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A BRIEF OVERVIEW OF THE BIOLOGICAL ACTIVITIES OF FABA BEAN (*VICIA FABA*)

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SUMMARY

Faba bean (*Vicia faba* L.) is a protein rich leguminous crop having a host of bioactive phytochemicals in its mature seeds, green pods as well as leaves. These phytochemicals including phenolic compounds, flavonoids, bioactive peptides, resistant starch, dietary fibres, γ-aminobutyric acid (GABA), l-3,4-dihydroxyphenylalanine (L-DOPA) etc.are mainly responsible for various biological activities like antidiabetic, anti-inflammatory, antihypertensive, antiviral, antibacterial, antifungal, antioxidant, anti- malarial, anticancer, cholesterol-lowering etc., Keeping in view, the recent growing interest on plant based nutraceuticals and nutritional and health benefits of faba bean, it has been considered pertinent to review the biological activities shown by various plant parts of faba bean.

Keywords : Faba bean, antibacterial, antifungal, L-DOPA, antidiabetic, antihypertensive, favism

Faba bean (*Vicia faba*) is a potential, versatile leguminous crop of *Fabacee* family which can be grown in varied climatic conditions throughout the world (Arya *et al*., 2018 & 2022). The crop, if used in rotation or as intercrop (Köpke and Nemecek, 2010; Arya *et al.*, 2019) with other cereal crops, provides agronomic, economic and, environmental benefits to the farmers in the form of reducing the requirement of inorganic fertilizers for next crops (Aschi *et al.,* 2017; Arya *et al*., 2020), by increasing the plant yields (Xiao *et al.,* 2018) and by breaking the vicious cycle of disease and pests (Zhang *et al.,* 2019). Faba bean also known as many names such as Field bean, Broad bean, Windsor bean, Horse bean, Tick bean, Longpod bean and Kaka Matar (Mínguez *et al*., 2021). It has been produced in Mediterranean region (Jensen *et al*., 2010) China, Africa, Europe, Middle East, Asia where it is most common crop for human and animal consumption. Faba bean (kernel as well as mature dry seed) with well-balanced aminoacid profile (Martineau *et al*., 2022) is a rich source of protein, (Multari *et al*., 2015) carbohydrates, minerals (Rahate *et al*., 2020), vitamins (Oomah *et al*., 2011); and other bioactive phytochemicals along with some anti-nutritional compounds (Mattila *et al*., 2018). During European Union- Competitiveness of Agriculture and Management of Agricultural Resources (EU-CAMAR) data collection (1990 -1995) program, it has also been established that the genotypes possess both genotypic and environmental effects together may have both the qualities of rich protein content and higher methionine and cysteine (sulphur containing amino acids) content. The lysine and arginine content is higher in faba bean, whereas limiting in sulphur-containing amino acids such as methionine and cysteine (Duc *et al.,* 1999). The oil content in faba bean found to be low (1-3%) as compared to soybean.

Nutritional Profile of faba bean

The *V. faba* seeds has many nutritional properties as well as anti-nutritional properties.Faba bean provides a balance diet of carbohydrates, protein, fibers and vitamins and the protein content comparable to meat and fish (Macarulla *et al.,* 2001; Vioqne *et al.,* 2012). It is popularly known as "Poor man's meat". Due to its highly nutritional properties, low cost and improving soil fertility, it is being greatly important feed crop.

Besides nutritional potential, faba bean possesses anti-nutritional factors such as saponins, tannins,phytic acid,lectins, oxalates, trypsin inhibitor

TABLE 1
Chemical Composition of Faba Bean Seeds

Chemical Composition	Type and amount present
Carbohydrates	51 to 68 %
Proteins	20 to 41 % (globulins 79%, albumins 7%, gluteins 7%)
Lipids	2.30 to 3.91 %
Saturated fatty acids	Palmitic and Stearic acid
Unsaturated fatty acid	Myristic, arachidic, behenic acid, oleic acid, linoleic acid,
Vitamins	Folic acid, Niacin, Vitamin C
Minerals	Na, K, Ca, P, K, S, Al, B, Ba, Co, Cr, Cu, Fe, Ga, Li, Mn, Ni, Pb, Sn, Zn.

etc. particularly favisminducing vicine and convicine (Labba *et al*., 2021; Rizello *et al*., 2016; Luzzatto and Arese, 2018; Khazaei *et al*., 2019). On ingestion, vicine and convicine hydrolysed enzymatically or chemically forming a highly reactive aglyconesdivicine and isouramil. Divicine and isouramil have been identified as the main reason of favism in susceptible individuals having deficiency of glucose-6-phosphate dehydrogenase because they undergo autoxidation to form superoxide (Winterbourn *et al.,*1989) which is the cause of rapid oxidation of glutathione (GSH) in erythrocytes and can damage red blood cells by oxido-reductive cycle. Favism only occurs after digestion of faba bean by the G6PD deficient individuals as they are unable to regenerate reduced glutathione.However, reduction of the contents of theses anti-nutritional factors has been reported through food processing (Shi *et al*., 2017, 2018), sprouting (Singh *et al*., 2013), breeding schemes (Arbid and Marquardt, 1985b), germination (Goyoaga *et al.,* 2011) and fermentation (Coda *et al.,* 2015; Rizzello *et al.,* 2016).

Uses of Faba beans

Faba bean is an excellent source of protein, vitamins, minerals, fibers and bioactive compounds. The cost of faba bean is low almost half of the price of soybean and peas and suitable for gluten free products. Broad bean being a fabulous crop which is growing in cool and wet environments. Some uses of faba bean are as:

1. Edible bean : Faba bean is an edible bean like soybean and peas because of its nutritional properties. In China, Middle-East, Mediterranean region, Ethiopia, it is most commonly used in breakfast. In foods, faba bean can be used as sauces, canning, medamis (Stewed bean), Nabet soup (Boiled germinated beans), falafel (Deep fried cotyledons paste with some vegetable and spices). In India, roasted seeds of faba bean eaten.Faba beans consists of some anti-nutritional compounds but its anti-nutritional quality is reduced by roasting and heating and a new variety of faba bean has been explored.

Livestock feed : Faba beans can be used to feed a variety of livestock such as hogs, dairy beef cattle, lamb, poultry, fish and pigeon. Canadian research exhibits no difference in milk production when cows were fed either on faba bean or soybean (Singh, *et al,* 2013). Due to low amount of oil in faba bean, they do not require oil extraction before feeding, like soybean.

TABLE 2
Comparison of chemical composition (%) of Faba bean seed, Pea seed and Soybean.

S. No.	Chemical Composition (%)	Faba bean Seed	Pea Seed	Soybean Meal
1.	Starch	32.7	46	6.0
2.	Crude protein	25-30	23	49
3.	Crude fibre	7.8	5.5	6.1
4.	Dry matter	88.3	88.0	88.3

It is evident that faba bean is nutritional very rich, and the phytochemicals present in it could be a good source of biologically active compounds. Although there are a few reviews on the nutritional and nutraceutical potential (Martineau-Cote *et al*., 2022) of faba bean, however, a comprehensive review comprising the biological activities of it is still urgently needed.

Biological activity of faba bean

Faba bean, being as a crucial nutrient-rich legume along with some anti-nutritional factors, possesses phytochemical components which are bioactive in nature and also exhibit significant medicinal properties for the health benefits. *Vicia faba* plays

crucial role in treatment of human diseases and as an adjuvant in heart, renal,liver diseases, Parkinson's disease and AIDS (Ye *et al*., 2001; Hornykiewicz, 2002; Ye and Ng, 2002; Ellwood *et al.,* 2008). The important biological activities shown by faba bean are summarised as:

1. Antioxidant properties : Faba beans are rich source of polyphenolic compounds acting as antioxidants (Prabhu and Rajeshwari, 2018; Turco *et al*., 2016). They prevent the body from oxidation caused by free radicals. Studies have shown the antioxidant activity of faba beans against topoisomerases also. This property can also be utilised in using faba bean as anticancer agent(Tselepi *et al.* 2011). Randhir and Shetty (2003) observed that the antioxidant activity of L-DOPA and polyphenols in faba bean can be stimulated by microwaves. There was 59% increase in L-DOPA whereas the increase was 700% in polyphenolic content upon irradiation.

Loizzo and coworkers (2021) in their efforts towards studying the phytochemical content and nutraceutical potential of faba bean, its beans and pods were investigated as a strategy to counteract metabolic syndrome (MetS). The ethanol extract of pod had highest total phenol and flavonoid content which might be due to abundance of (+)-catechin and (−)-epicatechin in them as revealed by High Performance Liquid Chromatography (HPLC) analysis. Similar to the above findings, the pod extract also showed an ABTS radical scavenging ability (IC_{50}value of 1.5 mg/mL) comparable to ascorbic acid (IC_{50} value of 1.7 mg/mL). The edible part of the faba bean also showed a promising alpha-glucosidase inhibitory activity (IC_{50} value of 38.31 mg/mL).

Jus′kiewicz *et al*. in 2021 studied the effect of small amounts of proanthocyanidins (0.1 and 0.3%) extracted from faba bean seed coats on increase in the antioxidative properties of the rat diet without exerting an antinutritional effect. The addition of proanthocyanidin extract (two to four time higher than control) in rat diet had not significantly altered the coefficients of digestibility of crude protein, coefficient of biological value, and the daily nitrogen retention value of diet protein. It was also found that the blood serum of rats fed diets supplemented with proanthocyanidin extract did not affect the content of Vitamin A and aspartate aminotransferase activity; however, it has a slightly higher amount of vitamin E and alanine aminotransferase activity than those of the control group. The rats fed with proanthocyanidin supplemented diet had a lower activity of β-glucoronidase in their gut (caecum), however, the β-galactosidase activity was analogous and the malondialdehyde content in the heart, kidneys, erythrocytes and blood plasma of rats was decreased. The results clearly demonstrated that the proanthocyanidins did not exert any antinutritional effects, however, the pool of diet antioxidants and large bowel microflora were beneficially enhanced.

Rybinski, *et al*. (2019) extracted a host of phenolic compounds from seeds of 22 cultivars of faba bean in order to study the total phenolic compound and condensed tannins contents and their antioxidant activity potential. The range of total phenolic compounds was from 40.7 to 66.1 mg/g extract and from 326 to 574 mg/100 g seeds, for condensed tannins the range was from 2.40 to 49.9 mg/g extract and from 22.2 (FAB) to 365 mg/100 seeds.

The evaluation of in vitro antioxidant capacity of thirteen genotypes of faba bean showed high content of both flavonoids (>11.87 mg as rutin equivalent (RE)/g of dried plant) and total phenolics contents (>92.85 mg as gallic acid equivalent (GAE)/g of dried plant) were found for all genotypes during the vegetative and the reproductive stages, which also showed the highest antioxidant activity (FRAP value ≥1.157 mmol/g and DPPH radical-scavenging capacity N43.49%). These findings indicated faba bean's potential as natural source of antioxidant foods (Chaieb *et al.,* 2011).

The immature growing stage of faba bean had significantly higher phytochemical contents and displayed a better antioxidant activity than those of mature ones. The strongest antioxidant activity and highest level of phytochemicals were recorded in the seed coat. As other cooking practices caused significant decrease in the phytochemical bioactive contents, and antioxidant activity, steam cooking could be preferred to preserve the bioactive phytochemicals of faba bean (Boukhanouf *et al*., 2016).

Roasting faba beans for 120 min decreased the total equivalent antioxidant capacity, 2,2-diphenyl-1-picrylhydrazyl radical scavenging activity and ferric reducing antioxidant power by15, 48 and 8%, respectively. It also decreased the proanthocyanidin, lavonoid and total phenolic contents by 30, 42 and 42%, respectively. Although roasting initially lowers the bean antioxidant capacity, prolonged roasting at 150 °C for 60 min and longer causes generation of new phenolic compounds and an increased antioxidant capacity. These findings encourage a wider utilisation

of faba beans for roasted or baked human food products (Siah *et al*., 2014).

2. Anti-inflammatory activity : Pyrimidine ring is an important chemical constituent in many biological molecules such DNA, RNA, Vitamins etc. Hence, naturally existing pyrimidines can also be used as pharmacological agent in various roles. Much research is being done on anti-inflammatory properties of pyrimidine of which vicine and divicine form a part being naturally available as faba beans. The research done by Hussein *et al.* (2012) has demonstrated the anti-inflammatory properties of vicine and divicine. The albino rats were injected with fresh egg albumin (0.5 ml/kg) resulting into swelling/oedema 120 minutes after injection. However, administration of 150 mg/kg of vicine and divicine inhibited the oedema to 59.56% and 45.65% respectively (the inhibition being 100% for diclofenac sodium at 100 mg/kg). Hence, both vicine and its aglycone can show potential anti-inflammatory action with vicine being more active than divicine.It was also found that the anti-inflammatory action of vicine and convicine is due to inhibition of enzymes participating in inflammatory process. Vicine and divicine act on biological pathways reducing the production of anti-inflammatory substances derived from arachidonic acid (itself formed *via* cyclooxygenase and 5-lipoxygenase pathways) by Zeinab *et al*. in 2011, in inhibition of some enzymes involved in the synthesis.

3. Antifungal activity : Along with antimicrobial and antioxidant agents, some compounds with significant antifungal activity are also isolated from faba beans. Trypsin inhibitor(Egyptian Trypsin Inhibitor, VFTI-E1) isolated from faba beans has antifungal activity against fungus *Valsamali* (Fang *et al*., 2010). Other than this, Chymotrypsin inhibitor, Chitinase, Wyerone and wyerone epoxide are also antifungal compounds isolated from *V. faba* (Ye and Ng, 2002; Wang *et al.,* 2012).

Bjerg *et al.,* 1984 tested for antifungal activity of vicine and convicine on fungus *Ascochytafabae, Botrytis cinerea, Pyrenophoragraminae*and found inhibition in growth for the three species. Pavlik *et al.,* 2002, studied vicine in lower concentration (25µg/ml) than young faba beans. They were tested against *C. herbarum, B. cinerea, Pyrenophoragraminae* and found complete inhibition. Some hyphae with discontinuing growth were observed with *F. solani, F. culmorum* and *A. alternata.* There were slight changes in experimental conditions from Bjerg *et al.* experiment (use of liquid medium instead of agar) by Pavlik group and it was conferred that vicine can act as antifungal agent.

4. Antibacterial Activity : Zhang and Lewis (1997) isolated two new antimicrobial peptides named as Fabatin related to γ-thionine family from the acid extract of faba bean contains 47 peptide residues that have shown antimicrobial activity against both Gram positive and Gram negative bacteria i.e. *P. aeruginosa*, *E. coli*, and *E. hirae* but have not shown any activity against *Saccharomyces* or *Candida* spp (Zhang *et al.* 2019). The two peptides differed by one amino acid. They were found inactive against the yeasts *Saccharomyces cerevisiae*and fungus *Candida albicans*.

Gholmali and Khorsandi (2007) studied the antimicrobial activities of ethanoic, methanolic, water and 2-methylbutan-1-ol extracts obtained from various plant parts including seeds, seed hulls, leaves and flowers of faba bean plant. The bacterial strains used were *Bacillus subtilis*, *Serratia marcescens*, *Staphylococcus aureus*, *Escherichia coli,Klebsiella pneumoniae*, *Shigella* sp. and *Micrococcus pyogenes*. The methanol and 2-methylbutan-1-ol extract was inactive against the studied bacteria. The sterial distilled water extract of of faba bean leaves showed better antimicrobial activity with 13 -32 mm zone of inhibition. The flower and seed hull extract inhibited the growth of *Escherichia coli, Bacillus subtilis*, *Shigella* sp., *Serratia marcescens*, *Staphylococcus aureus* and *Micrococcus pyogenes*. The ethanol extract of flowers showed 15 -16 mm zone of inhibition against *Micrococcus pyogenes* and *Bacillus subtilis*. However, the ethanol extract of leaves, seed hull and flowers exhibited 25-34, 15-17 and 15mm zone of inhibition against E. coli, respectively. It was concluded that the sterile distilled water extract of faba bean leaves and flowers can be used as antibacterial medicine after toxicity tests.

5. Antiviral activity : The pp150 gene of human cytomegalovirus (HCMV) was transferred into Vicia faba plants by Agrobacterium tumefaciens-mediated transformation. Three of five *V. faba* plants were identified as positive by PCR and the pp150 protein isolated from them provided resistence against Human Cytomegalo Virus (HCMV). Results were confirmed with immunization of mice with pp-150 transgenic *V. faba* seeds hence paving the way for

edible vaccine against HCMV infection(Yan *et al.,*2010)

6. Antidiabetic activity : *Vicia faba* with antioxidants help in rejuvenation of β-cells of pancreas by scavenging free radicals and defends cytotoxic streptozotocin effect which helps in treating diabetes mellitus. It was thus believed that V-C are showing the antidiabetic activity in faba beans (Fatima and Kapoor, 2006). A rapid decline in blood glucose and lipid levels was observed along with increase in insulin hormone level, high density lipoproteins, ferritin, haemoglobin, superoxide dismutase, catalase, glutathione peroxidase and glutathione-S-transferase. Faba bean could be ideal for inclusion in the diets of diabetics due to their inhibition of intestinal α-glucosidases which delays the digestion and absorption of carbohydrates. This leads to suppression of postprandial hyperglycaemia (Turco *et al*., 2016).

7. Anticancer activity : *Vicia faba* has been considered as a potential anticancer agent in colon cancer. The lectin present in faba beans weakens the malignant colon cells by morphological differentiation into gland like structures, hence, halting colon cancer progression (Lima, *et al.,* 2016) believed that metalloproteinases are factors related to cancer growth and metastization and bioactives present in faba beans inhibit a subgroup of metalloproteins making them potential anticancer agents. Siah *et al*. (2012)observed that the faba bean extracts demonstrated cellular protection ability against H_2O_2-induced DNA damage, and inhibited the proliferation of all human cancer cells. However, the effect of faba bean extracts on the non-transformed human cells was negligible. Flow cytometric analyses showed that faba bean extracts successfully induced apoptosis of acute promyelocytic leukaemiacells. The faba bean extracts also exhibited ACE, a-glucosidase and pancreatic lipase inhibitory activities. These results help in promoting the utilisation of faba beans in human diets for various health benefits.

8. Antimalarial activity : It has been observed that G6PD deficient individuals are protected against malaria (Luzzatto and Arese, 2018). Faba bean consumption leads to haemolytic anaemia as a result of oxidative stress (Arese and De Flora, 1990) and malaria parasites also inflict oxidative stress. Therefore, the growth of *Plasmodium falciparum* was retarded in G6PD deficient cells. Ginsberg *et al.* (1996) carried out an experiment with *Plasmodium falciparum* with normal and G6PD deficient cells and evaluation of β-glycosidic activity, phagocytosis and parasitic growth was done upon exposure of cultures to increasing concentrations of vicine and convicine. It was observed that convicine is more potent inhibitor of *Plasmodium* growth. Addition of β-glucosidase (from external source) increase inhibitory ability and parasites in G6PD deficient RBCs were more sensitive to V-C. Also, pro-oxidants rendered normal and G6PD deficient RBCs more prone to phagocytosis (Arese and DeFlora, 1990). Divicine is shown to be more toxic to *P. vinckei* in vivo (Clark *et al.,*1984) and isouramil to *P. falciparum* in culture (Golenser *et al.,* 1988).

9. In treatment of Parkinson's disease : L-DOPA (an amino acid) is precursor for neurotransmitters such as dopamine, adrenaline and noradrenaline (Etemadi *et al*., 2019, Gautam*et al.,* 2012). It is synthesized from L-tyrosine in mammalian body and brain (Randhir and Shetty, 2004; Miller *et al.,* 2009). L-DOPA is used in treatment of Parkinson's disease as main component and in treating hormonal imbalance(Surwase*et al.,*2012; Inamdar*et al.,*2013; Hu *et al.,* 2015; Etemadi*et al.,* 2018 b). It is synthetically available but causes side effects(Patil*et al.,* 2013). Hence, natural sources of L-DOPA such as legumes (Chattopadhyay*et al.,*1994; Inamdar *et al.,* 2013), banana (Gautam *et al.,* 2012) can be used in treatment of the disorder. So, the cultivation of faba bean containing considerable amount of L-DOPA in various parts (Etemadi *et al.,* 2015) can be utilised as a cost effective and safer treatment of Parkinson's disease.

Amount of L-DOPA is varied in different cultivars (Etemadi *et al.,* 2014), environmental conditions (Multari *et al.,* 2015), growth stage (Geng, 2012) and organs (Etemadi *et al.,* 2014). There is also non-uniform distribution of L-DOPA content in different plant parts (Geng, 2012). L-DOPA concentration is found to be maximum in earlier growth stages (Etemadi *et al.,* 2018b) while, L-DOPA yield which is product of concentration and biomass can be highest in later plant growth stages (max. biomass stages). Topal and Bozoglu, (2016) studied various genotypes of faba bean in Samsun province, Turkey to determine the L-DOPA content of leaf, flower and pod. L-DOPA levels in leaves, flowers, and fresh pods ranged from 10.88 to 33.41, 40.95 to 96.37 and 4.16 to 52.28 mg/g, respectively on dry weight basis. Flowers from 20 genotypes were tested for L-DOPA

content. The average L-DOPA content of faba bean leaves, flowers, and pods was 9.36, 75.87, and 25.27 mg/kg, respectively. The amount of L-DOPA in flowers was found to be higher than in leaves and pods. Furthermore, the L-DOPA concentration in plant parts may be influenced by processing methods applied on them. Echeverria and Bressani, 2006; Vadivel and Pugalenthi, 2010 indicated the destruction of L-DOPA by cooking and soaking in alkaline solution. Approximately 10 mg/gm of L-DOPA content in raw beans was reduced to almost nil after thermal treatment (roasting and boiling) under specified conditions (Randhir and Shetty, 2004; Cardador-Martinezet al. 2012). On the contrary, microwave treatment and germination increase the content of L-DOPA (Shetty *et al.,* 2001; Randhir and Shetty, 2004).

Conclusion and way forward

Faba bean is an agronomically viable alternative crop to cereal crops as it can fix free nitrogen allowing farmers to practise sustainable agriculture and meet environmental development goals. Being a legume, faba beans are a great source of protein that is high in lysine as well as many other critical elements. Faba beans are an excellent source of high-nutrition proteins because they have higher amounts of all essential amino acids, with the exception of tryptophan. In particular, leucine and arginine are abundant. Faba beans contain L-DOPA, a precursor to dopamine that has the potential to be employed as a bioactive molecule in the treatment of Parkinson's disease. The numerous isolated chemicals may be crucial in the development of drugs and health supplements due to their strong antioxidant capabilities and therapeutic potential. Faba beans are a potential source of nutraceuticals and functional foods and are consumed often in many different parts of the world.

To assist increase and secure its position in the expanding and competitive worldwide plant-based market, further study is required to better understand the health advantages and hazards (especially the allergenicity) connected with faba bean use.

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