Exploratory study: nutritional, antinutritional, and techno-functional properties of faba bean (*Vicia faba* L. spp. minor) cultivars

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Abstract

Consumption of faba beans (*Vicia faba* L. ssp. minor) as a protein source of local origin has a lower climate impact than consumption of meat or imported soybeans. This study assessed the food potential of locally grown faba beans in the Netherlands by evaluating ten different cultivars. The cultivars were assessed for yield, nutritional composition, antinutritional factors, and techno-functional properties, and compared to soybeans and yellow peas. All faba bean cultivars had higher protein contents (26.4-29.6% d.m.) than yellow peas (20.7% d.m.) but lower than soybeans (33.1% d.m.). However, faba beans had a higher protein yield (1.54-2.05 tons ha^{-1}) compared to literature values for soybeans (0.96-1.19 tons ha^{-1}), but their amino acid composition was less favorable. Faba bean cultivars exhibited higher vicine and convicine levels compared to soy and yellow pea. Dehulling largely reduced the tannin content in the faba bean cultivars. The tannin content of faba beans was lower than that of soy but higher than that of yellow pea. Most faba bean cultivars contained higher levels of phytic acid than soy and yellow pea, and the trypsin inhibitor concentration was comparable to that of yellow pea but markedly lower than in soy. In terms of techno-functional properties, faba bean cultivars showed good foaming capacity and stability, as well as adequate water and oil holding capacities compared to soybeans and yellow peas, with no significant differences between cultivars. Despite the study including measurements of a single growing season and limited replicates, these results highlight faba beans as a promising alternative to soybeans and animal-derived proteins. Selecting the appropriate cultivar is essential to ensure optimal (anti)nutritional composition and techno-functional properties for specific food applications.

Keywords: Field bean; Protein transition; Legume; Nutrients; Antinutrients; Techno-functionality

1 Introduction

The large-scale production and consumption of animal proteins harm the environment (Ferrari et al., 2022). To replace these animal protein sources, alternative protein sources need to be considered to develop comparable food products (Deprá Costa et al., 2022). Plant sources with a high protein content are primarily of interest. Among these plant protein sources with a high protein content, soybean is one of the most commonly used. However, its cultivation is not well-suited to the climates of Northern and Western Europe (Korevaar, 2016). Consequently, soy of-

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ten needs to be imported over long distances, which contributes to higher greenhouse gas emissions (Wiedenhof, 2023). Another drawback of soy as a protein alternative is its association with deforestation (Fehlenberg et al., 2017). Moreover, soybeans are commonly grown as a genetically modified crop, which makes their import in Europe disputable. These concerns underscore the importance of creating food products based on locally cultivable alternatives. One such crop is the faba bean, which is gaining popularity in the Netherlands. The carbon footprint of Dutch-grown faba beans is 32-67% lower compared to European soybeans and even 74-97% lower compared to Brazilian soybeans (Wiedenhof, 2023).

Faba bean (*Vicia faba* L. spp. minor), also known as field bean, is recognized for its high protein content (∼30%), high yields, and nitrogen-fixing capability, reducing the need for fertilizers in crop rotation schemes (Augustin & Cole, 2022). Compared to soy, the protein content and protein availability are lower; however, the protein content of faba beans is higher than that of yellow peas (Liu, 1997; Setia et al., 2019). Moreover, faba bean is not known to be allergenic, is non-GMO (genetically modified organisms), and overall has good functional properties in food applications (Martineau-Côté et al., 2022). While faba beans are high in protein, their drawback is the presence of several antinutritional factors (ANF). The ANFs that are present in faba beans are vicine, convicine, tannins, phytic acid, and trypsin inhibitors. Ingestion of vicine and convicine can trigger acute hemolysis in persons with a genetic glucose-6-phosphate dehydrogenase (G6PD) deficiency, also known as favism, while tannins, phytic acid, and trypsin inhibitors reduce protein bioavailability (Mayer Labba et al., 2021).

Within *Vicia faba* L. subspecies minor, many different cultivars exist. Since faba bean is an emerging crop in the Netherlands, improvements by breeding strategies for specific cultivars have been less prominently developed compared to well-established crops like soy ((Lippolis et al., 2023). Therefore, the differences in most characteristics of faba bean cultivars are unclear except for characteristics like (anti)nutritional composition, which have been described in the literature for a few cultivars grown in other parts of the world (Crépon et al., 2010; Etemadi et al., 2018; Mayer Labba et al., 2021). More faba bean cultivars may be potentially of interest to Dutch agriculture geared towards human consumption. The present study aimed to explore the nutrient composition, antinutritional factors, and techno-functional properties of ten faba bean cultivars grown in the Netherlands. The evaluation focused on characteristics relevant to food applications, aiming to identify cultivars best suited for human consumption and ultimately contributing to the advancement of protein-rich food alternatives with reduced climate impact.

2 Method

2.1 Faba bean cultivars

We assessed the ten different faba bean cultivars (*Vicia faba* L. subspecies minor) for their (anti)nutritional composition and techno-functional properties. The cultivars were provided by CAV Agrotheek B.V. (Wieringerwerf, the Netherlands) to the agricultural research center Vertify (Zwaagdijk, the Netherlands). Vertify cultivated the faba beans in 2022 at their experimental fields in Wieringerwerf, the Netherlands. The faba beans were sown on March 17^{th} and harvested on August 30^{th} of 2022. This growing season had an average temperature of 14.3 ^{o}C and a total rainfall of 243.5 mm, as recorded by the Sencrop weather station in Wieringerwerf. The soil (pH 7.5) consisted of 58% sand, 22% silt, 11% clay, and 2% organic matter. The faba beans were sown at a row distance of 50 cm on fields of 45 m^2, and these cultivation experiments were performed in duplicate. All plants were treated equally with a standard application of protection products. The included cultivars were Allison, Birgit, Bobas, Caprice, Cartouche, Fanfare, Taifun, Tiffany, Trumpet, and Viper. Allison, Fanfare, Taifun, Tiffany, and Trumpet are from NPZ Hans-Georg Lemke (Hohenlieth, Germany). Banquise, Cartouche, and Viper are from Limagrain (Saint-Beauzire, France), Bobas from Jorion Philip-Seeds (Hacquegnies, Belgium), and Birgit and Caprice from P.H. Petersen (Grundhof, Germany). Flour made from these faba bean cultivars (see 2.3. Sample preparation) was compared to locally purchased full-fat soy flour and yellow pea flour (Supreme, Oriental Group, Hoofddorp, the Netherlands).

2.2 Total yield, protein yield, and thousand kernel weight

The yield of each cultivar was determined as weight per hectare using the harvesting equipment Sampo 2010 (Sampo Rosenlew, Pori, Finland). After determining the protein content, the protein yield was calculated and expressed in kilograms of protein per hectare. Moreover, the thousand kernel weight (TKW) was estimated by counting how many beans were present in 100 grams. This value was used to calculate the weight of one thousand seeds (beans).

2.3 Sample preparation

The hulls were removed from the inner part of the faba bean using a Retsch GM 200 (Retsch, Haan, Germany). The used settings were 'hit' at 4000 RPM with an interval setting for 4 seconds (2 pulses). Then, the hulls were separated from the beans manually. The dehulled beans were analyzed for their (anti)nutritional composition. To evaluate the techno-functional properties, flour was made by grinding the dehulled beans using the Retsch at 4000 RPM for 10 seconds, without intervals. The resulting powder was then sieved with a flour sieve (mesh size 0.5 mm).

2.4 Nutritional composition

The nutritional composition of the dehulled faba beans was measured by Eurofins (Graauw, the Netherlands). Soy and yellow pea flour were also assessed. The analysis included a standardized set of measurements referred to as the "Big 8" (EC 1169/2011), which comprised the protein content, fat composition, carbohydrate content, and fiber content. Protein content was measured by the Kjeldahl titration method (adapted from EC 152/2009; European Commission (2009)) and computed with a nitrogen-to-protein conversion factor of 5.4, which is adequate for legumes, like faba beans, soybeans, and yellow peas (Mariotti et al., 2008). Total starch content was determined by enzymatic determination according to the international standard ISO 15914 (International Organization for Standardization, 2004). The amino acid composition was measured by using IC-UV (ISO 13903; International Organization for Standardization (2005)), and tryptophan was measured by using LC-FLD (ISO 130904; ISO, International Organization for Standardization (2016)). The results of the fat composition, carbohydrate content, and fiber content are given in the Supplementary Materials.

2.5 Antinutritional composition

The content of antinutritional factors (ANF) of the whole beans and the dehulled faba beans was measured by Nutrilab (Giessen, the Netherlands). Soy and yellow pea flour were also measured. Tannins were determined by the Folin-Denis assay according to the method of Swain and Hillis (1959). Phytic acid was determined by using a phytic acid assay kit (K-PHYT) from Megazyme (Neogen, Lansing, Michigan, U.S.). The method was performed according to the kit's protocol. Vicine and convicine were determined by high-performance liquid chromatography (HPLC) according to the method of Khamassi et al. (2013). Lastly, the trypsin inhibitor activity was measured according to the standard ISO 14902 (International Organization for Standardization, 2001).

2.6 Foam capacity and stability

Foam capacity (FC) and foam stability (FS) were evaluated based on the method described by Sharan et al. (2022). Suspensions of 1% w/w protein were made using demineralized water and flour of the ten dehulled faba bean cultivars, soybeans, or yellow peas. The suspensions were kept overnight in the refrigerator (4 ^{o}C) for hydration. 50 mL of the suspensions were whipped with a milk frother (CA6500/60, Philips, Eindhoven, the Netherlands) for 2 min without heating. The resulting foam was transferred to a 250 mL measuring cylinder, and the foam volume was immediately recorded. After 60 min, the remaining foam volume was used to determine the FS. Foam volume was corrected for drainage by accounting for the liquid that accumulated at the bottom of the cylinder over time. FC and FS were calculated using the following equations:

$$\text{FC } (\%) = \frac{V_f - V_0}{V_f} \times 100 \tag{1}$$

$$\text{FS } (\%) = \frac{V_t}{V_f} \times 100 \tag{2}$$

In which V_0 is the initial volume of the suspension before whipping, V_f is the volume of the foam after whipping, and V_t is the volume of the foam after 60 min.

2.7 Water hydration capacity and oil holding capacity

Water hydration capacity (WHC) and oil holding capacity (OHC) were determined for all faba bean flours derived from dehulled beans, as well as for soy and yellow pea flour, following the method of Stone et al. (2019). 10 mL of demineralized water (for WHC) or 10 mL of canola oil (for OHC) was added to 1 g of flour in a preweighted centrifuge tube. The suspension was vortexed for 10 s every 5 min over 30 min. After vortexing, the samples were centrifuged at 1000 g for 15 min using a Heraeus Megafuge 8 Centrifuge (Thermo Scientific, Waltham, United States). After centrifugation, the supernatant was decanted, and the weight of the remaining wet pellet was quantified. WHC and OHC values were derived using the following equation:

$$\text{WHC or OHC} = \frac{W_w - W_d}{W_w} \tag{3}$$

In which W_w is the wet sample weight and W_d is the dry sample weight.

2.8 Statistical analysis

Nutritional and antinutritional analyses were based on single measurements and were therefore not subjected to statistical analysis. To estimate measurement uncertainty, the nutritional composition of the cultivar Taifun and the antinutritional composition of Cartouche were analyzed in duplicate. Although the dataset is based on single measurements, it provides informative insights for comparing the overall characteristics of the faba bean cultivars as a group with those of soy and yellow pea. The nutritional data of the dehulled beans are given in the Supplementary Materials. The yield and TKW were determined in duplicate, and FC, FS, WHC, and OHC were determined in triplicate. These results are expressed as mean values ± standard deviation. Statistical analyses were conducted using R (version 4.4.1) and RStudio (version 2024.04.2-764). A one-way analysis of variance (ANOVA) followed by Tukey's HSD Post Hoc test ($p < 0.05$) was applied to assess significant differences among the ten faba bean cultivars, soy, and yellow pea.

3 Results and Discussion

3.1 Yield, protein content, and thousand kernel weight

The yield, protein yield, protein content, and TKW of the ten different faba bean cultivars are presented in Table 1. The cultivars showed no statistically significant differences in yield (all p-values ≥ 0.73), likely due to high variability between fields, as reflected by the standard deviations. The yields of the cultivars tested in this study were higher than those reported by Segers et al. (2022) for several cultivars, including Bobas, Fanfare, Cartouche, and Tiffany, grown in the Netherlands in 2019. In that year, Cartouche showed the highest yield at 4.3 tons ha^{-1}. However, in 2020, the same study reported Cartouche as having the lowest yield at 2.0 tons ha^{-1}. This shows that the yield varies a lot from year to year, primarily influenced by environmental conditions.

As expected, all tested faba bean cultivars had a lower protein content than soybeans but a higher protein content than yellow peas. Mayer Labba et al. (2021) also analyzed the protein content of several faba bean cultivars, including Birgit, Fanfare, Tiffany, and Taifun, and reported lower values than in this study. This may indicate a considerable variation in protein content depending on the year and the growing conditions.

Table 1: The yield (tons ha^{-1}), indicative protein yield (tons ha^{-1}), and calculated protein content (% d.m.), and the TKW expressed in grams for the ten faba bean cultivars.

Cultivar	Yield (tons ha^{-1})^a	Protein yield (tons ha^{-1})	Protein content (% d.m.)^{bc}	TKW (g)^a
Cartouche	6.12 ± 0.98^a	1.81	29.6	500 ± 7^{bcd}
Bobas	5.52 ± 0.13^a	1.63	29.5	522 ± 14^{cd}
Viper	6.97 ± 1.37^a	2.05	29.4	493 ± 7^{bc}
Fanfare	6.46 ± 0.19^a	1.89	29.2	563 ± 7^e
Caprice	5.86 ± 0.69^a	1.66	28.3	527 ± 16^{cde}
Birgit	5.89 ± 0.17^a	1.65	28.0	513 ± 11^{cd}
Tiffany	6.14 ± 0.24^a	1.71	27.9	509 ± 5^{bcd}
Taifun	5.82 ± 0.57^a	1.60	27.5	476 ± 6^{ab}
Allison	5.80 ± 0.13^a	1.54	26.6	533 ± 10^{de}
Trumpet	6.65 ± 1.66^a	1.76	26.4	451 ± 1^a

[a] data represented as means ± SD. Means that share the same superscript letter are not significantly different ($p > 0.05$)
[b] Taifun was measured in duplicate to check the reliability of the applied method, showing mean ± SD
[c] Protein content was calculated using a nitrogen-to-protein conversion factor of 5.4

The high protein yield of faba bean supports sustainability by reducing land use while also lowering costs. When compared to data from the literature, faba beans demonstrated a higher protein yield than soybeans cultivated in Brazil. Brazilian soybean yields range from 2.9 to 3.6 tons ha^{-1}, corresponding to protein yields of around 0.96 - 1.19 tons protein ha^{-1} (U. S. Department of Agriculture, 2024). Since the climate in Brazil is more favorable for soybean production than in the Netherlands, the Dutch yields are lower: around 2.5 - 3.0 tons ha^{-1} (Sikkema, 2021).
Among the faba bean cultivars, Trumpet had the lowest TKW, while Fanfare had the highest, which was about 25% greater than Trumpet. Higher plant density increases the yield and the number of pods but decreases the TKW. Competition among pods to use environmental resources causes the plant to develop less (Derogar & Mojaddam, 2014).

3.2 Nutritional profile

The Supplementary Materials show the nutritional profiles of ten faba bean cultivars, soybeans, and yellow peas, focusing on amino acid, starch, fiber, and fatty acid content. Amino acid profiles (mg g^{-1} protein) of all samples exceeded Food and Agriculture Organization adult requirements (Food and Agriculture Organization, 2013), except for sulfur-containing amino acids (methionine and cysteine) in faba beans, which were lower than in soybeans and yellow peas. The sulfur-containing amino acid content in yellow peas exceeded values reported in the literature (Millar et al., 2019). However, it should be taken into account that processing, such as heat treatment, may affect amino acid bioavailability (Gu et al., 2023). The starch content varied from 48.2% d.m. to 53.3% d.m. for the faba bean cultivars with an amylose/amylopectin ratio ranging from 0.47 to 0.55, showing similar values to yellow pea. These contents influence gelling properties which are relevant for food applications (Pither, 2003). Soybeans had negligible starch content due to unmeasured resistant starch. For soy, Warle et al. (2015) reported a starch content of 12.2% with an amylose/amylopectin ratio of 0.94. Fiber content in faba beans (13.4-15.8% d.m.) was lower than that of soybeans (18.3% d.m.) but similar to that of yellow peas (15.5% d.m.), primarily consisting of insoluble fiber (Mayer Labba et al., 2021). Fatty acid content was significantly higher in soybeans (21.9% d.m.) and yellow peas (1.6% d.m.) compared to faba beans (0.74-1.30% d.m.). Variations in fatty acid profiles may influence shelf-life and sensory properties in food applications related to oxidation (Akkad et al., 2019; Roland et al., 2016). These findings highlight compositional differences relevant for food applications, though based on single measurements.

3.3 Antinutritional factors

The consumption of faba beans as a plant-based source of fiber and protein has benefits in terms of health and sustainability. However, the drawback of faba beans and many other pulses is the content of ANF. The faba bean cultivars, soybeans, and yellow peas were investigated for the content of vicine, convicine, tannin, phytic acid, and trypsin inhibitor activity. The content of antinutritional factors (ANF) of whole faba beans and dehulled faba beans is shown in Table 2.

Vicine and convicine

Vicine and convicine were practically absent in soy and yellow peas (Table 2). Among all faba bean cultivars, Allison and Tiffany exhibited the lowest concentrations of vicine and convicine. Due to their reduced antinutritional compound content in the dehulled form, Allison and Tiffany are considered to pose the lowest risk for individuals with G6PD deficiency. Nonetheless, there is no known minimum threshold established at which favism is induced, as this depends on the severity of the G6PD deficiency and the preparation of the faba beans (Gallo et al., 2018; Martineau-Côté et al., 2022). The vicine and convicine content increased for almost all faba bean cultivars after dehulling. This means these molecules are mainly present in the cotyledon, which is in line with the literature (Khamassi et al., 2013). Ivarsson and Neil (2018) reported vicine and convicine levels of 6.6 to 7.9 and 2.5 to 4.4 g/kg d.m., respectively, and Choi et al. (2024) documented a wider range of 5.4 to 15.0 and 1.1 to 22.9 g/kg d.m., respectively. Most cultivars in Table 2 lie within these ranges, considering that Tiffany and Allison are specific genotypes with low vicine and convicine content. Genotypes low in vicine and convicine have been reported in literature to contain 0.16 to 0.60 vicine and 0.017-0.04 g/kg d.m. convicine (Purves et al., 2018). Also, Mayer Labba et al. (2021) measured the ANF content of different faba bean cultivars, including Birgit, Fanfare, Tiffany, and Taifun. In that study, the reported convicine levels were lower than those presented in Table 2, while the vicine levels were more comparable.

Tannin

Tannins are compounds that cause a bitter taste and reduce protein bioavailability by binding and precipitating proteins. Moreover, tannins can interfere with iron absorption (Sarwar Gilani et al., 2012). Table 2 indicates that dehulling greatly decreased the tannin content of faba beans. It is known that tannins are mainly present in the hull (Van Der Poel et al., 1991). The tannin content is also linked to the flower color. Cultivars with colored flowers tend to have higher tannin levels than those with white flowers (Griffiths & Jones, 1977). Among the ten cultivars, Taifun was the only cultivar with white flowers, which is indicated in Table 2 by the lower tannin levels in whole beans compared to the other cultivars. Faba beans are often dehulled for human consumption. The tannin content of all dehulled faba beans was lower than that of soy but higher than that of yellow peas. A disadvantage of breeding for low-tannin cultivars is their increased susceptibility to diseases (Gnanasambandam et al., 2012). The tannin content in Table 2 is similar to that reported by Duc et al. (1999), who found from 0.01% d.m. in low-tannin cultivars to 1.0% d.m. in high-tannin cultivars. Only Taifun showed a higher value than expected.

Phytic acid

Phytate is the partially ionized form of phytic acid. It functions as a storage of phosphate in plant cells. Phytate can interfere with protein digestion and amino acid absorption by inhibiting digestive enzymes (Sarwar Gilani et al., 2012). Additionally, phytate can bind dietary miner-

Table 2: Vicine content (mg kg^{-1}), convicine content (mg kg^{-1}), tannin content (%), phytic acid content (%), and trypsin inhibitor activity (mg g^{-1}) of whole faba beans and dehulled faba beans of the ten cultivars compared to soy flour and yellow pea flour. All data are presented on a dry weight basis.

Cultivar	**Vicine**		**Convicine**		**Tannin**		**Phytic acid**		**Trypsin inhibitor**	
	WB	DB	WB	DB	WB	DB	WB	DB	WB	DB
Soy	n.d.	2.0	n.d.	7.1	n.d.	0.93	n.d.	1.69	n.d.	10.8
Yellow pea	n.d.	2.7	n.d.	9.1	n.d.	0.51	n.d.	0.58	n.d.	2.0
Cartouche[a]	5574 ± 239	6813 ± 239	2833 ± 313	3240 ± 122	1.76 ± 0.02	0.82 ± 0.01	1.55 ± 0.27	1.76 ± 0.11	2.1 ± 0.1	2.1 ± 0.2
Bobas	7441	8117	3543	4143	1.63	0.87	2.06	1.86	2.5	2.7
Viper	8465	9707	4277	4965	1.70	0.78	1.32	1.61	2.0	1.8
Fanfare	5968	6757	3828	4512	1.75	0.79	1.80	1.66	2.0	1.4
Caprice	5079	5756	3223	3650	1.67	0.77	1.76	2.10	2.5	2.3
Birgit	6532	7207	4065	4757	1.64	0.80	1.08	1.81	2.5	2.7
Tiffany	824	813	376	466	1.65	0.73	1.81	2.13	1.6	1.4
Taifun	6982	7658	4828	5443	0.80	0.77	2.03	2.00	2.4	1.8
Allison	758	713	255	388	1.62	0.70	0.68	1.64	2.3	2.8
Trumpet	3378	3941	2105	2574	1.71	0.74	1.78	2.03	1.6	1.9

WB = Whole beans; DB = Dehulled beans

[a] Cartouche was measured in duplicate to check the reliability of the applied method, showing mean ± SD.

als and inhibit their absorption (Rahate et al., 2021). For example, a meal containing a molar ratio of phytate:zinc larger than 15 or phytate:iron larger than 1 is associated with impaired absorption (Hallberg et al., 1989; Turnlund et al., 1984). The phytic acid concentration in soy was similar to that of the different faba bean cultivars, whereas yellow peas exhibited a lower concentration (Table 2). Low phytic acid concentrations in plants have been associated with increased susceptibility to diseases, lower germination success, poor seed development, and poor yield (Pramitha et al., 2021; Silva et al., 2021). Since the yields of the cultivars showed no significant differences (Table 1), our data do not demonstrate this relationship. Mayer Labba et al. (2021) also determined the phytate content in several cultivars, including Birgit, Fanfare, Tiffany, and Taifun, but reported substantially lower concentrations (0.61 - 0.82%). These variations may be attributed to differences in the methods used to measure phytate and phytic acid concentrations or to varying growing conditions.

From Table 2, no clear relation can be seen between dehulling and the phytic acid content. An increase in phytic acid concentration was expected for the cultivars, as phytic acid is predominantly present in the cotyledon, according to the literature (Sarwar Gilani et al., 2012). This result is likely due to the large standard deviation associated with the used method, as observed for Cartouche. Especially since the values involve single measurements, hard conclusions cannot be drawn.

Trypsin inhibitor

Trypsin inhibitors are proteins that interfere with the activity of the digestive protein trypsin, thereby hindering the breakdown of dietary proteins in the small intestine. Therefore, trypsin inhibitors reduce the protein bioavailability. Table 2 displays that the trypsin inhibitor concentrations of the faba bean cultivars were lower than those in soy and comparable to those in yellow peas. By comparing these values with those from Mayer Labba et al. (2021) for faba beans and converted values from Gu et al. (2010) for soy, it can be concluded that soybeans have much higher levels of trypsin inhibitor activity than faba beans. The activity of the trypsin inhibitors in faba beans ranges from 1.2 to 23.1 trypsin inhibitor units/mg between different cultivars. There is no clear relation between dehulling and the trypsin inhibitor concentration.

Trypsin inhibitors can be present in both the hull and the cotyledon (Sharma & Sehgal, 1992).

3.4 Foaming capacity and stability

FC was determined using 1% protein suspensions, and the FS was determined by evaluating the height of the foam after 60 min (Figure 1). Faba bean showed a good FC and FS, with both a higher foam volume and a more stable foam compared to soy. Bobas and Birgit were the only cultivars that did not show a significantly higher value than soy ($p = 0.22$ and $p = 0.17$, respectively). The volume of the faba bean sample more than doubled for most cultivars after whipping. The capacity ranged from 200% to 222%. The FC of faba beans was comparable to that of yellow peas, but the stability was higher. After 60 min, foams of soy flour and yellow pea flour had significantly lower stability than that of all faba bean cultivars (all p-values < 0.001). The FS of the faba bean cultivars ranged from 51.7% to 58.4%, compared to 18.4% for soy and 27.5% for yellow peas. For food applications such as chicken egg replacement, faba beans may therefore be preferable.

3.5 Water hydration capacity and oil holding capacity

From Figure 2, it can be seen that the WHC of soy flour was more than twofold higher than that of faba beans. Also, the OHC of soy flour was approximately 1.6 times higher than that of faba beans. The WHC for the faba bean cultivars ranged from 1.03 g g^{-1} to 1.12 g g^{-1}. The higher WHC and OHC of soy flour compared to faba bean suggest it may be more suitable for industrial applications requiring high water or oil retention, such as meat analogs or bakery products. There were no significant differences in WHC between the ten faba bean cultivars. The difference was significantly larger in comparison to soy and yellow peas, which showed values of 2.30 g g^{-1} and 1.20 g g^{-1}, respectively. Only Viper, Allison, and Trumpet did not have significantly smaller WHC compared to yellow pea ($p = 0.46$, $p = 0.27$, and $p = 0.57$, respectively). Similarly, Stone et al. (2019) reported a higher WHC for soy beans and yellow peas relative to faba beans. Whereas the faba bean cultivars could take up slightly more water than their weight, this is somewhat less than their weight for oil. Also, no significant differences between faba bean cultivars were found for the OHC. The OHC ranged from 0.85 g g^{-1} to 0.92 g g^{-1}. While yellow peas (0.91 g g^{-1}) had an OHC similar to faba beans, soy displayed a considerably higher OHC of 1.43 g g^{-1} (all p-values < 0.001). Contrary to our data, other studies reported that faba beans had a higher OHC than soybeans and yellow peas (Ferawati et al., 2021; Setia et al., 2019; Stone et al., 2019). The finer particle size of the commercial soy and yellow pea flour could have contributed to their higher WHC and OHC.

3.6 Limitations of the study

This exploratory study aimed to provide an overview of essential nutrients, antinutritional factors (ANFs), and selected techno-functional properties of faba bean cultivars grown in the Netherlands, to improve strategies for developing sustainable food products for human consumption. To gain insight into how these cultivars compare to soybeans and yellow peas, we employed commercial laboratories to analyze their nutritional and ANF profiles. The number of measurements was minimized by including only one cultivar in duplicate each time. Such an approach guaranteed the quality of the data but allowed no extensive statistical comparisons of the mono-fold measurements. Another limitation of the study is that only data is included for the year 2022, which was a year that resulted in relatively high yields compared to, e.g., 2021 and 2023.

4 Conclusion

Faba beans cultivated locally in the Netherlands represent an alternative with a lower climate impact than imported soy. Although their crude protein content is lower, the higher protein yield ha^{-1} of faba beans makes them a promising protein source. Amino acid profiles met most Food and Agriculture Organization adult requirements, but the sulfur-containing

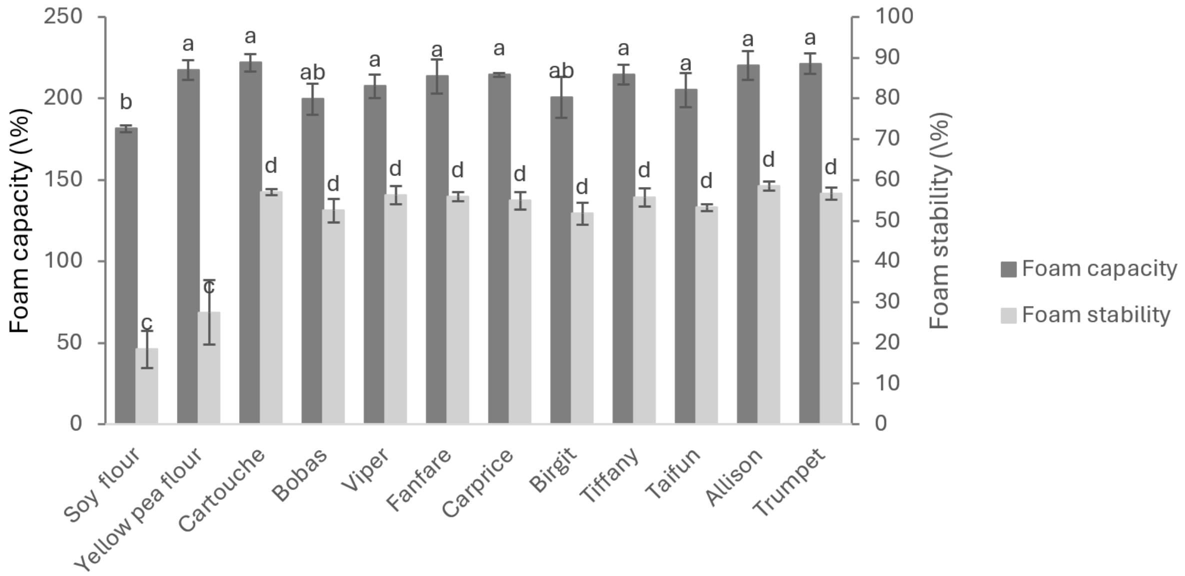

Figure 1: Foam capacity (dark) and foam stability (light) after 60 min of 1% w/w protein suspensions of soy flour, yellow pea flour, and flour of the ten faba bean cultivars. Means that share the same letter are not significantly different (p > 0.05).

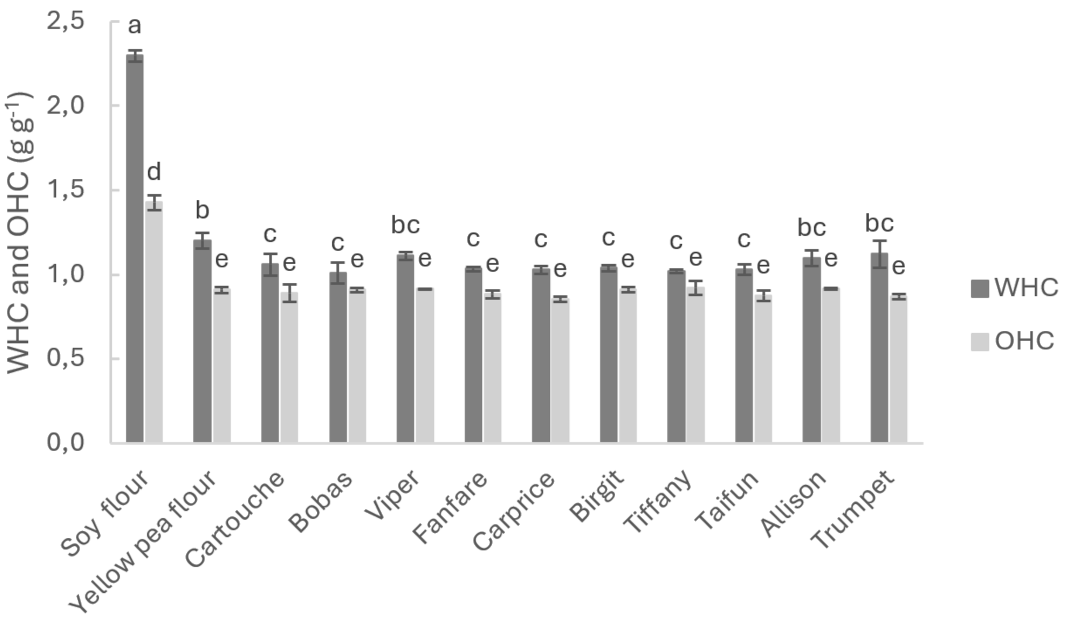

Figure 2: Water hydration capacity (dark) and oil holding capacity (light) of soy flour, yellow pea flour, and flour of the ten faba bean cultivars. Means that share the same letter are not significantly different (p > 0.05).

amino acids are the limiting amino acids in faba beans. Therefore, combining them with complementary protein sources is advisable in diet formulation. Dehulling reduced tannins effectively and results in levels below soy but above yellow peas. Vicine/convicine levels showed large variation between cultivars, which can be taken into account to minimize the risk of favism, and phytic acid and trypsin inhibitors were comparable to or lower than soy. Faba beans also exhibit higher foaming capacity and stability than soy and yellow pea. The water and holding capacities of faba beans are lower than for soy but higher than for yellow pea. That makes faba beans well-suited for food applications that require high foam capacity, foam stability, and adequate water and oil holding capacities. These findings underscore the potential of locally grown faba beans to support the protein transition. More future cultivar-specific research can enable breeders, the food industry, and policy-makers to improve approaches for local cultivation and product innovation.

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