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Effects of polysaccharide of *Atractylodes macrocephala* Koidz combined with microecological preparations on growth performance and serum hormone levels of pigs

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Abstract

This study investigates the effects of varying concentrations of polysaccharide from *Atractylodes macrocephala* Koidz and microecological preparations on the growth performance and serum hormone levels of weaned piglets. A total of 120 piglets, averaging 7 kg, were randomly assigned to five groups over a 148-day trial, including a control group, an antibiotic group, and three experimental groups with different dietary enhancements. Results indicated that the experimental groups exhibited significantly improved average daily gain and feed-to-meat ratios, particularly in the group receiving both microecological preparations and polysaccharide ($p < 0.05$). Serum analyses revealed increased levels of hormones and proteins, with significant rises in IGF-1, total protein, and globulin content ($p < 0.05$), while triglycerides and cholesterol levels decreased significantly in the combined treatment group ($p < 0.05$). These findings suggest that incorporating polysaccharide from *Atractylodes macrocephala* and microecological preparations into piglet diets enhances growth performance and positively affects serum biochemical indicators, with the most beneficial effects observed in the combined treatment group.

Keywords: Polysaccharide of *Atractylodes macrocephala* Koidz, Microecological preparations, Growth performance, Serological indicators

1. Introduction

There is growing concern about the potential threat to human health and the environment posed by the misuse of antibiotics in livestock and poultry farming. Compared with antibiotics, the use of plant polysaccharides and microecological preparations in livestock and poultry is safer, does not cause resistance problems, and does not have a negative impact on the environment, and the combined use of the two is currently receiving attention. However, due to a variety of reasons, the application effect of microecological preparations is not stable. *Atractylodes macrocephala* Koidz polysaccharide is an extract from the roots and stems of Compositae. Due to the complexity of the active components in the plant, the effect is not stable enough. Therefore, the study of the synergistic effect of microecological preparation and polysaccharide is the key to achieve the microecological balance and realize the wide application of both.

At present, many research results support that the combined application of plant polysaccharides and microecological preparations can promote animal growth, improve animal immunity, and improve animal hormone levels. Wu Liyang^[5] found that the combined application of achyranoba polysaccharide and microecological preparations could promote the growth of pigs, and improve the immunity and hormone levels of pigs. Yang Yuanyou *et al.* and Zhang Xi *et al.*^[6, 7] showed that the combined application of astragalus polysaccharide and complex probiotics could improve the survival rate of nurseries pigs, promote the growth of pigs, enhance the immune system and improve intestinal health. Wang Hongling *et al.*^[8] found that the combined application of 0.2% compound microecological preparation and 2.5% astragalus polysaccharide could enhance the growth performance of broilers, significantly increase the average daily gain, reduce the ratio of feed to gain, improve the structure of intestinal flora and enhance the immunity of broilers.

Yang Ying *et al.* [9] showed that Yupingfeng polysaccharide compound microecological preparation could promote the growth and development of grass carp and improve the intestinal microbial balance of grass carp. These cases provided theoretical support for the combined use of polysaccharides and microecological preparations of *Atractylodes macrocephala* Koidz. The purpose of this experiment was to study the effects of polysaccharide of *Atractylodes macrocephala* Koidz, microecological preparation and their combined use as "green feed additives" added to the basic diet of pigs, paying attention to the feeding effects of pigs at different physiological stages, and exploring the effects of these additives on growth performance and serum hormone, physiological and biochemical levels of pigs during growth and fattening period. In order to provide a theoretical basis for widely used in pig production. In addition, the long-term use of these additives in the healthy breeding of pigs as green, healthy and effective growth promoters for livestock and poultry has important market practical significance and broad market prospects.

2. Materials and Methods

2.1 Test materials

The microecological preparation is provided by Jinseifu (Beijing) Biotechnology Co., LTD. It contains *Bacillus subtilis* producing antimicrobial peptide, and the total number of viable bacteria per gram reaches or exceeds 1.0×10^8 cfu. The polysaccharide of *Atractylodes macrocephala* Koidz was supplied by Shaanxi Senyuan Biotechnology Co., LTD., and the polysaccharide content was 30%.

2.2. Experimental design

A total of 120 weaned piglets with good health and body weight of (7 ± 0.46) kg were selected as the study subjects and randomly divided into 5 groups with 4 replicates in each group and 6 pigs in each replicate. The experimental diets were basal diet group (basal diet); Antibiotic supplementation group (basal diet +100 mg antibiotic); Trial group 1 (basal diet +0.1% microecological preparations +5.0% polysaccharide of *Atractylodes macrocephala* Koidz); Experiment group 2 (basal diet +5.0% polysaccharide of *Atractylodes macrocephala* Koidz); Experimental group 3 (basal diet +0.1% microecological preparation). The experimental design was shown in Table 1.

Table 1: Experimental design

Handling	Description
Base diet group	Include only base diets
Antibiotic group	Base diet + 100 mg aureomycin
Trial Group 1	Base diet + 5.0% polysaccharide of <i>Atractylodes macrocephala</i> Koidz + 0.1% microecological preparation
Trial Group 2	Basal diet + 5.0% polysaccharide of <i>Atractylodes macrocephala</i> Koidz
Trial Group 3	Basal diet + 0.1% microecological preparation

The experiment was divided into 3 stages, during which the experiment was conducted according to daily feeding management, and the experiment was divided into 3 stages according to pig weight, including nursing stage, growth stage and fattening stage. The pre-test lasted for 6 days and the formal experiment lasted for 148 days. The corresponding basal diets were shown in Table 2.

Table 2: Formula and nutrient level of experimental diet

Ingredients /%	Nursery stage	Growth stage	Fattening stage
Corn	39.3	67	70.5
Puffed corn	25	-	-
Bran	-	4.7	7
Soybean meal	29	23.8	18
Soybean oil	2	1	1
calcium hydrogen phosphate	1.5	1	0.9
Calcium carbonate	0.8	1	1.2
Salt	0.3	0.4	0.4
Mildew repellent	0.1	0.1	-
Premix	2.00 *	1.00 **	1.00 ***
Total	100	100	100
Digestive energy/(MJ/Kg)	4	13.72	13.61
Crude protein%	17.5	16.1	14.22
Lysine%	1.14	0.91	0.69
Calcium%	0.75	0.7	0.74
Phosphorus%	0.6	0.54	0.52

Note:

- Premix is provided for each kg of full price feed: VA 5000IU, VD₃ 1600 IU, VE 60IU, VK₃ 3.12 mg, VB₁ 1.87 mg, riboflavin VB₂ 8 mg, VB₆ 5 mg, VB₁₂ 0.025 mg, niacin 50 mg, calcium pantothenate 13 mg, folate 0.62 mg, biotin 0.4 mg, VC 100mg, choline chloride 500 mg, Fe 120 mg, Cu 15 mg, Zn 100mg, Mn 50 mg, I 0.25 mg, Se 0.15 mg, Co 0.1 mg
- Premix is provided for each kg of full price feed: VA 3750 IU, VD₃ 1200 IU, VE 60 IU, VK₃ 2.2 mg, VB₁₂ 17.6ug, riboflavin 8 mg, niacin 20.3 mg, pantothenic acid 6.8 mg, choline chloride 351 mg, Fe 80 mg, Cu 10 mg, Zn 80 mg, Mn 30 mg, Cu 10 mg.
- Premix for each kg of full price material: VA 2500 IU, VD₃ 1200 IU, VE 60 IU, VK₃ 1.5 mg, VB₁₂ 27.6ug, riboflavin 8 mg, niacin 30.3 mg, pantothenic acid 13.8 mg, choline chlorid 551mg, Fe 80 mg, Cu 10 mg, Zn 80 mg, Mn 30 mg, Cu 10 mg, I 0.3 mg, Se 0.3 mg.
- Nutrient levels were calculated.

2.3 Determination indexes and methods

2.3.1 Determination of production performance

During the test, each test pig was weighed on an empty stomach every day, and the feed amount and remaining amount were recorded daily.

Average daily feed intake = total feed consumption per pig/test days
 Average daily gain = (final weight of test pig-initial weight of test pig)/test days;
 Feed to meat ratio = average daily feed intake/average daily gain.

2.3.2 Determination of serum hormone levels

The day before the end of the experiment, the subjects were stopped from providing food and fasting for 12h. In each replicate, 2 pigs were randomly selected to collect blood from the anterior vena cava, and the supernatant (serum) obtained after centrifugation was placed in the centrifuge tube, the group and date were marked, and the serum was stored in the refrigerator at -20°C. The contents of growth hormone (GH), insulin (INS), insulin growth factor (IGF-I) and thyroid hormone (T₄) in the serum of the experimental pigs were detected by ELISA kit, and the operation was carried out according to the instruction manual.

2.3.3 Determination of serum biochemical indexes

MindraysBS-420 automatic biochemical analyzer was used to analyze the serum samples of experimental pigs to determine the contents of total protein (TP), albumin (ALB), globulin (GLB), albumin/globulin ratio (A/G), immunoglobulin IgG, IgM, total cholesterol (TC) and triglyceride (TG). The kit was derived from Zhongsheng North Holding Co., LTD., and the operation procedure followed the instruction manual.

2.4 Data processing and analysis

The experimental data were sorted by Excel software, one-way ANOVA was performed by SPSS 26.0, and multiple comparisons were performed by Duncans. The results were

presented in the form of mean plus or minus standard deviation. When the P-value of the result was less than 0.05, the difference was significant. When the result P-value is greater than 0.05, it means that the difference is not significant.

3. Results and Analysis

3.1 Effects of different treatment groups on daily gain of pigs

According to the data in Table 3, we can draw the following conclusion: During the nursing phase, the average daily gain level of trial Groups 1, 2 and 3 was increased compared with that of the base diet group. In the growth stage, the daily gain in trial group 1 was significantly higher than that in the basal diet group ($p < 0.05$), and higher than that in the antibiotic group ($p > 0.05$). Compared with the basal diet group, the daily gain of trial groups 2 and 3 had a tendency to increase ($p > 0.05$). At fattening stage, the average daily gain of trial groups 1, 2 and 3 was higher than that of basal diet group, and the daily gain of trial group 1 was higher than that of antibiotic group. In the whole feeding stage, the average daily gain of trial groups 1, 2 and 3 was higher than that of basal diet group, and there was no significant difference compared with antibiotic group ($p > 0.05$). The daily gain level of trial group 1 was higher than that of antibiotic group and trial groups 2 and 3, and the data performance was the best.

Table 3: Effects of different treatment groups on growth performance of pigs

Project	Basal diet group	Antibiotic group	Experiment Group 1	Experiment Group 2	Experiment Group 3
Nursing stage					
Initial weight/kg	7.25±1.46	7.26±1.54	7.21±1.48	7.23±1.52	7.27±1.44
Daily weight gain/g	267.22±22.33	315.05±35.56	305.82±46.5	286.61±24.89	282.33±38.45
Feed-to-Gain Ratio F/G	2.91±0.13 ^b	2.49±0.08 ^a	2.53±0.26 ^{ab}	2.63±0.12 ^{ab}	2.59±0.18 ^{ab}
Growth stage					
Initial weight/kg	29.32±3.85	31.85±2.03	30.98±3.98	29.87±3.21	30.35±3.42
Daily weight gain/g	475.75±40.31 ^a	565.35±35.27 ^{ab}	589.56±24.97 ^b	511.83±48.42 ^{ab}	553.26±32.96 ^{ab}
Feed-to-Gain Ratio F/G	3.92±0.05	3.31±0.01	3.27±0.02	3.34±0.13	3.30±0.08
Fattening stage					
Initial weight/kg	50.77±7.19	57.85±4.88	57.12±7.48	53.24±6.50	56.45±3.33
Daily weight gain/g	572.55±47.04	603.89±22.73	623.78±53.1	602.98±46.50	608.76±66.58
Feed-to-Gain Ratio F/G	4.61±0.06	4.44±0.08	3.54±0.10	4.35±0.02	4.25±0.03
The entire feeding period					
Initial weight/kg	7.25±1.46	7.26±1.54	7.21±1.48	7.23±1.52	7.27±1.44
Final weight/kg	87.89±9.18	94.56±4.62	96.87±10.01	90.28±6.36	93.89±2.70
Daily weight gain /g	403.85±65.25	436.35±34.28	448.08±70.3	415.11±45.70	433.35±46.82
Feed-to-Gain Ratio F/G	3.91±0.10	3.54±0.12	3.22±0.05	3.52±0.11	3.45±0.15

Note: In peer data, the same lowercase letters or no letters in shoulder label indicate no significant difference ($p > 0.05$), while completely different lowercase letters indicate significant difference ($p < 0.05$).

3.2 Effects of different treatment groups on feed/meat ratio of pigs

Table 3 shows that in the three stages of nursing, growth and fattening, the ratio of feed to meat in test groups 1, 2 and 3 is lower than that in the basal diet group; in the growth and fattening stage, the ratio of feed to meat in test groups 1 and 3 is lower than that in the antibiotic group. Among the three groups of the experiment, the ratio of feed to meat in test group 1 was lower than that in test group 2 and 3 at different stages. In the whole experimental stage, the feed to meat ratio of trial group 1 was decreased by 17.64% compared with the basal diet group and 9.03% compared with the antibiotic group, and the data performance was the best.

3.3 Effects of different treatment groups on blood hormone levels of fattening pigs

In this study, we compared the serum levels of four hormones (thyroid hormone T₄, insulin INS, insulin-like growth factor IGF-1, growth hormone GH) in each group. The data results in Table 4 showed that compared with the basal diet group at the fattening stage, the serum contents of four hormones in trial groups 1, 2 and 3 showed an increasing trend, and the IGF-1 content in group 1 was significantly increased ($p < 0.05$). The serum IGF-1 content in trial group 1 was higher than that in antibiotic group, but the difference was not significant ($p > 0.05$). Further analysis of the three experimental groups showed that the serum IGF-1 content in trial group 1 was significantly higher than that in trial group 2 ($p < 0.05$), but there was no significant difference between trial group 1 and trial group 3 ($p > 0.05$), and there was no significant difference in INS, T₄ and GH contents ($p > 0.05$).

Table 4: Relationship between serum hormone levels in different treatment groups and finishing pigs

Items	Base diet group	Antibiotic group	Trial Group 1	Trial Group 2	Trial Group 3
Thyroid hormone T ₄ (pmol/l)	171.52±14.30	206.12±26.50	194.67±34.50	168.08±25.46	179.35±10.31
Insulin INS (mu/l)	4.66±1.13	6.36±2.27	6.17±2.96	6.08±1.85	5.65±1.74
Insulin-like growth factor IGF-1 (ug/l)	5.59±0.39 ^a	6.46±0.46 ^{ab}	7.11±1.39 ^b	5.73±0.59 ^a	6.11±0.21 ^{ab}
Growth Hormone GH (ug/l)	3.71±0.38	4.47±0.42	4.25±0.83	3.86±0.69	3.71±0.12

Note: In peer data, the same lowercase letters or no letters indicated no significant difference ($p>0.05$), while completely different lowercase letters indicated significant difference ($p<0.05$).

3.4 Effects of different treatment groups on physiological and biochemical indexes of pigs at fattening stage

According to the data in Table 5, we could find that compared with the basal diet group, the contents of total protein and albumin in other treatment groups had an increasing trend, and globulin content was significantly increased ($p<0.05$). The contents of IgG and IgM showed an increasing trend, but there were no significant differences ($p>0.05$). Triglyceride content was significantly decreased ($p<0.05$), and total cholesterol content was significantly decreased in group 1 ($p<0.05$). Compared with antibiotic group, the contents of total

protein, globulin and IgM in three experimental groups were increased ($p>0.05$), while the contents of albumin and IgG were not significantly different ($p>0.05$), and the contents of triglyceride and total cholesterol were decreased ($p>0.05$).

Among the three experimental groups, the contents of total protein, albumin and globulin in group 1 were higher than those in the other two groups ($p>0.05$), the contents of IgG and IgM in group 1 were higher than those in the other two groups ($p>0.05$), and the contents of triglyceride and total cholesterol in group 1 were lower than those in the other two groups ($p>0.05$).

Table 5: Relationship between serum physiological and biochemical indexes of finishing pigs in different treatment groups

Item	Basal diet Group	Antibiotic Group	Test 1 Group	Test 2 Group	Test 3 Group
Total protein TP/(g/L)	7.81±0.21	7.91±0.19	8.11±0.25	7.92±0.18	7.94±0.23
Albumin ALB/(g/L)	4.22±0.12	4.28±0.22	4.25±0.24	4.18±0.19	4.24±0.21
GLB/(g/L)	3.77±0.12 ^b	4.16±0.16 ^a	4.29±0.22 ^a	4.26±0.18 ^a	4.22±0.21 ^a
Albumin/globulin	1.12±0.09 ^a	1.02±0.06 ^{ab}	0.99±0.03 ^b	0.98±0.03 ^b	1.00±0.05 ^b
IgG(g/L)	0.54±0.26	0.85±0.15	0.89±0.12	0.77±0.19	0.72±0.17
IgM(g/L)	0.99±0.27	1.05±0.22	1.23±0.19	1.13±0.18	1.08±0.09
Triglycerides TG/(mmol/L)	0.65±0.02 ^a	0.58±0.03 ^b	0.47±0.01 ^b	0.49±0.02 ^b	0.54±0.03 ^b
Total cholesterol TC/(mmol/L)	2.19±0.12 ^a	2.12±0.15 ^{ab}	1.99±0.16 ^b	2.08±0.09 ^{ab}	2.03±0.18 ^{ab}

Note: In peer data, the same lowercase letters or no letters indicated no significant difference ($p>0.05$), while completely different lowercase letters indicated significant difference ($p<0.05$).

4. Analysis and Discussion

It has been found that polysaccharides of *Rhizoma atractylodes* have various physiological activities [10, 11], including antioxidant, anti-inflammatory and immunomodulatory effects [12, 13]. Adding polysaccharide of *atractylodes macrocephala* Koidz to animal feed can promote the growth and development of animals, improve digestion and absorption [14], improve feed utilization, and enhance the body's resistance to disease [15]. Microecological preparations can regulate the microbial community in the intestinal tract of animals, improve the utilization rate of feed, improve animal health, and enhance animal growth performance [16-18].

The results of this experiment showed that compared with the basal diet group, the daily gain of pigs could be increased, the growth of pigs could be promoted and the ratio of feed to meat of pigs could be decreased by adding white rhizome polysaccharide or microecological preparation alone in the diets of nursing pigs, growing pigs and finishing pigs, although the effect was not as good as that of antibiotic group, but the difference was not significant ($p>0.05$). The study of Peng Huizhen *et al.* [19] showed that adding *atractylodes macrocephala* Koidz crude polysaccharide to the diet could significantly increase the average daily gain and feed reward of animals, while reducing the frequency of diarrhea. Qiao Jiayun [20] reported that the effect of *Lactobacillus* added to the basal diet was better than that of flavomycin added to the diet, which increased the average daily feed intake and average daily gain, and reduced the feed to meat ratio of weaned piglets. These results are consistent with the results of this experiment, indicating that adding polysaccharide of *atractylodes macrocephala* Koidz or microecological

preparations in animal feed can produce significant effects, and can improve the growth and feed utilization efficiency of animals.

The results of this study showed that the combined use of microecological preparation and microecological preparation in feed was better than that of microecological preparation or microecological preparation or microecological preparation in feed in increasing daily gain and reducing feed to meat ratio. Cen Lu *et al.* [21] study showed that piglets fed with probiotics combined with astragalus polysaccharide found that the experimental group had higher daily gain and lower feed to meat ratio than the blank group, indicating that the combined use of microecological preparation and polysaccharide had better effects, which was consistent with the results of this study. This may be related to the improvement of immunity and digestion and absorption of polysaccharide of *atractylodes macrocephala* Koidz, and the improvement of anti-stress ability of pigs by microecological preparation [22]. The two are mutually beneficial when used in combination.

4.1 Effects of different treatment groups on blood hormone levels of finishing pigs

Growth hormone (GH), insulin (INS), insulin growth factor (IGF-I) and thyroid hormone (T₄) are important indicators [23] [24]. Microecological preparation can interact with the intestinal microorganisms of animals, affect the function of their endocrine growth axis, and then affect the stability of the endocrine system and growth regulation function, and then promote more effective nutrient absorption and utilization, and promote the growth and development of animals. Zhu Xiao [25] confirmed this by studying the effects of *Bacillus*

bacillus on hypothalamus, pituitary and target organs in mice. Plant polysaccharides and microecological preparations may directly or indirectly promote the secretion and signal transduction of GH, INS, IGF-I and T₄ by regulating metabolic pathways or by affecting the function of the neuroendocrine system, and then promote cell growth, proliferation and protein synthesis to promote body growth.

The results of this experiment showed that the addition of microecologic preparation alone or the combination of polysaccharide and microecologic preparation could contribute to the increase of the content of 4 hormones in pig serum, which was consistent with the results of growth performance. It is worth noting that the concentration of growth hormone and the growth rate of the body may not be consistent in different animals [26]. The results obtained by Ni Yaodi *et al.* [27] showed that the growth rate of experimental chickens eating the feed supplemented with microecological preparations was significantly increased, but the plasma growth hormone content showed a decreasing trend, which was contrary to the conclusion obtained by Chen Qinghua and this experiment. This may be because growth hormone acts through specific receptors on cell membrane, and there are breed differences among different animals. Some studies have shown that growth hormone receptors in rabbit and pig liver can be up-regulated, while growth hormone receptors in poultry liver can be down-regulated [28].

4.2 Effects of different treatment groups on serum biochemical indices of finishing pigs

Total protein (TP), albumin (ALB), globulin (GLB) and albumin/globulin ratio (A/G) are commonly used to evaluate the nutritional status, liver function and immune function of animal proteins. A/G ratio close to 1 is normal, and there are no abnormal results in the five groups. Immunoglobulin IgG and IgM have the function of maintaining the body's immune balance and resisting pathogens. High levels of triglycerides and total cholesterol are associated with an increased risk of cardiovascular disease.

The results of this experiment showed that adding rhizoma polysaccharide or microecological preparations, alone or in combination, increased total protein, albumin, globulin, IgG, IgM, triglycerides, and cholesterol levels in experimental pigs. In summary, the three experimental groups outperformed the antibiotic group. Xie Yali *et al.* [29] found that adding polysaccharide from *Niudali* to pig feed reduced triglyceride and cholesterol levels. Du Hongming *et al.* [30] demonstrated that adding yeast or lactic acid bacteria to pig diets increased total protein (TP) and albumin (ALB), consistent with this study's findings. Plant polysaccharides and microecological preparations may improve intestinal flora balance, promote nutrient absorption, regulate protein synthesis and breakdown, and enhance liver metabolism, thereby affecting total protein, albumin, and globulin levels. They also improve albumin's ability to transport cholesterol, enhancing immune capacity and lowering cholesterol levels. Additionally, these preparations can regulate the immune system, influencing immunoglobulin synthesis and secretion, promoting thyroid hormone transport, thus enhancing immunity and improving growth performance.

5. Conclusions

In the stages of pig nursing, growth and fattening, the diet supplemented with microecological preparations or polysaccharide of *Atractylodes macrocephala* Koidz alone, or both, can improve the growth performance of pigs, and the

combined use of the two agents has the best effect during the whole experiment period, and there is no significant difference with antibiotics. In the fattening stage, the contents of IGF-1, T₄ and GH in serum could be increased by the combination of microecological preparation and microecological preparation in the diet. The contents of total protein, albumin, globulin and immunoglobulin IgG and IgM, and the levels of triglyceride and total cholesterol can be increased by adding microecological preparation and polysaccharide or the combination of the two in pig feed. There was no significant difference in the effect compared with the antibiotic group.

Conflict of Interest

Not available

Financial Support

Not available

6. Reference

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