Science Letters ISSN 2345-5463 DOI: https://doi.org/10.47262/SL/10.1.132021028

Review article
2022 | Volume 10 | Issue 1 | Pages 24-31

ARTICLE INFO

Received
November 14, 2021
Revised
January 12, 2022
Accepted
January 17, 2022
Published
February 25, 2022

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Keywords
Chicken meat
Cholesterol
Human health
Medicinal plants

How to cite
Falowo AB. Potential of medicinal plants as Hypocholesterolemic agents in chicken meat production. Sci Lett 2022; 10(1):24-31

Open Access

Potential of Medicinal Plants as Hypocholesterolemic Agents in Chicken Meat Production

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Abstract

Chicken meat is one of the most valuable and widely eaten meats across the world because of its moderate energy content, highly digestible proteins, unsaturated lipids, vitamin, and minerals. Besides red meat, chicken meat also contains a high amount of cholesterol content. High cholesterol intake increases the risk of atherosclerosis and other related diseases such as diabetes, cancers and brain diseases in humans. Recent growing awareness of the risk of cholesterol-rich food has necessitated the search into the use of cholesterol-reducing agents in food and meat products. Several medicinal plants have been considered as an effective panacea to reduce the cholesterol content in meat products due to their inherent enormous phytochemicals and fiber contents. Interestingly, these medicinal plants are currently used as natural growth promoters in animal nutrition to replace antibiotics (synthetic), which have been reported to cause antibiotic residues in animal products and antibiotic-resistant bacteria strains in consumers. Their application as growth promoters has played enormous roles in poultry production ranging from antioxidant, antimicrobial, immune-modulatory, and anti-stress activities to improve the immune system, nutrient absorption, growth performance, and meat quality. The potential of medicinal plants in animal diets to improve the performance, health, and antioxidant capacity of broiler chicken has been extensively reviewed, while only a few studies have discussed their hypocholesterolemic activities. Thus, this study aimed to discuss the source of cholesterol, factors influencing their deposition, and the potential of medicinal plants in lowering their concentration in animal muscle.

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Introduction

Cholesterol is a lipid biomolecule that is found in all animal and human cell membranes. It is required in the formation of cell membranes and structures. It aids in the regulation of membrane fluidity over a wide temperature range. It is an important source of bioactive compounds such as corticosteroids, estrogen, progesterone, and testosterone, as well as vitamin D and bile acids, which assist in the regulation of cellular metabolism [1]. Generally, cholesterol is produced in the organs and glands such as the liver, gonads, adrenal glands, and intestines or synthesized from a wide variety of foods, particularly saturated fats from animal sources [2]. On estimate, the consumption of animal products, such as meat, eggs, and dairy products are known to produce 20 –25 percent of the cholesterol in our body [2]. An intake of a high-saturated-fat diet can trigger the body to produce extra or excessive cholesterol content. Accumulation of excessive cholesterol in the inner walls of blood arteries may lead to the formation of plaque (thickening of arteries) and obstruction of blood flow through a process called atherosclerosis [2, 3]. Atherosclerosis has been reported as the second-highest death-causing cardiovascular disease in humans [3, 4]. In addition, other human disorders such as Smith-Lemli-Opitz syndrome (SLOT), non-insulin-dependent Diabetic Mellitus, brain ailments, and cancers can be caused by aberrant cholesterol or its precursors [2]. To avoid this, a dietary cholesterol intake of 200-300 mg/day has been recommended to ensure healthy living [5]. Regular consumption of meat and meat products in large amounts has been reported to naturally increase serum total cholesterol levels [6]. Evidence has shown that muscle foods (meat) contribute 42 percent of total cholesterol intake while eggs and other food products contribute the remaining percentage [7].

The cholesterol content in pork, beef, mutton, chevron, chicken, turkey and rabbit meat has been analyzed to range from 58 to 73 mg/100 g [8], 36 to 70 mg/100g [9,10], 53 to 75.3 mg/100g [11], 34 to 36.5 mg/100g [12], 47.1 to 81 mg/100 g [9, 13] and 59 mg/100g [14] of fresh tissues, respectively. However, the level of cholesterol content in animal tissue could be reduced through the dietary application of medicinal plants as natural feed additives due to their inherent bioactive compounds and high fiber content. Medicinal plants are a group of plants that possess therapeutic and prophylactic properties when used in the biological system. They are rich in antioxidants and nutrients such as protein, crude fiber, vitamins, and minerals. In poultry production, medicinal plants are used as natural growth promoters to enhance growth performance, increase antioxidant capacity, boost the immune system, improve meat quality and reduce gut disease. Several studies have revealed that dietary application of these plants can directly influence the metabolism of cholesterol in animals and also alter the cholesterol level in their meat and eggs [15, 16]. This is because the plant is rich in soluble fiber and low in saturated fat, which in turn helps to lower cholesterol content in animal muscle. Many studies have reviewed the potential of medicinal plants as an effective antioxidant, antimicrobial, and natural growth promoters in poultry production while little is known regarding their hypocholesterolemic capacity in animal muscle. Thus, this study reviewed the potentials of medicinal plants as a feed additive in lowering cholesterol content in broiler chicken meat.

Discovery, structure and types of cholesterol

The word "cholesterol" was created by combining the Greek words "chole" (meaning bile) and "stereos" (meaning solid) and added the chemical suffix "ol" to the end for alcohol. Poulletier de la Salle first discovered cholesterol in human gallstones in 1769 [17, 18], and Chevreul rediscovered it in 1815, naming it "cholesterine" [18]. Other biological chemists discovered in the 19th century that cholesterol is found not only in gallstones but also in the blood, brain, and liver [19]. Structurally, cholesterol consists of 27 carbon atoms, 46 hydrogen atoms and one oxygen atom ($C_{27}H_{46}O$) (Fig. 1). It has a molecular weight of 386.65, melting point of 140°C, gravity range of 1.06 to 1.07 and IUPAC name (3S, 8S, 9S, 10R, 13R, 14S, 17R)-10, 13–dimethyl –17-[(2R)-6-methylheptan–2-yl] 2, 3, 4, 7, 8, 9, 11, 12, 14, 15, 16, 17-dodecahydro-1H- cyclopenta [a] phenanthren-3-ol. It is relatively soluble in water but insoluble in blood.

Cholesterol is divided into three types: bad cholesterol, also known as low-density lipoprotein (LDL), good cholesterol, known as high-density lipoprotein (HDL), and very-low-density lipoprotein (VLDL), which is identical to LDL. Low-density lipoproteins (LDL) are lipoproteins that transport cholesterol through the circulation

from the liver and intestine to the body's cells and tissues. While high-density lipoprotein (HDL) is a type of lipoprotein that transports cholesterol from cells and tissues to the liver, lowering cholesterol levels in the blood [20]. Lipoprotein is an association between protein and lipids in the cell. This association exists to allow lipids to move across the cell, using protein as an emulsifier and carrier since cholesterol is insoluble in blood. Cholesterol normally travels within the body by associating with these proteins. Examples of lipoproteins include enzymes, antigens, toxins and adhesins [20].

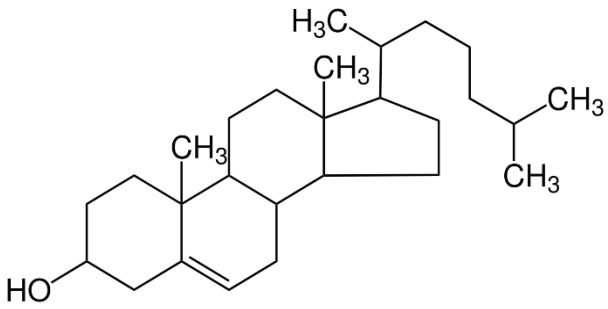

Fig. 1 Structure of cholesterol.

Dietary sources of cholesterol

Cholesterol is produced in the body by two main sources. This comprises both exogenous (dietary) and endogenous (*de novo*) sources. The endogenous cholesterol is synthesized by the liver, intestine and reproductive organs in the body [21]. The dietary sources are derived from ingestion of animal and animal products such as meat (beef, pork, poultry, mutton, etc.), dairy products (milk, cheese, butter) and egg (egg yolks) [22]. This is because animal and animal products are essentially rich in lipid and fatty acids, which are a precursor for the deposition of cholesterol in cells and tissues. Other sources of dietary cholesterol include fat and oil, fast foods, snack foods, and fried or baked goods. Except for some plant products like peanuts and flax seeds, which contain cholesterol-similar substances called phytosterols (such as sitosterol, campesterol, stigmasterol, etc.), cholesterol is absent in plants and plant materials [23, 24]. These phytosterols are beneficial in lowering cholesterol levels in the body. They can also compete with cholesterol in the gut, in order to inhibit their reabsorption [23]. This is because they are poorly absorbed and are rapidly excreted in the body during digestion [24].

Factors influencing deposition of cholesterol in animal tissue

The body makes most of the cholesterol needed in a day, especially in the liver. Several studies have shown that nutrition is the major factor influencing cholesterol deposition in animal tissues. Particularly the type of feed ingredient that is used to compound the diet. Factors such as sex, breed, age, etc. have been detected to exert an insignificant effect on the deposition of cholesterol in animal muscles [10, 25-27].

Medicinal plants in animal nutrition

Medicinal plants refer to any group of plants (herbs, spices and their extracts, etc.) that contain secondary metabolites and can be used to treat or prevent various diseases in animals and human beings [28]. The potential of medicinal plants to exhibit therapeutic and prophylactic properties has been widely attributed to their inherent antioxidant, antimicrobials, anti-inflammatory, anthelmintic, immuno-stimulatory/immune-modulatory, and anti-stress compounds [29, 30]. Most medicinal plants are known to contain huge amounts of nutrients, including protein, lipid, crude fibers, amino acids, fatty acids, minerals, vitamins, and phytochemicals, which made them a suitable candidate for feed additives or ingredients in animal nutrition. Nowadays, medicinal plants are used as natural growth promoters in animal nutrition to replace antibiotic growth promoters due to the deposition of antibiotic residues in animal products and the development of antibiotic-resistant bacteria strains in consumers [30, 31]. Many studies have reported the utilization of medicinal plants as effective feed additives to enhance growth performance, improve feed digestibility and gut health, and boost the immune and health system, without leaving residues in the products of broiler chickens [30-33]. Besides, the use of medicinal plants as animal feed additives has been noted to improve meat quality and reduce cholesterol content. This is indicating that medicinal plant feed additives can be used in broiler production to produce healthier and leaner meat that is acceptable to consumers and has a reduced cholesterol content. The effectiveness of medicinal plants to enhance the performance and health of animal has been linked to the synergistic activity of individual bioactive and phytochemical compounds inherent in the plant. Different parts of

Table 1 Utilization of medicinal plant leaves as an anti-cholesterolemic agent in broiler chicken meat.

Plants	Animal species and age	Concentration and feed duration	Meat type	Ref.
Phyllanthus buxifolius leaf meal	Broiler (21 days old)	5% for 21 days	Breast	[4]
Pluchea indica L. leaf meal	Broiler (day old)	2, 4 & 8% for 28 days	Thigh	[51]
Great tea powder	Broiler (2 weeks old)	0.5 & 1% for 12 weeks	Breast	[52]
Sauropus androgynous leaf meal	Female Broiler (15 days old)	5% for 20 days	Thigh	[53]
Bay leaf meal	Female Broiler (15 days old)	5% for 20 days	Thigh	[53]
Basil leaf meal	Female Broiler (15 days old)	5% for 20 days	Thigh	[53]
Papaya leaf meal	Female Broiler (15 days old)	5% for 20 days	Thigh	[53]
Wild sunflower and goat weed leaf meals composite mix	Broiler (day old)	0.4, 0.8 & 1.2% for 6 weeks	Breast	[30]
Syzygium aromaticum leaf	Broiler (day old)	0.25% for 6 weeks	Breast	[33]
Mango leaf meal	Broiler (day old)	5 g/kg for 6 weeks	Breast	[44]
Ocimum basilicum leaf meal	Broiler (day old)	0.50, 0.75, 1.0 & 1.25%	Breast	[54]
Moringa oleifera leaf meal	Broiler (2 weeks old)	6, 9 & 12% for 5 weeks	Breast	[56]

medicinal plants, including leaf, seed, root, fruits, flower, stem, etc. have been exploited as a feed additive in animal nutrition to improve the performance and health of broiler chicken [30, 34-35]. Interestingly, the majority of medicinal plants are affordable, accessible and safe without adverse effects compared to antibiotic growth promoters. The performance response of animals to dietary utilization of medicinal plants depends largely on the dosage and bioavailability of the bioactive compounds inherent in individual plant and plant parts [36]. The concentration of phytochemicals or bioactive compounds inherent in plants may vary depending on factors such as the plant part, season and time of harvest, physiological status, geographical origin and technique of processing the plants [37].

Medicinal plants and meat quality of broiler chicken

The introduction and utilization of medicinal plants as natural growth promoters in animal production was due to the prohibition of the use of synthetic (antibiotic) growth promoters as feed additives by the European Union in 2006. As well as consumers rising demand for animal products that are healthy and free of antibiotic residues [38]. Presently, medicinal plants can be used as feed additives to improve carcass traits, digestive organ size and physicochemical properties of poultry meat during production. Because of their abundant inherent aromatic compounds, medicinal plants have been incorporated into the diet to improve the organoleptic properties of chicken meat such as taste, flavor, aroma, juiciness, palatability, and tenderness [39, 40]. Other studies have also reported that dietary utilization of medicinal plants is effective in preventing oxidative changes, lowering meat cholesterol concentration, and elevating meat endogenous antioxidants, such as glutathione peroxidase, catalase, glutathione S-transferase, superoxide dismutase and total phenols content in broiler chicken [33, 39, 41-43]. In addition, the meat of broiler chicken fed diets supplemented with medicinal plants has been reported to show improved color stability, water-holding capacity, tenderness, and lowered cooking loss percentages [44-45]. Also, the dietary supplementation of medicinal plants was reported to increase the contents of polyunsaturated fatty acids, omega -3 and omega-6 polyunsaturated fatty and decreased thrombogenic index and abnormal fat in breast meat of broiler chickens [46].

Hypocholesterolemic activity of medicinal plant leaf in broiler chicken meat

Medicinal plants are widely distributed and easily accessible across the world. As presented in Table 1, different medicinal plant leaves such as *Moringa oleifera*, *Phyllanthus buxifolius*, *Pluchea indica L*., *Sauropus androgynous*, great tea, *Syzygium aromaticum* and *Ocimum basilicum* leaves, have been utilized as effective feed additives to lower cholesterol content in muscle tissue. The hypocholesterolemic activity of these medicinal plant leaves has been associated to their phytochemicals and high fiber content. It is known that dietary fiber can slow down the absorption of cholesterol and reduce the amount of cholesterol

Table 2 Utilization of medicinal plant seeds as an anti-cholesterolemic agent in broiler meat.

Plants	Animal species and age	Concentration and feed duration	Meat type	Ref.
Moringa oleifera seed meal	Broiler chicks (day old)	2, 4, 6, and 8% for 42 days	Breast	[55]
Nutmeg *(Myristica fragrans)* seed meal	Broiler chicks (day old)	0.25% for 42 days	Breast	[33]
Irvingia Gabonensis seed meal	Broiler chicks (day old)	0.25% for 42 days	Breast	[41]
Chia (*Salvia hispanica L.*) seed meal	Broiler chicks (day old)	10 and 20% for 49 days	Breast	[56]
Garlic root powder	Broiler chicks (day old)	1.5, 3.0, & 4.5% for 21 days	Breast	[58]
	Broiler chicks (day old)	0.5 & 1.0g/100g for 42 days	Breast, thigh, drumstick	[35]
Black pepper meal	Broiler chicks (day old)	0.5 &1.0g/100g for 42 days	Breast, thigh, drumstick	[35]
Hot red pepper meal	Broiler chicks (day old)	0.5 & 1.0g/100g for 42 days	Breast, thigh, drumstick	[35]

that the liver can produce by inhibiting the digestion and absorption of dietary fat, and also modulating the absorption and metabolism of bile acid [47]. In addition, the phytochemicals in medicinal plants, such as phenolic acid, flavonoid, saponin, phytate, alkaloid, have been shown to lower serum cholesterol by binding bile acids and increasing fecal loss or by inhibiting the cholesterogenesis and fat accumulation in the carcass and organs [48], or by forming insoluble complexes bond with cholesterol from food in the gastrointestinal tract, so that cholesterol cannot be reabsorbed by the intestine [49, 50].

Hypocholesterolemic activity of medicinal plant seed in broiler chicken meat

As presented in Table 2, common dietary medicinal plant seeds that have been reported to exert hypocholesterolemic activity in the muscle of broiler chicken during production include nutmeg (*Myristica fragrans*) seed, Chia (*Salvia hispanica L.*) seed, Moringa (*Moringa oleifera*) seed, Irvingia *Gabonensis* seed, and garlic roots, etc. Plant seeds are considered important sources of phytochemicals because they contain a huge amount of phytates, tannins, saponin, oxalates, alkaloids, phenolics, flavonoids, and other bioactive compounds, which enables them to act as hypocholesterolemic agents in animal muscles. Dietary supplementation of moringa seed meal has been reported to aid the growth and multiplication of beneficial bacteria such as *Lactobacillus* in the gut of broiler chicken, which in turn decrease the pH level and absorption of cholesterol in the digestive tract [57, 58]. The reduction in cholesterol level has been attributed to the ability of lactic acid bacteria to degrade cholesterol concentration into coprostanol in the digestive tract [57, 58]. Coprostanol is a substance that cannot be absorbed by the intestine, which is later excreted with feces [58]. Other studies have also attributed the ability of medicinal plant seeds to lower meat cholesterol content of inherent antioxidant compounds [30].

Conclusions

Consumers' knowledge of dietary cholesterol has risen considerably in recent years due to the link between excessive cholesterol levels and the risk of heart disease, leading to a decrease in the rate of meat consumption. Findings from this study have revealed that supplementation of medicinal plants that are rich in phytochemicals (such as flavonoids, polyphenols, terpenoids, etc.) and nutrients (such as protein, crude fiber, vitamins and minerals, etc.), in animal diets can be utilized to lower the cholesterol content of broiler chicken meat. This is because these medicinal plants possess the properties of antioxidants, which can help to produce healthy meat and reduce the health hazard linked with the consumption of meat and meat products. Conversely, the dietary inclusion of medicinal plants at high concentrations (above 5%) has been reported to impair growth rate in broiler production due to interference of inherent anti-nutritional factors (such as tannin, saponin, phytate) with nutrient utilization in the animal. It is believed that this menace could be reduced or eradicated through the inclusion of vitamins (such as Vit C and E) which are natural antioxidants and anti-stress agents. Dietary vitamin C is used to improve the performance and antioxidant capacity

of birds that are sensitive to nutritional and oxidative stresses during production. However, further research needs to be conducted in this area to validate its efficacy on the broiler performance.

Conflict of Interest

The authors declare that they have no conflict of interest

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