Mung bean (Vigna radiata L.) is an important and nutritious food grain legume which plays a vital role in human nutrition due to its plentiful nutrients like proteins, dietary fibers, minerals and vitamins. Besides nutrition, presence of significant amounts of various bioactive compounds in mungbean, make this crop as a good alternative functional food. Developing countries are facing problems in securing healthy and nutritive diet to poor people. Keeping in view of the above facts, mungbean could prove to be a healthy and nutritive part of daily human diet. Mungbean can be consumed in various forms and commonly in the form of germinated seeds or sprouts. In particular mungbean is a highly beneficial recommended diet in current lockdown situation due to COVID-19 worldwide. Health status of poor people could be improved significantly especially in circumstances or places where people cannot afford fresh vegetables, fruits, dairy products and animal-based diet routinely. Present review summarizes the updates on mungbean derived bioactive compounds, their role on human health and their use as a potent medicinal food.

**Keywords:** Bioactive compounds, Mungbean, Medicinal values, Phenolic compounds, Proteins, COVID-19.

**Abstract**

Mungbean harbors a remarkably balanced nutrients comprising of proteins, dietary fibers, minerals, vitamins, and significant abundance of bioactive compounds (Mubarak 2005; Nair et al., 2013; Gan et al., 2017). From historical perspective also, the mungbean has been a common cereal-based food consumed in Asian countries including India and China. Consumption of the mung bean in combination with cereals tends to increase the quality of protein, as these cereals are quite rich in sulfur-containing amino acids while deficient in lysine (Boye et al., 2010). More so mungbean is an enriched source of easily digestible proteins for the vegetarians at a lower cost (Mubarak 2005; Yi-Shen et al., 2018). Therefore, mungbean could also be referred as “the poor man’s meat” (Hall et al., 2017). Mungbean has been reported to be suitable for children as well keeping in view of its lesser flatulence and hypoallergic properties (Dahiya et al., 2014; Bazaz et al., 2016; Ali et al., 2016).

Mungbean has been laden multiplex of properties having clinical and pharmacological attributes (Min 2001; Liyanage et al., 2018; Xie et al., 2019). This nutritious crop has a long history of usage as traditional medicine for its detoxification activities, reduction of fever, recuperation of mentality and alleviation of heat stroke (Yao et al., 2008; Ali et al., 2014; Gupta et al., 2018). Moreover, extracts of mungbean hold great potential to regulate gastrointestinal disturbances, glucose metabolism, lipid metabolism, modulation of immune system, reduction of cholesterol level and moisturization of skin (Soucek et al., 2006; Randhir and Shetty 2007; Yao et al., 2008). Due to the presence of high levels of proteins, amino acids, oligosaccharides, and polyphenols in its various parts particularly, germinated seeds, seed coat and sprouts, mungbean is known to have many health promoting benefits (Randhir et al., 2004; Anjum et al., 2011; Tang et al., 2014). Several studies have reported that extracts of mungbean possess excellent health benefits including hypoglycaemic effects, diuretics, antioxidant, antimicrobial, anti-inflammatory, antidiabetic, antihypertensive, anti-melanogenesis, hepatoprotective and anticancer activities (Lopes et al., 2018; Chai et al., 2019; Hou et al., 2019; Xie et al., 2019).

People, especially from poor and low-income countries cannot afford healthy and nutritive diet which may lead to compromised health state. In the current situation, due to long term lock down and curfew (COVID-19), poor or low-income population are facing problems in getting fresh vegetarian diet paving the way for mungbean as a potent major diet in current context keeping in view of its nutritive, protein content and variety of pharmacological properties. In this review, variety of pharmacological properties associated with mungbean have been discussed justifying its potential use as a major staple food in routine life as well as during troubled times.

**Bioactive compounds and their underlying significance**

Bioactive compounds are also known as phytochemicals or secondary metabolites which occurs
Review on health promoting biological activities of mungbean: A potent functional food of medicinal importance

naturally in plants and exert health benefits (Shukla and Tyagi, 2017; Xue et al., 2016). Exposure of the plant species towards environmental stresses (biotic or abiotic stresses) leads to greater accumulation of these compounds as a defense mechanism. The bioactivity, functionality, and applications of various plants derived chemical components depend upon various factors (Figure 1) including geographical location, climate change, light (intensity and duration), and temperature as well (d’Archivio et al., 2010; Li et al., 2014a). Plant food extracts and phytochemicals derived from mungbean, comprise of a variety of compounds having positive health benefits (Shukla and Tyagi 2017). Significant amounts of secondary metabolites such as flavonoids (vitexin and isovitexin), phenolics (free or bound phenolic acids, total phenolic), and anthocyanin, have been reportedly harbored in mungbean. Majority of the bioactive phytochemicals or compounds have been reportedly contained in mung bean seed coat (Khan et al., 2006; Cao et al., 2011). These bioactive compounds have shown promising biological effects as antioxidant, antiseptic, antiinflammatory, antitumor and antimelanocyes, and antiangiotensin I-converting enzyme activities (Figure 1) (Kim et al., 1998; Kim et al., 2012; Li et al., 2006; Li et al., 2012; Lee et al., 2013; Yao et al., 2013; Yeap et al., 2013). There are several studies which have highlighted the pharmacological properties of bioactive compounds derived from mungbean seeds, seed coat and sprouts (Peng et al., 2008; Zhang et al., 2013; Yeap et al., 2015). Another study revealed that the MBSC extract significantly reduced the oral bioavailability of Cyclosporine A (CsA), which is an important calcineurin inhibitor by inhibiting its absorption (Li et al., 2014b). Tang et al (2014) summarized the nutritional value, chemical constituents, and metabolite changes during the sprouting process, as well as pharmacological activities, and clinical applications of mung beans, which will provide a better understanding of the potential applications of this common food (Tang et al., 2014). Regular consumption of food having high carbohydrate and fat but low protein content increases rates of metabolic syndromes, such as hyperglycemia, dyslipidemia, and inflammation (Popkin et al., 2012). Various health organizations have recommended making serious changes in the dietary patterns at global level. Uses of plant-based functional foods in the diet have been reported to improve health status and prevent chronic diseases (Espin et al., 2007; Kumar et al., 2018; Hou et al., 2018). Recently, Hou et al., (2019) summarized the utilization of mungbean in food products to improve human nutrition (Hou et al., 2019).

Mungbean is a future crop of nutritional and pharmacological importance which makes it a good alternative functional food in present scenario (Gupta et al., 2018; Xie et al., 2019). Different bioactive compounds (polyphenols, polysaccharides, proteins, and peptides) in various parts of mungbean exert significant health benefits to humans (Table 1) (Hou et al., 2019; Xie et al., 2019). Germination of mungbean seeds or seedlings causes changes in the nutritive contents, biochemical composition, growth parameters and photosynthetic pigments. Improved nutritional values of mungbean may help in alleviation of food crisis i.e. malnutrition, food scarcity and security for the continuously rising population (Figure 1). Thus, it is encouraged to increase the consumption of germinated mung beans for enhanced nutrition uptake and disease prevention (Tang et al., 2014; Madar et al., 2017; Hou et al., 2019).

Polyphenols

Mungbean is rich in polyphenolic compounds. But the composition and content of bioactive compounds in different plant parts depend on many factors, (Figure 1) e.g., their cultivars, the color of their seed coats, the climatic and agronomic conditions of their growth, and the extraction and analytical methods (Zhang et al., 2013; Singh et al., 2017a). Most of the phenolic compounds are present in the seed coat as compared to the seeds or cotyledon of mungbean (Table 1). The major phenolic constituents in the mung bean are phenolic acids, flavonoids and tannins (Lee et al., 2011a; Shi et al., 2016; Singh et al., 2017b). Phenolic acids are primarily synthesized through the pentose phosphate pathway (PPP) and shikimate and phenylpropanoid pathways (Randhir et al., 2004). These compounds are mainly present in free or bound forms in plant cells. But the bound phenolics (ferulic, caffeic, chlorogenic, syringic, p-coumaric, gentisic acids) have been seen to have more significant health benefits. This effect may be due to their escape from upper gastrointestinal digestion, along with cell wall materials, and absorption into blood plasma during microflora digestion activity (Yao et al., 2013; Shi et al., 2016).

Plant derived natural phenolic metabolites contain a spectrum of phenolic antimicrobials directed toward certain spectrum of microbes. Hence, the plant phenolic metabolites are potential antimicrobial agents (also known as ‘biocides’) against human pathogens (Smid and Gorris 1999; Randhir et al., 2004; Lambert 2008). These compounds play significant role in prevention and treatment of human disease. For example, polyphenol extracts from mung bean sprouts also exert antibacterial activity against Helicobacter pylori causing gastroduodenal disease in human beings (Randhir et al., 2004). Germinated seeds or sprouts have stronger defenses and metabolic pathways due to presence of significant amount of nutrients and bioactive compounds as compared to the parent seeds (Fernandez-Orozco et al., 2008; Singh et al., 2017b). The phenolic compounds also protect the cells from potential oxidation-induced deterioration (Lambert 2008). Previous studies have isolated a combination of antimicrobial protein from mung bean against a range of bacteria and fungi. Authors also emphasized that the sprouting of seeds improves the antioxidant and antibacterial activity (Sawa et al., 1999; Hafidh et al., 2011; Singh et al., 2017b).

Flavonoids

Flavonoids are the most abundant secondary metabolites in the mung bean which mainly constitutes different subclasses i.e., flavones, flavonols, isoflavonoids, and anthocyanins (Guo et al., 2012; Yeap et al., 2015). Seed germination and fermentation process can significantly improve the concentration of these metabolites in mung bean. Because, the total contents of flavonoids (vitexin and isovitexin), increase during germination which is near about 7 times higher in mung bean sprouts than the raw mungbean seeds (Mohd Ali et al., 2013; Paja et al., 2014; Yeap et al., 2015). Flavonoids are involved in initial development of plants, signaling pathways (i.e., nodulation in legume), protection against biotic (insect /mammalian herbivores) or abiotic stress (oxidative and heat stress) factors prevailing in the environment stress protection (Koes et al., 1994). The testa of mungbeans contains more vitexin, isovitexin, and d-chiro-inositol as compared to the seeds (DCI) (Peng et al., 2006; Cao et al., 2010; Paja et al., 2018). Recently, Hou et al., (2019) summarized the utilization of mungbean in food products to improve human nutrition (Hou et al., 2019).
Mungbean is an excellent source of proteins which release peptides upon digestion and exhibit certain bioactivity (Xie et al., 2019). But the protein or peptide activity of mungbean was affected by many factors, such as types of hydrolysates, enzymatic hydrolysis time, and amino acid compositions, sequences, and molecular weight. Germination process causes a remarkable increase in these proteins and amino acids, de novo synthesis of new proteins and accumulation of certain existing proteins compared to the dry mungbean seeds (Madar et al., 2017). Modern investigations are mainly focused on the bioactivity of plant derived peptides along with the effect on angiotensin I-converting enzyme (ACE) inhibition (Aluko 2008; Tang et al., 2014; Hou et al., 2019). Inhibition of ACE by ACE inhibitors is a useful strategy used to control hypertension. This prevents the conversion of Angiotensin I hormone to Angiotensin II which is the active form of the hormone. Angiotensin II raises blood pressure by acting directly on blood vessels, sympathetic nerves and adrenal glands (Kader 1996; Yamazaki et al., 2003). However, the un-hydrolyzed mung bean isolates of protein did not exhibit any inhibitory activity on ACEs (Li et al., 2005). Xie et al. (2019) isolated peptides of different molecular weights from the mung bean protein hydrolysates. Authors suggested that the peptide with small molecular weight (<3 kDa), showed higher ACE inhibitory effect and antioxidant activities (DPPH and OH radicals scavenging) and metal-chelating activity, than another two peptides having high molecular weights (Xie et al., 2019). The relatively high concentrations of aromatic amino acids (10.56%) in the amino acid composition of the small molecular weight peptides may be another important explanation for its higher activity (Xie et al., 2019).

Mungin is an anti-fungal protein (18 kDa protein), isolated from mungbean seeds (Ye et al., 2000) possessing a novel N-terminal sequence homologous to cyclophilins. It exerts greater anti-fungal activity against Rhizoctonia solani, Coprinus comatus and Botrytis cinerea as compared to Mycosphaerella arachidica and Fusarium oxysporum (Ye et al., 2000). Mungin protein displayed inhibitory activity against α- and β-glucosidases but not against HIV-1 reverse transcriptase and β-glucuronidase. This protein also exhibited anti-mitogenic activity (Ye et al., 2000). Wang et al. (2004) isolated an anti-fungal and antibacterial protein, nSLTP (9.03 kDa), from the mungbean seeds which showed anti-pathogenic activity. The nSLTP protein is able to bind and transfer a variety of very diverse lipids between membranes in vitro (Kader 1996; Lin et al., 2005). This protein showed anti-fungal activity against Fusarium solani, Fusarium oxysporum, Pythium aphanidermatum and Sclerotium rolfsii while antibacterial effect observed against Staphylococcus aureus, but not against Salmonella typhimurium (Lin et al., 2005). Chitinase (30.8 kDa protein) is another important enzyme isolated from mung bean seeds (Wang et al., 2005). It exerts antifungal activity against R. solani, F. oxysporum, M. arachidica, P. aphanidermatum, and S. rolfsii (Wang et al., 2005). Clinical importance of these peptides or proteins suggest their use as an alternative to synthetic drugs, since peptides are thought to cause fewer side effects (Gracia et al., 2013). Besides this, the mungbean protein hydrolysate can also be used as anticancer agent or drug carrier (Wongekal et al., 2011; Xie et al., 2019). Mung bean proteins and their hydrolysates hold great promise as sources of compounds with significant nutritional, functional and bioactive potential.
Conclusion and Future Prospects

Mungbean is an important nutritious food crop. It has abundance of easily digestible protein and significant amounts of bioactive compounds with health promoting benefits. These compounds are involved in regulation of metabolism, immune system and intestinal microflora composition. Plant derived natural compounds (Phenolics, flavonoids, proteins, peptides, polysaccharides) can also be used in pharmaceuticals, nutraceuticals and industrially important products i.e. enzymes or proteins. Mungbean should be chiefly included in diet pattern of humans as a functional food for staying healthy and for future health. Also, we need to focus on global higher production and yield of mungbean adversely affected by the climate changes. We recommend that in the prevailing situation of lockdown due to COVID-19 pandemic, mungbean could be a suitable nutritive and healthy diet for the large proportion of the population that cannot afford fresh fruits, vegetables and other dairy products.

Table 1: Major bioactive compounds isolated from mungbean and their pharmacological significance

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Class</th>
<th>Sub-class</th>
<th>Compounds/Extracts</th>
<th>Properties characterized</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Phenolic acids</td>
<td>Hydroxycinnamic acid;</td>
<td>Aqueous or alcoholic extracts of mungbean</td>
<td>Antiseptic, Anticancer, Antioxidant, Hypoglycemic, and Hypolipidemic activities</td>
<td>Yao et al., 2013; Pajak et al., 2014; Meenu et al., 2016; Bai et al., 2017</td>
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<tr>
<td></td>
<td></td>
<td>Hydroxybenzoic acid</td>
<td>seeds (raw, boiled, fermented), seed coat,</td>
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<td></td>
<td></td>
<td></td>
<td>cotyledon and hull; Processed mung bean</td>
<td></td>
<td></td>
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<tr>
<td>2</td>
<td>Flavonoids</td>
<td>Isoflavanoids; Flavones;</td>
<td>Aqueous or alcoholic extracts of mungbean</td>
<td>Anticancer, Antihypertensive, Antioxidant, Hypolipidemic and Hypoglycemic activities</td>
<td>Yao et al., 2013; Pajak et al., 2014; Meenu et al., 2016</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Flavanols; Anthocyanins</td>
<td>seed coat (Vitexin and isovitexin)</td>
<td></td>
<td></td>
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<tr>
<td>3</td>
<td>Polysaccharides</td>
<td>Arabinogalactan; Pectin;</td>
<td>Water or Alkali extracts of mungbean</td>
<td>Antioxidant activities, Immunoregulation, Macrophage activation, Immuno-modulation</td>
<td>Lai et al., 2010; Zhong et al., 2012; Yao et al., 2016a; Yao et al., 2016b; Ketha and Gudipati, 2018</td>
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<tr>
<td></td>
<td></td>
<td>Hemicellulose</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>4</td>
<td>Proteins/Peptides</td>
<td>Vicilin; Mungin; Chitinase</td>
<td>Mungbean protein hydrolysates</td>
<td>Antihypertensive and Antimicrobial activities</td>
<td>Ye et al., 2000; Wang et al., 2004; Li et al., 2005; Li et al., 2006; Yao et al., 2012; Jeong et al., 2016; Xie et al., 2019;</td>
</tr>
</tbody>
</table>
Conflict of interest: None to declare

Acknowledgement

Authors are thankful to Head, Department of Biotechnology, Maharishi Markandeshwar (Deemed to be University), Mullana-Ambala, India.

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