

Pharmacodynamic Study of *Abrus Cantonensis* Polysaccharides in Alleviating Hepatic Steatosis in Laying Hens

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Abstract: Fatty Liver Hemorrhagic Syndrome (FLHS) is a common nutritional-metabolic disease in laying hens and constitutes a major factor causing decreased egg production and even death of laying hens. At present, prevention and treatment of this disease mostly rely on measures such as feed replacement or reduction of energy-yielding substances in diets. Nevertheless, such approaches not only require long therapeutic cycles, but also tend to impair the stability of laying-hen productive performance due to dietary adjustment, and can hardly satisfy the efficient prevention-and-treatment demands of breeding industries. *Abrus cantoniensis* polysaccharides possess unique advantages in regulating lipid metabolism and preventing-treating Fatty Liver Hemorrhagic Syndrome in laying hens. This paper discusses research advances of *Abrus cantoniensis* polysaccharides for alleviating hepatic steatosis in laying hens from aspects including extraction technology and pharmacological basis of *Abrus cantoniensis* polysaccharides, pathogenesis of FLHS and its correlation with intestinal microbiota, as well as action mechanisms of *Abrus cantoniensis* polysaccharides for alleviating hepatic steatosis in laying hens. It aims to provide objective references for clinical application of *Abrus cantoniensis* polysaccharides to relieve hepatic steatosis in laying hens.

Keywords: *Abrus cantoniensis* polysaccharides; Fatty liver hemorrhagic syndrome (FLHS) in laying hens; Intestinal microbiota; Gut-liver axis; Chinese veterinary materia medica

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1. Introduction

Fatty Liver Hemorrhagic Syndrome (FLHS) in laying hens is a prevalent metabolic disorder in laying-hen breeding. It originates from excessive hepatic lipid deposition associated with high-energy low-protein feed, genetic susceptibility, defects in caged-rearing management and abnormal hormonal regulation, which results in hepatocyte degeneration, fragile blood vessels, hemorrhage and death^[1]. This disease was first discovered in the United States and initially named Fatty Liver Syndrome. It was renamed after the core pathological

feature of hepatic hemorrhage was identified. Shortly afterwards, scholars systematically reported this disease for the first time and clarified its correlation with high-energy feed and abnormal estrogen metabolism. Subsequent researches further revealed mechanisms whereby high estrogen levels in high-yield laying hens promote hepatic lipogenesis. Meanwhile, intestinal microbiota dysbiosis, mycotoxins and stress also participate in disease onset. Clinical manifestations include sharp decline in egg-laying rate, pale combs, pendulous abdomen and sudden death. Necropsy shows enlarged and fragile liver with hemorrhagic spots, and massive fat accumulation around abdominal cavity and internal organs, which causes remarkable economic losses to the laying-hen industry ^[2]. Conventional prevention-and-treatment measures mainly consist of adjusting dietary nutrient ratios, supplementing anti-lipid factors, optimizing feeding management and breeding low-susceptibility varieties. Traditional modes relying on nutritional regulation and pharmaceutical intervention suffer from drawbacks such as drug residues. As a characteristic Lingnan Chinese herbal medicine, *Abrus cantoniensis* exerts anti-inflammatory and hepatoprotective activities. Its polysaccharide fraction boasts advantages of immunomodulation and anti-oxidation and holds broad application prospects in the field of healthy animal breeding ^[3]. *Abrus cantoniensis*, also known as yellow-head grass, is one of the characteristic Lingnan Chinese medicinal herbs. *Chinese Pharmacopoeia* records that *Abrus cantoniensis* possesses effects of clearing heat-toxin and anti-inflammation. In recent years, numerous studies have demonstrated that *Abrus cantoniensis* can clinically treat various hepatic diseases such as acute and chronic infectious hepatitis and liver cirrhosis. Thanks to favorable immunomodulatory and anti-oxidant activities, *abrus cantoniensis* polysaccharides exhibit promising application prospects in healthy animal breeding ^[4].

2. Extraction technology and pharmacological basis of *Abrus cantoniensis* polysaccharides

2.1. Extraction procedure of *Abrus cantoniensis* polysaccharides

Dried decoction pieces of *Abrus cantoniensis* after sun-drying are crushed and sieved, followed by degreasing with petroleum ether to remove lip-soluble impurities. Then the ultrasonic-assisted enzymatic extraction process is adopted. Under suitable environmental conditions, synergistic reactions proceed for sufficient duration. After centrifugation, supernatant liquid is diluted to appropriate concentration. The phenol-sulfuric acid method is used to determine absorbance at specified wavelength. Crude-polysaccharide extraction rate is calculated according to corresponding regression equation, and ideal measured extraction effects can be achieved ^[5]. The extract is de-proteinized with Sevag reagent and decolorized by activated carbon. Multiple volumes of absolute ethanol are added for ethanol precipitation. Precipitates are sequentially washed with absolute ethanol and acetone to eliminate residual impurities. After precipitate collection by centrifugation, freeze-dryer is used for drying under low-temperature vacuum conditions to obtain finished *Abrus cantoniensis* polysaccharides. Through response-surface optimization design, multiple experimental points are set with parallel replicates for each point to establish optimal parameter combination. The model presents favorable fitting degree. The whole extraction strictly complies with laboratory operating specifications to guarantee polysaccharide purity and bioactivity.

2.2. Immunomodulatory effects of *Abrus cantoniensis* polysaccharides

Multiple animal experiments and cell assays have verified that *Abrus cantoniensis* polysaccharides can significantly enhance organismal immune functions. Its mechanism mainly lies in activating proliferation and

differentiation of T-lymphocytes and B-lymphocytes, promoting synthesis and secretion of immunoglobulins, and up-regulating expression of cytokines such as interleukin-2, so as to strengthen anti-inflammatory and anti-oxidant capacities of organisms. It can restrain excessive release of inflammatory factors, elevate activities of anti-oxidant enzymes including superoxide dismutase (SOD), and reduce levels of oxidative products such as malondialdehyde (MDA). In laying-hen production, such immunomodulatory effects can effectively boost disease-resistant capacity of laying hens, lower incidence of common diseases such as Newcastle disease and avian influenza. Meanwhile, immune-response modulation alleviates hepatic metabolic burden, improves liver functions, and ultimately raises egg-laying rate and egg quality, providing important support for sound and efficient development of laying-hen breeding ^[6].

2.3. Anti-oxidant effects of *Abrus cantoniensis* polysaccharides

Oxidative stress constitutes one of the critical mechanisms for occurrence and progression of FLHS. *Abrus cantoniensis* polysaccharides exert remarkable anti-oxidant activity, scavenge free radicals *in vivo*, mitigate hepatocyte injury induced by oxidative stress and protect hepatic functions. Its specific anti-oxidant mechanism is closely related to activation of key intracellular anti-oxidant signaling pathways, for instance the ARE pathway — the core regulatory network for cellular response to oxidative stress. When *Abrus cantoniensis* polysaccharides act on hepatocytes, they promote translocation of Nrf2 from cytoplasm into cell nucleus for binding with anti-oxidant-response elements, and further induce expression of downstream anti-oxidant enzymes including superoxide dismutase. Synergistically, these enzymes can directly scavenge free radicals such as superoxide anions and enhance cellular resistance against oxidative damage. In addition, they suppress oxidative-stress-triggered inflammatory responses and mitigate hepatocyte damage from oxidative stress at multiple levels ^[7].

Researches show that in FLHS animal models induced by high-fat diets, after intervention with *Abrus cantoniensis* polysaccharides, the level of malondialdehyde (MDA), a marker product of oxidative stress in hepatic tissues, drops significantly, while activities of anti-oxidant enzymes such as SOD rise markedly. Accumulation of reactive oxygen species within hepatocytes is effectively controlled, and pathological changes including hepatocyte steatosis and inflammatory infiltration are alleviated accordingly, which directly proves hepatoprotective effects derived from its anti-oxidant property ^[8]. Moreover, anti-oxidant effects of *Abrus cantoniensis* polysaccharides can indirectly ameliorate lipid metabolism closely associated with oxidative stress. Oxidative-stress disturbs activities of key lipid-metabolizing enzymes and gives rise to excessive hepatic lipid deposition. By relieving oxidative stress, *Abrus cantoniensis* polysaccharides restore normal functions of such enzymes, accelerate lipolysis and lipid transport, thereby reducing hepatic lipid content and ameliorating disorders of lipid metabolism, and further retard FLHS progression. Such multi-faceted effects of “anti-oxidation-hepatocyte-protection-lipid-metabolism-improvement” make it a promising natural active ingredient for FLHS prevention and treatment.

2.4. Lipid-metabolism regulation by *Abrus cantoniensis* polysaccharides

Studies indicate that polysaccharide ingredients can realize precise balanced regulation of lipogenesis and lipolysis by modulating expression of key lipid-metabolism genes and core signaling pathways. On the one hand, they inhibit activity of sterol regulatory-element-binding protein 1c (SREBP-1c), the master transcription factor for lipogenesis, and further down-regulate expression of its downstream target genes acetyl-CoA carboxylase and fatty-acid synthase, so as to directly suppress rate-limiting steps of lipogenesis.

On the other hand, they promote gene expression of key lipolytic enzymes: adipose triglyceride lipase and hormone-sensitive lipase, accelerating hydrolysis and decomposition of hepatic triglycerides ^[9]. These synergistic actions reduce total-cholesterol deposition in liver. The core pathological mechanism of Fatty Liver Hemorrhagic Syndrome is hepatocyte degeneration, necrosis and hemorrhagic injury induced by excessive hepatic lipid accumulation. Hence, *Abrus cantoniensis* polysaccharides lay solid theoretical foundation for its application in FLHS alleviation via balancing lipid metabolism and mitigating hepatic fat deposition.

3. Pathogenesis of FLHS and its relationship with intestinal microbiota

3.1. Pathogenesis of FLHS

The pathogenesis of FLHS is complex and involves multiple factors including heredity and nutrition. Essentially, it results from synergistic effects of “production overload” and “transport paralysis” triggered by nutritional imbalance. To sustain continuous egg-laying, high-yield laying hens force their livers to overwork for synthesizing massive lipids required for yolk development, which represents the physiological state of “production overload”. When excessive high-energy substances are supplied by feeds, liver converts them into fats. Nevertheless, if key raw materials for lipoprotein synthesis — proteins, essential amino acids, vitamin B12 and choline — are insufficient, “transport paralysis” occurs: large quantities of fats are synthesized yet cannot be exported out of hepatocytes due to lack of “transport carriers”. Consequently, fats keep accumulating inside hepatocytes and fatty liver develops. Such accumulated fats are not inert; they are oxidized to generate large quantities of harmful substances. On the one hand, they directly attack and injure hepatocytes and result in hepatocyte degeneration and necrosis. On the other hand, they impair hepatic synthesis of coagulation factors and induce abnormal blood-clotting mechanisms ^[10]. Ultimately, the liver becomes enlarged and extremely fragile due to massive fat accumulation. Sharp rise in intra-abdominal pressure during egg-laying in laying hens readily causes hepatic rupture, massive hemorrhage and even sudden death. In addition, insufficient physical activity of laying hens lowers lipid-metabolizing rates, while intestinal-microbiota dysbiosis may affect lipid absorption and metabolism. Both factors further facilitate onset and progression of FLHS via disturbing lipid metabolism and intestinal-barrier functions.

3.2. Relationship between intestinal microbiota and FLHS

As the largest microbial community of host organisms, intestinal microbiota exerts great influences over host nutrient absorption, immunomodulation and metabolic homeostasis. Studies reveal that when intestinal-microbiota dysbiosis occurs in laying hens, especially with proliferation of harmful bacteria and decline of beneficial bacteria, hepatic burdens are aggravated from multiple perspectives. For one thing, dysbiotic microbiota disrupts intestinal-mucosa barrier, rendering harmful substances such as endotoxins more liable to enter blood circulation and reach liver directly, which triggers hepatic inflammation and injury. For another, disturbed microbiota interferes with normal metabolism of nutrients. It may produce more lipogenic substances while reducing components facilitating lipid metabolism. Such dual effects jointly exacerbate hepatic fat deposition, oxidative stress and inflammatory responses, render liver more vulnerable, and accelerate and deteriorate progression from simple fatty liver to hemorrhagic syndrome ^[11]. Therefore, maintaining healthy intestinal microbiota is critical for FLHS prevention.

4. Action mechanisms of *Abrus cantoniensis* polysaccharides for alleviating hepatic steatosis in laying hens

4.1. Modulating homeostasis of intestinal microbiota

Findings from project-based researches demonstrate that *Abrus cantoniensis* polysaccharides can markedly modify intestinal-microbiota composition of FLHS-affected laying hens, raise proportions of beneficial bacteria, reduce counts of harmful bacteria, restore intestinal-barrier functions, decrease endotoxin translocation toward liver, so as to mitigate hepatic inflammation and fat deposition. High-throughput sequencing technology was adopted to successfully screen key bacterial strains sensitive to *Abrus cantoniensis* polysaccharides, and further researches were conducted to investigate roles of such strains in lipid-metabolism regulation^[12].

4.2. Exerting effects through the gut-liver axis

The “gut-liver axis” refers to bidirectional communication between intestine and liver through portal-vein system, biliary tract system and other pathways. By regulating homeostasis of intestinal microbiota, *Abrus cantoniensis* polysaccharides change categories and quantities of intestinal metabolites, and further influence hepatic lipid metabolism and inflammatory responses via the gut-liver axis^[13]. Metabolomics technology was utilized in this project to detect metabolite variations in serum and liver of FLHS laying hens before and after *Abrus cantoniensis*-polysaccharide intervention. Metabolomics analysis indicates that pathways including glycerophospholipid metabolism, arachidonic-acid metabolism and biosynthesis of unsaturated fatty acids are significantly altered in polysaccharide-treated groups^[14]. Lipogenic metabolites decrease while anti-lipogenic metabolites increase. Bile-acid metabolism modulates lipid metabolism via FXR receptors, inhibits VLDL secretion and accelerates fatty-acid oxidation.

5. Application prospects and challenges

5.1. Application prospects

Against the background of large-scale breeding of poultry and livestock, non-standard antibiotic usage brings severe drug residues in livestock products and increased organismal drug resistance. Announcement No. 194 issued by Ministry of Agriculture and Rural Affairs of China stipulates that production, import and operation of partial feed-use medicinal additives except Chinese herbal medicines shall be terminated. Since then, “antibiotic prohibition” and “antibiotic-replacement” have become hot topics in animal-husbandry industry. Among numerous antibiotic-replacement schemes, Chinese veterinary materia medica serves as the mainstay for antibiotic substitution. Polysaccharide-based immunostimulants can trigger immune responses and relieve oxidative damage, and enhance animal resistance against infectious diseases and adverse environments^[15]. As natural active ingredients with merits of safety and absence of drug resistance, *Abrus cantoniensis* polysaccharides display promising application prospects in alleviating hepatic steatosis in laying hens. In the future, *Abrus cantoniensis* polysaccharides are expected to be widely applied in laying-hen breeding as Chinese veterinary drugs or feed additives, improve productive performance and health status of laying hens, and promote sustainable development of breeding industry.

5.2. Existing challenges

Despite remarkable effects of *Abrus cantoniensis* polysaccharides on alleviating hepatic steatosis in

laying hens, its large-scale application still confronts several challenges. First, extraction and purification technologies for *Abrus cantoniensis* polysaccharides need further optimization to improve its purity and bioactivity. Second, its concrete action mechanisms have not been fully clarified, and in-depth studies on its molecular-biological mechanisms are required. Third, clinical application effects of *Abrus cantoniensis* polysaccharides need further verification to guarantee its safety and effectiveness.

6. Conclusion

This paper comprehensively reviews research advances of *Abrus cantoniensis* polysaccharides in alleviating hepatic steatosis in laying hens. *Abrus cantoniensis* polysaccharides significantly mitigate hepatic fat deposition and inflammatory responses in FLHS-affected laying hens via regulating intestinal-microbiota homeostasis, exerting functions through gut-liver axis and modulating expression of lipid-metabolism-related genes. In the future, along with further researches and technological progress, *Abrus cantoniensis* polysaccharides are expected to play vital roles in laying-hen breeding and boost green and sustainable development of animal-husbandry industry.

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Disclosure statement

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