New Opportunities for Faba Bean

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Nitrogen fixation by faba bean, which leads to a series of ecosystem benefits, is unparalleled in annual seed crops adapted to cool-season agricultural systems. Cropping systems that include faba bean benefit from lower energy input, which results in a smaller atmospheric carbon footprint; improved soil structure, resulting from deeper roots; and improved soil microbial activity, stemming from residual fixed nitrogen. In addition, faba bean is resistant to a root rot that commonly plagues pea and lentil, thus extending crop rotation options. In northern temperate ecosystems, faba bean seeds contain about 30% protein and produce more protein per unit of land cropped than all other annual legumes, including soybean. In spite of its benefits, faba bean production has been stagnant globally for 40 years. One of the barriers to its wider use has been the presence of vicine and convicine (V-C) in faba bean seeds.

The Importance of V-C

V-C are compounds that are potentially toxic for humans who have a specific enzyme deficiency (variants of glucose-6-phosphate dehydrogenase [G6PD]). For the small proportion of people with a genetically inherited G6PD enzyme deficiency in their red blood cells, V-C–related compounds in faba bean cause the destruction of red blood cells, which presents as an acute hemolytic anemia known as favism. This inherited blood enzyme deficiency is most common in people in the peri-Mediterranean region and affects populations that have the highest faba bean consumption. V-C compounds pose no health risk for the vast majority (>95%) of individuals who do not have this enzyme deficiency.

Traditional means of estimating V-C contents are expensive and require highly sophisticated equipment. Recent efforts have led to the successful development of a new biological test (bioassay) and laboratory methods to detect V-C content in faba bean (2). These methods are relatively inexpensive and can have a turn-around time of as little as one week. The results of the newly developed bioassay are in agreement with the "gold standard" analytical methods for measuring V-C, which are performed by specialized analytical chemists using sophisticated equipment (5). Using the new bioassay ingredient suppliers and food manufacturers will be able to test faba bean-based products, which will support public acceptance of use of this nutritious pulse crop in everyday food products.

Development of New Faba Bean Varieties

Faba bean breeders now have the targets and tools to improve the benefits of faba bean while reducing its potential toxicity. A naturally occurring faba bean variety that produces seeds with 99% less V-C was discovered about 20 years ago. Breeding pure varieties of faba bean is complicated, however, because bees readily cross-pollinate faba beans, making it difficult to maintain pure seed. In addition, the traditional biochemical methods available for measuring V-C, gas or liquid chromatography, are expensive and difficult to use. In 2017, plant breeders discovered a molecular marker for the low V-C gene (vc^{-}) that makes it easier to quickly develop new varieties with this trait (4).

Further advancements in breeding include reducing seed size to facilitate the use of current agricultural equipment for seeding and harvesting faba bean, making it easier to harvest compared to seeding and harvesting problems associated with large-seed varieties. Breeders are also developing zero-tannin faba bean varieties to decrease antinutritional compounds associated with tannins. When ground, the light-colored seed coats can be used as a source of dietary fiber in food products. Genetic research on faba bean is accelerating due to the imminent availability of a sequenced genome and the development of coordinated international research.

Dry and Wet Fractionation of Faba Bean for Protein and Starch Isolation

Similar to other plants belonging to the *Leguminosae* family, faba bean is a starchy legume that accumulates protein during seed development; typically about 25–28% of the whole seed consists of protein. The faba bean seed coat (hull), which contains the majority of the fiber, color, and flavor and most of the antinutritive compounds, must be removed prior to extraction and purification of the protein and starch fractions for food use. The efficiency of dehulling depends on the seed variety, maturity, moisture content, age, and storage conditions. The dehulled beans can be milled into flour for use in subsequent food applications or downstream processing by employing an impact-milling technique, such as hammer or pin milling.

Dry fractionation of protein and starch using air-classification requires the majority of dehulled flours to be milled to a finer (50–75 µm) particle size. Usually optimal separation can be obtained when the particle size distribution curve of the flour and starch granules overlaps with the protein bodies, which are smaller particles compared with starch granules. Faba bean contains large starch granules compared with protein bodies and, therefore, is easier to fractionate using air-classification (6). The fine protein fraction has a protein purity of 65–75%, and an 18–22% yield can be achieved using select faba bean varieties (internal data). The coarse starch fraction (which also contains protein and fiber) produced as a coproduct from air-classification can be used in various food formulations.

A trial was conducted to extract protein concentrates and isolates from Snowdrop, a small-seed, low-tannin faba bean variety. Generally, the method chosen for protein extraction depends on the quality (color, particle size, functionality) of the protein powder needed for the target product application. Faba bean crude protein concentrate (71% protein purity) and acid-precipitated (86% protein purity) and membrane-separated (90% protein purity) protein isolates have demonstrated higher degrees of solubility and emulsifying properties compared with commercial

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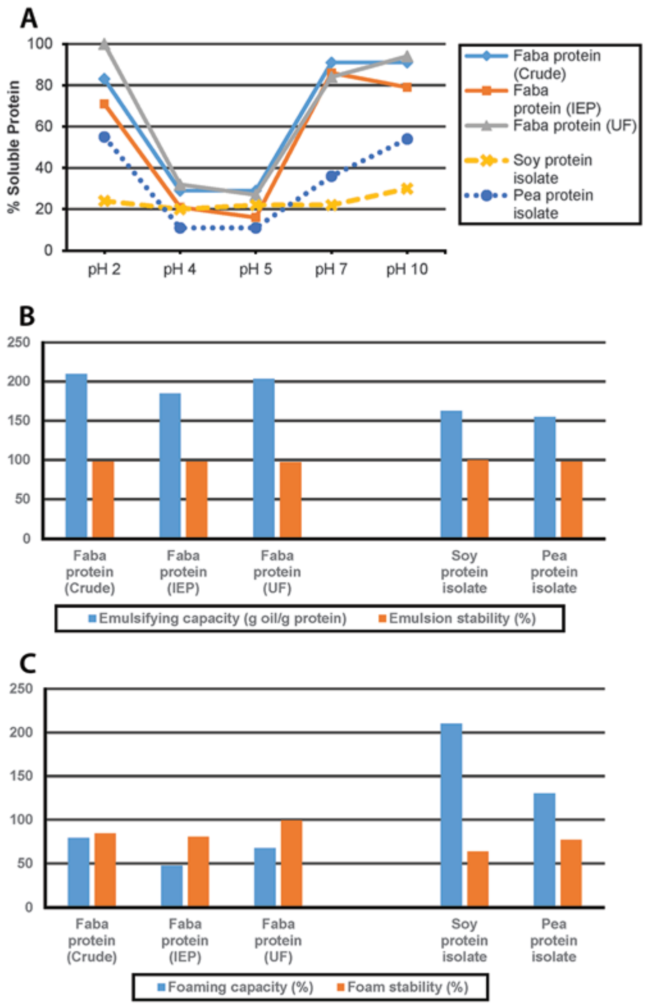

Fig. 1. Solubility (**A**), emulsification (**B**), and foaming (**C**) properties of a protein concentrate and isolates produced through wet fractionation of faba bean flour. Commercial soy protein (79% protein purity) and pea protein (82% protein purity) were used as control samples. IEP: isoelectric precipitated, UF: ultrafiltration membrane separated.

soy and pea proteins tested as control samples (Fig. 1A and B). However, the foaming capacity and stability of these proteins were lower than for the soy and pea protein isolates tested (Fig. 1C). Among the proteins produced during the trial, the membrane-separated faba bean protein contained the lowest amount of residual V-C (Table I). Although wet extraction uses more water and energy compared with dry fractionation, protein isolates produced through wet fractionation have higher purity and improved flavor properties compared with protein concentrates produced through dry fractionation.

Applications

One of the reasons faba bean has the potential to be favored as an ingredient compared with other pulses is its overall high protein content, which enables food manufacturers to readily use the flour and protein fractions to enhance the protein content in products. In applications such as breads and pastas, faba bean flour have worked well as a protein enhancer. Replacing wheat flour with 30% faba bean flour in a bread formulation increased protein content from 11.6 to 16.5% (1). Similarly, for pasta, substituting bread flour with 30% faba bean flour significantly improved the protein quality and fiber content of spaghetti noodles without affecting sensory attributes or physicochemical properties (3).

Table I. Vicine and convicine levels in faba bean flour and proteins produced through wet fractionation[a]

Sample[b]	Vicine (mg/g, dw)	Convicine (mg/g, dw)
Faba bean IEP-extracted protein	7.28	1.60
Faba bean UF-extracted protein	0.89	0.08
Faba bean crude protein extract	22.5	4.78
Snowdrop faba bean flour	5.64	0.94

[a] Method: Purves et al. (5).
[b] EIP: isoelectric precipitation; UF: ultrafiltration membrane separated.

Observations from an extensive ongoing study on faba bean product development suggest that protein concentrates produced by wet fractionation can successfully be applied in the production of shakes and smoothies, while faba bean starches are promising ingredients for use in gluten-free baked products such as cookies and cakes. Faba bean starches also produced viscous pastes when cooked, which would be suitable for soup and sauce applications.

Faba bean ingredients have been tested in extrusion applications as well and were found to work well in products such as breakfast cereals, crisps, and puffs due to their excellent expansion properties. The varying levels of protein in faba bean fractions and ingredients allows for the production of extruded products with a wide range of protein contents. Faba bean has the additional advantage of being naturally neutral in flavor and color. When extruded, these neutral characteristics of faba bean products enable the application of a variety of colors and flavors to suit consumer preferences.

Conclusions

Advancements in faba bean breeding to develop low V-C varieties and development of new food applications are expected to enhance the growth of faba bean production and processing sectors for human consumption. Nutritionally, the high protein content of faba bean makes this pulse crop an attractive choice for incorporation as a protein alternative or protein enhancer in various food products. Promising applications of faba bean ingredients in processes such as extrusion and baking are being tested. It is important to continue focusing on research and product innovation that can help drive increased production and consumption of faba bean.

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