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Antihypercholesterolemic potential of bioactive compounds in *Phaseolus vulgaris*: A narrative review

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Abstract

Background: Hypercholesterolemia is a metabolic disorder characterized by increased cholesterol levels, especially low-density lipoprotein (LDL), in the blood circulation. This condition contributes significantly to the incidence of coronary heart disease and stroke, and is a global public health burden. Standard therapy using lipid-lowering drugs such as statins has been proven effective, but is associated with adverse effects, such as myopathy, hepatotoxicity, and long-term treatment resistance. Therefore, the search for safer and more affordable natural therapeutic alternatives is important. One potential plant that is widely consumed and relatively safe is beans (*Phaseolus vulgaris* L.).
Purpose: To narratively review scientific evidence related to the hypercholesterolemic activity of bioactive compounds in beans (*Phaseolus vulgaris* L.) based on in vitro and in vivo research results.
Method: This narrative review involved a literature search conducted in three electronic databases: Google Scholar (n = 58), ScienceDirect (n = 11), and PubMed (n = 2), yielding a total of 71 articles. The search strategy employed Boolean operators using the following keywords: ("beans" AND "Phaseolus vulgaris L." AND "hypercholesterolemia" AND "bioactive compounds" AND "isolation") OR "fractionation". The inclusion criteria comprised original research articles published between 2015 and 2025, with full-text availability. Articles were excluded if they were duplicates, did not present primary research data, or had titles that were not relevant to the predefined search keywords.
Results: Bioactive compounds in *Phaseolus vulgaris* L. work through multiple mechanisms, including inhibition of cholesterol synthesis, increased excretion, and protection against LDL oxidation. *Phaseolus vulgaris* demonstrates considerable therapeutic potential as a safe and effective herbal therapy in the management of hypercholesterolemia.
Conclusion: Current preclinical evidence indicates that bioactive compounds in *Phaseolus vulgaris* may support cholesterol reduction through several complementary mechanisms. However, well-designed human clinical trials are required to confirm their efficacy and safety.

Keywords: Active Compounds; Hypercholesterolemia; Legumes; *Phaseolus vulgaris* L.

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INTRODUCTION

Hypercholesterolemia is a major risk factor for cardiovascular disease, including coronary heart disease and stroke. This disorder is characterized by elevated blood levels of total and LDL cholesterol and is often associated with a diet high in saturated fat. Although pharmacological therapies such as statins are commonly used, long-term side effects and resistance to therapy have prompted the search for safer alternatives. Hypercholesterolemia, characterized by elevated total cholesterol (TC), LDL-C, or non-HDL-C, is commonly grouped under dyslipidemia, which may also involve reduced HDL-C, increased triglycerides, or qualitative lipid abnormalities. Dyslipidemia is typically defined as TC, LDL-C, triglycerides, apolipoprotein B, or lipoprotein(a) above the 90th percentile, or HDL-C and apolipoprotein A-I below the 10th percentile. These thresholds, however, are not absolute; for example, lipoprotein(a) levels at or above the 80th percentile are already linked to increased cardiovascular risk (Verbeek, Hoogeveen, Langsted, Stiekema, Verweij, Hovingh, & Stroes, 2018).

Statins are clinically used to reduce serum cholesterol levels and thereby reduce the risk of heart disease (Chavez-Santoscoy, Gutierrez-Uribe, Granados, Torre-Villalvazo, Serna-Saldivar, Torres, & Tovar, 2014). However, the National Cholesterol Education Program Expert Panel has stated that dietary strategies should be used before introducing medications to treat hypercholesterolemia. Several dietary modifications have been proposed to reduce serum cholesterol levels, including the consumption of soy protein, polyunsaturated fatty acids (PUFAs), and dietary phytosterols, among other bioactive compounds. Previous studies have also demonstrated, natural phytochemicals can have synergistic effects, and lower doses of each bioactive compound can attenuate hypercholesterolemia (Bladé, Baselga-Escudero, Salvadó, & Arola-Arnal, 2013).

The use of plants in Indonesia has been passed down through generations, becoming a tradition in every region to meet daily needs for food, clothing, shelter, medicine, and art, among other purposes. The use of plants as medicine remains widely practiced due to their low cost, safety, and ease of processing. It is estimated that there are around 40,000 plant species on Earth, with 30,000 of these species living in the Indonesian archipelago. It is known that at least 9,600 of these plant species have medicinal properties, and around 300 species have been used by the traditional-medicine industry (Diniatik, Lestari, & Galistiani, 2021).

Legumes have long been recognized as functional foods rich in bioactive compounds, and have been widely used for both nutrition and health promotion. These plants synthesize a variety of phytochemical compounds in their cells, such as isoflavones, flavonoids, phenolic compounds, lignins, lignans, alkaloids, and cyanogenic glucosides, all of which have health benefits (Sevilla, López, & Knauth, 2020).

Phaseolus vulgaris L. is the most important legume consumed worldwide. Its seeds are composed primarily of carbohydrates and are a good source of nitrogen and protein. These legume seeds are rich in bioactive compounds such as enzyme inhibitors, lectins, phytates, oligosaccharides, and phenolic substances, which play a role in metabolism in humans and animals. Biological activities associated with these compounds include antioxidant capacity, cholesterol reduction, low-density lipoprotein (LDL) reduction, and protective effects against cardiovascular disease. Furthermore, this plant has shown positive results against cancer due to the antimutagenic and antiproliferative properties of its phenolic compounds, lectins, and protease inhibitors. In addition, *P. vulgaris* has demonstrated effects against obesity and diabetes due to its resistant starch content and α-amylase inhibitors (Sevilla et al., 2020).

Several studies have shown that consumption of green beans contributes to decreasing LDL-C concentrations, which is strongly suspected due to its high content of flavonoids, saponins, phytosterols, and fiber. Beans (*Phaseolus vulgaris* L.) are an important source of phytochemicals with hypolipidemic activity; dietary fiber, oligosaccharides, resistant starch, and phenolic compounds are the main bean components responsible for lowering triglycerides. The cholesterol-lowering mechanisms by *Phaseolus vulgaris* L. include binding of bile acids, interference with the formation of cholesterol micelles, increased cholesterol excretion through feces, and activation of LDL receptors in the liver to increase lipoprotein clearance (Ramírez-Jiménez, Reynoso-Camacho, Tejero, León-Galván, & Loarca-Pina,

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2015). Several mechanisms have been proposed to explain this effect, including increased satiety neuropeptides via activation of FFAR by dietary fiber metabolites in the colon, increased clearance rate, higher hepatic low-density lipoprotein receptor (LDLR) expression, and modulation of lipogenic enzymes (fatty acid synthase, FAS; and Acetyl CoA-Carboxylase, ACC) (Thompson, McGinley, Neil, & Brick, 2017). Studies using animal models have shown that consumption of cooked beans decreases circulating triglycerides and visceral adiposity, total cholesterol, and induces the expression of CPT1, a transcription factor that stimulates β-oxidation (Almuaigel, Seif, Albuali, Alharbi, & Alhawash, 2017). In addition, it was also reported the effect of consuming roasted corn/peanut snacks on lower serum lipids and different liver gene expression in high-fat-fed C57BL/6 mice by inhibiting PPARy and SREBF2 (Dominguez-Uscanga, Loarca-Piña, & de Mejia, 2017).

One of the main bioactive compounds found in *Phaseolus vulgaris* L. is flavonoids, including quercetin, kaempferol, myricetin, catechin, and procyanidin. These compounds are commonly found in the seed coat and are known to possess antioxidant and anti-inflammatory activities, as well as the ability to reduce the risk of cardiovascular disease. Anthocyanins, which are also flavonoids and are responsible for the dark color of the seeds, have a protective effect against oxidative stress and are associated with a reduced risk of cancer and degenerative diseases. In addition to flavonoids, these beans also contain tannins, which are polymeric flavonoids found abundantly in the seed coat. Tannins have the ability to inhibit the growth of pathogenic microorganisms and also exhibit anticancer and antioxidant activities. Phenolic acids such as vanillic, sinapic, ferulic, and chlorogenic acids, which are commonly found in seed tissue, act as precursors for other complex phenolic compounds and contribute to the plant's antioxidant capacity (Bhide, Nehete, & Bhambar, 2022; Nyau, 2014).

Saponins are also present in low concentrations, possessing a triterpenoid or steroidal structure that can bind bile acids and form complexes with cholesterol, thus inhibiting its absorption in the intestine. Phytosterols in *Phaseolus vulgaris* L. work synergistically with saponins to lower cholesterol levels by disrupting the formation of cholesterol micelles and inhibiting the action of lipogenic proteins in the liver. Equally important, the high dietary fiber content, particularly soluble fiber and resistant starch, helps lower total and LDL cholesterol levels in the blood by increasing cholesterol excretion and the production of short-chain fatty acids from fermentation in the colon. Another compound of interest is the natural α-amylase inhibitor found in *Phaseolus vulgaris* L. seeds, which can inhibit carbohydrate digestion, control blood glucose levels, and lower the glycemic index of foods—all of which are beneficial in preventing obesity and type 2 diabetes (Alharbi, 2016).

These findings indicate the combination of bioactive compounds in beans provides a strong scientific basis for their use as functional food ingredients and potential candidates in the development of natural therapies for the control of hypercholesterolemia and other metabolic disorders.

RESEARCH METHOD

A narrative review is a type of literature review that synthesizes evidence from previously published studies. A literature search was conducted using Google Scholar (n=58), ScienceDirect (n=11), and PubMed (n=2) databases, yielding a total of 71 articles. The literature search was conducted using the Boolean search strategy: "beans" AND "*Phaseolus vulgaris* L." AND "hypercholesterolemia" AND "bioactive compounds" AND "isolation" OR "fractionation." Article inclusion criteria included research articles published between 2015 and 2025, with full text available. Exclusion criteria included duplicate articles, articles not containing primary data, and titles lacking keywords.

A total of 71 articles were identified through the literature search. After the initial screening, 16 articles were excluded because they were published outside the specified year range or were not original research articles. Subsequently, 28 articles were excluded based on discrepancies identified in the title, abstract, or full-text screening. An additional 19 articles were excluded because they were not relevant to the objectives of this review. Consequently, 8 articles met the inclusion criteria and were included in the final narrative review.

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RESEARCH RESULTS

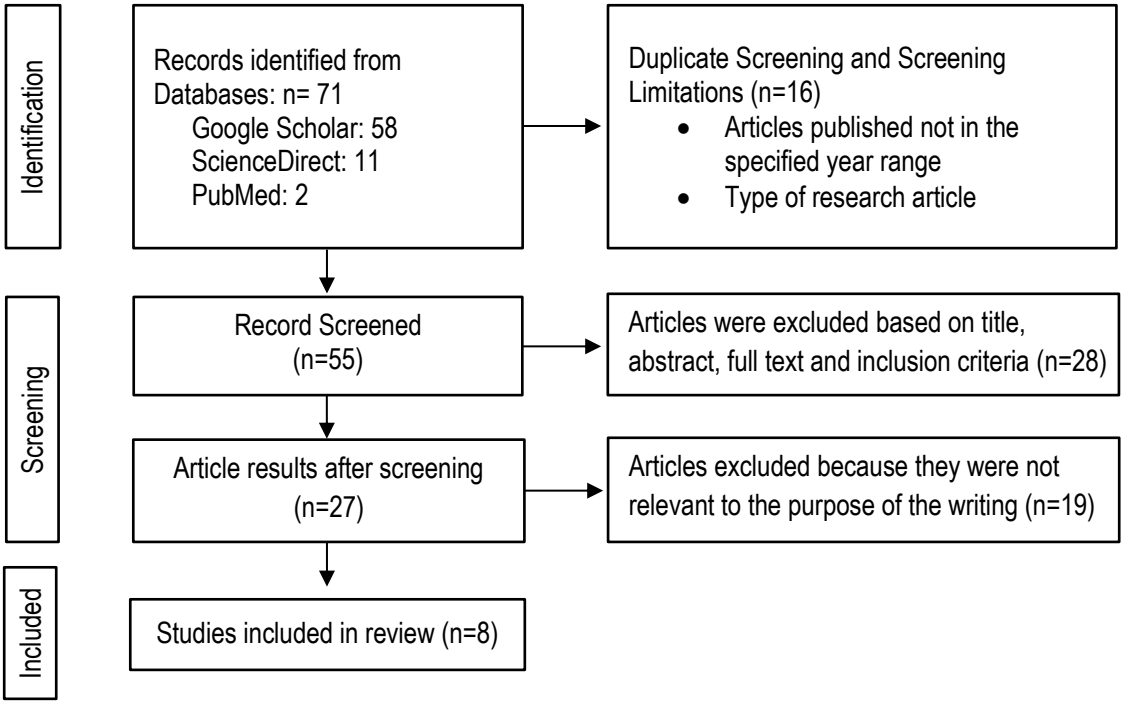

Figure 1. Flow Diagram of Article Selection

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Table 1. Article Data Mapping Results

(Author, Year) (Country)	Purpose	Sample	Research methods	Potential compounds	Research results
(Angeles et al., 2021) Philippines	To understand the relationship of identified genes from legume studies, we performed gene network analysis, pathway, and gene ontology (GO) enrichment.	Cowpea, Jack Bean, Mung bean, Lentil, Chickpea	In Vivo Test (ACE-inhibitor activity test, measurement of lipid levels (TC, HDL, LDL, TAG) in animals).	Bioactive peptides, 7S globulin protein, concanavalin A, ACE-inhibitor peptides.	Proteins and peptides from these seeds exhibit antihypertensive, hypolipidemic, and anti-obesity effects in animal models.
(Sulastri et al., 2020) Indonesia	To investigate the effects of several extracts (n-hexane, ethyl acetate, and aqueous) of green bean fruit on the reduction of cholesterol levels in male Sprague Dawley rats induced with quail egg yolk, 0.02% PTU, and an atherogenic diet for 14 days.	Chickpeas	In Vivo Test (Cholesterol induction in Sprague Dawley rats (atherogenic feed, quail egg yolk, PTU); cholesterol test with Easy Touch® cholesterol meter.	Alkaloids, Flavonoids, Saponins, Steroids/Triterpenoids, Phytosterols (Stigmasterol).	Water fraction dose of 100 mg/kg BW reduced cholesterol by 41.31%, higher than simvastatin (38.60%).
(Chavez-Santoscoy et al., 2015) Mexico	To identify and quantify primary saponins and flavonoids extracted from black bean seed coats, and to study their effects on lipid metabolism in primary rat hepatocytes and C57BL/6 mice.	Black bean	In Vivo Test (Expression of lipid metabolism related genes in mouse hepatocytes and in vivo test in C57BL/6 mice).	Flavonoids: quercetin 3-O-glucoside Saponins: soyasaponin Af and others.	Decreases the expression of SREBP1c, FAS, and HMGCR. Increases the expression of ABCG5/8, CYP7A1, and PPAR-α. Decreases liver lipid levels.
(García-Cordero et al., 2021) Mexico	To determine the antioxidant and antigenotoxic effects of phaseolin (isolated from *Phaseolus vulgaris*) against mouse colon and liver damage induced by azoxymethane (AOM) and its colon chemo preventive effect.	Bean seed	In Vivo Assay (Azoxymethane (AOM)-induced mice: oxidative stress, DNA damage, and CAC).	Phaseolin (main storage protein in seeds).	Phaseolin inhibited 100% of lipid peroxidation, 90% of DNA damage, and 84% of CAC formation (rats).

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(Author, Year) (Country)	Purpose	Sample	Research methods	Potential compounds	Research results
(Almuaigel et al., 2017) Saudi Arabia	To evaluate the reduction potential of aqueous extract of casing of pods of *Phaseolus vulgaris* in blood glucose and lipids levels among hyperglycemic streptozotocin (STZ)-induced rats.	*Phaseolus vulgaris* (pods)	In Vivo Test (Streptozotocin (STZ)-induced diabetic rats; measurement of blood glucose, cholesterol, and triglycerides).	Active compounds in water extract (not specifically stated).	PPVEt (200 mg/kg) lowered blood glucose, cholesterol, and triglycerides more effectively than glibenclamide.
(Bolayo & Torio, 2024) Philippines	To formulate a functional beverage from common bean seeds, isolate the proteins and evaluate their anti-hypertensive and anti-cholesterolemic properties.	White common bean	In Vitro Test (ACE inhibitory assay Cholesterol micelle solubility inhibition assay).	Bioactive peptides (protein hydrolysates)	ACE inhibitor by 77.60% Inhibition of cholesterol micelle solubility by 2 7.38%.
(Ashraf et al., 2020) China	To compare the effect of thermosonication on degree of hydrolysis, releasing of peptides and cholesterol inhibition of hydrolysates (<3KDA) from mung bean and white kidney bean.	Mung bean (*Vigna radiata*) and White kidney bean (*P. vulgaris var. albus reniformis*).	In vitro assay (Cholesterol micelle solubility inhibition assay HMG-CoA reductase inhibition assay)	Bioactive peptides resulting from protein hydrolysis (molecular weight < 3 kDa).	Cholesterol inhibitory activity in micelles (up to 45% for mung bean).
(Caponio et al., 2020) Italy	To discuss the mechanisms of action of soy proteins and peptides on cholesterol metabolism and potential beneficial reflections on human health.	Soybean (*Glycine max*).	In vitro assays (LDLR activity, HMGCR inhibition, bile acid binding).	Bioactive peptides: IAVPGEVA, IAVPTGVA, LPYP, YVVNPDNDEN, FVVNATSN, lunasin.	Peptides increase LDLR expression, lower cholesterol through activation of SREBP-2 and AMPK.

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DISCUSSION

Legumes are plants belonging to the family *Leguminosae*. Most legumes are dehiscent fruits that release their seeds by splitting open along two lines, although some species, such as the peanut (*Arachis hypogaea*) and carob (*Ceratonia siliqua*), do not naturally open. These plants come in various sizes and shapes, many of which are long and slender, with seeds arranged in a single row. When mature, legume fruits are typically dry and papery or hard and woody; the legume fruits of some food crops, such as snow peas (varieties of *Pisum sativum*), edamame (*Glycine max*), and green beans (*Phaseolus vulgaris*), are harvested while still green and fleshy. This review article focuses on leguminous plants with potential antihyperlipidemic properties, including common beans (*Phaseolus vulgaris*), black beans, soybeans (*Glycine max*), seed beans, mung beans (*Vigna radiata*), chickpeas (*Cicer arietinum*), cowpeas (*Vigna unguiculata*), jack beans (*Canavalia ensiformis*), white beans (*Phaseolus vulgaris var. albus)*, and white kidney beans (*Phaseolus vulgaris var. albus reniformis)*.

The ten plant species from the *Leguminosae* family mentioned above have great potential as alternative therapies for lowering blood cholesterol levels, especially in cases of hypercholesterolemia. In the eight articles reviewed, various extracts and bioactive compounds were identified and tested using in vitro and in vivo approaches. The main bioactive compounds identified include flavonoids, saponins, phytosterols, polyphenols, and bioactive peptides.

Previous research showed that the aqueous fraction of ethanolic chickpea extract at a dose of 100 mg/kg body weight reduced cholesterol levels by up to 41.31%, significantly higher than simvastatin (38.60%). This confirms that polar compounds such as water-soluble flavonoids and saponins are key to the cholesterol-lowering mechanism (Sulastri, Syafalia, & Isa, 2020).

Fractionation and enzymatic hydrolysis methods were widely used in the reviewed studies, demonstrating the superiority of this approach in isolating active compounds such as bioactive peptides (e.g., IAVPTGVA from soybean glycinin) that have the effect of inducing LDLR expression, as well as inhibiting key enzymes such as HMG-CoA reductase, which is also the target of statin action.

Another research study also added an important dimension by exploring anthocyanins from black bean skin using Pressurized Liquid Extraction (PLE) technology, which demonstrated significant antioxidant and antitumor effects through various assays such as DPPH, ABTS, and MTT assays. This demonstrates the broad potential of *Phaseolus vulgaris* L. not only in metabolic aspects but also as a preventive agent against degenerative diseases (Kuasnei, Leonarski, Dartora, Bredun, Burin, Cesca, & Zielinski, 2025).

Furthermore, other studies have highlighted the role of protein hydrolysates from legumes in inhibiting cholesterol micelle formation and the activity of blood pressure-regulating enzymes such as ACE, providing additional benefits for the overall prevention of cardiovascular disease (Bolayo & Torio, 2024; Ashraf, Liu, Awais, Xiao, Wang, Zhou, & Zhou, 2020).

In general, the hypocholesterolemic mechanisms of bioactive compounds in legumes can be explained through several pathways, including:

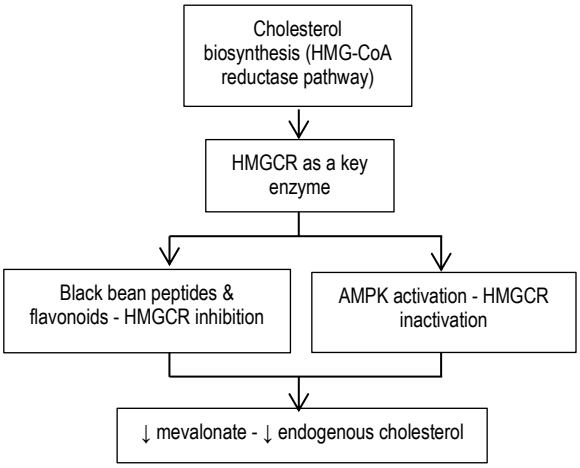

Figure 2. Cholesterol Biosynthesis Pathway Mechanism

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Cholesterol Biosynthesis Pathway (Mevalonate Pathway/HMG-CoA Reductase Pathway)

Cholesterol biosynthesis in hepatocytes is controlled by the key enzyme 3-hydroxy-3-methylglutaryl-coenzyme A reductase (HMGCR) as illustrated in figure 2 above. Inhibition of this enzyme directly reduces the production of mevalonate, the primary precursor of cholesterol. Several previous studies have shown that legume protein peptides (mung bean, kidney bean) and black bean flavonoids can inhibit HMGCR activity. Other studies reported that soybean peptides induce the activation of AMP-activated protein kinase (AMPK), which then phosphorylates and inactivates HMGCR. Thus, inhibition of this pathway is implicated in reducing endogenous cholesterol production by the liver, resulting in lower plasma cholesterol levels (Caponio, Wang, Di Ciaula, De Angelis, & Portincasa, 2020; Ashraf et al., 2020; Chávez-Santoscoy et al., 2015).

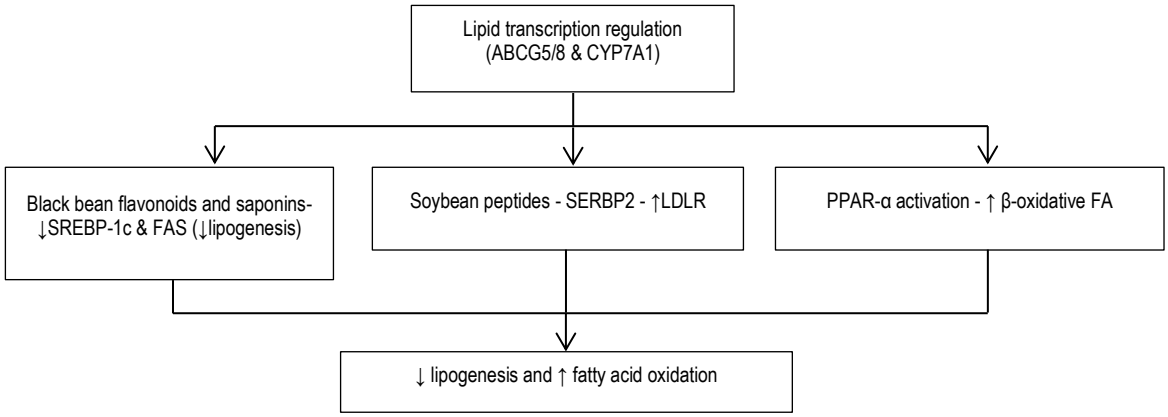

Figure 3. Lipid Transcription Regulation Pathway Mechanism

Lipid Transcriptional Regulation Pathway (SREBP and PPAR Pathway)

Transcriptional regulation of lipogenic and lipolytic genes is controlled by key transcription factors such as sterol regulatory element-binding proteins (SREBPs) and peroxisome proliferator-activated receptor-α (PPAR-α) as illustrated in figure 3 above. Previous studies have shown that black bean flavonoids and saponins suppress the expression of SREBP-1c and fatty acid synthase (FAS), which play a role in lipogenesis (Chavez-Santoscoy et al., 2015). Soybean peptides also affect SREBP-2, which indirectly increases the expression of the LDL receptor (LDLR). Activation of PPAR-α by active compounds in legumes stimulates fatty acid β-oxidation, thereby reducing lipid accumulation in the liver. Collectively, this pathway directs metabolism toward decreased lipogenesis and increased fatty acid oxidation (Caponio et al., 2020).

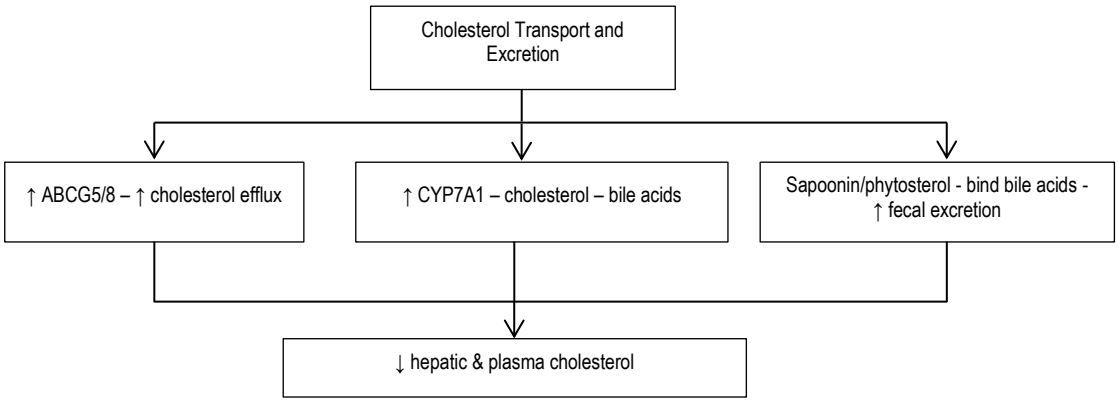

Figure 4. Cholesterol Transport and Excretion Pathways Mechanism

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Cholesterol Transport and Excretion Pathways (Cholesterol Efflux and Bile Acid Pathway)

In figure 4 above, cholesterol excretion from the liver to the intestine is regulated by the ABCG5/8 transporter and the cholesterol 7α-hydroxylase (CYP7A1) enzyme, which converts cholesterol into bile acids. Previous research has reported that black bean consumption increases ABCG5/8 expression, increasing cholesterol efflux into bile. CYP7A1 activity is also induced, resulting in greater conversion of cholesterol to bile acids (Chávez-Santoscoy et al., 2015). Saponins and phytosterols in chickpeas and soybean peptides play a role in binding bile acids in the intestine, which increases fecal excretion and forces the liver to use cholesterol for new bile acid synthesis. Consequently, hepatic and plasma cholesterol reserves are reduced (Sulastri et al., 2020; Caponio et al., 2020).

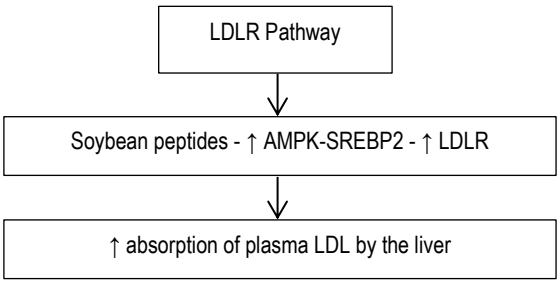

Figure 5. LDL Receptor Pathway Mechanism

LDL Receptor Pathway (LDLR Pathway)

Figure 5 above shows that plasma cholesterol homeostasis is significantly influenced by the liver's ability to absorb LDL through the LDL receptor. Previous research has shown that soy peptides can increase LDLR expression through AMPK-SREBP2 regulation. With increased LDLR levels, more circulating LDL particles are captured and recycled by hepatocytes. This mechanism contributes significantly to lowering plasma LDL levels, a major risk factor for atherosclerosis (Caponio et al., 2020).

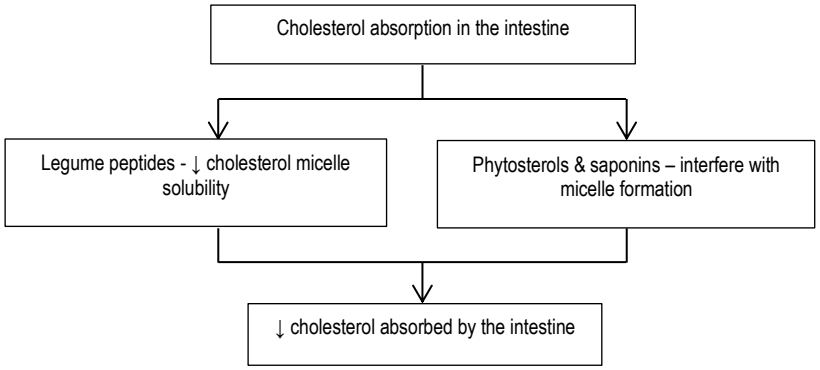

Figure 6. Intestinal Cholesterol Absorption Pathway Mechanism

Intestinal Cholesterol Absorption Pathway

Dietary cholesterol can only be absorbed if it dissolves in micelles formed by bile salts. Mung bean and kidney bean peptides, as well as white bean protein hydrolysate, have been shown to reduce the solubility of cholesterol micelles, thus decreasing intestinal cholesterol absorption (Ashraf et al., 2020; Bolayo & Torio, 2024). Chickpea phytosterols and saponins compete with cholesterol for entry into micelles, and some bind bile acids, disrupting micelle stability. This mechanism directly reduces the amount of cholesterol that can be absorbed in the intestine, resulting in lower cholesterol levels, as seen in figure 6 above (Sulastri et al., 2020).

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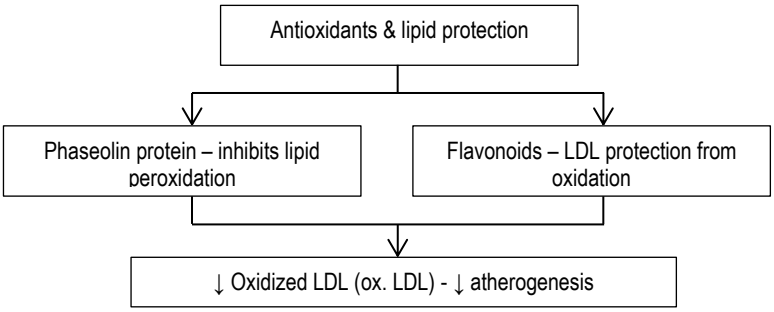

Figure 7. Antioxidant Pathway and Lipid Protection mechanism

Antioxidant Pathway and Lipid Protection (Oxidative Stress Pathway)

LDL oxidation produces oxidized LDL particles (ox-LDL), the most atherogenic form of cholesterol. Previous research reported that the phaseolin protein from bean seeds can inhibit lipid peroxidation by up to 100% and DNA damage by 90%. Flavonoids in chickpeas also have strong antioxidant capacity. Through this activity, the bioactive components of legumes protect lipids and lipoproteins from oxidation, thereby preventing the formation of ox-LDL, which plays a major role in atherogenesis. This mechanism can also be seen in figure 7 above (Gabriele, Pucci, La Marca, Lucchesi, Della Croce, Longo, & Lubrano, 2016; García-Cordero, Martínez-Palma, Madrigal-Bujaidar, Jiménez-Martínez, Madrigal-Santillán, Morales-González, & Álvarez-González, 2021; Sulastri et al., 2020).

CONCLUSION

Legumes have a significant hypocholesterolemic effect through multiple, complementary mechanisms — inhibiting cholesterol synthesis, increasing its clearance, reducing its absorption, and neutralizing LDL oxidation — giving them strong potential for development as a comprehensive, safe herbal therapy for hypercholesterolemia. Although current evidence supports the lipid-lowering potential of *Phaseolus vulgaris*, most available studies remain preclinical. Further well-designed clinical trials are needed to validate its efficacy and safety in humans.

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