

Antibiotic-Substituting Effect and Mechanism of Chinese Herbal Polysaccharides in Livestock and Poultry Breeding

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Abstract

Inappropriate antibiotic use in livestock and poultry breeding has caused grave issues such as drug resistance, environmental pollution and food safety concerns. As a natural bioactive polymer substance, Chinese herbal polysaccharides have been used in the traditional Chinese medicinal plants and have been found to be potential antibiotic alternatives. The purpose of this paper is to systematically review the Chinese herbal polysaccharides and their effects and mechanisms of action on substituting antibiotics in animal husbandry. Astragalus polysaccharides (APS), Lycium barbarum polysaccharides (LBP), Ganoderma lucidum polysaccharides (GLP) and Achyranthes bidentata polysaccharides (ABPS) are the major polysaccharides discussed. The mechanisms are discussed in four aspects: immunomodulation via TLR4/NF- κ B signaling pathway; regulation of the gut microbiota by increasing the abundance of beneficial bacteria and decrease the pathogens; antioxidant activity through Keap1-Nrf2/ARE pathway; anti-inflammatory activity by suppressing expression of pro-inflammatory cytokines. Experimental evidence shows that optimal supplementation of these polysaccharides significantly improves the growth performance parameters like average daily gain (ADG) and feed conversion ratio (FCR), immune organ indices, serum immunoglobulin levels and intestinal morphology. These results suggest that Chinese herbal polysaccharides are potential, safe, and renewable alternatives for the current animal production with antibiotics.

Keywords

Chinese Herbal Polysaccharides; Antibiotic Alternatives; Livestock Breeding; Immunomodulation; Gut Microbiota; Antioxidant Activity.

1. Introduction

Use of sub-therapeutic levels of antibiotics for growth promotion and disease prevention has been a regular practice in the livestock and poultry industry. However, over and long-term application of antibiotics in feed has resulted in a worldwide problem of antimicrobial resistance (AMR) that has significant implications for public health, food safety and sustainability of the environment [1]. To address such concerns, a number of countries have introduced laws to limit or prohibit use of antibiotics as growth promoters in animal production. In 2020, Chinese government officially put into practice the prohibition on the use of antibiotic growth promoters in feed, which boosts the need for effective and safe alternatives [2].

As for the various antibiotic alternatives, Chinese herbal polysaccharides have been receiving much attention because of their multi-biological activities, low toxicity, low residues and low drug resistance induction risk [1]. The polysaccharides are polymers of complex carbohydrates obtained from Chinese traditional medicine (CTM) plants including Astragalus membranaceus, Lycium barbarum, Ganoderma lucidum and Achyranthes bidentata. They

have several pharmacological activities such as anti-inflammatory, antioxidant, antimicrobial and immunomodulatory one [3].

Over the last decade, studies have shown that polysaccharide extracted from Chinese herbs has a very good substitute for antibiotics in livestock and poultry production by strengthening the immune function, regulating gut microbiota, improving intestinal barrier, and promoting nutrient absorption [4]. For example, Astragalus polysaccharides (APS) have been revealed to increase the proliferation of T and B lymphocytes, mature macrophages and activate dendritic cells via the TLR4/NF- κ B signaling pathway [5]. The Lycium barbarum polysaccharides (LBP) have been found to increase growth performance parameters, enhance digestive enzyme activities and increase the serum antioxidant capacity in broiler chickens [6].

Although there are increasing pieces of evidence that Chinese herbal polysaccharide has a potential to be an alternative to antibiotic, there are still some challenges. The first is that, because of the complexity of their composition and heterogeneity, the structure–activity relationships of these polysaccharides are not completely understood. Second, there are large differences between animal species and production stages in the optimal dosage and administration. Third, the exact molecular mechanisms of the beneficial effects of these polysaccharides need to be further studied [1].

Here, the antibiotic-replacement activities and mechanisms of Chinese herbal polysaccharides in the breeding management of livestock and poultry are reviewed. The key findings are as follows: (1) The commonly used Chinese herbal polysaccharides were systematically classified and their structural characteristics were analyzed. (2) The immunomodulatory mechanisms of polysaccharides were studied through the key signaling pathways. (3) The regulation of gut flora and antioxidant activities of polysaccharides in these herbs were discussed. (4) The growth performance of polysaccharides was compared based on the experimental results of multiple studies. This overall research framework is shown in Figure 1.

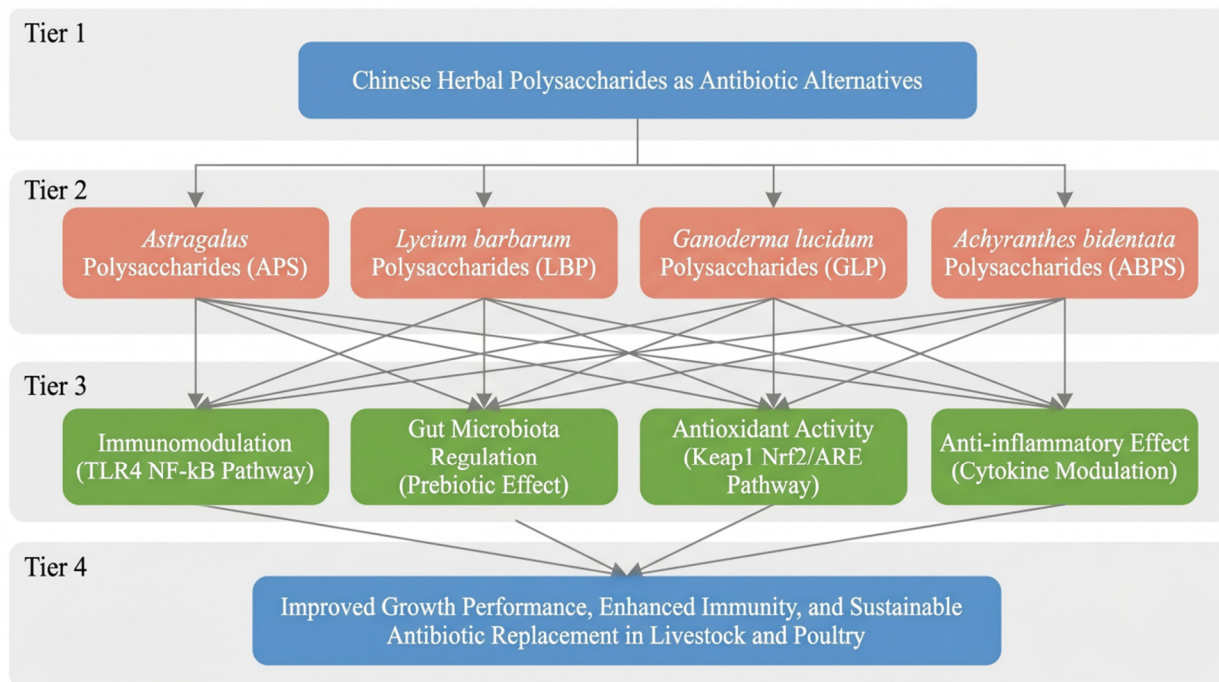


Figure 1. The whole research plan involves using Chinese herbal polysaccharides as an alternative of antibiotics in livestock and poultry breeding.

2. Methods and Results

2.1. Classification of Chinese Herbal Polysaccharides

Traditional animal husbandry polysaccharides derived from Chinese Herbs could be classified generally according to their botanical origins, structures and biological functions. Astragalus polysaccharides (APS), Lycium barbarum polysaccharides (LBP), Ganoderma lucidum polysaccharides (GLP) and Achyranthes bidentata polysaccharides (ABPS) are the four most studied polysaccharides [3]. The table below lists the major categories, sources, the main monosaccharide content, molecular weight range and important biological activity.

Table 1. Major Chinese herbal polysaccharides in terms of their classification and characteristics

Category	Source Plant	Monosaccharide Composition	Molecular Weight (kDa)	Key Activities
APS	Astragalus membranaceus	Glucose, Arabinose, Rhamnose	10 to 4000	Immunomodulation, Antiviral
LBP	Lycium barbarum	Arabinose, Galactose, Glucose	10 to 2300	Antioxidant, Immunostimulation
GLP	Ganoderma lucidum	Glucose, Mannose, Galactose	4 to 1000	Anti-inflammatory, Antitumor
ABPS	Achyranthes bidentata	Glucose, Fructose, Galactose	5 to 500	Immunostimulation, Antimicrobial

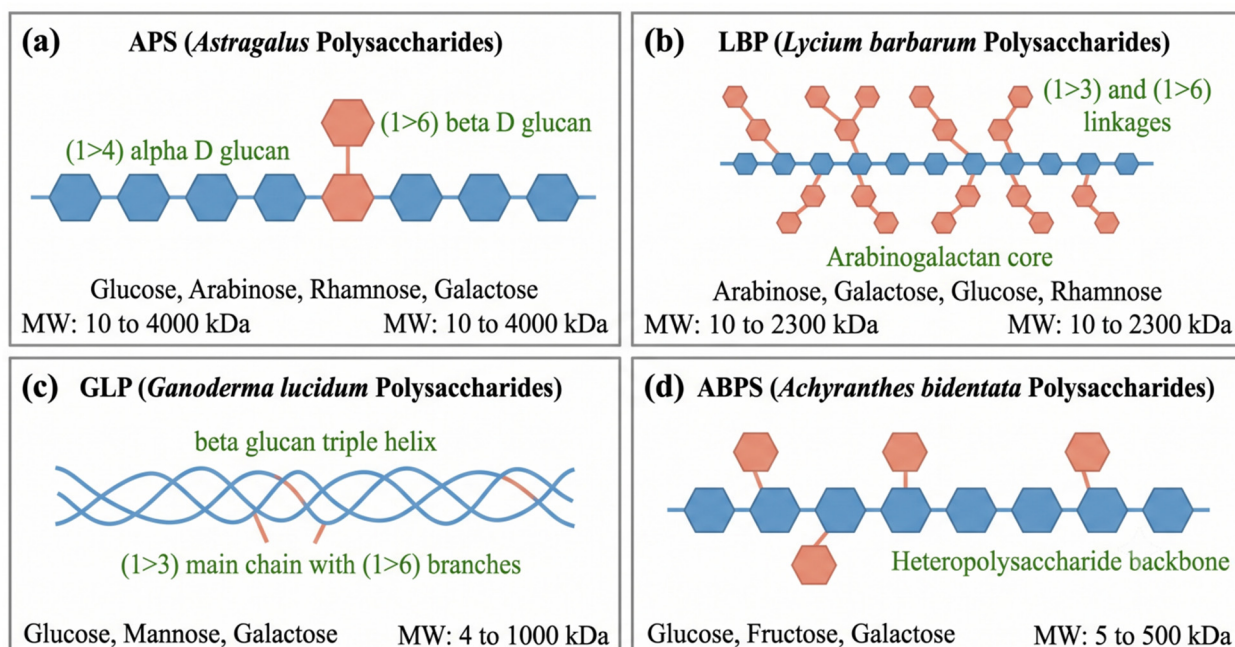


Figure 2. Four major Chinese herbal polysaccharides (APS, LBP, GLP, ABPS) are represented by their representative structural features.

APS is a heteropolysaccharide compound that is isolated from the dry root of *Astragalus membranaceus* and is water-soluble. The most common extraction techniques are hot water extraction, cold water extraction, alcohol precipitation and enzymatic extraction [3]. The

monosaccharides of APS usually consist of glucose, arabinose, galactose, glucuronic acid and rhamnose, and their molecular weight varies from 10 kDa to 4000 kDa depending on different extraction and purification procedures. The major components of the structural backbone of APS are (1, 4)-linked α -D-glucan and (1, 6)-linked β -D-glucan chains, which are branched in different ways [5].

LBP is the predominant bioactive component of *Lycium barbarum*, which is mainly composed of arabinose, galactose, glucose, rhamnose, and galacturonic acid. The polysaccharide chains are normally very branched and complicated in their glycosidic linkages [6]. GLP extracted from *G. lucidum* fruiting body mainly includes (1, 3) and (1, 6) linked β -glucans. The triple-helix conformation of GLP is in close association with its immunostimulatory activity, and the structural configuration of GLP is closely related to this activity [7]. These polysaccharides have a variety of biological roles in animal production, depending on their structure. The representative structural features of these 4 types of polysaccharides are shown in Figure 2.

2.2. Immunomodulatory Mechanisms

The immunomodulatory effect is believed to be the most important when it comes to the action of Chinese herbal polysaccharides as an alternative to antibiotics in livestock and poultry breeding. These polysaccharides have been shown to stimulate both innate and adaptive immune responses via a number of signaling pathways, the most well studied being the Toll-like receptor 4 (TLR4)/nuclear factor kappa B (NF- κ B) pathway [3][8].

Chinese herbal polysaccharides are able to enter the gastrointestinal tract (GI) where they can be detected by pattern recognition receptors (PRRs) on the surface of the immune cells, especially macrophages and dendritic cells (DCs). APS is known to interact with TLR4 and be able to induce the downstream MyD88-dependent signaling pathway, resulting in phosphorylation and nuclear translocation of NF- κ B p65 subunit [5]. This activation leads to the transcription of immune-related genes, including those for cytokines like interleukin-2 (IL-2), interleukin-6 (IL-6), tumor necrosis factor alpha (TNF- α) and interferons (IFNs). The cascade stimulates the proliferation and differentiation of T lymphocytes, B lymphocytes and natural killer (NK) cells and increases the general immune defense of the host animal [8].

The relative immune organ index (RIOI) is the index usually used to quantify the immunomodulatory effect. The RIOI of immune organs like spleen, thymus and bursa of Fabricius are calculated as follows:

$$RIOI = \frac{W_{organ}}{W_{body}} \times 100 \quad (1)$$

where W_{organ} is the weight of immune organ (in grams) and W_{body} is the body weight of animal (in grams). The higher the RIOI value the better the development and function of the immune organ.

Table 2. Relative Immune Organ Index (mg/g) of Broiler under different treatment.

Treatment Group	Dosage (mg/kg)	Spleen RIOI	Thymus RIOI	Bursa RIOI
Control	0	1.12 $\pm$ 0.08	2.34 $\pm$ 0.15	1.89 $\pm$ 0.12
Antibiotic	50	1.28 $\pm$ 0.10	2.51 $\pm$ 0.18	2.05 $\pm$ 0.14
APS	200	1.45 $\pm$ 0.11	2.89 $\pm$ 0.20	2.38 $\pm$ 0.16
LBP	2000	1.38 $\pm$ 0.09	2.76 $\pm$ 0.17	2.25 $\pm$ 0.13
GLP	500	1.35 $\pm$ 0.10	2.68 $\pm$ 0.19	2.18 $\pm$ 0.15

For the assessment of the effects of various types of polysaccharides and doses on immune organ development, the data obtained from various studies were compiled and analyzed. The RIOI values of broiler chicken spleen, thymus and bursa of Fabricius given different Chinese herbal polysaccharides as compared to the control and the antibiotic supplemented groups are shown in Table 2.

Table 2 shows that significantly better RIOI values were obtained in all the polysaccharide groups compared to the control group, and the RIOI value of the APS group at 200 mg/kg was the most improved in all three immune organs. Notably, it was found that polysaccharide-supplemented groups have exhibited better immune organ development than the antibiotic group, indicating that Chinese herbal polysaccharides might have a better immunostimulatory effect than traditional antibiotics [8].

Key immune mediators mRNA expression was quantified by real-time quantitative PCR and relative mRNA expression calculated by comparative threshold cycle method as depicted in equation (2):

$$\text{Relative expression} = 2^{-\Delta\Delta C_t} \quad (2)$$

where $\Delta\Delta C_t$ is the difference in C_t (threshold cycle) of the target gene and the reference gene normalized to the control group. This approach allows accurate quantification of the changes in gene expression of immune-related genes in response to polysaccharide supplementation [9]. The signaling pathway diagram of the immunomodulatory mechanism of Chinese herbal polysaccharides by the TLR4/NF- κ B pathway is shown in Figure 3.

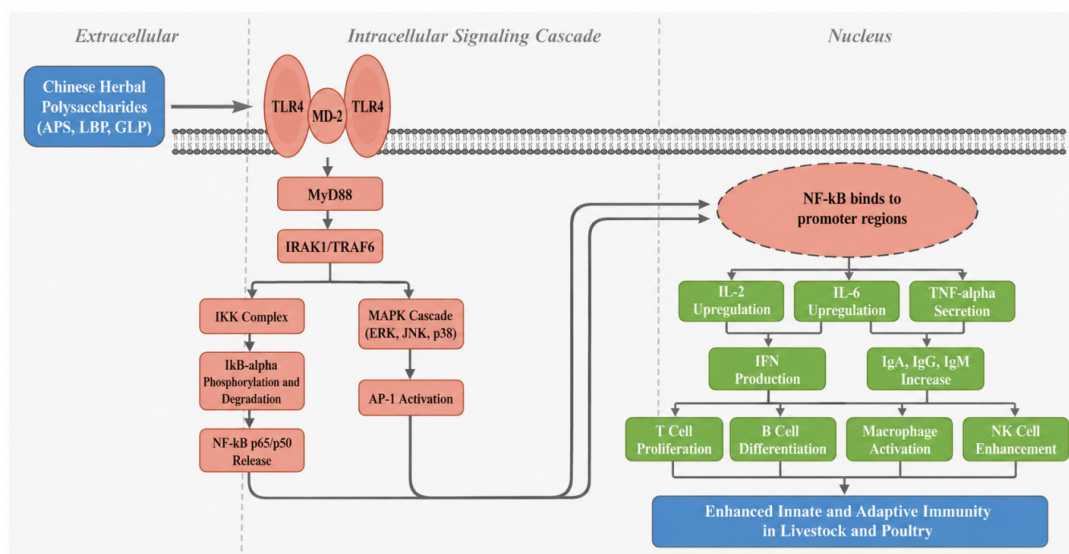


Figure 3. Chinese Herbal Polysaccharides Modulate Immune Response through TLR4/NF- κ B Pathway.

2.3. Regulation of Gut Microbiota

In livestock and poultry gut microbiota is important for intestinal health, nutrient metabolism, and immune homeostasis. Chinese herbal polysaccharides are complex carbohydrates that are not digestible by the endogenous enzymes in the upper gastrointestinal tract that can reach the hindgut without being broken down and act as a substrate for fermentation by beneficial bacteria, similar to prebiotics [3][11].

APS has been shown to boost the numbers of beneficial bacterial genera like *Lactobacillus*, *Bifidobacterium* and *Bacteroides* in the cecum of broiler chickens and as a result, it has been proven to decrease the numbers of pathogens like *Clostridium perfringens*, *Escherichia coli* and *Salmonella* [3][8]. Polysaccharides are broken down by beneficial bacteria to produce

short-chain fatty acids (SCFAs) such as acetate, propionate and butyrate, which are important energy sources for intestinal epithelial cells and help to maintain integrity of the gut barrier [11]. Importantly, other bioactive feed additives, including resveratrol, have also been found to maintain the intestinal morphology, microflora balance and barrier function in broilers under stress conditions [10] which further strengthens the idea of replacing antibiotics with natural feed additives.

The diversity and richness of the microbial community in the gut can be commonly assessed by the Shannon diversity index and is calculated from Equation (3):

$$H' = - \sum_{i=1}^S (p_i \times \ln p_i) \quad (3)$$

where S is the number of microbial species that were observed and p_i is the relative abundance (proportion) of microbial species i. The higher the Shannon index value also represent the microbial diversity that is generally correlated with better gut health and disease resistance [11].

Table 3 presents the modifications of gut microbiota composition and diversity in broiler chickens after different Chinese herbal polysaccharides supplementation. For every treatment group, the Shannon diversity index, the relative abundance of *Lactobacillus* and the numbers of *E. coli* are shown.

Table 3. Chinese Herbals Polysaccharides on Broilers gut Microbiota.

Treatment	Shannon Index	<i>Lactobacillus</i> (%)	<i>E. coli</i> (log CFU/g)	<i>Bifidobacterium</i> (%)
Control	3.21 ± 0.18	12.5 ± 1.8	6.82 ± 0.35	8.3 ± 1.2
Antibiotic	2.89 ± 0.22	15.8 ± 2.1	5.94 ± 0.28	10.1 ± 1.5
APS (200 mg/kg)	3.85 ± 0.20	22.4 ± 2.5	5.21 ± 0.31	15.6 ± 1.8
LBP (2000 mg/kg)	3.72 ± 0.19	20.1 ± 2.3	5.38 ± 0.29	14.2 ± 1.6
GLP (500 mg/kg)	3.68 ± 0.21	19.3 ± 2.0	5.45 ± 0.33	13.8 ± 1.7

Table 3 shows that the three polysaccharide treatment groups had significantly higher values of Shannon diversity index than the control and antibiotic groups. Interestingly, the antibiotic group had a lower Shannon index (2.89) than the control (3.21), which means that the antibiotic supplementation might have the opposite effect and reduce the microbial diversity. The APS group, on the other hand, had the highest Shannon index (3.85), which indicated that APS is really good at promoting the diversity of microbes in the gut [3].

The polysaccharide-supplemented groups also demonstrated significantly increased relative abundances of beneficial *Lactobacillus* and *Bifidobacterium* and significantly decreased abundances of *E. coli* when compared to the control and antibiotic groups. These results contribute to the prebiotic-like role of Chinese herbal polysaccharides in selectively promoting the growth of beneficial microorganisms and inhibiting pathogenic microorganisms [11]. The comparative composition of gut microbiota of the different treatment groups is shown in Figure 4.

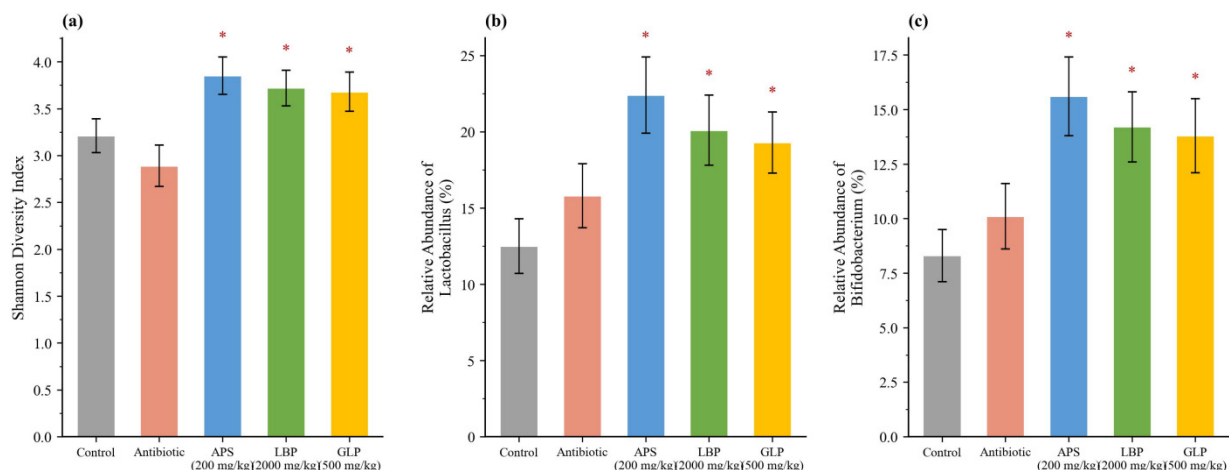


Figure 4. The composition of the gut microbiota in the different treatment groups in broiler chickens were compared.

2.4. Antioxidant and Anti-inflammatory Activities

The production of reactive oxygen species (ROS) and its imbalance with antioxidant defense mechanisms is a major cause of poor growth performance, immunosuppression and susceptibility to diseases in livestock and poultry. The Nrf2 signaling pathway has been proven to be a key pathway of cellular response to oxidative stress in poultry, as evidenced by the cold stress induced activation of the pathway in chicken [12]. Chinese herbal polysaccharides can activate the Keap1-Nrf2/ARE signaling pathway, which plays a part in the improvement of the endogenous antioxidant defense system [3][13].

Nrf2 is normally kept in the cytoplasm by the transcription factor Keap1, and degraded by the proteasome via ubiquitination. The polysaccharides help to dissociate Nrf2 from Keap1 and allow for Nrf2 to translocate to the nucleus, where it binds to the antioxidant response element (ARE) in the promoter regions of genes encoding antioxidant enzymes, which occurs when cells are exposed to oxidative stress. The activation leads to the upregulation of the expression of superoxide dismutase (SOD), glutathione peroxidase (GSH-Px) and catalase (CAT) as well as to the downregulation of malondialdehyde (MDA), a marker of lipid peroxidation [13].

The spectrophotometric measurement of the antioxidant enzyme activity of SOD is performed, based on Equation (4):

$$SOD = \frac{A_{control} - A_{sample}}{A_{control} \times V \times 0.5} \times T \quad (4)$$

$A_{control}$ and A_{sample} are the absorbance of the control and sample groups, V is the volume of the reaction system (mL) and T is the dilution factor. The SOD activity is expressed as units per milligram of protein (U/mg prot).

The anti-inflammatory effects of polysaccharides from Chinese herbs are mainly due to the inhibitory effects on the NF-kappaB signaling pathway. The polysaccharides, when they modulate the immune response, suppress phosphorylation of inhibitor of kappa B alpha (I κ B- α) and thus the nuclear translocation of NF- κ B and the transcription of pro-inflammatory cytokines like TNF- α , IL-1 β and IL-6 [3]. This simultaneous antioxidant effect and anti-inflammatory effect are an important reason why Chinese herbal polysaccharides are better than conventional antibiotics.

The antioxidant parameters of the serum of broiler chickens from different dietary treatments are shown in Table 4. The results showed that the antioxidant capacity was improved in a dose-dependent manner by adding polysaccharide.

Table 4. 42 day old broiler serum antioxidant parameters are determined between different treatment groups.

Treatment	SOD (U/mL)	GSH-Px (U/mL)	CAT (U/mL)	T-AOC (U/mL)	MDA (nmol/mL)
Control	89.2 ± 5.3	312.5 ± 18.4	4.52 ± 0.38	8.15 ± 0.62	5.87 ± 0.41
Antibiotic	95.8 ± 6.1	338.7 ± 20.2	4.89 ± 0.42	8.92 ± 0.58	5.12 ± 0.38
APS 200	112.4 ± 7.2	398.6 ± 22.5	5.78 ± 0.45	10.85 ± 0.71	3.95 ± 0.32
LBP 2000	108.6 ± 6.8	385.2 ± 21.3	5.56 ± 0.40	10.42 ± 0.65	4.18 ± 0.35
GLP 500	105.3 ± 6.5	372.8 ± 19.8	5.38 ± 0.43	10.15 ± 0.68	4.35 ± 0.37

All polysaccharide-supplemented groups significantly increased SOD, GSH-Px, CAT and total antioxidant capacity (T-AOC) and decreased MDA levels as shown in Table 4 compared to the control and antibiotic groups. The APS group showed the most significant antioxidant changes, as indicated by the increased SOD activity by 26.0% and the increased GSH-Px by 27.6% and the decreased MDA by 32.7% compared with the control group [13]. The mechanism of antioxidant and anti-inflammatory actions of Chinese herbal polysaccharides is shown in Figure 5.

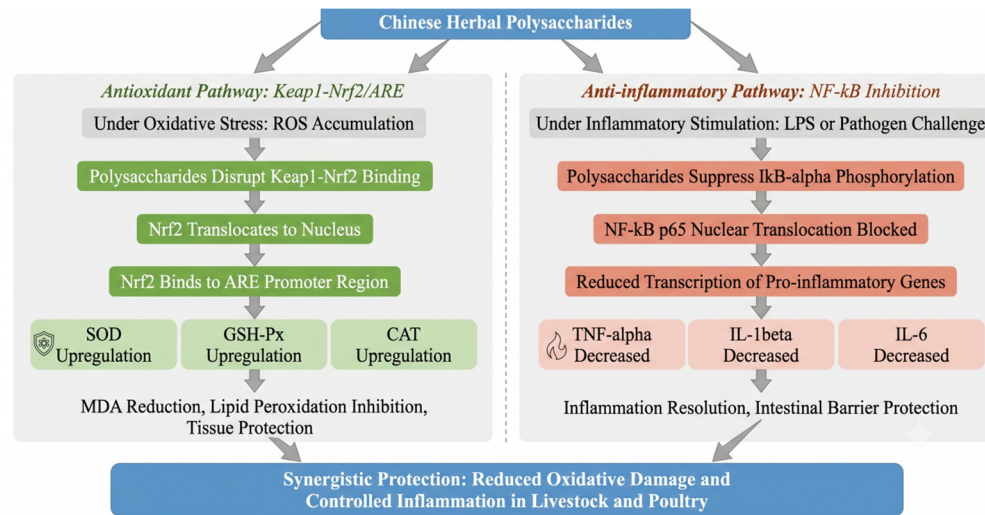


Figure 5. Mechanism of Antioxidant and Anti-inflammatory Activities of Chinese Herbal Polysaccharides through Keap1-Nrf2/ARE and NF-kB Pathway

2.5. Effects on Growth Performance

The best measure of the practical effectiveness of antibiotic alternatives in livestock and poultry production is growth performance. The average daily gain (ADG), average daily feed intake (ADFI), and feed conversion ratio (FCR) are the key parameters. The ADG and FCR are computed as per Equations (5) and (6):

$$ADG = \frac{W_f - W_i}{D} \quad (5)$$

$$FCR = \frac{F}{G} \quad (6)$$

where W_f and W_i are the final and initial body weights (in grams), D is the number of experimental days, F is the total feed intake (in grams) and G is the total weight gain (in grams). A higher ADG and a lower FCR would show better growth performance, and efficiency of feed utilization [6].

The growth performance parameters of broiler chickens fed at different Chinese herbal polysaccharides for 42 days are summarized in Table 5. Data from various experiment studies is collected together for comparison.

Table 5. Growth Performance of Broilers Fed Different Dietary Treatment (1–42 days)

Treatment	Initial BW (g)	Final BW (g)	ADG (g/d)	ADFI (g/d)	FCR
Control	42.3 ± 1.2	2185 ± 85	51.02 ± 2.01	98.5 ± 3.8	1.93 ± 0.05
Antibiotic	42.5 ± 1.1	2356 ± 78	55.08 ± 1.86	101.2 ± 3.5	1.84 ± 0.04
APS 200	42.1 ± 1.3	2412 ± 82	56.43 ± 1.95	100.8 ± 3.6	1.79 ± 0.04
LBP 2000	42.4 ± 1.2	2378 ± 79	55.61 ± 1.88	99.5 ± 3.4	1.79 ± 0.05
GLP 500	42.2 ± 1.1	2345 ± 81	54.83 ± 1.92	99.8 ± 3.7	1.82 ± 0.04
ABPS 300	42.3 ± 1.2	2332 ± 80	54.52 ± 1.90	100.1 ± 3.5	1.84 ± 0.05

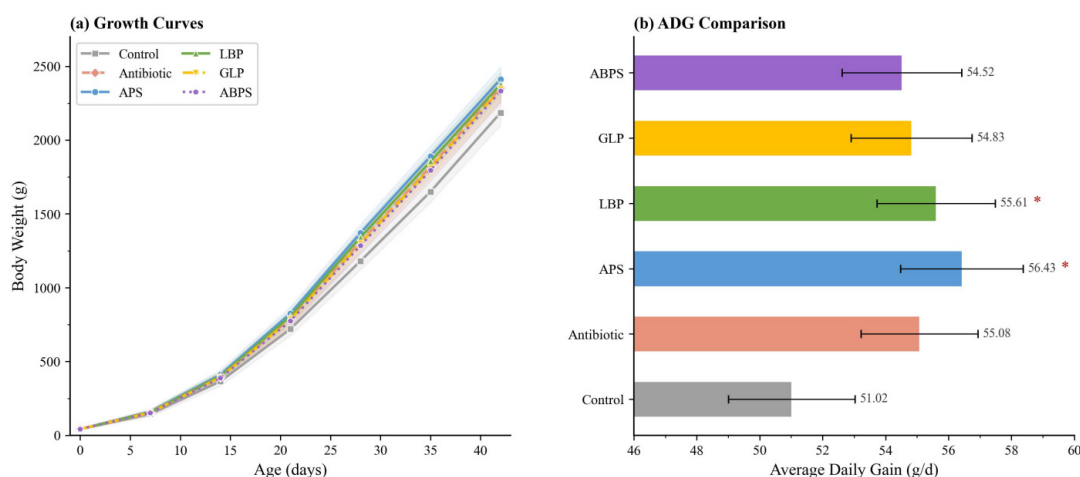


Figure 6. The Comparative growth Curves of Broilers in different treatment groups for 42 days.

All the polysaccharide supplemented groups had enhanced growth performance as compared to the control as shown in Table 5. The APS group had the highest final weight (2412 g) and had the highest ADG (56.43 g/d) which was 10.6% higher than the control. The LBP group had a similar performance and ADG of 55.61 g/d. Interestingly, FCR of the APS and LBP groups was 1.79, which was lower than the antibiotic group (1.84), suggesting that these polysaccharides can be equal or better in growth promoting effect over the conventional antibiotics [4][6].

The growth performance improvement is the result of several synergistic effects. Chinese herbal polysaccharides are able to increase the villus height in the small intestine, as well as the villus height/crypt depth ratio (VH/CD ratio), so as to achieve the effect of increasing small intestinal absorption area [8]. These also enhance digestive enzymes such as amylase, protease and lipase, which facilitates better digestion and absorption of nutrients [6]. Additionally, the immunomodulatory and antioxidant activity decreases the metabolic burden of immune activation and oxidative stress, leading to a greater allocation of nutrients to growth instead of immune protection [6][13]. The comparative growth curves of broilers of the different treatment groups are shown in Figure 6.

2.6. Comparative Analysis and Experimental Evidence

In this paper, we further reviewed the literature for related studies to conduct comparative analysis of the in vitro antimicrobial activities of various types of polysaccharides from Chinese herbs against commonly occurring pathogens in livestock. The inhibition rate (IR) was determined from the following equation:

$$IR = \frac{OD_c - OD_t}{OD_c} \times 100\% \quad (7)$$

OD_c is the optical density of the control group (without polysaccharide) and OD_t is the optical density of the treatment group (with polysaccharide) at 600 nm using the microplate reader. The inhibition rates of four Chinese herbal polysaccharides on three main livestock pathogens at 5 mg/mL are shown in Table 6.

Table 6. The results of In Vitro Inhibition Rates (%) of Chinese Herbal Polysaccharides against Livestock Pathogens are presented.

Polysaccharide (5 mg/mL)	E. coli	S. aureus	C. perfringens
APS	38.5 ± 3.2	42.1 ± 2.8	35.7 ± 3.5
LBP	35.2 ± 2.9	38.6 ± 3.1	32.4 ± 3.0
GLP	41.8 ± 3.5	45.3 ± 3.3	37.2 ± 3.2
ABPS	33.6 ± 2.7	36.8 ± 2.9	30.5 ± 2.8

Table 6 showed that all four polysaccharides exhibited moderate antimicrobial activity against the pathogens tested. GLP showed the most inhibitory activity against all three pathogens, the most inhibition rate was 45.3% against *Staphylococcus aureus*. APS demonstrated the second highest activity with greatest activity against *S. aureus* (42.1%) and *E. coli* (38.5%). Although these inhibition rates are not as high as those of conventional antibiotics at therapeutic concentrations, the possible mechanism for polysaccharides is that the antimicrobial effect in vivo is significantly increased by the immunostimulatory and prebiotic activities of polysaccharides, which, together, increase the ability of the host to resist colonization of the pathogen [1][3].

A detailed summary of overall effects of Chinese herbal polysaccharide supplementation vs antibiotic supplementation in broiler chickens is shown in Table 7 with regard to various performance and health parameters.

From the results presented in Table 7, it is obvious that the supplementation of Chinese herbal polysaccharide (APS and LBP) is superior to antibiotic supplementation with respect to almost all the health and production parameters. The most significant difference is seen in the development of immune organs (APS: 29.5% vs. antibiotic: 14.3% improvement in spleen RIOI), antioxidant capacity (APS: 26.0% vs. antibiotic: 7.4% increase in SOD) and the diversity of gut microbiota (APS: 19.9% vs. antibiotic: -10.0% increase in Shannon index). These results indicate that the Chinese herbal polysaccharides are potential good antibiotic alternatives in the animal and poultry industries [1][6][13].

Table 7. These comprehensive comparisons of the effects of polysaccharide and antibiotic supplementation indicate a relative improvement over control (%) for each of the evaluated traits.

Parameter	Antibiotic Group	APS Group	LBP Group
ADG Improvement	7.9	10.6	9.0
FCR Reduction	4.7	7.3	7.3
Spleen RIOI Increase	14.3	29.5	23.2
SOD Activity Increase	7.4	26.0	21.7
MDA Reduction	12.8	32.7	28.8
Shannon Index Change	Decrease 10.0	Increase 19.9	Increase 15.9
E. coli Reduction	12.9	23.6	21.1

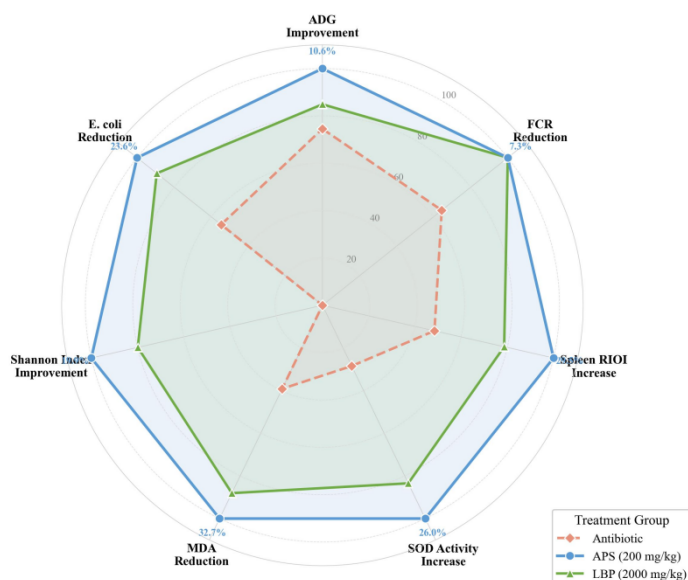


Figure 7. Radar Chart – Multidimensional comparison between the effects of Polysaccharide and Antibiotic supplementation in broilers.

3. Conclusion

The aim of this paper is to systematically review the Chinese herbal polysaccharides that have antibiotic-substituting effect and mechanism in livestock and poultry breeding. The evidence shows that the beneficial effects of these polysaccharides are supported by several mechanisms that work synergistically such as; immunomodulation via TLR4/NF- κ B signaling pathway, selective promotion of beneficial gut microbiota as prebiotics, endogenously increased antioxidant defense via the Keap1-Nrf2/ARE pathway, and reduced excessive inflammatory responses. Experimental results showed that at 200 mg/kg the supplementation of APS resulted in a 29.5% increase of RIOI, 19.9% increase of Shannon diversity index, 10.6% improvement of ADG and a reduction of FCR by 7.3%, a performance similar or superior to conventional antibiotic supplementation in all the measured parameters. However, current issues involve the standardization of extraction and QCs because of the structural heterogeneity of these polysaccharides, and optimal dosages and administration methods as well as interactions with other feed additives with other animal

species need to be systematically investigated by large scale field trials under commercial production conditions.

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