

REVIEW OF ARTICLES ON THE HEALTH BENEFITS AND PHYTOCHEMICAL COMPOSITION OF COMMON BEANS (*PHASEOLUS VULGARIS L.*): POLYPHENOL EXTRACTION AND ANALYSIS

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ABSTRACT

Common beans (*Phaseolus vulgaris L.*), which are famous for their high nutritional profile, are gaining popularity as a "superfood" due to their health promoting bioactive compounds. This study focuses on the extraction and characterization of polyphenolic compounds from different kinds of beans to explore their role in medicinal world. Beans contain proteins, fiber, vitamins, and polyphenols, which are bioactive substances with known anti-inflammatory, anti-mutagenic, anti-obesity, anti-diabetic, and anti-carcinogenic properties. The study successfully showed that how these important polyphenols were being extracted by using modern solvent extraction techniques with methanol and ethanol, and optimized Soxhlet extraction. Black beans were found to have a high concentration of anthocyanin content. Mass spectrometry (MS) and high-performance liquid chromatography (HPLC) were used to identify and quantify specific phenolic components. Extraction techniques using methanol and ethanol, optimized by Soxhlet extraction. Using the Ferric Reducing Antioxidant Power (FRAP) test and the DPPH Radical Scavenging Assay, the antioxidant power of these compounds was thoroughly assessed. Both tests confirmed that the strong antioxidant ability of the extracts was connected with their rich phenolic contents. According to our study, common beans can have a major positive impact on oxidative stress reduction and the prevention of chronic illnesses. The study highlights the health benefits of common beans. It is suggested that common beans should be included in our diets to maximize health benefits and improve overall well-being.

Keywords: Common Beans (*Phaseolus vulgaris*), Polyphenolic Compounds, Antioxidant Power, Health Benefits, Phytochemicals

INTRODUCTION

Phaseolus vulgaris L., or common beans, are famous legumes that were recognized for their high nutritional profile and possible health advantages. They are a necessity in many diets because of their abundance in proteins, fiber, vitamins, and phytochemicals. Common beans were believed to have their health advantages and antioxidant qualities because they are composed of polyphenols and other bioactive substances. In many regions of the world, dry beans are essential and because of their many health advantages, they are currently becoming known as a superfood [1].

Morphology

A wide variety of morphological characteristics can be observed for common beans (*Phaseolus vulgaris*), including variations in plant structure, leaf shape, flower characteristics, and seed growth. The leaves of common beans are trifoliated with white, pink, or purple flowers [2]. They have a bushy or climbing structure. The fruits are cylindrical or bent pods, with 4–10 oval seeds of different sizes ranging from 0.5 cm to 2.5 cm and weight (approximately from 100 to 600 mg per seed) [3]. Morphological characters such as leaf area, pod length, and seed weight show many differences among cultivars due to genetic diversity and adjustment to regional environments [4] [5].



Figure 1 Varieties of Common Beans

Phytochemical Composition of Common Beans

Phaseolus vulgaris L. common beans are good sources of protein, carbs, fiber, vitamins and minerals, and thus offer a good source of energy. They also include bioactive substances such as polyphenols, flavonoids, and saponins, etc. Also, beans contain bioactive substances such as polyphenols, flavonoids, and saponins, etc. Additionally, they have a lot of healthy unsaturated fats including oleic and linoleic acids [6]. Besides, beans are important sources of protein, including kidney bean (29.45%), pinto (26.8%), black bean (25.31%), and navy (24.48%) [7]. Furthermore, beans contain carbohydrates in various amounts, which constitute 50–60% of dry matter [8] [9]. Most types of proteins in beans are globulins (54–79%) and albumins (12–30%) [7]. Beans consist

of three essential amino acids: lysine, cysteine, and methionine [7]. Legumes typically contain 5% to 20% lectin concentration [10].

They also contain zinc and iron [11] [12]. The zinc concentration in old varieties ranged from 17.81 to 37.90 mg/kg, while in modern cultivars ranged from 25.03 to 35.41 mg/kg [6].

Polyphenols in Common Beans

Beans are the best source of phytochemicals like polyphenols etc., which are recognized for their antioxidant powers against destructive diseases [8]. Polyphenols have been extracted by using suitable solvent extraction techniques. To optimize yield, both methanol and ethanol were used, with careful adjustment of solvent type, concentration, and extraction period [13]. Soxhlet extraction was used to increase

extraction quantity. In a comparative extraction study on common beans, it was found that 80% acetone served as the most efficient solvent for extracting phenolic compounds. The extraction was performed at 60 °C for 60 minutes, producing the highest recovery of phenolic. The overall extract yields varied between 12.2% and 20.6% (w/w), with black beans showing the maximum yield, while white beans produced the lowest; red and brown beans exhibited intermediate yields [14]. The extraction of free phenolic compounds from *Phaseolus vulgaris* was carried out using a unique method. In this method, 5 g of lyophilized bean powder was mixed with 17 mL of methanol and stirred for 1 hour. After keeping the mixture for 15 minutes, the solvent was removed from its beaker and replaced with a fresh portion of methanol, followed by another 90 minutes of stirring. This extraction step was repeated twice to confirm the complete recovery of phenolics. All methanolic extracts were then combined and centrifuged at 4,400 rpm for 5 minutes. To clear the extract, the resulting solution was treated with 0.1 M ZnSO₄ and 0.1 M Ba(OH₂) solutions (2.1 mL each). The clarified solution was again centrifuged under the same conditions, and the resulting solution was evaporated using a rotary evaporator (rotavapor) to evaporate the solvent. The quantity of free phenolic compounds was 1.12 g/100 g - 1.36 g/100 g depending upon the types of common beans [15]. Boiling and pressure cooking boosted phenolic content and antioxidant activity in extracts of four *Phaseolus vulgaris* types, while soy had the opposite effect [16]. There are two types of phenolic chemicals found in beans: free and insoluble conjugated forms. These forms include flavonoids, anthocyanins, and phenolic acids.

Studies reveal that anthocyanins are specifically present in black beans [17] [8]. The phenolic content can be altered by cooking and germination; germinated beans may preserve or even increase their antioxidant activity. On the basis of phenyl ring structures, they are divided into several groups: phenolic acids (such as hydroxybenzoic, hydroxyphenyl acetic, hydroxyphenyl pentatonic, and hydroxyl cinnamic acids), stilbenes, and lignin; flavonoids (such as flavones, flavanols, flavanones, isoflavones, anthocyanins, chalcones, dihydrochalcones, and catechins) and or phenolic acids [1][17]. Polyphenols are rich in dry beans, especially in the seed coat where they account for around 11% of the entire amount of seeds [18]. Several phenolic substances, including isoflavonoids, chalcones, dihydrochalcones, flavones, and flavanols, are present in the seed coat. On the other hand, phenolic acids such as hydroxycinnamic acids and hydroxybenzoic are primarily found in the cotyledons [1]. The color of seed coat is effected by the quantity of anthocyanins and tannins found in dark-colored beans, such as red, black, and pink kinds. Since the 1960s, research has identified and discovered several anthocyanins, flavanols and tannins in various bean cultivars. Mexican wild-type beans have a high anthocyanin content. Free radicals, which are dangerous chemicals, can damage our cells, but antioxidants are molecules that can stop this from happening [19].

A broad class of chemicals known as phenolic compounds is present in plants and is distinguished by the presence of one or more hydroxyl groups joined to an aromatic ring. Multiple phenolic units are present in polyphenols, a subclass of phenolic chemicals that are well-known for their antioxidant

qualities. Phenolic acids, tannins, lignans, stilbenes, and flavonoids are among the main varieties of phenolic chemicals [19]. Hydroxybenzoic acids include protocatechuic acid and gallic acid. These molecules are

Structure of Major Phenolic Acids

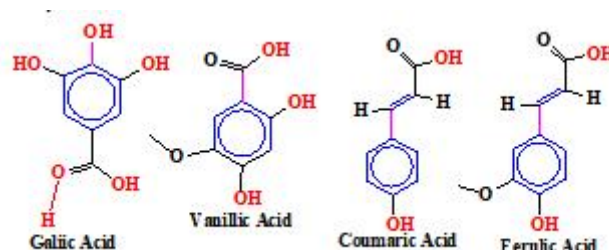


Figure 2: Structure of Some Phenolic Acids [21]

Flavonoids

Flavanols: For instance, quercetin is polar due to its abundance of hydroxyl groups. One polar molecule that belongs to flavanones is naringenin. The highly polar compounds called anthocyanin are responsible for the red, blue, and purple colors of plants.

Stilbenes: Resveratrol is one example of a moderately polar molecule that may have health benefits that have been investigated by previous studies. Phenolic acids, which are derived from benzoic and cinnamic acids, are found in beans [22]. Ferulic acid is the most prevalent phenolic acid, followed in order by gallic, vanillic, p-hydroxybenzoic, and p-coumaric acids.

Evaluation of Health Benefits

Health Benefits Analysis: Polyphenol-rich common beans will be evaluated for their antioxidant, diabetes-preventive, anti-obesity, anti-inflammatory, anti-mutagenic, and cancer-preventive potential benefits [15] [23] [24]. The reduction of diabetes, obesity, coronary heart disease, and colon cancer is one of these advantages [25]. Because of their strong antibacterial and antioxidant characteristics, these substances have the ability to function as organic food

highly polar due to the presence of carboxyl and hydroxyl groups. Both caffeic and ferulic acids are hydroxycinnamic acids. Significant polarity was another characteristic of these compounds [20].

preservatives [26] [27]. This would allow lower-quality items, such hard-to-cook beans, to be used instead of synthetic additives. It was discovered that a mild extract from common bean seeds had potent anti-aging activities[28]. Bioactive phytochemicals known as polyphenols have a variety of forms as well as important pharmacological and health-promoting properties. Primarily behaving as antioxidants, polyphenols are essential in minimizing degenerative illnesses such as cancer and metabolic disorders [29]. Consumption of beans in the diet lowers the cholesterol level [8] [30].

Biological Activity

Common beans (*Phaseolus vulgaris* L.) have many kinds of biological activities, including high antioxidant, anti-inflammatory, and anti-diabetic properties [31]. They also have anticancer, antibacterial, and cholesterol-lowering qualities due to their high phytochemical and phenolic content [32] [8] [20]. Their high fiber and protein content aids with digestion and weight management.

In vivo Experiment

Combining *P. vulgaris* seeds greatly lowered the recommended dose of glibenclamide (from 0.20 to 0.05 g/kg bw) in hyperglycemic animals and was beneficial in normal rats.

However, using it with a higher quantity (0.20 g/kg bw) resulted in prolonged hypoglycemia in normal rats. *P. vulgaris* seeds may have anti hyperglycemic effects by activating pancreatic B cells to

release excess insulin or increasing insulin sensitivity in peripheral tissues, such as adipose tissue, muscle, and liver, allowing for faster blood glucose usage and absorption [33].

Table 1: Effect of the drug and Common beans on fasting blood glucose levels (mg/dl) on rats

Rats Category	Blood glucose at different hours after the treatment					
Normal Rats	00 hour	01 hours	02 hours	03 hours	04 hours	05 hours
200 g/kg bw	81	100	125	87	82	71
100 g/kg	84	115	120	89	81	78
Hyperglycemic rats						
200 g/kg bw	90	117	135	133	131	127
100 g/kg	89	118	133	130	127	125

Invitro Experiments

Phytochemical Analysis

Assessment of Phytochemical Composition

Individual polyphenolic chemicals were being recognized and measured by high-performance liquid chromatography (HPLC) and mass spectrometry (MS).

Antioxidant Activity Assays

Assessment of Antioxidant Activity: DPPH Radical Finding Assay This experiment was tested the extracts' ability to neutralize DPPH free radicals. - A stable free radical [34] [35].

The Ferric-reducing Antioxidant Power (FRAP)Test

The FRAP test analyzes a substance's antioxidant activity by converting ferric ions (Fe^{3+}) to ferrous ions (Fe^{2+}). The drop of Fe^{3+} to Fe^{2+} causes a color change.

The study aimed to develop efficient extraction methods, analyze the phytochemical composition, and assess the potential health benefits of common beans (*Phaseolus vulgaris* L.), with a focus on their polyphenolic compounds and their antioxidant, anti-diabetic, anti-obesity, anti-inflammatory, anti-mutagenic, and anti-carcinogenic properties.

Influence of Environmental and Seasonal Factors on the Nutritional Composition of Common Beans

The content and quality of bean seeds were greatly effected by the growing season, year, and region. Despite being cultivated in the same field, the beans showed seasonal variations.[36]. In 2014, there were more monomeric anthocyanin and total polyphenols, whereas in 2015, flavonoids and antioxidant activity (DPPH) were greater [37]. These results indicate that environmental variables influence the Differences in hue and lightness [37]. Furthermore, the nutritional content and seed constitution in 2015 had increased hue (h°) and brightness (L^*). The bean samples differ in genetic and content due to geography, soil, and growing conditions, since they were collected from different multiple places [38] [37] [39].

Lectins are present in common beans (*Phaseolus vulgaris* L.). Lectins are glycoproteins that resist proteolysis in the digestive system and may agglutinate erythrocytes of certain blood types in vitro [40].

RESULTS AND DISCUSSION

The extraction of polyphenols from common beans with methanol and ethanol showed that methanol, particularly at 70% concentration, produced the highest polyphenol content, whereas Soxhlet extraction increased the yield more [41].

These studies showed that black beans had the high total phenolic content (TPC), with some important components such as quercetin, ferulic acid, and cyanidin-3-glucoside, especially in the seed coverings [39]. Tannins are also present common beans

[39]. Some Antioxidant tests demonstrated that black beans had the best antioxidant activity, with considerable neutralization of free radicals and ferric-reducing properties [25]. Bean extracts additionally showed importance in vitro health advantages, like diabetes-preventive, anti-obesity, anti-inflammatory, and cancer-preventive effects. These results accentuate the high nutritional and functional profile of common beans, particularly those of black seed coatings, emphasizing their potential as main foods and natural food preservatives.

Table 2: *Antioxidant Activity of Common Bean*

Bean Extract	Variety	Major Identified	Phytochemicals	Assay Used	Antioxidant Activity	Reference
Black (ethanolic extract)	bean	Phenolic acids, anthocyanins	flavonoids,	DPPH	78.5% radical scavenging activity	[42]
White (aqueous extract)	bean	Phenolic acids (ferulic acids)	(caffeic,	DPPH	36.4% inhibition	[43]

Common beans contain high levels of flavonoids, anthocyanins, and phenolic compounds, all of which contribute to their antioxidant potential. The type of solvent and bean color affect extraction efficiency; black beans yield the most phenolic when 80% acetone is used. Seasonal and regional differences greatly affected phytochemical content, with higher total polyphenols and anthocyanins in 2014 and higher flavonoid and antioxidant activity in 2015. Experimental investigations have also shown that *P. vulgaris* seeds reduce blood glucose levels, notably in hyperglycemic mice, thereby enhancing insulin release and sensitivity. The results shown show that the phytochemical composition of common beans is not only impacted by environmental conditions, but also has an important function in antioxidant and anti-diabetic activities [44].

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