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REVIEW ON HEALTH PROMOTING BIOLOGICAL ACTIVITIES OF MUNGBEAN : A POTENT FUNCTIONAL FOOD OF MEDICINAL IMPORTANCE

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Abstract

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.

Introduction

Mungbean (*Vigna radiata* L.) is an important warm season, annual, edible grain legume with a short life span of 70-90 days with low input requirements (Dahiya *et al.,* 2015; Sehrawat *et al.,* 2019). Mungbean is a native crop of India (Vavilov, 1926) with its seeds and sprouts are being widely used as a fresh salad vegetable or common food not only in Asian countries but also in the Western world. Moreover, it has a shorter life cycle with a unique ability of nitrogen fixation, making it aptly suitable for diverse agriculture cropping systems as a rotational crop in particular (Murakami *et al.,* 1991). About 6 million ha land is cultivated worldwide for the mungbean crop constituting approximately 8.5% of the global pulse area. Additionally this crop is relatively drought-resistant; therefore being widely cultivated in many Asian and some Western countries as well (Dahiya *et al.,* 2015).

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 ladened 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 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, antidiabetic, antiinflammatory, antitumor and antimelanocytes, 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.,* 2008). DCI can inhibit transforming growth factor beta (TGF-b) expression and development of insulin resistance. This can be used as a therapeutic agent for diabetic nephropathy (Sugiyama *et al.,* 1996; Peng *et al.,* 2008). Vitexin and isovitexin play significant role in the regulation of inflammation induced lipogenesis, oxidative stress, lipid synthesis, insulin resistance and modulation of glucose metabolism (Table 1) (Randhir and Shetty 2007; Hafidh *et al.,* 2011; Kang *et al.,* 2015). Beside this, vitexin and isovitexin inhibits the activity of starch-hydrolyzing enzymes (α-amylase and α-glycosidase) to regulate the glucose metabolism. These compounds reduce the intestinal absorption of carbohydrates, enhance insulin sensitivity, and reduce body hyperglycemia which helps in diabetes management (Yao *et al.,* 2013; Luo *et al.,* 2016). In addition, Mung beans derived polyphenols and flavonoids exert DPPH (1,1-diphenyl-2-picrylhydrazyl) radical scavenging activities, tyrosinase inhibition, and antiproliferative and alcohol dehydrogenase activities (Kim *et al.,* 2012; Tang *et al.,* 2014; Hou *et al.,* 2019).

Flavonoids are able to scavenge reactive oxygen species (ROS) involved in inflammatory pathology (Guo *et al.,* 2012; Li *et al.,* 2012; Mothana *et al.,* 2012). An aqueous extract of the mungbean coat having flavonoids (vitexin and isovitexin) showed anti-inflammatory properties against systemic inflammatory disease; sepsis (Zhu *et al.,* 2012). Compounds from ethanol extract of mungbean (polyphenols, gallic acid, vitexin, and isovitexin) have great potential to improve the clinical symptoms of inflammation-associated diseases, such as allergies, diabetes, toxic poisoning, heat stroke associated with thirst, irritability and fever (Lee *et al.,* 2011b; Bellik *et al.,* 2012). The ethanol extracts of mugbean were reported to exert promising anti-inflammatory effects on lipopolysaccharide (LPS)-stimulated macrophages, prevention of pro-inflammatory gene expression, down regulation of pro-inflammatory cytokines i.e. interleukin (IL)-1β, IL-6, IL-12β, tumor necrosis factor (TNF)-α, and inducible NO synthase (iNOS) without any cytotoxicity (Jeune *et al.,* 1999; Yeap *et al.,* 2012). Besides this, the extracts of mungbean play an important role in the modulation of human immunity and improvement in metabolic disorders (Kang *et al.*, 2015). Ali *et al.* (2014) evaluated *in vitro* and *in vivo* anti-inflammatory and antinociceptive activities of aqueous extracts of mungbean seeds (germinated and fermented seeds). Authors found that the aqueous extracts of germinated and fermented seeds have great potential as antinociceptive agents and analgesics (Ali *et al.,* 2014). These extracts can be commercially marketed as supplement or developed as drug for treatment of inflammatory diseases or metabolism associated disorders (Ali *et al.,* 2014; Kang *et al.,* 2015).

Polysaccharides/Proteins/Peptides as bioactive compounds

Besides phenolic acids and flavonoids, some bioactive polysaccharides have also been reportedly obtained from the mungbean. Majority of the reported polysaccharides were prepared from water extracts (solvent-free) of mungbean. These polysaccharides regulate various physiological activities. They also exhibited antioxidant and immuno-regulatory activities in several studies reported earlier in literature (Lai *et al.,* 2010; Zhong *et al.,* 2012; Yao *et al.,* 2016).

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 mung bean was affected by many factors, such as types of hydrolases, 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; Xie *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^- radical 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 arachidicola* 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. arachidicola*, *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 (Wongekalak *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 in foods, pharmaceuticals, other products and processes as well (Yi-Shen *et al.,* 2018; Xie *et al.,* 2019).

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, neutraceuticals 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.

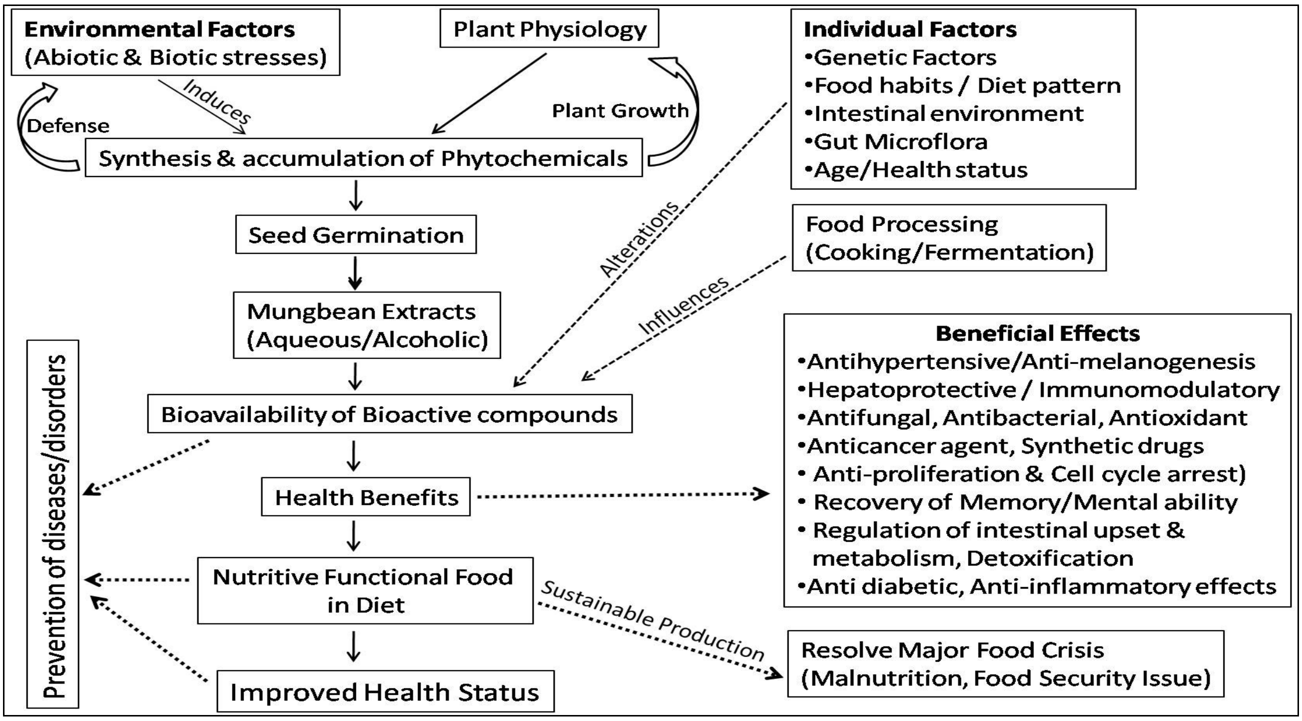

Fig. 1 : Factors affecting availability of bioactive compounds and their significance

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

Sr. No.	Class	Sub-class	Compounds/Extracts	Properties characterized	References
1.	Phenolic acids	Hydroxycinnamic acid; Hydroxybenzoic acid	Aqueous or alcoholic extracts of mungbean seeds (raw, boiled, fermented), seed coat, cotyledon and hull; Processed mung bean	Antisepsis, Anticancer, Antioxidant, Hypoglycemic, and Hypolipidemic activities	Yao *et al.,* 2013; Pajak *et al.,* 2014; Meenu *et al.,* 2016; Bai *et al.,* 2017
2.	Flavonoids	Isoflavanoids; Flavones; Flavanols; Anthocyanins	Aqueous or alcoholic extracts of mungbean seed coat (Vitexin and isovitexin)	Anticancer, Antihypertensive, Antioxidant, Hypolipidemic and Hypoglycemic activities	Yao *et al.,* 2013; Pajak *et al.,* 2014; Meenu *et al.,* 2016
3.	Polysacchari des	Arabinogalactan; Pectin; Hemicellulose	Water or Alkali extracts of mungbean	Antioxidant activities, Immunoregulation, Macrophage activation, Immuno-modulation	Lai *et al.,* 2010; Zhong *et al.,* 2012; Yao *et al.,* 2016a; Yao *et al.,* 2016b; Ketha and Gudipati, 2018
4.	Proteins/Pept ides	Vicilin; Mungin; Chitinase	Mungbean protein hydrolysates	Antihypertensive and Antimicrobial activities	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;

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References

Ali NM, Mohd YH, Yeap SK, Ho WY, Beh BK, Long K, Koh SP, Abdullah MP, Alitheen NB. (2014). Anti-inflammatory and antinociceptive activities of untreated, germinated, and fermented mung bean aqueous extract. Evid-Based Complement. Altern Med, 350507.

Ali S, Singh B, Sharma S. (2016). Response surface analysis and extrusion process optimisation of maize–mungbean-based instant weaning food. Int J Food Sci Technol 51: 2301–2312.

Aluko RE. (2008). Determination of nutritional and bioactive properties of peptides in enzymatic pea, chickpea, and mung bean protein hydrolysates. J Aoac Int 91: 947–956.

Anjum NA, Umar S, Iqbal M, Khan NA. (2011). Cadmium causes oxidative stress in mung bean by affecting the antioxidant enzyme system and ascorbate-glutathione cycle metabolism. Russian J Plant Physiol 58: 92–99.

Bazaz R, Baba WN, Masoodi FA, Yaqoob S. (2016). Formulation and characterization of hypo allergic weaning foods containing potato and sprouted green gram. J Food Meas Charact 10: 453-465.

Bellik Y, Hammoudi S, Abdellah F, Iguer-Ouada M, Boukraa L. (2012). Phytochemicals to prevent inflammation and allergy. Rec Pat Inflamm Allergy Drug Discovery. 6: 147-158.

Boye J, Zare F, Pletch A. (2010). Pulse proteins: Processing, characterization, functional properties and applications in food and feed. Food Res Int 43: 414-431.

Cao D, Li H, Yi J, Zhang J, Che H, Cao J, Yang L, Zhu C, Jiang W. (2011). Antioxidant properties of the mung bean flavonoids on alleviating heat stress. PLoS One 6.

Chai W-M, Wei Q-M, Deng W-L, Zheng Y-L, Chen X-Y, Huang Q, Ou-Yang C, Peng Y-Y. (2019). Anti-melanogenesis properties of condensed tannins from *Vigna angularis* seeds with potent antioxidant and DNA damage protection activities. Food Funct 10: 99–111.

d'Archivio M, Filesi C, Vari R, Scazzocchio B, Masella R. (2010). Bioavailability of the polyphenols: status and controversies. Inter J Mole Sci 11: 1321–1342.

Dahiya PK, Linnemann AR, Van Boekel MAJS, Khetarpaul N, Grewal RB, Nout MJR. (2015). Mung bean: Technological and nutritional potential. Crit Rev Food Sci Nutr. 55: 670–688.

Dahiya PK, Nout MJR, A.vanBoekel M, Khetarpaul N, BalaGrewal R, Linnemann A. (2014). Nutritional characteristics of mung bean foods. Br Food J. 116: 1031–1046.

Espin JC, Garcia-Conesa MT, Tomas-Barberan FA. (2007). Nutraceuticals: facts and fiction. Phytochem 68: 2986–3008.

Fernandez-Orozco R, Frias J, Zielinski H, Piskula MK, Kozlowska H, Vidal-Valverde C. (2008). Kinetic study of the antioxidant compounds and antioxidant capacity during germination of *Vigna radiata* cv. Emmerald, *Glycine max* cv. Jutro and *Glycine max* cv. Merit. Food Chem. 111: 622-630.

Gan R-Y, Lui W-Y, Wu K, Chan C-L, Dai S-H, Sui Z-Q, Corke H. (2017). Bioactive compounds and bioactivities of germinated edible seeds and sprouts: An updated review. Trends Food Sci Technol 59: 1–14.

García MC, Puchalska P, Esteve C, Marina ML. (2013). Vegetable foods: a cheap source of proteins and peptides with antihypertensive, antioxidant, and other less occurrence bioactivities. Talanta 106: 328–349.

Guo X, Li T, Tang K, Liu RH. (2012). Effect of germination on phytochemical profiles and antioxidant activity of mung bean sprouts (*Vigna radiata*). J Agric Food Chem. 60: 11050–11055.

Gupta N, Srivastava N, Bhagyawant SS. (2018). Vicilin- A major storage protein of mungbean exhibits antioxidative potential, antiproliferative effects and ace inhibitory activity. PLoS ONE 13: e0191265.

Hafidh RR, Abdulamir AS, Vern LS, Bakar FA, Abas F, Jahanshiri F, Sekawi Z. (2011). Novel in-vitro antimicrobial activity of *Vigna radiata* (L.) R. Wilczek against highly resistant bacterial and fungal pathogens. J Med Plants Res., 5: 3606-3618

Hall C, Hillen C, Garden Robinson J. (2017). Composition, nutritional value, and health benefits of pulses. Cereal Chem 94: 11–31.

Hou D, Yousaf L, Xue Y, Hu J, Wu J, Hu X, Feng N, Shen Q. (2019). Mung Bean (*Vigna radiata* L.): bioactive polyphenols, polysaccharides, peptides, and health benefits. Nutrients, 11: 1-28.

Hou D, Chen J, Ren X, Wang C, Diao X, Hu X, Zhang Y, Shen Q. (2018). A whole foxtail millet diet reduces blood pressure in subjects with mild hypertension. J Cereal Sci., 84: 13–19.

Jeong YM, Ha JH, Noh GY, Park SN. (2016). Inhibitory effects of mung bean (*Vigna radiata* L.) seed and sprout extracts on melanogenesis. Food Sci Biotechnol., 25: 567–573.

Jeune KH, Jung SM, Choi KM. (1999). Effects of mung bean lectin on cytokines gene expression from human perophered blood mononuclear cells. Korean J Pharmacol 30: 355–362.

Kader JC. (1996). Lipid-transfer proteins in plants. Annu Rev Plant Phys 47: 627–654.

Kang I, Choi S, Ha TJ, Choi M, Wi H-R, Lee BW, Lee M. (2015). Effects of mung bean (*Vigna radiata* L.) ethanol extracts decrease proinflammatory cytokine-induced lipogenesis in the KK-Ay diabetes mouse model. J Med Food, 18: 841–849.

Ketha K, Gudipati M. (2018). Purification, structural characterization of an arabinogalactan from green gram (*Vigna radiata*) and its role in macrophage activation. J Funct Foods, 50: 127–136.

Khan MA, Jacobsen I, Eggum BO. (2006). Nutritive value of some improved varieties of legumes. J Sci Food Agric 30: 395-400.

Kim DK, Jeong SC, Gorinstein S, Chon SU. (2012). Total polyphenols, antioxidant and antiproliferative activities of different extracts in mungbean seeds and sprouts. Plant Foods Hum Nutr., 67: 71–75.

Kim DK, Jeong SC, Gorinstein S, Chon SU. (2012). Total polyphenols, antioxidant and antiproliferative activities of different extracts in mungbean seeds and sprouts. Plant Foods Hum Nutr. 67: 71–75.

Kim BJ, Kim JH, Heo MY, Kim HP. (1998). Antioxidant and anti-inflammatory activation of the mung bean. Cosmetics and Toiletries 113: 71–74.

Koes RE, Quattrocchio F, Mol JNM. (1994). The flavonoid biosynthetic pathway in plants: function and evolution. BioEssays 16: 123–132.

Kumar A, Mosa KA, Ji L, Kage U, Dhokane D, Karre S, Madalageri D, Pathania N. (2018). Metabolomics-assisted biotechnological interventions for developing plant-based functional foods and nutraceuticals. Crit Rev Food Sci Nutr., 58: 1791–1807.

Lai F, Wen Q, Li L, Wu H, Li X. (2010). Antioxidant activities of water-soluble polysaccharide extracted from mung bean (*Vigna radiata* L.) hull with ultrasonic assisted treatment. Carbohydr Polym 81: 323–329.

Lambert PA. (2008). Mechanisms of action of biocides. In: Fraise, AP, Lambert, PA, Maillard, JY (eds) Principles and practice of disinfection, preservation and sterilization, Blackwell Publishing Ltd, pp. 139-153.

Lee SJ, Lee JH, Lee HH, Lee S, Kim SH, Chun T, Imm JY. (2011b). Effect of mung bean ethanol extract on pro-inflammtory cytokines in LPS stimulated macrophages. Food Sci Biotechnol. 20: 519–524.

Lee JH, Jeon JK, Kim SG, Kim SH, Chun T, Imm J-Y. (2011a). Comparative analyses of total phenols, flavonoids, saponins and antioxidant activity in yellow soy beans and mung beans. Int J Food Sci Technol 46: 2513–2519.

Lee M, Kim M,Kim S, Wi H, Park H, Choi W. (2013). Effects of mung-bean and black-bean ethanol extracts on inflammation related to obesity in the high fat induced obesity model. FASEB J 27: 865–870.

Li F-M, Lu Z-G, Yue M. (2014a). Analysis of photosynthetic characteristics and UV-B absorbing compounds in mung bean using UV-B and red LED radiation. J Analyt Meth Chem Article ID 378242, 5 pages.

Li X, Gao P, Zhang C, Wu T, Xu Y, Liu D. (2014b). Reduced bioavailability of cyclosporine A in rats by mung bean seed coat extract. Brazilian J Pharm Sci 50: 591-597.

Li GH, Wan JZ, Le GW, Shi YH. (2006). Novel angiotensin I-converting enzyme inhibitory peptides isolated from alcalase hydrolysate of mung bean protein. J Pept Sci., 12: 509–514.

Li GH, Le GW, Liu H, Shi YH. (2005). Mung-bean protein hydrolysates obtained with alcalase exhibit angiotensin I-converting enzyme inhibitory activity. Food Sci. Technol. Int. 11: 281–287.

Li H, Cao D, Yi J, Cao J, Jiang W. (2012). Identification of the flavonoids in mungbean (*Phaseolus radiatus* L.) soup and their antioxidant activities. Food Chem., 135: 2942–2946.

Lin K-F, Liu Y-N, Hsu S-TD, Samuel D, Cheng C-S, Bonvin AMJJ, Lu P-C. (2005). Characterization and structural analyses of nonspecific lipid transfer protein 1 from mung bean. Biochem. 44: 5703–5712.

Liyanage R, Kiramage C, Visvanathan, R, Jayathilake C, Weththasinghe P, Bangamuwage R, Chaminda Jayawardana B, Vidanarachchi J. (2018). Hypolipidemic and hypoglycemic potential of raw, boiled, and sprouted mung beans (*Vigna radiata* L.Wilczek) in rats. J Food Biochem 42: e12457.

Lopes LAR, Martins MDCCE, Farias LM, Brito AKDS, Lima GM, Carvalho VBL, Pereira CFC, Conde Júnior AM, Saldanha T, Arêas JAG, Silva KJDE, Frota KMG. (2018). Cholesterol-lowering and liver-protective effects of cooked and germinated mung beans (*Vigna radiata* L.). Nutrients 10: 821.

Luo J, Cai W, Wu T, Xu B. (2016). Phytochemical distribution in hull and cotyledon of adzuki bean (*Vigna angularis* L.) and mung bean (*Vigna radiate* L.), and their contribution to antioxidant, anti-inflammatory and anti-diabetic activities. Food Chem., 201: 350–360.

Madar IH, Asangani AH, Srinivasan S, Tayubi IA and Ogu GI. (2017). Nutritional and biochemical alterations in *Vigna radiata* (Mung Bean) seeds by germination. Int J Curr Microbiol App Sci 6: 3307-3313.

Meenu M, Kamboj U, Sharma A, Guha P, Mishra S. (2016). Green method for determination of phenolic compounds in mung bean (*Vigna radiata* L.) based on near-infrared spectroscopy and chemometrics. Int J Food Sci Technol., 51: 2520–2527.

Min L (2001). Research advance in chemical composion and pharmacological action of mung bean. Shanghai J Trad Chin Med 5: 18.

Mohd Ali N, Mohd Yusof H, Long K, Yeap SK, Ho WY, Beh BK, Koh SP, Abdullah MP, Alitheen NB. (2013). Antioxidant and hepatoprotective effect of aqueous extract of germinated and fermented mung bean on ethanol-mediated liver damage. Bio Med Res Int 9.

Mothana RAA, Al-Said MS, Al-Rehaily AJ *et al.* (2012). Anti-inflammatory, antinociceptive, antipyretic and antioxidant activities and phenolic constituents from *Loranthus regularis* Steud. ex Sprague. Food Chem., 130: 344–349.

Mubarak A. (2005). Nutritional composition and antinutritional factors of mung bean seeds (*Phaseolus aureus*) as affected by some home traditional processes. Food Chem., 89: 489–495.

Murakami T, Siripin S, Wadisirisuk P, Boonkerd N, Yoneyama T, Yokoyama T, Imai H. (1991). The nitrogen fixing ability of mung bean (*Vigna radiata*). In: Proceedings of the mungbean meeting, pp. 187–198. Chiang Mai, Thailand.

Nair RM, Yang R-Y, Easdown WJ. Thavarajah D, Thavarajah P, Hughes JdA, Keatinge J. (2013). Biofortification of mungbean (*Vigna radiata*) as a whole food to enhance human health. J Sci Food Agric 93: 1805–1813.

Paja k P, Socha R, Gałkowska D, Roz˙nowski J, Fortuna T. (2014). Phenolic profile and antioxidant activity in selected seeds and sprouts. Food Chem 143: 300–306.

Peng X, Zheng Z, Cheng KW, *et al.* (2008). Inhibitory effect of mung bean extract and its constituents vitexin and isovitexin on the formation of advanced glycation endproducts. Food Chem., 106: 475–481.

Popkin BM, Adair LS, Ng SW. (2012). Global nutrition transition and the pandemic of obesity in developing countries. Nutr Rev., 70: 3–21.

Randhir R, Lin YT, Shetty K. (2004). Stimulation of phenolics, antioxidant and antimicrobial activities in dark germinated mung bean sprouts in response to peptide and phytochemical elicitors. Proc Biochem 39: 637-646.

Randhir R, Shetty K. (2007). Mung beans processed by solid-state bioconversion improves phenolic content and functionality relevant for diabetes and ulcer management. Innov Food Sci Emerg 8: 197–204.

Sawa T, Nakao M, Akaike T, Ono K, Maeda H (1999). Alkylperoxyl radical-scavenging activity of various flavonoids and other phenolic compounds: Implications for the anti-tumor-promoter effect of vegetables. J Agric Food Chem., 47: 397-402.

Sehrawat N, Yadav M, Sharma AK, Kumar V, Bhat KV (2019). Salt stress and mungbean [*Vigna radiata* (L.) Wilczek]: effects, physiological perspective and management practices for alleviating salinity. Arch Agron Soil Sci., 65: 1287-1301.

Shi Z, Yao Y, Zhu Y, Ren G. (2016). Nutritional composition and antioxidant activity of twenty mung bean cultivars in china. Crop J. 4: 398–406.

Shukla S, Tyagi B. (2017). Comparative phytochemical screening and analysis of different vigna species in organic solvents. Austin J Biotechnol Bioeng 4: 1084.

Singh B, Singh, J.P.; Kaur, A.; Singh, N. (2017b). Phenolic composition and antioxidant potential of grain legume seeds: A review. Food Res Int. 101: 1–16.

Singh B, Singh JP, Shevkani K, Singh N, Kaur A. (2017a). Bioactive constituents in pulses and their health benefits. J Food Sci Technol 54: 858–870.

Smid EJ, Gorris LGM (1999). Natural antimicrobials for food preservation. In: Rahman, S (ed) Handbook of food preservation, CRC, New York.

Soucek J, Skvor J, Pouckova P, Matousek J, Slavik T. (2006). Mung bean sprout (*Phaseolus aureus*) nuclease and its biological and antitumor effects. Neoplasma 53: 402–409.

Sugiyama S, Miyata T, Horie K, *et al.,* 1996. Advanced glycation endproducts in diabetic nephropathy. Nephrol Dial Transplant 11: 91–94.

Tang D, Dong Y, Ren H, Li L, He C. (2014). A review of phytochemistry, metabolite changes and medicinal uses of the common food mung bean and its sprouts (*Vigna radiata*). Chem Cent J. 8: 4.

Vavilov NI. (1926). Studies on the origin of cultivated plants. Bull Appl Bot Genet Plant Breeding 16: 1–248.

Wang S, Wu J, Rao P, Ng TB, Ye X. (2005). A chitinase with antifungal activity from the mung bean. Protein Expr Purif. 40: 230–236.

Wang SY, Wu JH, Ng TB, Ye XY, Rao PF. (2004). A non-specific lipid transfer protein with antifungal and antibacterial activities from the mung bean. Peptides 25: 1235–1242.

Wongekalak L-o, Sakulsom P, Jirasripongpun K, Hongsprabhas P. (2011). Potential use of antioxidative mungbean protein hydrolysate as an anticancer asiatic acid carrier. Food Res Int 44: 812–817.

Xie J, Du M, Shen M, Wu T, Lin L. (2019). Physico-chemical properties, antioxidant activities and angiotensin-I converting enzyme inhibitory of protein hydrolysates from mung bean (*Vigna radiate*). Food Chem 270: 243–250.

Xie J, Du M, Shen M, Wu T, Lin L. (2019). Physico-chemical properties, antioxidant activities and angiotensin-I converting enzyme inhibitory of protein hydrolysates from mung bean (Vigna radiate). Food Chem 270: 243–250.

Xue Z, Wang C, Zhai L, Yu W, Chang H, Kou X, Zhou F. (2016). Bioactive compounds and antioxidant activity of mung bean (*Vigna radiata* L.), soybean (*Glycine max* L.) and black bean (*Phaseolus vulgaris* L.) during the germination process. Czech J Food Sci 34: 68-78.

Yamazaki T, Takaoka M, Katoh E, Hanada K, Sakita M, Sakata K, *et al.* (2003). A possible physiological function and the tertiary structure of a 4-kDa peptide in legumes. Eur J Biochem 270: 1269–1276.

Yao Y, Chen F, Wang MF, Wang JS, Ren GX (2008). Antidiabetic activity of Mung bean extracts in diabetic KK-Ay mice. J Agric Food Chem., 56: 8869–8873.

Yao Y, Yang X, Tian J, Liu C, Cheng X, Ren G. (2013). Antioxidant and antidiabetic activities of black mung bean (*Vigna radiata* L.). J Agric Food Chem., 61: 8104–8109.

Yao Y, Cheng X, Wang L, Wang S, Ren G. (2012). Mushroom tyrosinase inhibitors from mung bean (*Vigna radiatae* L.) extracts. Int J Food Sci Nutr., 63: 358–361.

Yao Y, Zhu Y, Ren G. (2016). Immunoregulatory activities of polysaccharides from mung bean. Carbohydr Polym 139: 61–66.

Yao Y, Zhu Y, Ren G. (2016b). Antioxidant and immunoregulatory activity of alkali-extractable polysaccharides from mung bean. Int J Biol Macromol 84: 289–294.

Yao Y, Zhu Y, Ren G. (2016a). Immunoregulatory activities of polysaccharides from mung bean. Carbohydr. Polym. 139: 61–66.

Ye XY, Ng TB. (2000). Mungin, a novel cyclophilin-like antifungal protein from the mung bean. Biochem Biophys Res Commun 273: 1111–1115.

Yeap SK, AliN M, Yusof HM, Noorjahan BA, Boon KB, Wan YH, Soo PK, Kamariah L. (2012). Antihyperglycemic effects of fermented and nonfermented mung bean extracts on alloxan-induced-diabetic mice. BioMed Res Int. 2012: 1–7.

Yeap SK, Yusof HM, Mohamad NE *et al.* (2013). *In vivo* immunomodulation and lipid peroxidation activities contributed to chemoprevention effects of fermented mung bean against breast cancer. Evid Based Complement Alternat Med, Article ID708464, 7 pages.

Yeap SK, Beh BK, Ho WY, Mohd Yusof H, Mohamad NE, Ali NM, Jaganath IB, Alitheen NB, Koh SP, Long K. (2015). In vivo antioxidant and hypolipidemic effects of fermented mung bean on hypercholesterolemic mice. Evid Based Complement Alternat Med. Article 508029.

Yi-Shen Z, Shuai S, FitzGerald R (2018). Mung bean proteins and peptides: nutritional, functional and bioactive properties. Food Nutr Res 62.

Zhang X, Shang P, Qin F, Zhou Q, Gao B, Huang H, Yang H, Shi H, Yu L. (2013). Chemical composition and antioxidative and anti-inflammatory properties of ten commercial mung bean samples. LWT Food Sci Technol., 54: 171–178.

Zhong K, Lin W, Wang Q, Zhou S. (2012). Extraction and radicals scavenging activity of polysaccharides with microwave extraction from mung bean hulls. Int J Biol Macromol. 51: 612–617.

Zhong K, Lin W, Wang Q, Zhou S. (2012). Extraction and radicals scavenging activity of polysaccharides with microwave extraction from mung bean hulls. Int J Biol Macromol., 51: 612–617.

Zhu S, Li W, Li J, Jundoria A, Sama AE, Wang H. (2012). It is not just folklore: the aqueous extract of mung bean coat is protective against sepsis. Evid Based Complement Alternat Med Article ID 498467, 10 pages.