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Exploring faba beans (*Vicia faba* L.): bioactive compounds, cardiovascular health, and processing insights

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ABSTRACT

Faba beans (*Vicia faba* L.), integral to the legume family, are a significant component of the global pulse market because of their nutritional richness and positive health implications. While existing reviews have extensively covered the nutritional composition and anti-nutritional factors of faba beans, and their utilization in food product development, the insights into the optimization of processing methods and upcycling the wastewater during faba bean processing remain insufficient. Therefore, this review focuses on consolidating information about their bioactive compounds, elucidating associated health benefits and unveiling the possible application of processing water derived from faba beans. Key issues discussed include the impact of bioactive compounds in faba beans on cardiovascular health and carcinogenic condition, the challenges in processing that affect bioactive content, and the potential nutritional and functional applications of processing water in food production.

KEYWORDS

Faba bean (*Vicia faba* L;), phytochemicals; proteins; cardiovascular disease; emulsifiers; processing water

Introduction

Legumes, or pulses, are flowering plants that usually form pods that dehisce longitudinally with seeds inside. The family of legumes is called Leguminosae or Fabaceae, the third largest flowering plant family, with over 750 genera and 19,000 species. The Food and Agriculture Organization (FAO) has identified eleven varieties of edible legumes: dry beans (*Phaseolus* spp., *Vigna* spp.), dry broad beans (*Vicia faba*), dry peas (*Pisum* spp.), dry cowpeas (*Vigna unguiculate/Dolichos sinensis*), chickpeas (*Cicer arietinum*), pigeon peas (*Cajanus cajan*), lentils (*Lens culinaris*), Bambara beans (*Vigna subterranean/Voandzeia subterranea*), vetches (*Vicia sativa*), lupins (*Luoinus* spp.), and other minor pulses (Tiwari et al. 2020).

Pulses have been extensively planted in many regions, including Asia, North America, the European Union, and the Middle East (Akibode and Maredia 2012). Pulses are consumed as a low-cost but nutritious food source high in protein content in both the human diet and as animal feed. The global pulse market was nearly US$ 45 billion in 2017 and is anticipated to approach around US$ 76 billion in 2025 (HexaResearch 2019). Among all pulse varieties, the global faba bean market share is projected to grow from US$ 3.18 billion in 2021 to US$ 3.47 billion in 2025. In developing countries, pulses are mainly used for food, while developed countries primarily utilize them for animal feed (Sepngang et al. 2020). Faba beans, in particular, are processed as a food source for the Middle East and North Africa, where they are used as a staple element of the population's diet, according to Sepngang et al. (2020). The share of faba bean in the human diet has increased with the trend toward plant-based meals. In countries like Spain, faba beans have been harvested fresh and canned for human consumption and have also been incorporated at levels up to 40% in bread (Sepngang et al. 2020).

The rising faba bean consumption results from the nutritional value it offers. Pulses are good diet choices for vegetarians or consumers who want to eat less meat as they are rich in carbohydrates and proteins but generally low in lipids. Additionally, recent research has suggested that faba beans have potential positive health impacts including preventing chronic diseases such as obesity, hypertension, and cancer (Ceramella et al. 2022; El-Feky, Elbatanony, and Mounier 2018). Recently, the nutritional composition and anti-nutritional factors in faba beans have been comprehensively reviewed by Rahate, Madhumita, and Prabhakar (2021). This work aims to address key scientific problems in the utilization of faba beans, focusing on (1) the impact of bioactive compounds found in faba beans on several health conditions and the underlying mechanisms of action; (2) the effect of common processing treatments on the retention and functionality of these bioactive compounds in faba beans; and (3) the functional potentials of the faba bean water produced during processing. By addressing these issues, this review seeks to enhance the value of faba beans in both health promotion and sustainable food production.

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Bioactive compounds in faba beans and their health impacts

Food has traditionally been considered in terms of its ability to deliver nutrients such as proteins, vitamins, minerals, and dietary fiber as essential components of a balanced diet. Bioactive compounds are key food components and molecules that present health benefits, disease prevention, or therapeutic possibilities. Additionally, in recent years, a growing body of evidence has shown that certain bioactive compounds present in foods can have potential beneficial health properties such as anti-inflammatory, antioxidant, anti-tumor, anti-hypertensive, and cholesterol-lowering effects. These compounds include polyphenols, carotenoids, anthocyanins, flavonoids, and phytosterols (Ceramella et al. 2022).

Chronic diseases, defined as long-lasting medical conditions that significantly impact health and quality of life, account for 74% of global deaths annually (World Health Organization 2023). Effective interventions are required to address the increasing incidence of chronic diseases, prompting interest in the potential role of bioactive compounds for prevention and management. A plethora of potentially bioactive compounds are present in faba beans, and their consumption has been linked to possible avenues for preventing chronic diseases.

Proteins

As summarized in Table 1, protein makes up 28% of whole faba bean seed and 14% of the bean pod (Mejri et al. 2018; Setia et al. 2019). Within the seed, protein made up 5.1% of the seed coat and 30.5% of the cotyledon (Setia et al. 2019). Proteins found in faba beans include storage proteins, enzymes, and lectins. In the faba bean seed, proteins are mostly stored in cotyledon, with globulins, albumin, prolamin, and glutenin being the most abundant, accounting for nearly 80% of the total seed protein in weight. Alghamdi (2009) examined broad beans and found that globulin accounted for 69.5–75.8% of total proteins, followed by glutelin (12.0–18.4%), prolamin (1.83 – 3.57%), and albumin (1.41 – 3.01%). Globulin is comprised of 7S vicilin-type globulins and 11S legumin-type globulins. According to Warsame et al. (2020), 50 and 27% of legumin and vicilin/convicilin were detected in the faba protein extract, respectively. Globulin provides the primary nutrition and amino acid supply. However, it was low in cysteine, methionine and tryptophan, while albumin, contains more cysteine and methionine (Liu et al. 2017). In addition, enzymes, such as proteases, amylases, and lipases, are another critical component of faba bean proteins and can be utilized to catalyze the hydrolysis of proteins and polypeptides. Lectins are proteins with non-catalytic carbohydrate-binding sites. During plant growth, lectins are responsible for innate immunity and defense mechanisms.

Protease hydrolyze proteins into smaller peptides or amino acids during the fermentation processes or as part of digestion. It is important to note that while large molecule proteins cannot be directly absorbed by the human body and their *in vitro* activity does not necessarily translate to *in vivo* efficacy, small molecule peptides derived from these proteins can be directly absorbed and exert significant biological effects. This distinction is crucial when interpreting the results of *in vitro* studies on faba bean proteins. For instance, Ashraf et al. (2020) reported faba bean protein hydrolysates after simulated digestion consisted of around 37% of peptides <500 Da, 36% of peptides ranging from 500 to 1000 Da, 24% of peptides between 1000 and 3000 Da, and 3% of peptides >3000 Da. Small peptides (<500 Da) are more likely to be absorbed and exhibit bioactivity *in vivo*. The peptides originated from convicilin, vicilin, α and β legumins. Asledottir et al. (2023) identified 1740 peptides in the faba bean protein digest, and 186 unique peptides were found. An overview of the amino acid of faba bean is presented in Table 2. Faba beans generally contain most amino acids but are low in two essential amino acids, i.e., tryptophan and methionine.

During the hydrolysis process, "bioactive peptides (BPs)" can be generated. These short amino acid sequences derived from food proteins after fermentation or gastrointestinal digestion provide physiological and biochemical functions (Indrati 2021). Faba bean derived-BPs have demonstrated cholesterol-lowering and antioxidant effects. According to Ashraf et al. (2020), faba bean BPs reduced cholesterol levels by disrupting two processes: absorption and synthesis. Firstly, as Ashraf et al. (2020) reported, BPs <3 kDa of faba bean had around 28% inhibition of cholesterol micelle solubilization. Cholesterol micellization is an essential process in absorbing cholesterol and requires the formation of bile salt micelles (Woollett et al. 2006). A possible mechanism is the hydrophobic amino acids in faba bean competing with cholesterol molecules within the micelles. These molecules, which spontaneously organize into micelles, exist in the free space between hydrophobic regions and are arranged in a line according to their interaction with bile salts (Megías et al. 2009). Secondly, some *in vitro* studies show that faba bean protein fragments have the potential to inhibit HMG-CoA reductase, the key enzyme catalyzing the rate-limiting step during cholesterol synthesis. Ashraf et al. (2020) revealed that BPs <3 kDa found in faba bean proteins reduced HMG-CoA reductase activity by nearly 16%. Some BPs have similar functional groups and are effective inhibitors of HMG-CoA reductase. These BPs could bind to the enzyme's active site and restrain the mevalonate pathway to inhibit cholesterol production (Ashraf et al. 2020). This has also been emphasized by Moreno et al. (2020), who found that protein hydrolysates of faba bean and other common legumes showed the potential to inhibit HMG-CoA reductase activity in a dose-dependent manner in the *in vitro* model. However, the *in vivo* evidence of this mechanism remains insufficient. In addition, faba protein has demonstrated a hypocholesterolaemia role by increasing fecal steroid excretion. Macarulla et al. (2001) studied the relationship between faba bean protein isolate and cholesterol status in the rat model and noted that both rats fed with faba bean protein isolates and faba bean whole seeds had lower levels of serum LDL and VLDL cholesterols as well as hepatic cholesterol and triacylglycerol, but no change in HDL cholesterol, which was attributed to the raising fecal excretion.

Table 1. Bioactive compounds found in different parts of faba beans.

Compounds	Whole beans	Pod	Whole seed	Seed coat	Cotyledon	Embryo	References
Protein & fiber							
Protein	–	13.8%	27.5%	5.1%	30.5%	–	Mejri et al. (2018); Setia et al. (2019); Askar (1986)
Dietary fiber	–	57.46%	27.5%	82.3%	–	–	Mejri et al. (2018); Boudjou et al. (2013)
IDF	–	30.8 ± 1.2%	9.07 ~ 11.5%	–	–	–	Shen (2020); Njoumi et al. (2019); Millar et al. (2019)
SDF	–	9.3 ± 0.6%	4.2%	–	–	–	
Sugars							
Fructose (mg/g DW)	–	–	0.04 ± 0.01 ~ 0.32 ± 0.05	–	0.04 ± 0.00 ~ 0.34 ± 0.04	0.80 ± 0.10 ~ 3.24 ± 0.06	Goyoaga et al. (2011)
Glucose (mg/g DW)	–	–	0.16 ± 0.07 ~ 0.16 ± 0.09	–	0.16 ± 0.02 ~ 0.19 ± 0.01	2.25 ± 0.00	
Galactose (mg/g DW)	–	–	5.51 ± 0.29 ~ 12.12 ± 0.16	–	5.74 ± 0.03 ~ 12.77 ± 0.11	71.94 ± 0.41 ~ 138.80 ± 0.60	
Sucrose (mg/g DW)	–	–	24.51 ± 0.54 ~ 31.13 ± 0.21	–	28.00 ± 0.29 ~ 35.55 ± 0.38	49.32 ± 1.35 ~ 62.70 ± 0.37	
Melibiose (mg/g DW)	–	–	1.67 ± 0.06 ~ 4.95 ± 0.28	–	1.93 ± 0.07 ~ 5.65 ± 0.23	5.84 ± 0.06	
Stachyose (mg/g DW)	–	–	9.22 ± 0.38 ~ 9.43 ± 0.19	–	10.34 ± 0.10 ~ 10.60 ± 0.51	37.80 ± 0.23 ~ 30.90 ± 0.24	
Verbascose (mg/g DW)	–	–	28.69 ± 0.73 ~ 29.60 ± 0.31	–	32.40 ± 0.30 ~ 33.47 ± 0.73	100.00 ± 0.54 ~ 100.40 ± 1.59	
Raffinose (mg/g DW)	–	–	4.03 ± 0.08 ~ 5.03 ± 0.12	–	4.40 ± 0.11 ~ 5.72 ± 0.05	12.02 ± 0.22 ~ 30.38 ± 1.09	
Ajugose (mg/g DW)	–	–	0.22 ± 0.01 ~ 1.64 ± 0.04	–	0.26 ± 0.03 ~ 1.90 ± 0.05	–	
Phenolics & antioxidant values							
TPC (mg GAE/g DW)	57.2	36.4	12.0	41.5	4.0	–	Boukhanouf, Louaileche, and Perrin (2016)
Flavonoids (mg QE/g DW)	0.91	1.61	0.17	0.37	0.10	–	
Proanthocyanins (mg CAE/g DW)	0.64	0.02	0.42	2.08	0.02	–	
Tannins (mg TAE/g DW)	–	–	5.08	35.77	2.25	–	Lu et al. (2018)
Condensed tannin (mg CAE/g DW)	–	–	–	2.66 ~ 7.91	0.10 ~ 0.16	–	
DPPH (mg GAE/g DW)	31.7	13.4	5.89	22.4	1.26	–	Boukhanouf, Louaileche, and Perrin (2016)
TAC (mg GAE/g DW)	319	136	60.7	192	34.0	–	
FRAP (Fe^{2+} mmol/g DW	0.70 ~ 4.46	–	0.28 ~ 0.83	0.27 ~ 0.93	0.16 ~ 0.73	–	Chaieb et al. (2011)
ABTS (mg/ml)	–	–	IC_{50}=0.97	–	–	–	Pasricha, Satpathy, and Gupta (2014)
Other phytochemicals							
Saponins (µg/g DW)	–	–	30 ~ 388	–	–	–	Shen (2020)
Soyasaponin Bb (µg/g DW)	–	–	6.9 ~ 68	–	–	–	
Soyasaponin βg (µg/g DW)	–	–	22.8 ~ 321	–	–	–	
Phytic acids (mg/100g DW)	–	–	112 ~ 1281	–	–	–	Pasricha, Satpathy, and Gupta (2014)
Trypsin inhibitors (TIU/mg DW)	–	–	1.2 ~ 23.1	–	–	–	
Lectins (HU/mg DW)	–	–	0.8 ~ 3.2	–	–	–	
Vicine (µg/g DW)	–	–	403 ~ 6818	–	–	–	
Convicine (µg/g DW)	–	–	35.8 ~ 3121	–	–	–	
L-DOPA (mg/g DW)	–	–	0.02	–	0	1.95 ~ 2.60	Goyoaga et al. (2008)

DW: dry weight basis; TPC: total phenolic content; GAE: gallic acid equivalent; QE: quercetin equivalent; TAE: tannin acid equivalent; CAE: catechin equivalent; DPPH: 2,2-diphenyl-1-picrylhydrazyl; TAC: total antioxidant capacity; FRAP: ferric reducing antioxidant power; ABTS: 2,2′-azino-bis-(3-ethlbenzothiazoline-6-sulfonic) acid; TIU: trypsin inhibitor unit; HU: hydroxyurea; L-DOPA: levodopa.

"–" Means no data found.

Table 2. Amino acid profile (g/16g N) of faba bean seeds (Schumacher et al. 2011).

Amino acids		Content (g/16g N)
Essential amino acids	Histidine (His, H)	2.4 ± 0.1
	Lysine (Lys, K)	6.3 ± 0.3
	Isoleucine (Ile, L)	4.2 ± 0.1
	Leucine (Leu, L)	7.1 ± 0.2
	Phenylalanine (Phe, F)	4.2 ± 0.1
	Threonine (Thr, T)	3.4 ± 0.1
	Tryptophan (Trp, W)	–
	Valine (Val, V)	4.6 ± 0.1
	Methionine (Met, M)	0.1 ± 0.0
Non-essential amino acids	Arginine (Arg, R)	8.8 ± 0.6
	Cysteine (Cys, C)	1.1 ± 0.1
	Glycine (Gly, G)	4.2 ± 0.1
	Proline (Pro, P)	3.5 ± 0.1
	Glutamine (Gln, Q)	–
	Tyrosine (Tyr, Y)	3.5 ± 0.2
	Serine (Ser, S)	4.3 ± 0.1
	Alanine (Ala, A)	3.9 ± 0.1
	Aspartic acid (Asp, D)	10.1 ± 0.3
	Asparagine (Asn, N)	–
	Glutamic acid (Glu, E)	16 ± 0.4

"–" Means not examined.

Similarly, Al-Masri (2015) reported significant decreases in serum LDL and VLDL cholesterols and an increase of HDL cholesterol in rats after consuming faba protein, suggesting the involvement of elevated excretion of cholesterols or less liver cholesterol secretion. Furthermore, the hypocholesterolaemia impact of faba bean whole seeds was higher than that of the protein isolates, indicating a positive interaction among faba bean bioactive compounds when regulating the cholesterol.

The antioxidant properties of BPs from faba bean have also been recognized in the literature. This is affected by the size and structural properties of the generated peptides. According to Samaei et al. (2020), faba bean BPs presented desirable ABTS- and DPPH-radical scavenging activities and ferrous ion-chelating ability. They indicated that the smaller the peptides, the higher the bioactivity. The higher proportion of terminal carboxylic and amino groups promotes the metal ion binding process. Nine antioxidant peptides from faba bean were identified by Samaei et al. (2020) that showed 100% homology with previously described peptides from literature, namely TETWNPNHPEL, FVPH, LY, IY, VY, YV, LW, IW, and AW.

Moreover, proteins extracted from faba bean have demonstrated tumor inhibitor potential. Some faba bean proteins may slow carcinogenesis by inhibiting key enzymes. Faba beans are rich in Bowman-Birk type trypsin inhibitors (VFTI-GI) with low molecular weight (7.5 and 15 kDa) which have anti-cancer properties. These protease inhibitors are known as anti-nutrients but exert positive health effects. Tumor growth and spread require protease activity. VFTI-GI was found to inhibit trypsin and significantly reduce the development of HepG2 liver cancer cells by promoting chromatin condensation and cell apoptosis (Fang et al. 2011; Ye, Ng, and Rao 2001). Matrix metalloproteinase-9 (MMP-9), an enzyme that plays a role in pathological processes, is typically regulated in healthy tissue, but its overexpression is often seen in various types of cancers and is linked to cancer progression, invasion, and spread. A study by Lima et al. (2016) has shown that water-soluble proteins extracted from faba beans inhibited the activity of MMP-9 and the migration of colon cancer cells. Lectins are other faba bean proteins that may prevent carcinogenesis. Lectins have anti-inflammatory properties and can suppress cytokines and chemokines. Additionally, faba bean proteins have antioxidant properties and can neutralize harmful compounds like free radicals that can cause cell damage and raise cancer risk. Figure 1 below illustrates representative bioactive peptide sequences and their activities found in faba beans in recent research.

Dietary fiber

Dietary fiber (DF) is made up of carbohydrate polymers with more than ten monomeric units that cannot be hydrolyzed or digested by endogenous enzymes in the human small intestine. Based on the solubility, DF is classified into soluble dietary fiber (SDF) and insoluble dietary fibers (IDF). SDF, including pectin and gum, dissolves in water, while IDF, such as cellulose and hemicellulose, do not dissolve in water and pass through the digestive system relatively unchanged (Gdala and Buraczewska 1997). Approximately one-third of the faba bean seed comprises DF, of which more than three-fourths are stored in the seed coat. The level of IDF (around 10%) is much higher than that of SDF (around 4%) in the faba bean seed. Interestingly, more than 50% of faba bean pods are DF (Mejri et al. 2018).

DF of faba bean has been shown to reduce blood sugar and cholesterol. Several mechanisms cause the decrease in cholesterol levels due to DF. Firstly, SDF binds to bile acids in the digestive tract, forming a complex that is not easily absorbed and is eliminated from the body through feces, signaling the liver to produce more bile acids (Cornfine et al. 2010). According to Çalışkantürk Karataş, Günay, and Sayar (2017), the bile acid binding capacities of faba bean seed coat and whole faba bean were 283 and 15% (taking the cholestyramine as 100%), respectively. This, in turn, increases the conversion of cholesterol to bile acids, thus reducing cholesterol levels. Additionally, DF in the gastrointestinal tract can increase the production of short-chain fatty acids (SCFAs), promoting bile acid excretion and altering hepatic lipogenesis (Pontifex et al. 2021). The study by Çalışkantürk Karataş, Günay, and Sayar (2017) examined the SCFAs produced by IDF from faba bean seed and seed coat and reported a similar proportion of two types of SCFAs, propionic and butyric acids, in comparison with brans (wheat, rye, and oat), grape seed and pomace, and inulin.

Sugars

Apart from polysaccharides, carbohydrates also include low molecular weight sugars, such as monosaccharides (glucose, fructose, galactose, and tagatose), disaccharides (sucrose, lactose, maltose, and isomaltose), and oligosaccharides (malto-oligosaccharides and non-digestible oligosaccharides including raffinose, stachyose, fructo- and galacto-oligosaccharides). Faba beans contain around 1–2% of total sugar on a dry

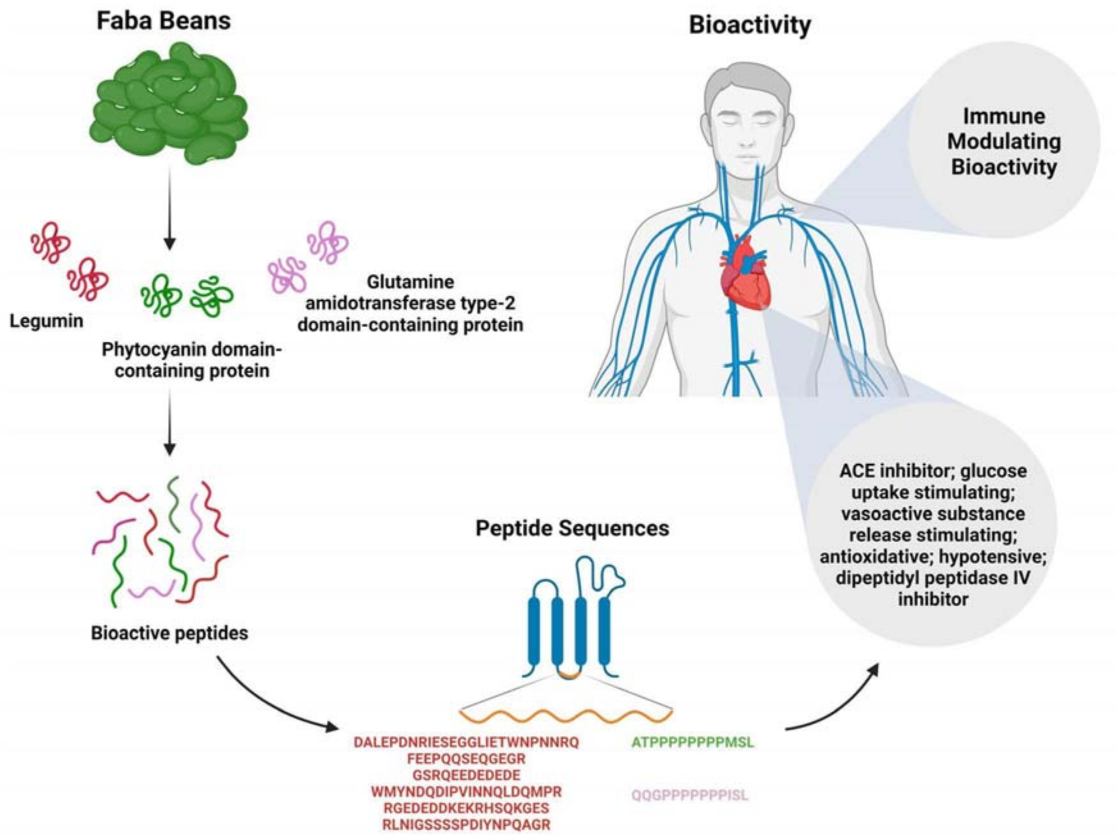

Figure 1. Representative bioactive peptides found in faba beans and their bioactivities. Data were retrieved from Jakubczyk et al. (2019) and Asledottir et al. (2023).

weight basis. Faba bean seeds contain disaccharides and oligosaccharides as their primary forms of sugar, with monosaccharides present in smaller quantities. As summarized in Table 1, sucrose and verbascose are the major disaccharides and oligosaccharides found in faba bean seeds, respectively. This distribution is consistent across seed cotyledon and whole seed. However, the embryo of the faba bean seeds demonstrates a notable presence of galactose and verbascose, along with lesser amounts of sucrose and stachyose, as well as other minor sugars (Goyoaga et al. 2011).

Sugars in faba beans, such as sucrose, provide energy and contribute to the beans' overall nutrient content. Oligosaccharides such as raffinose are not easily digestible in the small intestine. They pass into the large intestine and are fermented by bacteria to produce SCFAs like lactate, acetate, propionate and butyrate (Gullón et al. 2015). These SCFAs help lower cholesterol levels. The study of Finley, Burrell, and Reeves (2007) demonstrated the serum cholesterol-reducing property of beans by increasing colonic propionate formation, suggesting a decrease in cholesterol absorption from the gut.

Meanwhile, SCFAs produced by oligosaccharides increase the excretion of bile acids and modulate the expression of key genes involved in intestinal cholesterol biosynthesis (Alvaro et al. 2008; Matysik et al. 2021). SCFAs also reduce the risks of certain cancers and heart disease by modulating gut immunity and inflammation. By promoting the growth of beneficial microbiota in the gut and altering gut signaling and metabolism, oligosaccharides help maintain a healthy gut barrier and reduce chronic inflammation, thereby reducing the risk of colon cancer and other diseases (Mano et al. 2018). Butyrate is the primary energy source for the epithelial cells lining the large intestine. The increased butyrate production has been associated with a reduced risk of colon cancer, as it protects these cells against agents that cause cellular changes and may even impede tumor growth (Gullón et al. 2015). Research also demonstrated that in colon cancer prevention, SCFAs could regulate the gene expression involved in carcinogenesis *via* the modulation of microRNAs (Hu et al. 2011).

Phytochemicals

Phytochemicals are bioactive non-nutrient compounds found in food from plants such as fruits, vegetables, and grains, demonstrating certain potential health benefits when they participate in metabolism (Diep, Baranowski, and Baranowski 2014). Compounds including saponin, phenolics, lectin, phytic acid, trypsin inhibitor and some other oligosaccharides have been recognized as anti-nutrients or anti-nutritional factors for a long time in agriculture systems, mainly because they adversely influence the digestibility and bioavailability of some essential nutrients, such as proteins and minerals, and reduce the animal's growth rate (Gilani, Cockell, and Sepehr 2005). For example, Woyengo, Beltranena, and Zijlstra (2017) pointed out that the soybean, canola, and flaxseed feed products presented several anti-nutrients such as trypsin inhibitor limited feed intake and nutrient utilization in pigs and poultry. This results in low feed acceptance and animal performance (Kokou and

Fountoulaki 2018). More recently these anti-nutrients have been shown to have important positive properties including antioxidant, antimicrobial, anti-inflammatory, and anti-tumor abilities toward human health (Labba, Frøkiær, and Sandberg 2021; Worku and Sahu 2017). The amounts of common phytochemicals found in faba beans, including phenolics, saponins, phytic acids, trypsin inhibitors, lectins, vicine, convicine, and L-DOPA are displayed in Table 1. These compounds are discussed in the following sub-sections.

Phenolics

Phenolics are bioactive secondary metabolites widely distributed in plants. So far, more than 8000 phenolic structures have been found, and the most common types identified in legumes are tannins, flavonoids, and phenolic acids. Tannins are categorized into condensed tannins (hydrolysable) and proanthocyanins (non-hydrolysable) and are often found bound in complexes with polysaccharides or proteins. Flavonoids consist of seven sub-categories: anthoxanthins (flavanol and flavone), flavanones, flavanonols, flavans, chalchones, anthocyanins, and isoflavonoids.

As demonstrated in Table 1, in faba beans, the total phenolic content (TPC), flavonoid, tannins, and proanthocyanin found in seed coat were higher than those in the cotyledon, which is consistent with other legumes studies (Chaieb et al. 2011; Çalışkantürk Karataş, Günay, and Sayar 2017). Because of the higher values of TPC and flavonoids, the antioxidant levels (measured by obtained from DPPH scavenging, total antioxidant capacity and FRAP assays) of faba seed coat were higher than those of cotyledon (Lu et al. 2018). Meanwhile, the faba bean exhibits variety and diversity regarding the phenolic profile. Mekky et al. (2020) examined 17 flavonoids, including flavones, flavonols, and one flavanone, and nine phenolic acids in faba bean seeds, and El-Feky, Elbatanony, and Mounier (2018) discovered 17 phenolics and 16 flavonoids in faba bean pods.

Legume phenolics demonstrate an essential role in antioxidant capacities due to the redox abilities they exhibit. They can act as reducing agents, hydrogen donors, and singlet oxygen quenchers. Additionally, the faba bean's phenolic profile is associated with potential anti-cancer effects. A previous study (Ceramella et al. 2022) has reported significant reductive effects of faba pod phenolics on cancer cell lines, including normal human cells and other carcinoma cells, without causing cytotoxicity. Particularly, El-Feky, Elbatanony, and Mounier (2018) studied the anti-cancer impacts of four flavonoidal compounds of faba bean and claimed that apigenin demonstrated the most potential toward the breast cancer cell lines without cytotoxic effects. Likewise, polyphenols, such as catechin, from faba bean extract present synergistic actions and display inhibitions of oxidative stress and hyperglycemia in yeast cells (Choudhary et al. 2022). Isoflavones in faba beans have also been linked to anti-inflammatory effects by inhibiting the production of inflammatory mediators such as prostaglandins and leukotrienes. Moreover, faba bean phenolic extracts exhibited a hypocholesterolaemia effect by reducing the total and LDL cholesterols in the rat serum (Zdunczyk et al. 2002).

Phytic acid

Phytic acid, or myo-inositol hexa-phosphate (IP6), is the main form of phosphate stored in legume seeds, making up 50–80% of the total phosphorus content. In grain legumes, phytic acid usually exists in the form of mixed salts (phytate or phytin) of mineral cations (Fe^{2+}, Mg^{2+}, Ca^{2+}, and Zn^{2+}). The presence of phytic acid can adversely affect iron and zinc absorption in the gut due to the lack of endogenous hydrolytic enzymes for it in human metabolism, although this anti-nutritional property could be improved by the interaction with fructo-oligosaccharides (Wang et al. 2010). Phytic acid also reduces the absorption of proteins and lipids. Despite these adverse effects, there is also strong evidence that phytates possess health-promoting bioactive functions. Phytic acid demonstrates anticarcinogenic abilities due to its antioxidant capacity, immune system enhancement, and gene alteration, preventing different tumors (breast, colon, liver, skin, etc.) (Poonia et al. 2022).

Saponins

Saponins, a series of natural chemical compounds containing steroids or triterpenoid aglycones that are partially attached to one or more oligosaccharides, are found in grain legumes. Soyasaponins are the predominant saponins reported in legumes and are divided into three groups by the chemical structure of the aglycone: A, B, and E saponins. Soyasaponin Bb (I) and soyasaponin βg, both belonging to the B saponin group, are the only soyasaponins reported in faba bean (Shen 2020). Shen (2020) found that the total saponin content ranged from 30 to 388 μg/g of dry weight among various faba bean genotypes.

The cholesterol-lowering effects of saponin have been consistently demonstrated in both *in vitro* and *in vivo* models. This is a result of the ability of saponin to replace cholesterol and bind bile acid during the formation of dietary mixed micelles, thereby reducing cholesterol bioaccessibility. As a consequence, cholesterol precipitates and becomes unable to be absorbed or re-absorbed in the intestine, resulting in decreased levels in the serum (Vinarova et al. 2015). Meanwhile, a saponin-added diet could prevent the increase of total and LDL cholesterols in the serum in the animal model (Zhang et al. 2009). Omar et al. (2020) also found that soyasapogenol-A, the aglycone of soyasaponin, showed cytotoxic activity to a wide variety of cancer cells such as lung cancer, ovarian adenocarcinoma, osteosarcoma, breast adenocarcinoma, etc.

Vicine & convicine

Vicine and convicine are two alkaloid glycosides found mainly in faba bean seeds, and divicine is an aglycone of vicine. Faba bean is the main contributor of vicine and convicine, containing around 409 ~ 6818 and 36 ~ 3121 μg/g of dry seed weight, respectively (Labba, Frøkiær, and Sandberg 2021). Consuming high levels of them can cause favism symptoms (haemolytic anaemia) in people who lack glucose-6-phosphate dehydrogenase activity, but Khamassi et al. (2013) highlight that these same bioactives may also demonstrate beneficial biochemical effects. For example, Abd El-Maksoud, Hussein, and Kassem (2013) reported the potential positive impact of vicine and divicine from faba bean on glycaemic indicators in a streptozotocin diabetic context. It has been suggested that aglycones inhibit glucose uptake, while glycosides reduce the active transport of glucose. Also, Abd El-Maksoud, Hussein, and Kassem (2013) proposed that the hypoglycemic effect could be attributed to their protective action against damaged pancreatic β cells, facilitating the regeneration of damaged β cells or stimulating insulin release. Furthermore, the hypoglycemic results of vicine and divicine lead to the depletion of oxidative stress by increasing the enzymes (blood and liver SOD, CAT, GPx, GST, GSH) and reducing liver TBARs that are related to the oxidant levels (Hussein 2012).

L-DOPA

L-DOPA (L-3, 4-dihydroxyphenylalanine) is a naturally occurring amino acid in faba beans. According to Goyoaga et al. (2008), L-DOPA is mainly found in the embryo axis of faba beans, with an amount of 1.95 – 2.60 mg/g dry weight. L-DOPA is a precursor to dopamine, a neurotransmitter that regulates blood pressure and helps maintain cardiovascular health. Studies have found that supplementation with L-DOPA can lower blood pressure levels in hypertensive individuals and may have a blood pressure-lowering effect through its ability to stimulate the production of nitric oxide, which dilates blood vessels and reduces resistance to blood flow (Saito et al. 1991) and to minimize norepinephrine levels which further reduce the blood pressure (DiFrancisco-Donoghue et al. 2014). L-DOPA has been used as an effective treatment for Parkinson's disease, as dopamine depletion is a hallmark of the condition (Cucca et al. 2015). L-DOPA supplementation can help replenish dopamine levels and improve symptoms such as tremors, stiffness, and difficulty with movement (Cucca et al. 2015) (Figure 2).

Effects of processing conditions on faba beans

The absorption and metabolism of nutrient from faba bean seeds are often limited by several anti-nutritional factors. Various domestic and industrial processing techniques are applied to improve the palatability and shelf life of legumes while enhancing their nutritional value. Specifically, processing methods can improve the bioavailability of nutrients in faba beans previously hindered by anti-nutritional factors. These methods often involve a combination of mechanical or thermal treatments to alter or preserve the beans. Common processing techniques include soaking, cooking, blanching, steaming, autoclaving, microwave cooking and germination (Amoah et al. 2023). The processing conditions and parameters and the components and properties of faba beans studied are summarized in Table 3.

IVPD: in vitro protein digestibility

Although cooking had a limited effect on the total protein content (from 29 to 28%), it changed the protein profile of faba beans (Abdel-Hameed, Abdel-Hameed, and Latif (2019); Abusin, Hassan, and Babiker 2009). According to Abusin, Hassan, and Babiker (2009), the concentrations of albumin, globulin, and prolamin in faba bean seeds were significantly decreased by cooking, at around 58, 79, and 17%, respectively, while glutelin levels increased by about 167%. The cooking process also brought only minor change in terms of the concentration of total amino acids, with significant increases of arginine, lysine, phenylalanine, histidine and serine, and losses of methionine and sulphur-containing amino acids (Lisiewska, Kmiecik, and Słupski 2007). Steaming treatment increased high molecular weight protein fractions (>600 kDa) of faba bean, probably due to the formation of insoluble aggregates (Wolosiak et al. 2010). Likewise, the 500 kDa fraction increased from 0.1% in raw seeds to 2.3% in blanched seeds (Wolosiak et al. 2007). Meanwhile, the dominant fractions changed from 11S globulin (47 and 32 kDa) and 12 kDa fraction to 15 kDa protein fraction after blanching, and a fraction of 10 kDa was found (Wolosiak et al. 2007). Looking at protein quality, soaking, cooking, microwave cooking, and autoclaving all improved the IVPD of faba bean proteins (Abdel-Hameed, Abdel-Hameed, and Latif 2019; Abusin, Hassan, and Babiker 2009).

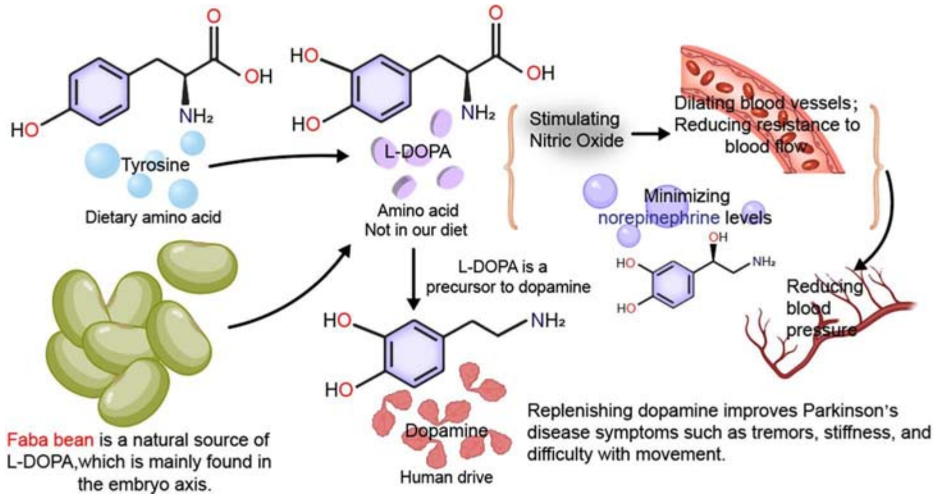

Figure 2. Action mechanisms of L-DOPA to lower blood pressure and reduce the risk of Parkinson's disease.

Table 3. Processing methods, conditions, and compounds during faba bean processing.

Processing method	Conditions	Components examined	References
Soaking	Soaked for 12 h at room temperature (~25 °C) in different solutions: 0.5, 1% baking powder, 0.5, 1% sodium bicarbonate and tap water used as control. A ratio of 1:4 (*w/v*) seeds to water was used	Proteins, IVPD TPC TAC	Abdel-Hameed, Abdel-Hameed, and Latif (2019)
	1:4 *w/v* Seeds to mineral water 1, 3, 6, 16 and 24 h 25 °C	DF Monosaccharides Disaccharides Alpha-galacto-oligosaccharides	Njoumi et al. (2019)
	Not mentioned	Protein Fe, Ca, P Thiamine DF	Khatoon and Prakash (2004)
	1:4 *v/v* Seeds to water 16 h 20, 30, 40 °C	Folate	Hefni, Shalaby, and Witthöft (2015)
	Raw seeds were soaked in distilled water for 12, 24, 36, and 48 h at a faba bean: water ratio of 1:10 (*w/v*)	Tannin Trypsin inhibitor Phytic acid Lectin IVPD	Luo and Xie (2013)
	Faba beans were washed and soaked in water for 12 h (1:2, *w/v*)	Saponin	Barakat, Reim, and Rohn (2015)
Cooking	The soaked seeds were washed with ordinary water and then cooked in tap water using the ratio of 1:4 (*w/v*) on a hot plate (~100 °C.) until they became soft (~90% of bean seeds) when felt between the fingers at various intervals	Proteins, IVPD TPC TAC	Abdel-Hameed, Abdel-Hameed, and Latif (2019)
	The seeds were soaked in the dark in tap water for 8 h. The soaked solution was drained off; then, the seeds were cooked in boiling water.	Proteins, IVPD Tannin Phytic acid	Abusin, Hassan, and Babiker (2009)
	The broad beans were placed in boiling water, and the cooking time, measured from when the medium came to a boil again to when the material reached the desired consistency, was 12 min.	AAs	Lisiewska, Kmiecik, and Słupski (2007)
	Raw bean seeds were cooked in distilled water (100 °C) at a faba bean: water ratio of 1:10 (*w/v*) for 30 min.	Tannin Trypsin inhibitor Phytic acid Lectin IVPD	Luo and Xie (2013)
	The fresh broad beans (100 g) were boiled using beans: water ratio of 1:5 (*w/v*) until they became tender	TPC Tannin TFC Beta-carotene DPPH, FRAP	Saini et al. (2016)
Blanching	Seeds were blanched in water at 92 °C for 5 min	Protein fractions TPC Condensed tannin ABTS, DPPH	Wolosiak et al. (2007)
Steaming	Steam cooked (100 °C) till consumption softness, that is, for the shortest time, allowing to obtain sensory-accepted product	Protein fractions TPC Condensed tannin ABTS, DPPH	Wolosiak et al. (2010)
Autoclaving	Pressure cooking of samples (100 g) was done in a pressure cooker for 20 min with water ratio of 1:3 (*w/v*)	TPC Tannin TFC Beta-carotene DPPH, FRAP	Saini et al. (2016)
	Not mentioned	Protein Fe, Ca, P Thiamine DF	Khatoon and Prakash (2004)
	121 °C 60 min	Folate\	Hefni, Shalaby, and Witthöft (2015)
	Faba bean seeds were autoclaved at 1.5×10^{6} Pa (121 °C) in distilled water at a faba bean: water ratio of 1:10 (*w/v*) for 20 min.	Tannin\ Trypsin inhibitor Phytic acid Lectin IVPD	Luo and Xie (2013)
Microwaving	100 g Of sample was dried at 160 °C for 15 min in a microwave oven	TPC Tannin TFC Beta-carotene DPPH, FRAP	Saini et al. (2016)
	Faba bean seeds were microwave-cooked in water (seed: water, 1:10) for 6 min	Tannin Trypsin inhibitor Phytic acid Lectin IVPD	Luo and Xie (2013)

(*Continued*)

Table 3. Continued.

Processing method	Conditions	Components examined	References
Germination	The seeds were screened for imperfections and placed in a constant environment chamber (40 seeds/tray; in duplicate) with a photoperiod of 8 h daylight per day at 20 °C on sand–water (5:1, *w/v*) in covered photography trays. Germinated beans and seedlings were rinsed daily and harvested at 0.5, 1, 2, 3, 4, 5, 6, 7, 8 and 9 days after imbibition (DAI)	Proteins Sugars Vicine Convicine L-DOPA	Goyoaga et al. (2011) Goyoaga et al. (2008)

Autoclaving eliminated lectin activity while cooking and microwaving reduced lectin activity by 75%, and soaking had no effect. Protein content also gradually decreased during the germination period, nine days after imbibition (DAI), from 0.18 to 0.10, 0.14 to 0.08 g/cotyledon pair, respectively, in two cultivars of faba beans (Goyoaga et al. 2011). The legumin fraction underwent more extensive degradation than the vicilin fraction (7S) due to the number of protein bands affected by 3 DAI. At the same time, most vicilins were stable throughout germination (Goyoaga et al. 2011).

As for fiber content, soaking does not cause a significant effect on IDF and SDF, even with longer soaking time. According to Njoumi et al. (2019), after the 24-h soaking, SDF slightly increased from 4.6 to 5.7 g/100g (dry weight), while IDF decreased from 30.3 to 27.7 g/100g (dry weight) after 3 h due to partial solubilization and then increased to 30.8 g/100g (dry weight) after 24 h. Similarly, both autoclaving and microwaving slightly increased IDF and SDF. Khatoon and Prakash (2004) suggested that Maillard products from protein and tannin condensation and resistant starch could form and be isolated as fiber components during cooking, likely due to the elevated DF levels.

Soaking faba beans significantly increased sucrose hydrolysis, resulting in increased glucose and fructose (Njoumi et al. 2019). Verbascose decreased quickly due to its solubility in water, but the decrease was offset by partial verbascose hydrolysis by alpha-galactosidase. Stachyose and raffinose decreased by 26 and 49%, respectively. Germination also showed a significant increase in fructose, glucose, melibiose, and sucrose and a decrease in galactose. In the cotyledon, the reduction in galactose might result from the hydrolyzation of raffinose family oligosaccharides, while in the embryo axis, monosaccharides increased initially but dropped after germination (Goyoaga et al. 2011).

Other bioactive compounds are also labile when exposed to water or heat treatment. Phytic acid slightly increased after processing, suggesting activation of the endogenous phytase during soaking and heat-stability of phytic acid during heat treatments (Luo and Xie 2013). These authors also reported that thermal treatments reduced trypsin inhibitor activity by more than 40% in faba beans, while soaking improved it. Regarding tannins, soaking caused a significant reduction by 11% with the soaking time of 48 h due to the water-soluble properties, but microwaving increased tannins from 6.16 to 6.98 mg TAE/g (Saini et al. 2016). Thermal treatments did not affect tannin levels except for steaming and blanching, during which the condensed tannins decreased by 13 and 76%, respectively (Wolosiak et al. 2007; Wolosiak et al. 2010). Total saponin content decreased from 113 to 74 μg/g DW after soaking due to decreased soyasaponin Bb and soyasaponin βg (Barakat, Reim, and Rohn 2015). Phenolics and antioxidant capacities (including TAC, ABTS, FRAP, and DPPH) decreased primarily during conventional cooking, microwave cooking, and steam cooking as phenolics are heat labile (Abdel-Hameed, Abdel-Hameed, and Latif 2019). Likewise, blanching also caused a significant decrease in TPC (from 735 to 430 mg/100g DW) (Wolosiak et al. 2007). Wolosiak et al. (2007) also found that blanching decreased the antioxidant properties, including ABTS and DPPH. Boiling, microwaving, and pressure cooking caused notable reductions in total flavonoids and beta-carotene levels (Saini et al. 2016). Vicine and convicine decreased slowly during germination in cotyledons, while in the embryo axis, vicine content was vastly reduced, but convicine slightly increased as sprouting progressed (Goyoaga et al. 2008).

While these traditional methods have been effective in modifying the nutritional and functional properties of faba beans, recent research has highlighted the benefits of synergistic use of physical and enzymatic methods in the processing of pulses that can also be applied in faba bean processing. Physical methods such as thermal treatment, high-pressure processing, and ultrasound disrupt cellular structures, making compounds like proteins and polysaccharides more accessible to enzymatic action (Ahmed et al. 2019). Enzymes then specifically target and break down these substrates, leading to improved extraction and modification of bioactive compounds in pulse seeds. For example, the application of high-pressure treatment in lentil proteins before enzymatic hydrolysis enhanced the hydrolytic efficiency and resulted in a complete degradation of lentil protein and increased level of BPs (<3 kDa) by all studied enzymes (Garcia-Mora et al. 2015). In another example, the high-pressure assisted and alcalase-treated protein hydrolysates of lentils increased the foaming ability and antioxidant activity although other functional characteristics including emulsifying property, foaming stability, and water holding capacity were significantly reduced (Ahmed et al. 2019).

It has been stated previously that faba bean proteins are predominantly composed of globulins, which are mostly comprised of legumin-type and vicilin-type globulins. While globulins are known for their nutritional value, their functionality in food applications are relatively poor compared to albumins, primarily due to lower solubility and foaming capacities (Sashikala et al. 2015). Physical methods such as ultrasound have been utilized to maximize the faba protein yield and improve functionality. For instance, ultrasound-assisted extraction of faba bean proteins contributed to higher protein purity and yield with no significant alterations in the primary structure and a similar protein profile, compared to the natural protein isolate (Badjona et al. 2024). The combination of heat and enzymatic treatments improved the solubility, gelling, emulsifying and water holding properties of faba bean proteins (Nivala et al. 2021).

The synergistic approaches that combine physical and enzymatic methods increased the efficiency and yield, enhanced the functional properties of pulses, and reduced the carbon footprint, which aligns with the principles of sustainability and circular economy. In this context of production sustainability, waste reduction can also be achieved by upcycling the wastewater generated during legume processing. Traditionally considered a by-product, this wastewater is rich in organic compounds that can be utilized for their functional properties (Liu et al. 2013). By reevaluating and re-purposing legume wastewater, this waste stream can possibly become a valuable resource, further closing the loop in sustainable food processing.

Unlocking legume wastewater potentials

Most of the treatments utilized for faba beans in the food industry, such as soaking, blanching, cooking, steaming, and autoclaving, require large amounts of water. Studies have shown that some bioactive compounds leach into the processing media, such as soaking and cooking water, during food processing. Dang, Arcot, and Shrestha (2000) have found that approximately 20 – 30% of folate content was present in soaking, boiling, and autoclaving water during the processing of chickpeas and peas, and specifically, 18–22% of unconjugated folate were detected. Xu and Chang (2008) found small amounts of TPC in soaking, cooking, autoclaving, and steaming (regular and pressure) water of green peas, yellow peas, chickpeas and lentils and measured DPPH free radical scavenging capacities and oxygen radical absorbing capacities in them except for steaming water. Likewise, an investigation into the changes in proximate composition and amino acid profile of navy beans during blanching showed that blanching water, based on the dry matter content, contained nearly 22% protein and 10% ash (mainly Fe and K) and had higher levels of tyrosine, glutamic acid, and lysinoalanine compared to raw navy beans (Deb-Choudhury et al. 2021). Moreover, alpha-galacto-oligosaccharides (raffinose, stachyose, and verbascose) were found in small amounts in soaking water, and high levels of their hydrolysis products (galactose, glucose, fructose) were also found in soaking water of faba beans, according to Njoumi et al. (2019). More recently, Ramos-Figueroa et al. (2023) examined faba bean cooking water and reported 24% sucrose, 42% alpha-galacto-oligosaccharides, 10% vicine, 4% convicine, and 1% L-DOPA in the supernatant of faba bean water, while the precipitate of the faba bean cooking water mainly consisted of starch (mostly low molecular weight amylose) and proteins (primarily vicilin, α-legume, and β-legumin).

Recently, the utilization of processing water generated during legume-related production has been explored. Firstly, legume wastewater has also been used to improve the texture and mouthfeel of bakery and confectionery products. Aquafaba, for instance, is chickpea processing water generated during pre-cooking and canning processes and has been successfully applied by vegans as a plant-based substitute for eggs during bakery product making. Raikos, Hayes, and Ni (2020) have previously summarized that Aquafaba contains around 5 g/100g dry matter content, with protein, dietary fiber, sugar, and ash contents at 1.27, 0.69, 0.64, and 0.44, respectively. There are also 0.3 mg/g TPC and 0.11 μg/mL tocopherols detected in Aquafaba. According to Raikos, Hayes, and Ni (2020), replacing eggs during mayonnaise production with Aquafaba demonstrated unaffected physical stability, consistency, and oxidative stability of mayonnaise. Also, Mustafa et al. (2018) stated that Aquafaba presented comparable foaming ability and stability to egg white. When making sponge cakes with Aquafaba instead of egg white, they revealed that the Aquafaba-based sponge cake had similar and acceptable color and texture measurements with traditional egg white cakes, in spite of the lower springiness and cohesiveness. Besides, Alsalman et al. (2020) have optimized the production of Aquafaba to achieve the best functional properties and protein level while minimizing anti-nutritional factors of Aquafaba. They found out cooking chickpeas for 60 min with a ratio of chickpea water as 1.5 to 3.5 approached the most desirable emulsifying, foaming, water holding, oil holding capacities and nutritional concentration.

In addition to Aquafaba, some other types of legume processing water have also been studied regarding the textural functions in recent years. Echeverria-Jaramillo et al. (2021) examined the emulsion properties of cooking water of black soybean, yellow soybean, small soybean, and chickpea and showed that the emulsifying capacities of three soybean types were all higher than Aquafaba, while the emulsifying stability of them was similar, attributed to the presences of proteins and soluble carbohydrates. Likewise, cooking water of haricot beans, whole green lentils, and split yellow peas exhibited foaming ability (39–97%), although lower than egg white (Stantiall et al. 2018). Besides, they also displayed specific water absorption capacity (0.07 – 2.20 g/g), oil absorption capacity (2.71 – 3.22 g/g), and emulsifying capacity (46–54%) (Damian, Huo, and Serventi 2018). When incorporated into meringue production, the acceptance taste of meringues made with split yellow pea cooking water was similar to that of egg white, while the other two were slightly lower (Stantiall et al. 2018). By analyzing the functionality of faba bean processing water, Ramos-Figueroa et al. (2023) revealed 530% foaming ability and 94% foaming stability values of the precipitate of faba bean cooking water, attributed with both protein (mainly vicilin, α-legumin, and β-legumin) and starch (mainly low molecular weight amylose) components. It is notably that Ramos-Figueroa et al. (2023) found the complex of globulin proteins and polysaccharides formed in faba bean cooking water precipitate resulted in the high foaming capacities, as enzymatic hydrolysis of either protein and starch led to the elimination of the foaming capacity values. This finding suggests that thermal treatment could denature globulin structure and increase the ability to participate in foaming process. This was supported by previous study of kidney bean proteins that 95 °C heat treatment induced the transformation of 7S-form vicilin to the 11S-form and other polymers, and moderate thermal processing time (15 to 30 min) significantly enhanced the protein solubility, foaming ability, and emulsifying property (Tang and Ma 2009). Apart from cooking water, pulse soaking water has pronmise as a foaming and emulsifying agent in food production. Kilicli and Toker (2022) investigated the physicochemical properties and recognized foaming ability at 130–170% and emulsifying ability at 76–99% in soaking water of faba bean, chickpea white bean, kidney bean, lentil, and green pea. Meanwhile, Huang et al. (2018) reported 6–50% emulsifying abilities of yellow soybean, whole green lentil, haricot bean, chickpea, and split yellow pea soaking water, and they recorded a direct correlation between emulsifying ability and the ratio of water-soluble carbohydrates to dry matter content in all types of pulse soaking water. Oligosaccharides and soluble fibers (polysaccharides) are most likely carbohydrates to leach into the soaking water. These carbohydrates contribute significantly to the stabilization of emulsions through their amphiphilic nature, which allows them to interact with both water and oil phases (Tan, Nakajima, and Tan 2018).

Furthermore, recent research has suggested the possibility of utilizing legume wastewater as a source of novel ingredients in food production. Several studies have examined the proximate compositions of several types of legume wastewater. Generally, soaking water of haricot bean, chickpea green lentil, split yellow pea, and yellow soybean presents 0.26 – 2.38% dry matter (Huang et al. 2018). Meanwhile, cooking water of chickpea yellow soybean, haricot bean, green lentil, and split yellow pea have 3.28 – 5.59% dry matter content, while blanching water of pea and navy bean has 3.77 – 4.80% (Deb-Choudhury et al. 2021; Raikos, Hayes, and Ni 2020). Specifically, soaking water contains relatively lower proximate compositions compared to cooking and blanching water, with 0.04 – 0.65% water soluble carbohydrate, 0.12 – 0.99% fibers, 0.03 – 0.60% protein, 0.07 – 0.39% ash, and non-detectable lipid (Huang et al. 2018). Pulse cooking water and blanching water contain 0.60 – 2.21% water soluble carbohydrate, 0.60 – 2.46% dietary fibers, 0.60 – 1.51% protein, 0.21 – 1.27% ash, and almost non-detectable lipid (Damian, Huo, and Serventi 2018); Deb-Choudhury et al. 2021; Raikos, Hayes, and Ni 2020; Sun et al. 2022). On the other hand, during processing, some non-nutritional bioactive compounds from raw legumes are released into the processing water. Legume soaking water contains 0.048 – 0.438 mg/g total phenolics and 1–3 mg/g saponins (Huang et al. 2018). Cooking water and blanching water exhibit higher levels of phytochemicals due to the thermal treatment. According to Damian, Huo, and Serventi (2018), approximately 0.3 – 0.7 mg/g total phenolics and 6.4–15 mg/g saponins were found in pulse cooking water, and Sun et al. (2022) examined 16.6 mg/g saponins in pea blanching water. Although no studies have thoroughly investigated the functional potential of faba bean wastewater, results from other pulse varieties indicate that faba bean processing water should also have the potential to be used as a novel ingredient in food production.

Conclusion

Faba beans (*Vicia faba* L.) have mainly been used as animal feed in agriculture, but have become a greater part of the human diet in recent years as an excellent alternative to meat, because of their high protein content and relatively balanced amino acid profile. They contain bioactive compounds (proteins and their hydrolysates, phenolic compounds, soyasaponins, phytic aicds, L-DOPA, etc.) with health benefits, such as hypocholesterolemia, antioxidant, and anti-cancer properties, despite the presence of anti-nutrients that affect protein and mineral absorption. Dietary fibers and sugars in faba beans also contribute to improved blood sugar, cholesterol levels, and gut health.

The typical processing methods (e.g., soaking, cooking, blanching, steaming) alter the concentration of bioactive compounds, affecting their nutritional value. Current studies have shed light on the potential of legume processing water as a sustainable textural agent with functional properties such as emulsifying, foaming, and water/oil absorption capacities. However, processing water of faba bean remains under-researched, especially the prospect of nutritional benefits it may present. Thus, this review offers the perspective that faba bean processing water can likely be upcycled as a functional food ingredient, additive, or substitute for animal-based products. Future research should examine the bioactive compound profile of faba bean processing water and its possible health advantage for cardiovascular diseases and other chronic conditions.

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