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Review Article

BIOMOLECULAR PROFILING OF *VICIA FABA* AND ITS THERAPEUTIC PROMISE IN PARKINSON'S DISEASE

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ABSTRACT

The broad bean, *Vicia faba*, is a species of flowering plant belonging to the Fabaceae family of beans and peas. It is widely grown as a crop for consumption by humans and has an unclear origin. It serves as a cover crop as well. Broad beans have a high protein content, and contain dietary fibre, folate, and B vitamins. In this study, we characterized the biomolecules present in *Vicia faba*, This review deals with various biochemical techniques to isolate and identify proteins, carbohydrates, lipids, and nucleic acids. The results showed a diverse range of biomolecules, each with unique structures and functions that contribute to the plant's physiology and biochemistry. Proteins are essential for various biological processes and amino acids are fundamental components found in broad beans. They contribute to the structure and function of proteins. Carbohydrates, particularly starch, were identified in the beans. Lipids were present in the form of phospholipids, glycolipids, and sterols, playing crucial roles in maintaining cell membrane integrity and signalling. Nucleic acids, DNA, and RNA, were found in all cells, carrying genetic information for the plant's growth and development. This comprehensive characterization of biomolecules in *Vicia faba* provides valuable insights into its biochemistry and can serve as a reference for future studies on this important crop species. The study also highlights the potential functioning of the present biomolecules beneficial in the controlling of Parkinson's Disease.

Keywords: *Vicia faba*, Proteins, Phospholipids, Nucleic acids, Parkinson's Disease.

INTRODUCTION

In the context of dwindling natural resources and growing population, there is a noticeable trend towards increased production of animal protein. This trend demands more energy and expands the land area needed for producing animal feed. One potential solution could be to source proteins from alternatives like plants. Legumes, for instance, are a significant source of protein (over 20g per 100g), along with carbohydrates, fats, and health-beneficial components. These nutrients not only positively impact the circulatory system but are also known to help combat neurodegenerative diseases (Żmudziński *et al*., 2021). Approximately 60% of the worldwide protein intake for human consumption comes from plants, with about a third of this derived from grain legumes belonging to the Fabaceae family. Beyond their nutritional value, the capacity of legume crops to fix atmospheric nitrogen through rhizobial symbiosis renders them essential elements of sustainable farming systems. The Faba bean (*Vicia faba*, or Vf), also referred to as the broad bean, horse bean, or field bean, is among the world's most ancient legume crops, with its cultivation tracing back to the 10th millennium BC(Crépon *et al*. 2010) . Soaking faba beans generally reduces their cooking duration, with a higher post-soak moisture level correlating to quicker cooking times. Techniques like hot soaking or using a pressure cooker can further decrease the time needed for preparing dried broad beans. Typically, faba beans are hydrated and cooked to enhance their taste, a process that can be quite lengthy and energy-intensive. Consequently, canned faba

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beans, which streamline or remove the need for this preparation and have a prolonged shelf life, could be advantageous in the market (Askar 1986).

Vicia faba, a member of the Fabaceae family, is among the earliest domesticated legumes. The first signs of its cultivation can be traced back to approximately 10,200 years ago in the Southern Levant region. Like other edible plant species, pulses were initially gathered by hunter-gatherers. Subsequently, in conjunction with cereals, pulses played a pivotal role in the "agricultural revolution," spreading across Europe after the Ice Age (Kole, 2011) . Vicia faba, also known as the Faba bean, possesses an efficient ability to fix atmospheric nitrogen, a process that contributes significantly to soil fertility. This, coupled with its adaptability to climate change, makes it a sustainable food source. Therefore, it holds great potential to nourish future generations. To elaborate, the nitrogen-fixing ability of Vicia faba is due to its symbiotic relationship with rhizobial bacteria (Benmoussa *et al*. 2022). These bacteria inhabit nodules in the roots of the plant and convert atmospheric nitrogen into a form that the plant can use for growth. This process reduces the need for synthetic nitrogen fertilizers, making Vicia faba a more environmentally friendly crop. Moreover, *Vicia faba's* adaptability to different climatic conditions enhances its resilience in the face of global climate change. This adaptability, combined with its high nutritional value, positions it as a crucial crop for ensuring food security in the future. As such, the cultivation of Vicia faba could play a significant role in sustainable agriculture and global food systems. (Pasqualone *et al*., 2020).

Kidney beans are nutritionally rich, providing an excellent source of dietary fibre, protein, carbohydrates, minerals, and phytochemicals, including phenolic compounds. The indigestible carbohydrates, such as dietary fibre and resistant starch, offer numerous health benefits. These include promoting weight loss, regulating blood sugar levels, reducing the risk of heart disease, and enhancing gut health(Arija *et al*. 2006). Dietary fibres also serve as functional ingredients that can alter the physiochemical properties of food products, influencing their consistency, texture, rheological behaviour, and sensory characteristics. Furthermore, kidney beans are abundant in pulse-based proteins. These proteins are gluten-free and are not commonly associated with allergens, as per Han *et al*., 2010. They are also a sustainable source of dietary protein and offer numerous nutritional benefits. To elaborate, the high fiber content in kidney beans aids in digestion and promotes a feeling of fullness, which can help in weight management (Hueda, 2017). The complex carbohydrates in kidney beans are slowly digested, providing a steady supply of energy, and helping to maintain stable blood sugar levels, making them suitable for people with diabetes. The pulse-based proteins in kidney beans are a complete source of protein, providing all the essential amino acids needed by the body. Being gluten-free, they are a great protein source for individuals with celiac disease or gluten sensitivity. Moreover, as kidney beans are plant-based, they have a lower environmental impact compared to animal-based proteins, making them a more sustainable choice for dietary protein. Their rich nutrient profile, coupled with these health and environmental benefits, underscores the nutritional advantages of kidney beans(Kan *et al.* 2017).

In this investigative study, our objective was to unravel the intricate web of biomolecules within Vf. Employing an array of biochemical techniques, we meticulously isolated and identified proteins, carbohydrates, lipids, and nucleic acids. The findings of our exploration unveiled a diverse spectrum of biomolecules, each wielding unique structures and functions that intricately contribute to the plant's physiology and biochemistry (Messina 2014). Proteins, indispensable for diverse biological processes, play a pivotal role in the growth and development of the plant. Amino acids, constituting the building blocks of proteins, emerge as fundamental components intricately involved in the structure and function of broad beans. Carbohydrates, with a spotlight on starch, were identified as the principal molecules for energy storage. Starch can be classified into two types: amylose and amylopectin. Amylose is a linear chain of glucose, while amylopectin is a branched chain of glucose. The ratio of amylose to amylopectin affects the properties of starch, such as its solubility, viscosity, and gelatinization. Carbohydrates serve as a reservoir, fuelling various physiological activities within the plant. Lipids manifested in forms such as phospholipids, glycolipids, and sterols, play a critical role in upholding the integrity of cell membranes and serve as crucial elements in cellular signaling processes. Nucleic acids, encompassing DNA and RNA, emerged as ubiquitous entities within the plant's cells, harboring genetic information crucial for the intricate processes of growth and development. As the building blocks of proteins, amino acids are fundamental components found in broad beans. They contribute to the structure and function of proteins, as well as other metabolic pathways. For example, some amino acids are precursors for neurotransmitters, hormones, and pigments. (Singh *et al*., 2021)

This comprehensive characterization of biomolecules within Vf offers invaluable insights into its biochemistry, establishing a solid foundation for future investigations into this vital crop species. Furthermore, this review delves into the nuanced details of the proteins present, exploring their structures, compositions, and genetic controls. The potential functionalities of these biomolecules are underscored, hinting at promising avenues for leveraging this botanical wealth in the management of Parkinson's Disease. The synergistic interplay of proteins, carbohydrates, lipids, and nucleic acids within Vf presents a captivating tapestry of biochemical intricacies, waiting to be further unraveled for the betterment of both agricultural practices and human health (Abdel-Sattar *et al*. 2021). Parkinson's Disease (PD) is a neurodegenerative disorder characterized by the progressive loss of dopamine-producing neurons, primarily in the substantia nigra pars compacta of the midbrain. This loss leads to hallmark motor symptoms such as tremors, rigidity, and difficulties with movement coordination (Randhir and Shetty, 2004).

The pathology of PD involves chronic inflammation, oxidative stress, protein aggregates in neurons, neurotransmitter depletion, abnormal ubiquitination, mitochondrial dysfunction, excitotoxicity, and blood-brain barrier disruption. While the exact cause of PD remains elusive, both genetic and environmental factors are implicated.(Nikkhah *et al*. 2023).

To manage the motor disturbances caused by dopamine depletion, patients are often treated with exogenous levodopa or L-DOPA, which provides symptomatic relief but does not halt disease progression. Continuous medication is typically recommended to improve patients' quality of life, although long-term use of synthetic medicines has been associated with adverse effects on liver and heart health.(Shetty *et al*., 2019). Emerging research suggests that natural sources of levodopa, such as broad beans, may offer potential benefits for PD symptoms. Broad beans contain levodopa, which can cross the blood-brain barrier and convert to dopamine, potentially replenishing neurotransmitter levels(Renna *et al*. 2020). However, the therapeutic efficacy and safety of broad beans for PD treatment are still under investigation, necessitating further research to validate their use as a natural remedy (Davie 2008). Vf, commonly known as the broad bean, is a nutritious and protein-rich crop that has been consumed for thousands of years. Despite its nutritional value, there is still much that we do not know about the biomolecules present in Vf. (Bloem *et al*., 2021)Recent advancements in technology have allowed us to better understand the genetic makeup of this plant and its potential impact on human health. In this article, we will explore the phytochemical content of both the beans and pods of Vf and discuss their potential pharmacological role in Parkinson's Disease(Poonia *et al*. 2022).

Vf seeds are known to contain roughly 29% protein on a dry matter basis, according to Feedipedia. Single seed weight varies from 0.2 up to 2.6 g of DM in faba bean (V. faba L.) genetic resources. Two types of varieties are cultivated: (1) cultivars with large flattened seeds, from 1 to 2 g DM per seed, named 'Vf major or broad beans' (2) varieties with medium to relatively small and round seeds, from 0.4 to 0.8 g DM per seed, named ''Vf minor or field beans or horse beans''(Yehmed *et al*. 2022). This high protein content provides cost-effective nutrition for countless individuals globally, earning it the nickname "the poor man's meat." In addition to proteins, Vf seeds are rich in various other nutrients such as fibers, starches, vitamins, and minerals, as stated by Vilariño *et al*., 2009. These additional constituents enhance their value as food, feed, and ingredients (Warsame 2021). Apart from its culinary applications, Vf is appreciated for its vast genetic diversity, which makes it an excellent specimen for studying diverse biological phenomena. Its large genome, ease of growth, and adaptability to various climates have made it a preferred choice for scientists exploring plant genetics, molecular biology, and crop enhancement(Grasso *et al*., 2025).

Parkinson's disease (PD), a type of neurodegenerative disorder, is a chronic and incapacitating condition that arises from the gradual degeneration of specific nerve cells known as dopaminergic neurons. These neurons are located in the Substantia nigra pars compacta, a region in the human midbrain, as stated by Double, 2012. Dopaminergic neurons play a crucial role in the human brain, regulating voluntary movement and various behavioral processes such as motivation, mood, arousal, reward, sexual satisfaction, and stress, as per Chinta and Andersen 2005. Consequently, the reduction of dopamine neurotransmitters leads to the manifestation of clinical symptoms including bradykinesia (slowness of movement), resting tremors, rigidity, hypokinesia (reduced bodily movement), and akinesia (loss of voluntary muscle movement), as noted by Blum *et al*, 2001; Nikam *et al*, 2009. Moreover, PD is also linked with the presence of an inclusion body and abnormal protein accumulation in the dopaminergic neurons. This is a clear indication of the terminal phase of the neuroinflammation process, as pointed out by Ross, 2004. To elaborate, Parkinson's disease is characterized by the progressive loss of dopaminergic neurons, which leads to a decrease in the production of dopamine, a neurotransmitter that plays a vital role in coordinating movement and behaviour. The symptoms of PD, such as tremors and rigidity, are a direct result of this dopamine deficiency. Additionally, the presence of inclusion bodies and abnormal protein aggregates in the neurons is indicative of the ongoing neurodegenerative process. These pathological features contribute to the progression of the disease and the worsening of symptoms over time. Despite ongoing research, PD remains an incurable condition, underscoring the need for continued exploration into its causes and potential treatments. (Magalingam *et al*. 2015)

Dopamine (DA) Levels and Parkinson's Disease

Dopamine (DA) is a neurotransmitter that is derived from the dietary amino acid tyrosine and plays crucial roles in various motor, cognitive, motivational, and neuroendocrine functions. The enzyme primarily responsible for DA synthesis is tyrosine hydroxylase (TyrH), which facilitates the conversion of tyrosine to DA(Stykel *et al*. 2025). This biosynthetic pathway results in the production of several catechol monoamines, including epinephrine and norepinephrine, which are vital for numerous brain functions such as attention, memory, and cognition(Yi *et al*., 2024). Therefore, any deficiencies in the synthesis of catecholamines can lead to a range of harmful effects, including hypertension, depression, and dystonia. Given that TyrH is the slowest enzyme in this pathway, understanding its regulatory mechanisms is of significant interest to neuroscientists (Watanabe *et al*., 2024). To elaborate, dopamine, epinephrine, and norepinephrine, collectively known as catecholamines, are neurotransmitters that play a pivotal role in the functioning of the nervous system. They are involved in regulating mood, attention, movement, and the body's response to stress. Deficiencies in the production of these neurotransmitters can lead to a variety of neurological and psychological disorders (Wang *et al*. 2024). For instance, a deficiency in dopamine is associated with Parkinson's disease, while imbalances in epinephrine and norepinephrine levels can contribute to mood disorders such as depression. Therefore, understanding the biosynthetic pathways of these neurotransmitters and the regulatory mechanisms of enzymes like TyrH is crucial for developing effective treatments for these conditions (Musthafa *et al*. 2014) . The neurons in the substantia nigra communicate with the basal ganglia's neurons by releasing dopamine (DA), which is essential for finely tuning an organism's movements. Specifically, the substantia nigra's pars compacta region dispatches dopaminergic messages to the striatum and other basal ganglia components(Partanen and Achim 2022) .This communication is key to maintaining a balance between starting and stopping movements . The basal ganglia, a complex set of brain structures, interpret these signals to manage motor activities, including initiating or halting motion and ensuring fluid, controlled movements [18]. When this signaling pathway is disrupted, it can result in movement disorders, such as those observed in Parkinson's disease(Castellani *et al*. 2024) .

The faba bean stores a lot of L-Dopa in its many sections. L-Dopa is a precursor of dopamine that is being utilised to treat Parkinson's disease and hormonal imbalances. L-Dopa is an amino acid that can be extracted naturally from a variety of legumes and other crops such as bananas (Musa spp.). L-Dopa is made in the mammalian body and brain from the amino acid L-tyrosine. Earlier research suggested that L-Dopa is an essential precursor for catecholamines, a group of neurotransmitters that includes dopamine, noradrenaline, and adrenaline. Synthetic L-Dopa is commonly used to treat parkinson's disease patients. Synthesized L-Dopa is costly, and it can cause nausea, vomiting, low blood pressure, drowsiness, and restlessness, among other things. To avoid potential negative effects, it is recommended that natural sources of L-Dopa be consumed (Fornstedt Wallin 2024). The yearly global demand for L-Dopa is projected to be around 250 tonnes, with a market value of around $101 billion. To circumvent adverse effects and the high cost of synthetic L-Dopa synthesis, it seems fair to cultivate crops rich in natural L-Dopa. In terms of L-Dopa content, faba bean comes in second behind velvet bean (Mucuna Pruriens L.). However, the amount of L-Dopa in faba beans is affected by genotypes, ambient conditions, growth stage, and organs(Abdelsalam *et al*., 2025). L-Dopa content varies widely among faba bean genotypes, with L-Dopa found in flowers from 197 cultivars, seedlings from 32 cultivars, and seeds from 52 cultivars with the green seed coat. There was a substantial difference in L-Dopa content between six faba bean lines with different bloom colours (Etemadi *et al*., 2019). L-Dopa is distributed unevenly throughout the faba bean, and different organs acquire L-Dopa at varying rates. However, many previous studies have focused on the amount of L-Dopa in seeds, with little attention paid to the amount of L-Dopa in other parts of the plant. In general, the concentration of L-Dopa in various faba bean organs peaks during the early phases of growth. However, because L-Dopa yield is a function of plant biomass and concentration, the largest L-Dopa yield can be obtained at later phases of growth when biomass is at its peak. The availability of nitrogen and phosphorus to faba bean plants may affect L-Dopa production. Deficiencies in N and P had a direct impact on phenylpropanoids accumulation. Even though the faba bean is an N-fixing plant, the impact of supplementary N fertilization on L-Dopa concentration is unknown. The amount of accumulated L-Dopa has no effect on the level of N stress.(Yagi *et al*. 2024) Because fresh faba beans are not always available in all regions, Parkinson's patients who rely on a fresh natural source of L-Dopa should have conserved a large quantity of plants for use. As a result, plants that are naturally high in L-Dopa can be processed in a variety of ways, including chopped frozen tissues or dried powdered plant components. Processing plant parts, on the other hand, may have a detrimental impact on L-Dopa concentration. Cooking and soaking in alkaline solutions can degrade L-Dopa in legumes. Cooking, but not roasting, degraded L-Dopa in velvet beans(Aydın *et al*. 2026). The L-Dopa content of faba bean leaves and seeds is affected by various processing processes. Content can be influenced by different processing method in such manner: Fresh material > frozen > oven-dried > air dried (2 days) > air dried (4 days) > air dried (7 days) > boiled(Etemadi *et al*. 2019)

Exploring the metabolic fate of phytochemicals in broad beans and their AHR-binding capacity

In traditional medicine, various parts of the Vicia faba plant, including leaves, roots, sprouts, pods, and beans, have been used either as an infusion or food for the natural treatment of numerous chronic diseases. These include certain types of cancer, diabetes, cardiovascular diseases, anemia, malaria, depression, Parkinson's disease, allergies, diarrhoea, and stomach ulcers. The beneficial properties of Vicia faba are often linked to the presence of non-nutritional compounds. With the help of modern analytical techniques, more than 240 bioactive phytocompounds have been identified in these pulses. Given that Vicia faba has the largest genome in the legume family, with 13.4 giga base pairs, a complex phytochemical profile is anticipated. To elaborate, the bioactive compounds found in Vicia faba contribute to its medicinal properties. These compounds can interact with biological systems and potentially influence health outcomes. For example, they may have antioxidant, anti-inflammatory, or anticancer properties. The large genome of Vicia faba suggests a high level of genetic diversity, which could result in a wide variety of bioactive compounds. This makes Vicia faba a valuable resource for discovering new compounds that could be used in the development of new treatments for various diseases. However, more research is needed to fully understand the potential health benefits and therapeutic uses of Vicia faba and its bioactive compounds(Méndez-López *et al*. 2022).

Alkaloids

The known pyrimidine glucosides, vicine and convicine, widely spread in Fabaceae, including V. faba, and two novel isomers were found by the proposed methodology. These isomers could have been underestimated by previous methodologies due to the use of stationary phases with higher particle size and UV detection.

Phenolic compounds

A total of 104 phenolics, mainly flavonoids, were characterized. This qualitative rich profile in phenolic compounds may explain in part the higher antioxidant activity of broad beans, in comparison with other vegetables.

Phenolic acids derivatives

Salicylic acid O-glucoside previously identified in V. faba, and three new compounds, 3-O-methyl (3, 4-dihydroxybenzyl tartaric acid; 3-O-methylfukiic acid), hydroxyeucomic acid, and hydroxybenzyl-malic acid (eucomic acid), were tentatively identified based on their MSandMS2 spectra together with the literature on Fabaceae.

Flavonoids

Flavanol monomers Gallocatechin, epigallocatechin, catechin, epicatechin are known compounds of V. faba and were characterized taking into account the elution and fragmentation patterns previously reported(Turco, Ferretti, and Bacchetti 2016). Flavanol oligomers (proanthocyanidins) Proanthocyanidins are among the most severe challenges in terms of chromatographic separation because of their structural diversity and large number of isomeric forms, which is supposed to be a difficult task for their study especially in biological samples, where gut microbiota may play a crucial role leading to their conversion into microbial metabolites. Remarkably, in our study, we succeeded in characterizing dimers and trimers with B-type linkage and constituted by at least one unit of (epi)gallocatechin (prodelphinidins) or only (epi)catechins (procyanidins), according to.(Jin *et al*. 2012)

Terpenoids

Semipolar terpenoids were classified according to the carbon chain backbone, being regular (multiples of 5) and irregular, as: (i) C12, the carotenoid metabolite 8--D-glucopyrano syloxy-2,7-dimethyl-2,4-decadiene-1,10-dioic acid, in Rosaceae; (ii) C13, the megastigmane norisoprenoid 3-hydroxyl-5,6-epoxy-acety--ionol-2-O--D-glucoside, in Moraceae;m(iii) C15, dihydrophaseic acid, in V. faba, its glucoside (dihydrophaseic acid 4-O--D-glucopyranoside;) reported in soybean (Fabaceae) and abscisic acid ; (iv) C20, the diterpenoids gibellerins A23, A17 or A13, and A19, in Fabaceae/V. faba. Rotenone is a highly lipophilic pesticide and herbicide, and hence readily crosses biological membranes. When administrated to rodents, it offers a valuable tool for examining the mechanisms of dopaminergic damage due to oxidative stress, which is known to play an important role in the pathology of Parkinsonism. The superior neuroprotective activity of polyphenols enriched sprout extract may be attributed to different mechanisms, which may include inhibition of Aβ, hyperphosphorylated tau, and the formation of α-synuclein misfolded aggregates. Natural polyphenols also inhibit the formation of inflammatory cytokines and reactive oxygen species. Moreover, they inhibit mitochondrial stress, NF-κB, and the MAPK signalling cascade (Boutagayout *et al*. 2024). The observed increase in aromatic amino acids upon germination may be a contributing factor to the neuroprotective activity against PD, as these amino acids are considered natural precursors for the neurotransmitter dopamine(Boutagayout *et al*. 2024).

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CONFLICT OF INTERESTS

The authors declare no conflict of interest

ETHICS APPROVAL

Not applicable

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AI TOOL DECLARATION

The authors declares that no AI and related tools are used to write the scientific content of this manuscript.

DATA AVAILABILITY

Data will be available on request

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