saturated, poly- and mono-unsaturated fatty acids were 0.32, 0.64, and 0.38 percent, respectively. The two winter-hardy lines had significantly different concentrations of several amino acids but variation for fatty acids was not significantly different. Concentrations of oil, protein, amino acids, and fatty acids in our studies were intermediate between soybean and pea seeds. Based on challenges with soybean and pea seeds, we conclude that faba bean seeds produced in Virginia provide a potential source of plant proteins.

Keywords: seed composition, plant proteins, amino acids, fatty acids, food legumes, alternative crops

1. Introduction

Faba bean (*Vicia faba* L.), a traditional food legume of worldwide importance, is receiving increasing attention as a source of plant proteins. It is one of the oldest domesticated crops with numerous nutritional, ecological and economic benefits (Xiao et al., 2021). It is a cool season legume grown on over 6.4 million acres in China, Ethiopia, the United Kingdom, Australia, France and Canada, mostly as a spring crop. In order to develop/establish faba bean as a viable crop for production in Virginia and the mid-Atlantic region of the United States, there is a need for winter-hardy crops. Availability of winter-hardy faba bean can provide an alternate crop for food use and use as a plant-protein source in Virginia and adjoining areas in the mid-Atlantic region of the United States. Additionally, production of winter faba bean can help in sustainable production of succeeding summer crops by providing residual nitrogen (Karkanis et al., 2018).

In recent years, the popularity of plant-based diets and the demand for plant-based protein has soared. With concerns about sustainability, animal welfare, and health driving consumer choices, plant-based protein has emerged as a viable alternative to traditional animal-based protein sources. Among the various plant-based proteins available, including soybean, pea, and hemp, faba bean protein stands out as a superior option for food production (Martineau-Cote, et al., 2022; NCC, 2025).

Faba bean protein is a lesser-known plant-based protein, but it is gaining recognition for its impressive nutritional profile and sustainability credentials. Faba beans, also known as broad beans, are legumes that have been cultivated for thousands of years and are native to the Mediterranean region (Martineau-Cote et al., 2022). Faba bean protein is a complete protein, containing all essential amino acids, and is also high in fiber, vitamins, and minerals. One of the key advantages of faba bean protein is its sustainability. Faba beans are known for their ability to fix nitrogen in the soil, which reduces the need for synthetic fertilizers and promotes soil health. They also require less water and have a smaller carbon footprint compared to other protein crops like soybean and pea (NCC, 2025).

We have previously reported that faba bean has potential as an alternate crop in Virginia to supply green immature seed for human consumption (Dhakal et al., 2024). The current study was conducted to characterize composition of mature faba bean seeds produced in Virginia.

2. Materials and Methods

Two faba bean lines (VSX-BL and VSX-BH) were used in these studies. These lines originated from our faba bean improvement efforts, which aim to identify/develop winter-hardy faba bean lines for commercial production during winter (planting in the fall season and harvesting in following summer season) in Virginia and the mid-Atlantic region of the United States of America. Each line was planted in the field in a Randomized Complete Block Design with two replications. Each plot consisted of 3.6 m long and consisted of four rows spaced 37.5 cm apart.

The field experiments were conducted at Randolph Farm of Virginia State University located in Ettrick, Virginia (Approximately 37°15'N and 77°30.8'W) on Abel sandy loam. Contents (mg kg⁻¹) of P, K, Mg, and Ca in Petersburg soil were 77, 54, 68, and 395. The pH and organic matter (percentage) of soil was 6.4 and 1.5. The plot area received 1 pint per acre of Treflan (Trifluralin) herbicide as a pre-plant incorporated treatment approximately one week before planting. Approximately 100 seeds were planted in each of the four rows of each plot with a research planter at about 2-3 cm on 23 November 2022 and harvested at maturity on July 24, 2023.

Seed composition traits (Concentrations of oil, protein, amino acids, and fatty acids), from both lines and two replications of each line, were determined by Eurofins (Des Moines, IA 50321) using standard analytical protocols (AOAC, 2016). All data were analyzed using SAS (2016) using 5% level of significance.

3. Results and Discussion

Results were encouraging (Table 1). This study only included two faba lines that are being developed as commercial winter-hardy varieties for commercial winter production in Virginia and the mid-Atlantic region of the United States. Even with this limited germplasm, variation existed between seeds of two lines for concentrations of protein and amino acids (glutamic acid, isoleucine, phenylalanine, serine, threonine, and valine). Both lines had similar concentrations of oil, fatty acids, and other amino acids (Table 1). These results demonstrate that considerable variation among faba bean germplasm should be expected and the lines selected for commercial production would need to be studied for these traits before this crop is considered for production in Virginia.

Table 1. Protein and amino acid concentrations (%) in mature seed of winter-hardy faba bean grown in Virginia

Trait		VSU-BL	VSU-BH	Mean	Soybean ⁻¹	Pea ⁻¹
Amino acids	Protein	24.4*	22.3	23.4	36.5	8.8
	Alanine	1.05	0.98	1.02	1.92	0.245
	Arginine	2.08	1.92	2.00	3.15	0.484
	Aspartic acid	2.68	2.47	2.58	5.11	0.656
	Glutamic acid	4.06 a	3.78 b	3.92	7.87	1.02
	Cystine	0.27	0.23	0.25	0.65	0.155
	Glycine	1.07	1.01	1.04	1.88	0.208
	Histidine	0.64	0.60	0.62	1.1	0.167
	Isoleucine	1.01 a	0.95 b	0.98	1.97	0.171
	Leucine	1.82 a	1.75 b	1.79	3.31	0.365
	Phenylalanine	1.06 a	1.00 b	1.03	2.12	0.251
	Proline	1.04	0.96	1.00	2.38	0.277
	Serine	1.20 a	1.14 b	1.17	2.36	0.299
	Threonine	0.89 a	0.84 b	0.86	1.77	0.186
	Total lysine	1.70	1.58	1.64	2.71	0.384
	Tyrosine	0.63	0.55	0.59	1.54	0.127
	Valine	1.16 a	1.06 b	1.11	2.03	0.22
	Methionine	0.20	0.17	0.19	0.55	0.069
	Tryptophan	0.24	0.22	0.23	0.59	n/a
Oil and Fatty acids	Oil	1.50	1.34	1.42	19.9	0.68
	Polyunsaturated	0.70	0.59	0.64	11.3	0.326
	Monounsaturated	0.40	0.36	0.38	4.4	0.061
	Saturated	0.32	0.32	0.32	2.88	0.124

Note. *: Means not followed by any letters, within rows for columns VSU-BL and VSU-BH, were not significantly different at 5 % level whereas means followed by different letters, within rows for columns VSU-BL and VSU-BH, were significantly different at 5% level of significance.

1: USDA, 2019.

Concentrations of protein in the green immature seeds of these lines were 26.0 and 26.5 percent, respectively (Dhakal et al., 2024) for BL and BH lines whereas the corresponding values for the mature seeds were 24.4 and 22.3 percent, respectively. This observation is valuable since it indicates that loss of protein concentration from physiological maturity (when the green beans were harvested for green succulent seeds) to full maturity was in the range of 6.2 to 15.8 percent, depending upon the line (genotype) and may affect identification of faba bean lines which could be used for harvesting at physiologic maturity for green immature seed and the harvest of the remaining plants for dry seed.

Concentrations of protein, oil, amino acids, and fatty acids compared well with other crops such as soybean and pea. The mean protein concentration in pea and soybean has been reported to be 23.4 and 40 percent, respectively whereas the protein concentration in mature faba bean seeds in our studies ranged from 22.3 to 24.4 percent with an overall mean of 23.4 percent. The faba bean is considered a high protein pulse, with a higher protein content than peas and most pulses on the market, such as beans (22.17%), lentils (22.15%), and chickpeas (19.53%) (Estefania et al., 2018) but lower than soy and lupin (40.0%) (Raikos et al., 2014). The faba bean, in addition to being a highly nutritive pulse, is not a genetically modified (non-GMO) and not a regulated allergen—these are competitive advantages when compared to soybean (Raikos et al., 2014; Kudelka et al., 2021). Although GMOs are safe to eat, some consumers are still reticent to include them in their diets (Wunderlich & Gatto, 2015). The dry faba bean seed is mainly composed of starch, proteins, and dietary fiber. The faba bean has a higher protein content than most pulses, including peas, chickpeas, lentils, and beans. The faba bean has an overall well-balanced amino acid profile that is intermediate between pea and soy, containing a high amount of lysine, leucine, isoleucine, threonine, histidine, and aromatic amino acids.

Soy protein has been a popular choice for plant-based protein for many years, and it is widely used in various food products such as plant-based meat alternatives, dairy alternatives, and protein supplements. Soy protein is a

complete protein, meaning it contains all nine essential amino acids required by the human body. It is also a good source of vitamins, minerals, and fiber. However, soy production has come under scrutiny due to concerns over deforestation, genetically modified organisms (GMOs), and potential allergenicity. Moreover, some studies have raised concerns about the potential hormonal effects of soy due to its isoflavone content, although more research is needed in this area. Also, the final product soy is not always the best tasting protein. Pea protein is another popular plant-based protein that is often used in plant-based meat alternatives, protein bars, and shakes. Pea protein is rich in essential amino acids, particularly lysine, which is often limited in other plant-based protein sources. It is also hypoallergenic and easily digestible, making it suitable for those with food sensitivities or digestive issues. The taste of pea protein can be an issue however for some products as it can have a somewhat earthy profile.

This study provides proof of the concept that production of faba bean for plant proteins, as an alternate winter food legume crop in Virginia, is possible. Most of the winter crops in Virginia consist of winter cereals (USDA, 2022) such as wheat and barley. Values of production of these two crops during 2021 were approximately 54 and 2 million dollars, respectively as compared to approximately 337 and 336 million dollars for summer field corn and soybean crops, respectively. Production of faba bean as a grain crop to meet plant protein needs can be helpful to farmers growing winter cereals via not only providing increased income but also due to positive rotation effects and addition of N from Symbiotic N Fixation for supporting succeeding summer crops.

The inclusion of winter faba bean in the cropping system of Virginia is expected to add diversity to Virginia's cropping system, add N for the subsequent crops, and provide specialized food for human consumption.

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Acknowledgments

The author greatly appreciates the assistance provided by the Manager of the Plant Science Research (William Townsend) and his crew in conduct of this study. Special thanks to Mr. Daniel Purdie, Laboratory and Research Technician in the New Crops Program of Virginia State University, for his extensive help with this study.

Authors Contributions

HLB conceptualized, designed the study, conducted the experiments, recorded the data, analyzed the data, and prepared and revised the manuscript.

Funding

This study was supported by Virginia State University with Evans-Allen funds from National Institute for Food and Agriculture of US Department of Agriculture.

Competing Interests

The author declares that there are no competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Informed Consent

Obtained.

Ethics Approval

The Publication Ethics Committee of the Canadian Center of Science and Education.

The journal's policies adhere to the Core Practices established by the Committee on Publication Ethics (COPE).

Provenance and Peer Review

Not commissioned; externally double-blind peer-reviewed.

Data Availability Statement

The data are not publicly available.

Data Sharing Statement

No additional data are available.

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