Progress in the Study of Active Ingredients and Pharmacological Actions of Mung Bean

Minghui Jiang*

The Affiliated International School of Shenzhen University, Shenzhen, 518071, China

Abstract: Mung bean contains a variety of active ingredients such as flavonoids, polysaccharides, and polyphenolic compounds. In this article, the differences in active ingredients and their types of mung bean obtained by different extraction methods are reviewed, the pharmacological actions of mung bean such as inhibition of bacterial growth, oxidation resistance, immune regulation, decreasing blood sugar, hypolipidemic effect, and anti-tumor effect and their mechanisms are summarized, and the active ingredients that function in different pharmacological actions are categorized. As mung bean has the efficacy of both medicine and food, this review provides a basis for the subsequent studies and development of mung bean to make it useful in daily consumption and pharmaceutical applications.

1. Introduction

Mung bean is the seed of the plant of the Phaseolus in the Papilionoideae, which is native to India and Myanmar, and nowadays is commonly cultivated in East Asian countries. China and Myanmar are the main growers and exporters of mung beans. According to the 2022-2028 Market Operation Condition and Investment Potential Research Report of China's Mung Bean Industry, the planted area of mung beans in China in 2022 is about 383,800 hectares, and the total output is about 508,000 tons.

Mung bean was first recorded in the Warring States period and recorded as food and medicine in the Tang Dynasty. Nowadays, mung beans are mostly used as food. However, pharmacological studies have found that mung beans contain a variety of active ingredients, including flavonoids, polysaccharides, polyphenols, phytosterols, coumarins, alkaloids, saponins, etc., which have detoxifying, antibacterial and antimicrobial, lipid-lowering and anti-tumor effects [1]. Therefore, mung beans have a broad prospect for development and application in clinical practice.

In this article, the active ingredients of mung bean and their pharmacological activities are summarized to lay the foundation for greater development of mung bean and its application in clinical practice and related scientific research.

2. Main active ingredients of mung bean

2.1. Flavonoids in mung bean

2.1.1. Structure and contents of flavonoids

Mung bean contains a variety of flavonoids, which are the main functional ingredients of the traditional Chinese food - mung bean soup [2]. These flavonoids have the structure of 2-phenylchromone or 3-phenylchromone structure, of which, the most abundant are vitexin and isovitexin, which account for 51.99% and 45.42% respectively of the total flavonoid content of mung bean [3]. These flavonoids are mainly found in mung bean seeds, mung bean coat and mung bean sprouts, and the content in mung bean coat is higher than that in the seeds and mung bean sprouts.

2.1.2. Extraction methonds of flavonoids and factors

There are a number of methods for extracting flavonoids from seeds, mainly including boiling, organic extraction and ultrasonic methods. It was found that the total flavonoid content obtained by different extraction methods varied, with 1.82mg/g of flavonoids obtained by boiling [4]; 27.57mg/g of flavonoids obtained by organic extraction [5]; and 1.966mg/g of flavonoids obtained by ultrasonic method [6]. It can be seen that the organic extraction method can obtain higher total flavonoids from mung bean seeds.

The extraction of flavonoids from mung bean coat was mainly carried out by ethanol extraction, in which changes in extraction temperature, ethanol concentration, solid-liquid ratio and extraction time all affect the total flavonoid content obtained. It was found that the higher the temperature, the better the extraction efficiency. However, when the temperature exceeds 80℃, the flavonoids will be oxidized, resulting in the destruction of their structure and loss of activity. Therefore, the best extraction results were achieved at an extraction temperature of 70℃. Through orthogonal tests, Chen Tingting et al. [5] found that the best extraction process

*Corresponding author's e-mail: minghui.mia.jiang@gmail.com

for total flavonoids of mung bean was under the solid-liquid ratio of 1:50, 40% ethanol, extraction time of 120 min, and the average recovery of total flavonoids reached 97.5%. Wei Li et al. found that the best extraction effect was achieved by refluxing the extract for 2 h under the condition of solid-liquid volume ratio of 1:6 at 70di 30% ethanol and extracting twice, the samples obtained were standardized with rutin, the average yield of flavonoids was 1.459% measured by Al(NO3)3 colorimetric method [7] at 510nm.

2.2. Polysaccharides in mung bean

2.2.1. Contents of polysaccharides

Another major efficacious ingredient in mung bean is polysaccharides. Polysaccharides are one of the four basic substances that form life activities. Among the polysaccharides in mung bean, water-soluble mung-bean polysaccharides are active, and their content accounts for about 8.45% of the total polysaccharides [8].

2.2.2. Extraction methods of polysaccharides and factors

It was found that polysaccharides can be extracted by different methods. Among them, the saccharides in mung bean coat and mung bean seed kernel can be extracted by boiling with the yield of 6.22% and 4.61% respectively [9]. The saccharides obtained by this method contain monosaccharides and polysaccharides. Monosaccharides are mainly composed of rhamnose (Rha), fucose (Fuc), arabinose (Ara), xylose (Xyl), mannose (Man), galactose (Gal), glucose (Glc), and galacturonic acid (GalA). The polysaccharides are complex in composition and structure and belong to heteropolysaccharides, which were identified and found to be MP1[10], etc.Better polysaccharide yield could be obtained by ultrasound-assisted composite enzyme method, and the optimal extraction process was at a water extraction temperature of 95°C, a water extraction time of 186min, an ultrasound time of 32min, and a solid-liquid ratio of 1:22 (g/ml), resulting in a yield of 5.77% [11]. In addition, Zhong Kui et al. [12] extracted polysaccharides with 9.70mg CE/g DW by the response surface method; Yu Wenwen et al. [13] extracted water-soluble polysaccharides from mung bean coat with 4.32% by water extraction and alcohol precipitation, and the polysaccharide purity was up to 50.35% and protein content was 31.26% after deproteinization by the Sevag method.

2.3. Plant polyphenol in mung bean

2.3.1. Structure and types of Plant polyphenol

Plant polyphenol is health-promoting compounds found in plant foods, which are compounds that contain multiple phenolic hydroxyl groups in their molecular structure. Mung bean polyphenols are mainly derived from phenolic acids, flavonoids, and a small amount of tannins [8]. Here, we mainly focus on phenolic acids to summarize the polyphenolic compounds in mung bean.

Phenolic acids in mung bean mainly include protocatechuic acid, gallic acid, ferulic acid and chlorogenic acid. As secondary metabolites in the development of mung bean sprouts, phenolic acids are mainly present in mung bean sprouts. Studies have shown that the phenolic acid content in mung bean after germination is 4.5 times higher than that before germination [8].

2.3.2. Extraction methods of plant polyphenol

Wei Meixia et al. [14] extracted plant polyphenol during mung bean germination and found that the plant polyphenol content could reach the highest when the sprout length was 4~5cm, which was 38% higher than that before germination, and the mung bean sprouts contained the richest variety of polyphenolic compounds at this stage. It was found that the plant polyphenol content obtained by ultrasonic-microwave (U-M) treatment for 30min at 40°C, solid-liquid ratio (g/ml) of 1:15, and 60% ethanol was 3.14mg/g, which is the optimal extraction condition for the traditional boiling method [15]. In addition, Sheng Yanan et al. [16] obtained a plant polyphenol extraction of 11.74mg/g by solvent extraction, which was carried out with the process of solid-liquid ratio (g/mL) of 1:12, extraction temperature of 46°C, and extraction time of 1.6h. It can be seen that the solvent extraction method has a higher yield of phenolic acid compounds compared with the boiling method.

2.4. Other active ingredients

In addition to flavonoids, polysaccharides, and polyphenols in mung beans, there are mung bean proteins, phytosterols, coumarins, alkaloids, saponins and other ingredients.

Mung bean protein is an important bioactive protein and the main source of plant protein in mung bean, and its content is second to starch in the proportion of mung bean [17]. The maximum extraction rate of mung bean protein was 88.80% under the mass ratio of mung bean powder to distilled water of 1:15, extraction temperature of 40°C, extraction time of 20min, and pH value of 9.0 [18].

Phytosterols are structurally similar to cholesterol and are found in a variety of plant foods. Mung bean contains three main phytosterols, namely, canola sterols, soy sterols and β-sterols, which are involved in steroid biosynthesis, and their total relative content varies among different strains of mung beans, ranging from about 3.13% in Jiulihu (JLH) mung bean to about 2.24% in Daming (DM) bean [17].

3. Pharmacological actions of mung bean

3.1. Antimicrobial and antibacterial effects

3.1.1. The stronger inhibition on particular bacteria

Studies have shown that mung bean extracts have a wide range of antibacterial activity, and the main ones that exert this effect are flavonoids, alkaloids, and saponins. Li Jian et al. [19] explored the antimicrobial activity of different extracts, the experimental results found that the antibacterial effect of n-butanol extract was better than that of chloroform and ethyl acetate extract, and further studies showed that n-butanol extract selectively inhibited the growth of pathogenic bacteria, mainly inhibited the growth of Bacillus subtilis, Staphylococcus albicans, Escherichia coli, Penicillium, but the inhibitory effect on Rhizoctonia solani and Trichoderma reesei was negligible. The ingredients that exerted antibacterial effects in n-butanol extract were mainly flavonoids, phenols, organic acids and saponins. Meanwhile, studies on the growth of bacteria showed that the alkaloids inhibited the growth of Bacillus subtilis more strongly than that of Staphylococcus aureus and Escherichia coli [20].

3.1.2. The influence factors

The antibacterial effects were affected by temperature and PH value but not ultraviolet irradiation. The experimental results showed that in the conditions of 30~70°C and PH value of 7.0~8.0, there is a stable antibacterial effect. Secondly, the alkaloids in mung bean also had significant antibacterial effect, its antibacterial effect was less affected by the temperature change, and still had good antibacterial effect at 121°C.

3.2. Antioxidant effect

Mung bean coat has strong antioxidant activity [21] [22], which is related to its rich content of flavonoids. The ingredients of mung bean coat that have been demonstrated to have antioxidant activity are vitexin and isovitexin, and the B-ring on the structure of these two compounds is the main active ingredient in scavenging free radicals, and the antioxidant activity is significantly enhanced when the B-ring is present in the neighboring hydroxyl structure. Pan Guoqing et al. [23] found that the neighboring hydroxyl group on the B-ring could significantly enhance the free radical scavenging ability of flavonoids, and quercetin's free radical scavenging ability was stronger than that of sanguinarine because of the extra neighboring hydroxyl group on the B-ring in its molecular structure. It can be seen that the neighboring hydroxyl group on the B-ring plays an important role in the antioxidant activity of flavonoids, and vitexin and isovitexin in mung bean coat also have antioxidant activity because of the neighboring hydroxyl group on the B-ring [3].

3.3. Hypoglycemic and hypolipidemic effects

Mung bean is one of the foods available for diabetics. The extracts from Mung bean have the function of regulating glucose metabolism. Shen Xinting et al. [24] [25] studied the effect of aqueous solution of sprouted mung bean polyphenols on the establishment of type II diabetic mice model by the method of high-fat diet combined with streptozotocin (STZ), and the experimental results found that different doses of aqueous solution of sprouted mung bean polyphenols could significantly reduce the fasting blood glucose value of diabetic mice, increase the level of glucose tolerance in mice, and reduce insulin resistance. The hypoglycemic mechanism of the aqueous solution of sprouted mung bean polyphenols alleviates the inflammatory response caused by diabetes by decreasing the levels of pro-inflammatory factors IL-6, TNF-α, and C-reactive protein (CRP), and increasing the level of the anti-inflammatory factor IL-10.

3.3.1. The benefit aspects bring by mung bean on mice model

Moreover, the aqueous solution of sprouted mung bean polyphenols improve the intestinal flora by adjusting the abundance of the bacterial flora and the diversity of the populations. In addition, Sprouted mung bean polyphenol extract could repair liver tissue cell morphology, reduce the viability of ALT and AST in the serum of the model mice, and reduce liver injury; and significantly reduced the content of TC, TG, and LDL-C in the serum, increased the concentration of LDL-H, and improved the disorder of lipid metabolism in the type II diabetic mice model. These studies suggest that sprouted mung bean polyphenol extract can effectively improve the symptoms of hyperglycemia and disordered lipid metabolism in type II diabetic mice.

3.4. Immunomodulatory activity

The ingredients of mung bean with immunomodulatory effects are mainly mung bean polysaccharides and mung bean protein [26]. Mung bean polysaccharides can promote the proliferation and phagocytosis of macrophage RAW264.7 and promote the secretion of cytokines. Studies have shown that polysaccharides bind to the TLR4 receptor to activate the MAPK and NF-κB signaling pathways, induce the production of NO, cytokines (TNF-α, IL-1β and IL-6) and ROS, and regulate the immune activity of RAW264.7 macrophages, thus exerting an immunomodulatory effect [26]. Diao Jingjing et al. [27] found that mung bean peptide could activate macrophages, and the experimental results showed that mung bean peptide could activate macrophages by promoting the proliferation and phagocytosis of RAW264.7 macrophages, and also had a promoting effect on the secretion of cytokines (TNF-α, IL-1β and IL-6). Additionally, mung bean peptide could increase the vitality of its own metabolic enzyme, SOD, reduce lipopolysaccharide (LPS)-induced inflammatory response and cell autophagy, improve cellular immune function [28]. Thus, mung bean has an important role in immunomodulation.

3.5. Anti-tumor effect

Studies have shown that mung bean is rich in Bowman-

Birk trypsin inhibitor (BBI), which has been shown to be present in legumes. BBI has demonstrated significant anticancer activity in a wide range of cancers, including intestinal cancer, prostate cancer, breast cancer and osteosarcoma. Huang Rui et al. [29] collected bacteriophage from a positive clone of recombinant plasmid pET30a-GPBBI (6-33) and fused it with His-GPBBI (6-33) protein to obtain a high-purity mung bean BBI (6-33) protein, and found that His-GPBBI (6-33) significantly inhibited the growth and proliferation of breast cancer cells A549, promoted the apoptosis of tumor cells, and inhibited tumor cells from migrating. In addition, mung bean BBI active fragment (LysGP33) could effectively inhibit the migration of intestinal cancer cells SW480, but it had no significant effect on the proliferation of SW480 cells [30].

3.6. The other effects of mung bean

In addition to the above mentioned pharmacological actions, mung beans have other functions including anti-inflammatory, heat-clearing and detoxicating, anti-allergic, appetite-enhancing, and liver-protecting effects.

4. Prospect and Discussion

As a common food, mung bean is cheap, easily available and produced all over the world, and the study of its pharmacological actions is of far-reaching significance, which can lead to a wide range of applications of mung bean as a medicine. Mung bean has a wide variety of active ingredients, different extraction methods can obtain different ingredients, such as the ingredients obtained are mainly mung bean polysaccharides with water as a solvent for extraction [11] [12] [13], and the ingredients obtained are mainly flavonoids and polyphenolic compounds with ethanol as a solvent for extraction [5] [7] [14] [15]. In addition, different composition ratios and changes in extraction conditions under the same extraction method may also affect the active ingredients obtained in mung bean [2] [14]. Therefore, when we apply mung bean to exert different pharmacological actions, we should adopt the appropriate extraction method to obtain the best active ingredients based on the needs.

With the progress of human society and the improvement of living standards, hyperglycemia and hyperlipidemia have become one of the key issues affecting human health, and it was found that the patients with hyperglycemia and hyperlipidemia tends to be younger, so the prevention and treatment of hyperglycemia and hyperlipidemia has become an urgent problem. Since mung beans have obvious hypoglycemic and hypolipidemic effects [24] [25] [26] and can be used for both medicinal and dietary purposes, normal people can prevent hyperglycemia and hyperlipidemia by increasing the intake of mung beans in their daily diets; patients with hyperglycemia and hyperlipidemia can be treated with mung beans as their daily diet. In addition, the immunomodulatory effect and the inhibition of tumor cell growth of mung bean provide a theoretical basis for mung bean to become one of the main foods in popular recipes.

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