Journal of Agricultural Science; Vol. 16, No. 8; 2024
ISSN 1916-9752 E-ISSN 1916-9760
Published by Canadian Center of Science and Education

A Preliminary Evaluation of Faba Bean as a Green Shell Bean in Virginia, USA

Ramesh Dhakal[1], Anwar Hamama[1] & Harbans Bhardwaj[1]

[1] Agricultural Research Station, Virginia State University, Petersburg, VA, USA

Correspondence: Harbans Bhardwaj, Agricultural Research Station, Virginia State University, Petersburg, VA 23806, USA. Tel: 1-804-524-6723. E-mail: hbhardwaj@vsu.edu

Received: May 25, 2024 Accepted: June 27, 2024 Online Published: July 15, 2024

doi:10.5539/jas.v16n8p109 URL: https://doi.org/10.5539/jas.v16n8p109

Abstract

Even though faba bean (*Vicia faba* L.) is an important food crop on worldwide basis, its use as a vegetable i.e. use of green seeds as food is limited. We were interested in characterizing production and food quality traits of faba bean grown in eastern USA. Our main objective is to develop faba bean as a winter alternative crop for this region to diversify cropping system that currently mainly depends upon cereal grain crops. This necessitates existence of winter-hardy faba bean varieties. We conducted a preliminary experiment with two winter-hardy faba bean breeding lines to record production and seed composition traits. Two faba bean lines (VSX-BL and VSX-BH) were planted in the field in November 2022 and green pods were harvested in June 2023 at physiological maturity. Values of most of the traits under study were statistically similar between the two lines except for concentration of phosphorus. Results demonstrated that faba bean green pod and green seeds yields could be approximately 5700 and 2100 kg ha^{-1}. The shelling percent in green faba bean pods was approximately 37 whereas seed number per pod was approximately 2.6. Concentrations (g 100 g^{-1}) of fructose, glucose, and sucrose were 0.245, 0.668, 2.9021, respectively whereas concentrations of Fe and Zn (mg kg^{-1}) were 103.7 and 69.7, respectively. Green faba bean seeds contained small amounts of RFO carbohydrates. Seed composition traits of green faba bean seeds compare well with green seeds of pea, soybean, and white lupin. Our results provide a positive proof of concept that production of green faba bean as an alternate winter food legume crop in eastern USA is possible.

Keywords: green pods, green seeds, food legumes, seed composition, alternative crops

1. Introduction

Green shell beans are beans that are fully formed but pods have not yet started to dry. These beans are known by different names including immature shell beans, immature beans, shell beans, fresh shell beans, etc. The consumption of green legumes such as edamame (vegetable soybean), green pea, and lima beans in the U.S. has significantly increased in the last decades and considerable quantities of these legumes have been imported to meet the domestic demand (Duncan et al., 2020). Frozen vegetables provide access to high-quality protein vegetable sources year-round. About 70% of the pea grown domestically are processed and frozen for sale (Biddle, 2017).

Faba bean (*Vicia faba* L.) is an important worldwide dry food legume crop especially as a source of plant protein. Even though dry, fully-mature faba seeds are mostly used for human and livestock nutrition, several countries including China and Chile grow faba bean for human consumption as a vegetable (Lu et al., 2018; Baginsky et al., 2013). Literature about green faba bean seeds (physiologically mature seeds) is scant. However, results from cowpea (*Vigna unguiculata* L. Walp) indicate that cowpea immature pods and seeds are rich sources of protein, minerals and phenolics compared to dry grains (Carvalho et al., 2022) and can be used to promote healthy diet and at same time to stimulate grain legume production. Consumers are increasingly looking for diversity and healthy vegetables, thus, an increase in demand for green seeds is expected in the future. Additionally, introduction of green pods/seeds as new products can help farmers since the green/immature seeds need a shorter growing season compared to dry grains, allowing the crop to escape several abiotic stresses such as drought and high temperatures imposed by climate changes (Carvalho et al., 2022).

Legumes consumed as vegetables contain more water and less protein than those consumed as dry pulses. On the other hand, soluble carbohydrates are higher and starch content is lower in fresh vegetable legumes, which makes them more palatable than dry pulses. Moreover, vegetable legumes are richer sources of antioxidants and other health promoting compounds contained mainly or only in fresh plant biomass, such as carotenoids, phenolics, chlorophyll, vitamin A, and vitamin C (Bhattacharya & Malleshi, 2012). Consequently, their consumption provides a more balanced nutrition full of healthy compounds rather than to serve as a primary protein source. Furthermore, vegetable legumes, which contain much more water than dry pulses, are short season crops that can be grown more than once a year being offered to the market as a fresh food with a limited shelf life.

Commercial green shell bean industry in Virginia is essentially non-existent. Green pea (*Pisum sativum* L.) and lima bean (*Phaseolus lunatus* L.) are produced on the Delmarva Peninsula, mostly in the state of Delaware. Washington State produced most green pea in the United States in 2021 followed by Minnesota and Wisconsin. Three states (Washington, Minnesota, and Wisconsin) produced more than 100 million pounds of green pea in 2021. Washington and Minnesota accounted for roughly 70% of the green pea produced in the U.S. in 2021. A considerable amount of common bean are grown in Puerto Rico, with most of the planted acres harvested as green shell beans and dry bean markets in Puerto Rico is met with imports from mainland states (Beaver et al., 2020). We are not aware of any commercial faba bean production in the mid-Atlantic region of the United States for either dry or green immature seeds.

The New Crops Program of Virginia State University has studied Faba bean as a potential alternative crop, off and on, since mid-1990s (Bhardwaj et al., 1999). Even though Faba bean can be grown as either a spring crop or a winter crop, we are interested in growing it as winter crop (Duc, 1997; Salih & Mustafa, 2008). Our enhanced focus on faba bean in recent times has identified two faba bean lines as winter-hardy.

Given that green immature faba bean seeds could provide consumers a healthy food vegetable and help Virginia's agricultural economy, we conducted a preliminary study to determine potential of producing faba bean and characterize its' green immature seeds for nutritional quality traits. We are not aware of any commercial faba bean production in the mid-Atlantic region of the United States for either dry or green immature seeds.

Based on their analysis of ten samples of fresh faba bean varieties produced in Chile, Baginsky et al. (2013) suggested that the food industry might prefer faba beans with high phenolic content to promote the benefits for human health with the consumption of vegetable with a higher content of antioxidant compounds. The large amount of variation observed among the ten varieties is promising for future efforts to develop and improve strains of faba beans in Chile for maximal nutritional content, taste, and phenotypic growth characteristics.

Green shell beans can supply nutritious and easily digestible physiologically mature seeds and also provide stover for use as a feedstock as livestock feed and biofuels. These crops can be harvested after a shooter growth period as compared to harvest of dry seeds at full maturity, therefore facilitating production of more than one crop per year. Bean varieties are available that can produce immature green seeds in a few weeks as compared to several months for most legumes when grown for harvest of dry seeds.

Consumption of legume vegetables has been associated with health promotion, particularly related with prevention of cardiovascular and metabolic diseases. Legume vegetables are rich in protein, carbohydrates, and dietary fiber. In addition, they constitute an important source of essential micronutrients for humans, including vitamins and minerals, which contribute to maintenance of proper metabolic functions in cells and tissues due to their role as cofactors of metabolic reactions, coenzymes, regulators of gene transcription, and radical scavenging molecules (Bouchenak & Lamri-Senhadji, 2013; Septembre-Malaterre et al., 2017).

Our objectives were to record preliminary production and seed composition data for faba bean green seeds, compare it to other crops, and make an assessment about potential for development of faba bean as vegetable crop.

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 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 on 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 077°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, respectively. 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 November 23, 2022.

Green pods were harvested on 7 June 2023 from 3 m row length of middle two rows of each plot manually. This stage of faba bean growth corresponds, in general terms, to physiological maturity in soybean (R6 stage, Fehr & Caviness, 1971). At harvest, data were recorded on number of pods, pod weight, number of seeds, fresh and dry weights of seeds, and fresh and dry weights of shells. Shelling percentages were calculated by dividing total number of seeds from total pod weights. Seeds and shells were dried for 48 hours at 60 °C.

Contents of N and various minerals were determined according to Association of Analytical Chemists (AOAC, 2016) methods by Waypoint Laboratory, Richmond, VA. Protein content was determined by multiplying N content with 6.25. Sugars were extracted from seed samples (1 g) and analyzed by HPLC following the methods optimized by Johansen et al. (1996). Sugars in the extracts were identified by comparing their retention times with standard sugars. For quantification, trehalose was used as internal standard and the sugar concentration was expressed as g/100 g meal (Bhardwaj & Hamama, 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. This limited germplasm resulted in lack of statistical significance between the two lines. Values of most of the traits under study were statistically similar between the two lines except for concentration of phosphorus. Results demonstrated that faba bean green pod and green seeds yields could be approximately 5700 and 2100 kg ha^{-1}. Green pod yield in white lupin (*Lupinus albus* L.)—a winter legume crop that has been studied extensively in Virginia—was about three times that of the faba bean (Bhardwaj & Hamama, 2012). Extensive research with white lupin over 20+ years has developed high-yielding lines that are adapted to winter production in Virginia whereas faba bean is a relatively new crop in Virginia. We believe that development/identification of superior faba bean varieties would result in better pod yield. The shelling percent in green faba bean pods was approximately 37 whereas seed number per pod was approximately 2.6.

Table 1. Characteristics of green seeds from faba bean grown as green shell beans in Virginia during 2022-23

Trait/Genotype	VSX-BH	VSX-HH	Overall mean
Green pod yield (kg ha^{-1})	5887	5547	5717
Green seed yield (kg ha^{-1})	2304	1897	2100
Seed (number pod^{-1})	2.7	2.4	2.6
Seed (wt g^{-100})	61.7	64.0	62.9
Shelling [a]	40.1	35.0	37.5
Seed moisture [a]	35.6	30.9	33.2
Protein [a]	26.0	26.5	26.3
Fructose [a]	0.212	0.278	0.245
Glucose [a]	0.664	0.672	0.668
Sucrose [a]	2.609	3.192	2.901
Raffinose [a]	0.483	0.269	0.376
Stachyose [a]	0.560	0.366	0.463
Verbascose [a]	0.615	0.578	0.597
S [a]	0.185	0.175	0.180
P [a]	0.675 b	0.740 a	0.707
K [a]	1.345	1.550	1.447
Mg [a]	0.220	0.195	0.207
Ca [a]	0.395	0.270	0.332
B [b]	6,500	5.500	6.000
Zn [b]	73.0	66.5	69.7
Mn [b]	58.0	35.5	46.8
Fe [b]	120.5	87.0	103.7
Cu [b]	22.5	20.0	21.2

Note. [a]: g 100 g^{-1}; [b]: mg kg^{-1}.

x: Means not followed by letters between VSX-BH and VSX-HH columns were not different at 5% level according to Fisher's Protected LSD.

Concentrations of various minerals and sugars are presented in Table 1. Concentrations of protein and calcium in faba bean green seeds were approximately 26 and 0.4 g 100 g^{-1}, respectively whereas concentrations of copper, iron, and zinc were approximately 22.5, 120, and 73 mg kg^{-1}, respectively. Concentrations of fructose, glucose, and sucrose in green faba bean seeds were approximately 0.245, 0.668, and 2.901 g 100 g-1, respectively. Green faba bean seeds contained anti-nutritive carbohydrates (Raffinose, Stachyose, and Verbascose) but their concentrations were smaller in magnitude compared to that of sucrose but similar to fructose and glucose. Recent research has indicated that these non-nutritive carbohydrates can have some positive effects on human gut health such as modulating of the gut microbiota composition, treating constipation, lowering blood cholesterol levels, reducing the formation of putrefactive compounds from protein (Anggraeni, 2022). These non-nutritive carbohydrates are sometimes anti-nutritional compound because they caused flatulence due to excessive gas production. Presence of raffinose-family oligosaccharides (RFOs) along with phytic acid, trypsin inhibitors, lectins, etc. in legume seeds is considered undesirable. Green seeds contain substantially less RFOs than dry seeds and thus the consumption of legume vegetables is much less negatively affected by these anti-nutrients than that of dry pulses (Karapanos et al., 2017).

The nutritional profile of green faba bean seeds compared well with green seeds of white lupin, pea, and soybean (Table 2). Faba bean green seeds had higher protein, calcium, magnesium, and glucose concentrations as compared to pea and soybean and lower than or similar to that in white lupin. As of now, white lupin green seeds, due to alkaloids, is not suitable for human consumption unless some specialized processing to eliminate/reduce alkaloids. However, faba bean is readily suitable for human consumption and is a readily marketable and a sought-after commodity. We have some farmers who grown spring type faba beans and are able to sell faba bean green pods for about \$2 per pound (approximately \$5 per kg) indicating an impressive potential income of approximately \$25,000 to \$30,000 ha^{-1}). Faba bean has advantages over pea and soybean due to availability as a fresh green seeds.

Table 2. Comparison of faba bean green seeds to green seeds of white lupin, pea, and soybean

Trait	Faba bean[1]	White lupin[2]	Pea[3]	Edamame[3]
Protein [a]	26.3	33.0	5.42	12.95
P [a]	0.675	0.4	1.08	1.94
K [a]	1.345	1.3	2.44	6.20
S [a]	0.185	0.2	na	na
Ca [a]	0.395	0.4	0.25	0.20
Mg [a]	0.220	0.2	0.33	0.65
Fe [b]	120.5	55.9	14.7	35.5
Mn [b]	58.0	224	4.10	5.47
Cu [b]	22.5	7.8	1.76	1.28
Zn [b]	73.0	56.1	12.4	9.90
B [b]	6.000	21.7	na	na
Fructose [a]	0.212	0.2	0.39	na
Glucose [a]	0.664	0.4	0.12	na
Sucrose [a]	2.609	2.7	4.99	na
Raffinose [a]	0.483	1.2	na	na
Stachyose [a]	0.560	6.0	na	na
Verbascose [a]	0.615	1.3	na	na
Total [a]	5.143	11.9	5.67	na

Note. [a]: g 100 g^{-1}; [b]: mg kg^{-1}.

[1]: Values are from current study; [2]: Values are from Bhardwaj and Hamama (2013); [3]: Values from USDA (2012).

This study provides a proof of concept that production of green faba bean as an alternate winter food legume crop in Virginia is possible. Karapanos et al. (2017) and Goncalves et al. (2016) observed that use of different legumes species as vegetables for fresh consumption is not yet very common and suggested that green seeds of food legume crops should be used for human nutrition. The review by Ntatsi et al. (2018) showed that legume species have considerable potential as vegetables. Fostering the introduction of these crops in the agricultural systems has positive overall effects, since the crop growth period is much shorter than growing the same crop for dry seeds. However, this does not represent less plant biomass since the plant has already reached its maximum biomass potential, even in the root system where the biological nitrogen fixation has already been established. After harvesting the fresh product, the incorporation of this green biomass in the soil creates a much more beneficial impact on the soil physical and chemical characteristics. Legumes consumed as fresh vegetables are indeed short-season crops with all the benefits on crop rotations, costs of production and overall a more sustainable production, since the required general inputs are much lower. Since water is a very scarce resource, these short-season crops use less water and the water use efficiency is higher than in crops growing further until the production of dry seeds. Growing legumes to be consumed as fresh vegetables provides a high quality product when compared to other vegetables; the product can be much faster prepared than dry pulses fitting into the modern and more demanding consumption habits of consumers.

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 vegetable for green seeds and green pods can be helpful to farmers growing winter cereals via not only providing increased income but also doe to positive rotation effects and addition of N from Symbiotic N Fixation for supporting succeeding summer crops.

Inclusion of winter faba bean in 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.

Our results demonstrate that faba bean has potential as a green shell bean in Virginia. However, our results were obtained from one year's data from a single location. We wish to emphasize that variables analyzed may be affected by varying weather conditions and, in lesser degree, by edaphic conditions. The varieties tested might perform differently under other environmental conditions.

References

Anggraeni, A. A. (2022). Mini-Review: The potential of raffinose as a prebiotic. *IOP Conf. Series: Earth and Environmental Science 980*. The 4th International Conference on Food and Agriculture. IOP Publishing. htttps://doi.org/10.1088/1755-1315/980/1/012033

AOAC (Association of Official Analytical Chemists). (2016). *Official Methods of Analysis* (20th ed.). AOAC, Arlington, VA. Retrieved December 18, 2023, from http://www.aoac.org/aoac_prod_imis/AOAC/AOAC_Member/PUBSCF/OMACF/OMAP_M.aspx

Baginsky, C., Silva, P., Auza, J., & Acevedo, E. (2013). Evaluation for fresh consumption of new broad bean genotypes with a determinate growth habit in central Chil2. *Chilean Journal of Agricultural Research, 73*(3), 225-232. htttps://doi.org/10.4067/S0718-58392013000300004

Beaver, J. S., de Jensen, C. E., Miklas, P. N., & Porch, T. C. (2020). Contributions of Puerto Rico to bean, *Phaseolus* spp., research. *J. Agric. University of Puerto Rico, 104*(1), 43-111. https://doi.org/10.46429/jaupr.v104i1.18287

Bhardwaj, H. L., & Hamama, A. A. (2013). Cultivar and growing location effects on fatty acids, minerals, and sugars in green seeds of white lupin (*Lupinus albus* L.). *The Open Horticulture Journal, 6*, 1-8. https://doi.org/10.2174/1874840601306010001

Bhardwaj, H. L., & Hamama, A. A. (2016). Cultivar, planting date, and row spacing effects on Mungbean seed composition. *Journal of Agricultural Science, 8*, 26-32. https://doi.org/10.5539/jas.v8n10p26

Bhardwaj, H. L., Rangappa, M., & Hamama, A. A. (1999). Chickpea, Faba Bean, Lupin, Mungbean, and Pigeonpea: Potential New Crops for the Mid-Atlantic Region of the United States. In J. Janick (Ed.), *Perspectives on new crops and new uses* (pp. 202-205). ASHS Press, Alexandria, VA. Retrieved from http://www.hort.purdue.edu/newcrop

Bhattacharya, S., & Malleshi, N. G. (2012). Physical, chemical and nutritional characteristics of premature-processed and matured green legumes. *J. Food Sci. Techn., 49*, 459-466. https://doi.org/10.1007/s13197-011-0299-y

Biddle, A. J. (2017). *Peas and beans* (p. 179). Oxfordshire, United Kingdom. https://doi.org/10.1079/9781780640914.0000

Bouchenak, M., & Lamri-Senhadji, M. (2013). Nutritional quality of legumes, and their role in cardiometabolic risk prevention: A review. *J. Med. Food, 16*, 1-14. https://doi.org/10.1089/jmf.2011.0238

Carvalho, M., Carnide, V., Sobreira, C., Castro, I., Coutinho, J., Barros, A., & Rosa, E. (2022). Cowpea immature pods and grains evaluations: An opportunity for different food sources. *Plants, 11*, 2079. https://doi.org/10.3390/plants11162079

Duc, G. (1997). Faba bean (*Vicia faba* L.). *Field Crops Research, 53*, 99-109. https://doi.org/10.1016/S0378-4290(97)00025-7

Duncan, S., Zhang, B., Thomason, W., Ellis, M., Meng, N., Stamper, M., … Drape, T. (2020). Securing Data in Life Sciences—A Plant Food (Edamame) Systems Case Study. *Frontiers in Sustainable Food Systems, 1*, 600394. https://doi.org/10.3389/frsus.2020.600394

Fehr, W. R., Caviness, C. E., Burmood, D. T., & Pennington, J. S. (1971). Stage of development descriptions for soybeans, *Glycine max* (L.) Merrill. *Crop Science, 11*, 929-931. htttps://doi.org/10.2135/cropsci1971.0011183X001100060051x

Goncalves, A., Goufo, P., Barros, A., Dominingues-Perles, R., Trindade, H. H., Rosa, E. A. S., … Rodrigues, M. (2016). Cowpea (*Vigna unguiculata* L. Walp), a renewed multipurpose crop for a more sustainable agri-food system: nutritional advantages and constraints. *J. Sci. Food Agric., 96*, 2941-2951. htttps://doi.org/10.1002/jsfa.7644

Johansen, H. N., Gilts, V., & Knudsen, K. E. N. (1996). Influence of Extraction Solvent and Temperature on the Quantitative Determination of Oligosaccharides from Plant Materials by High-Performance Liquid Chromatography. *J. Agric. Food Chem., 44*, 1470-1474. https://doi.org/10.1021/jf950482b

Karapanos, I., Papandreou, A., Skouloudi, M., Makrogianni, D., Fernández, J. A., Rosa, E., … Savvas, D. (2017). Cowpea fresh pods—A new legume for the market: Assessment of their quality and dietary characteristics of 37 cowpea accessions grown in southern Europe. *J. Sci. Food Agric., 97*, 4343-4352. htttps://doi.org/10.1002/jsfa.8418

Kumar, V., Sinha, A. K., Makkar, H. P. S., Boeck, G. de, & Becker, K. (2012). Dietary Roles of Non-Starch Polysachharides in Human Nutrition: A Review. *Critical Reviews in Food Science and Nutrition, 52*(10), 899-935. htttps://doi.org/10.1080/10408398.2010.512671

Lu, Y. H., Tian, C. R., Gao, C. Y., Wang, B. N., Yang, W. Y., Kong, X., ... He, Y. H. (2018). Phenolic composition, antioxidant capacity and inhibitory effects on α-glucosidase and lipase of immature faba bean seeds. *International Journal of Food Properties, 21*(1), 2366-2377. https://doi.org/10.1080/10942912.2018.1522331

Ntatsi, G., Gutiérrez-Cortines, M. E., Karapanos, I., Barros, A., Weiss, J., Balliu, A., … Savvas, D. (2018). The quality of leguminous vegetables as influenced by preharvest factors. *Scientia Horticulturae, 232*, 191-205. htttps://doi.org/10.1016/J.SCIENTA.2017.12.058

Salih, M., & Mustafa, A. (2008). A substance in broad beans (*Vicia faba*) is protective against experimentally induced convulsions in mice. *Epilepsy and Behavior, 12*, 25-29. https://doi.org/10.1016/j.yebeh.2007.08.016

SAS. (2016). *SAS/STAT® 14.2 User's Guide High-Performance Procedures*. SAS Institute Inc.: Cary, NC, USA.

Septembre-Malaterre, A., Remize, F., & Poucheret, P. (2017). Fruits and vegetables, as a source of nutritional compounds and phytochemicals: changes in bioactive com-pounds during lactic fermentation. *Food Research International, 104*, 86-99. https://doi.org/10.1016/j. foodres.2017.09.031

USDA. (2022). *Virginia Agricultural Statistics 2022 Annual Bulletin*. USDA, National Agricultural Statistics Service. Retrieved December 18, 2023, from https://www.nass.usda.gov/Statistics_by_State/Virginia

USDA. (2023). *National Nutrient Database for Standard Reference*. U.S. Department of Agriculture, Agricultural Research Service. Retrieved December 18, 2023, from https://fdc.nal.usda.gov/fdc-app.html#/food-details/170419/nutrients

Acknowledgments

Not applicable.

Authors Contributions

All three authors contributed towards conceptualization, study design and execution, data recording and analysis, manuscript preparation, and revising.

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 authors declare that they have no known 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 that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Data Sharing Statement

No additional data are available.