

Effects of Dietary Supplementation with Fermented Asparagus By-products on Serum Antioxidant Capacity, Immune Function, and Inflammatory Factor Levels in Sows and Suckling Piglets (Postprint)

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Abstract

This experiment was conducted to investigate the effects of supplementing fermented asparagus byproducts to sows during late gestation and lactation on serum antioxidant capacity, immune function, and inflammatory cytokine content in sows and suckling piglets. Fifteen pregnant sows with similar body condition, parity, and expected farrowing date were selected and randomly divided into 3 groups with 5 replicates per group and 1 sow per replicate. Sows in groups A (control), B, and C were supplemented with 0, 0.25, and 0.50 kg of fermented asparagus byproducts per sow per day, respectively. The trial commenced on day 85 of gestation and concluded on day 21 postpartum. Ear vein blood samples were collected from sows at farrowing and weaning, and anterior vena cava blood samples were collected from piglets at 10 and 21 days of age for serum index determination. The results showed: 1) Serum total superoxide dismutase (T-SOD) activity in group C sows at weaning was extremely significantly higher than that in the control group ($P < 0.01$), and serum malondialdehyde (MDA) content at both farrowing and weaning was extremely significantly lower than that in the control group ($P < 0.01$). Serum T-SOD activity in group B suckling piglets at 10 days of age was significantly higher than that in the control group ($P < 0.05$), while serum MDA content was significantly lower than that in the control group ($P < 0.05$). 2) Serum growth hormone (GH) content in group C sows at farrowing was significantly higher than that in the control group ($P < 0.05$). 3) Serum immunoglobulin A (IgA) and immunoglobulin G (IgG) contents in group C sows at farrowing were significantly higher than those in the control group ($P < 0.05$). 4) Serum interleukin-6 (IL-6) content in groups B and C sows was extremely significantly lower than that in the control group at both farrowing and weaning ($P < 0.01$). Serum tumor necrosis factor- (TNF-) content in

group C sows at weaning was significantly lower than that in the control group ($P < 0.05$). Serum TNF- content in group C suckling piglets at 10 days of age was significantly lower than that in the control group ($P < 0.05$). In conclusion, supplementing sows with 0.50 kg of fermented asparagus byproducts daily can enhance their antioxidant capacity and immune function, increase GH content, reduce inflammatory responses, while also improving the antioxidant capacity of piglets and reducing the occurrence of inflammatory responses.

Full Text

Effects of Supplementary Feeding of Sows with Fermented Asparagus By-Product on Antioxidant Capacity, Immune Function and Contents of Inflammatory Factors in Serum of Sows and Suckling Piglets

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Abstract: This study investigated the effects of supplementary feeding sows with fermented asparagus by-product during late gestation and lactation on serum antioxidant capacity, immune function, and inflammatory factor levels in both sows and suckling piglets. Fifteen pregnant sows with similar body condition, parity, and expected farrowing dates were randomly allocated to three groups with five replicates per group and one sow per replicate. Sows in groups A (control), B, and C received daily supplements of 0, 0.25, and 0.50 kg fermented asparagus by-product per head, respectively. The trial period spanned from day 85 of gestation to day 21 postpartum. Blood samples were collected from sows via ear vein at farrowing and weaning, and from piglets via anterior vena cava at 10 and 21 days of age for serum analysis. The results showed: (1) At weaning, serum total superoxide dismutase (T-SOD) activity in group C sows was significantly higher than in the control group ($P < 0.01$), while serum malondialdehyde (MDA) content was significantly lower at both farrowing and weaning ($P < 0.01$). In 10-day-old piglets, group B showed significantly higher serum T-SOD activity ($P < 0.05$) and lower MDA content ($P < 0.05$) compared to the control. (2) Serum growth hormone (GH) content in group C sows was significantly higher than in controls at farrowing ($P < 0.05$). (3) Serum immunoglobulin A (IgA) and immunoglobulin G (IgG) contents in group C sows were significantly higher than in controls at farrowing ($P < 0.05$). (4) Serum interleukin-6 (IL-6) content in groups B and C sows was significantly lower than in controls at both farrowing and weaning ($P < 0.01$). Serum tumor necrosis factor- (TNF-) content in group C sows was significantly lower than in controls at weaning ($P < 0.05$), and serum TNF- content in 10-day-old piglets was also significantly lower in group

C ($P < 0.05$). In conclusion, daily supplementation with 0.50 kg fermented asparagus by-product enhanced sow antioxidant capacity and immune function, increased GH levels, and reduced inflammatory responses, while simultaneously improving piglet antioxidant capacity and decreasing inflammatory reactions.

Keywords: fermented asparagus by-product; sows; suckling piglets; serum indexes

Introduction

China is a major asparagus producer, with approximately 6.96 million tons of asparagus produced in 2015, generating about 2 million tons of asparagus by-products. Asparagus by-products, the waste from asparagus processing, are rich in vitamins, polysaccharides, essential amino acids, and bioactive compounds such as saponins and flavonoids. Previous research demonstrated that feeding asparagus by-products to lactating cattle and sheep significantly increased milk yield and improved milk quality, while supplementation in finishing pigs enhanced daily weight gain and feed conversion efficiency. However, fresh asparagus by-products are difficult to preserve, contain high levels of crude fiber, and have poor palatability, limiting their widespread application in animal production. Micro-storage treatment effectively extends the preservation period and reduces crude fiber content. Our previous studies found that solid-state fermentation improves the nutritional value and palatability of asparagus by-products, and supplementation during late gestation and lactation enhances intestinal motility, reduces constipation, and improves milk quality in sows. However, the effects of fermented asparagus by-products on serum indices of sows and their piglets have not been reported. This experiment investigated the impacts of supplementary feeding fermented asparagus by-products to sows during late gestation and lactation on serum antioxidant indices, hormone levels, immunoglobulin contents, and inflammatory factors, providing technical support for the rational use of fermented asparagus by-products in healthy sow production.

Materials and Methods

1.1 Fermented Asparagus By-Product Preparation

Fresh asparagus by-products were washed, crushed to approximately 3 cm pieces, and air-dried until no juice remained between fingers when squeezed (moisture content ~65%). Straw fiber decomposition agent (containing enzymes, emulsifiers, probiotics, etc.), corn meal, and soybean meal were added at 0.1%, 5.0%, and 5.0% respectively, mixed thoroughly with the dried asparagus pieces, then sprayed with 1.0% sodium chloride solution and mixed again. The mixture was packed into 25 kg fermentation bags filled to 2/3 capacity, air was expelled, bags were sealed with cable ties, and fermentation proceeded at room temperature for 14 days. The main nutrient composition is shown in Table 1 .

1.2 Experimental Design

Fifteen “Landrace × Yorkshire” crossbred sows with moderate body condition, 2-3 parities, and expected farrowing dates within one week were randomly divided into three groups with five replicates per group and one sow per replicate. Group A (control) received basal diet only, while groups B and C received basal diet plus 0.25 and 0.50 kg fermented asparagus by-product per head daily, respectively. All sows received identical basal diet amounts formulated according to NRC (1998) standards. Basal diet composition and nutrient levels are shown in Table 2 .

1.3 Management

The trial was conducted at Wanjia Pig Farm, Yaoyu Town, Xinyu City, Jiangxi Province, from day 85 of gestation to day 21 postpartum. Piglet mortality was recorded, and piglets were weighed at birth and at 21 days of age after overnight fasting. Fermented asparagus by-product was fed twice daily, 2 hours before the complete diet. A 7-day pre-trial period preceded the formal experiment. Other management and disease prevention procedures followed the farm’ s normal protocols.

1.4 Sample Collection

Sow blood: Collected from the ear vein within 24 h after farrowing and at weaning at 08:00 after overnight fasting. Five mL of blood was drawn, left to stand at 4 °C for 30 min, centrifuged at 3,000 r/min for 15 min, and serum was aliquoted into 0.5 mL tubes and stored at -20 °C until analysis.

Piglet blood: Collected from the anterior vena cava of healthy piglets with similar body weight at 10 and 21 days of age at 08:00 after overnight fasting using the same method as for sows.

1.5 Measurements

Serum immunoglobulins [immunoglobulin A (IgA), immunoglobulin G (IgG), immunoglobulin M (IgM)], inflammatory factors [interleukin-1 (IL-1), interleukin-6 (IL-6), tumor necrosis factor- (TNF-)], and hormones [growth hormone (GH), insulin (INS)] were measured by enzyme-linked immunosorbent assay. Serum total superoxide dismutase (T-SOD) activity was measured by hydroxylamine method, and serum malondialdehyde (MDA) content was measured by thiobarbituric acid (TBA) method. All kits were purchased from Nanjing Jiancheng Bioengineering Institute.

1.6 Data Processing and Statistical Analysis

Raw data were organized using Excel 2003 and analyzed by one-way ANOVA using SPSS 17.0 software. Differences among group means were tested by Dun-

can' s multiple comparison test. Results are expressed as “mean \pm standard error.”

Results

2.1 Effects on Growth Performance of Suckling Piglets

As shown in Table 3 , supplementary feeding of fermented asparagus by-product during late gestation increased average piglet birth weight compared with the control group, though not significantly ($P>0.05$). Continued supplementation during lactation improved average piglet survival rate ($P>0.05$), thereby increasing the number of piglets weaned at 21 days ($P>0.05$). However, supplementation had no significant effect on average weaning weight at 21 days ($P>0.05$).

2.2 Effects on Serum Antioxidant Indices

As shown in Table 4 , at farrowing, serum T-SOD activity did not differ significantly among sow groups ($P>0.05$), while serum MDA content in group C was significantly lower than in groups A and B ($P<0.01$). At weaning, group C sows showed significantly higher serum T-SOD activity ($P<0.01$) and lower MDA content compared to controls ($P<0.01$). In 10-day-old piglets, group B had significantly higher serum T-SOD activity ($P<0.05$) and lower MDA content ($P<0.05$) than controls, while group C did not differ significantly from other groups ($P>0.05$). At 21 days, no significant differences were observed in serum T-SOD activity or MDA content among piglet groups ($P>0.05$).

2.3 Effects on Serum Hormone Contents

As shown in Table 5 , at farrowing, serum GH content in group C sows was significantly higher than in controls ($P<0.05$), while group B did not differ from controls ($P>0.05$). At weaning, no significant differences were observed among sow groups ($P>0.05$). Serum INS content did not differ significantly among sow groups at either time point ($P>0.05$). No significant differences were found in serum GH or INS contents among piglets at 10 or 21 days of age ($P>0.05$).

2.4 Effects on Serum Immunoglobulin Contents

As shown in Table 6 , at farrowing, serum IgA content in group C sows was significantly higher than in controls ($P<0.05$), and IgG content was significantly higher than in both control and group B sows ($P<0.05$). Group B did not differ from controls in IgA, IgG, or IgM contents ($P>0.05$). At weaning, no significant differences were observed among sow groups in IgA, IgG, or IgM contents ($P>0.05$). Similarly, no significant differences were found in serum IgA, IgG, or IgM contents among piglets at 10 or 21 days of age ($P>0.05$).

2.5 Effects on Serum Inflammatory Factor Contents

As shown in Table 7, at farrowing, sow serum IL-1 content did not differ significantly among groups ($P>0.05$). At weaning, group C had the lowest IL-1 content, which was significantly lower than group B ($P<0.05$) but not significantly different from controls ($P>0.05$). Groups B and C showed significantly lower IL-6 content than controls at both farrowing and weaning ($P<0.01$). TNF- content did not differ significantly among sow groups at farrowing ($P>0.05$), but at weaning, group C was significantly lower than controls ($P<0.05$). In 10-day-old piglets, TNF- content in group C was significantly lower than in controls ($P<0.05$), while group B did not differ from controls ($P>0.05$). No significant differences were observed in TNF- content among 21-day-old piglets ($P>0.05$). Serum IL-6 and IL-1 contents did not differ significantly among piglets at either age ($P>0.05$).

Discussion

3.1 Effects on Weaned Piglet Numbers

The number of piglets weaned per sow per year is a key metric for evaluating modern pig farm productivity and profitability, with higher numbers yielding greater economic benefits. Improving suckling piglet survival rate is crucial for increasing weaned piglet numbers, and piglet disease resistance directly affects survival. Research indicates that increasing immunoglobulin content in sow milk significantly enhances piglet disease resistance, and supplementary feeding of fermented asparagus by-product effectively increases immunoglobulin levels in colostrum and milk while reducing pro-inflammatory factor content. When piglets consume milk rich in immunoglobulins, their disease resistance improves, thereby increasing survival rates. This represents an important mechanism by which fermented asparagus by-product supplementation increases weaned piglet numbers.

3.2 Effects on Serum Antioxidant Indices

T-SOD and MDA are biochemical markers reflecting antioxidant capacity. T-SOD is a crucial antioxidant enzyme that scavenges endogenous free radicals, reducing cellular damage from oxidative stress. MDA attacks unsaturated fatty acids in cell membranes, causing lipid peroxidation and cellular toxicity. Studies show that asparagus polysaccharides effectively scavenge free radicals and exhibit strong antioxidant activity in rat serum, cells, and organelles. Asparagus flavonoids protect T-SOD from inactivation, reduce MDA content, and repair damaged tissues and cells. Ethanol extracts from asparagus bases significantly increase serum T-SOD activity in mice, with high doses reducing serum MDA content. Previous research found that fermented asparagus by-product supplementation significantly increased T-SOD activity in sow milk and decreased MDA content, with milk antioxidants primarily derived from blood. The current results demonstrate that 0.50 kg/day fermented asparagus by-product signifi-

cantly increased serum T-SOD activity at weaning and decreased MDA content at both farrowing and weaning, indicating improved antioxidant capacity. Sow serum antioxidants can be transferred to milk, potentially affecting piglet antioxidant status. Supporting this, 0.25 kg/day supplementation significantly increased serum T-SOD activity and decreased MDA content in 10-day-old piglets, confirming that sow supplementation enhances antioxidant capacity in both sows and piglets.

3.3 Effects on Serum Hormone Contents

GH promotes metabolism of the three major nutrients and improves nutrient absorption. Increased GH levels significantly enhance pig weight gain and sow milk yield. Rutin exhibits weak estrogenic effects, and estrogen can indirectly regulate GH secretion. Milk-derived INS stimulates small intestine growth and affects intestinal morphology in newborn piglets. Previous studies found no significant effects of fermented asparagus by-product supplementation on GH and INS contents in sow milk. However, this study showed that 0.50 kg/day supplementation significantly increased serum GH content in sows at farrowing, likely due to the weak estrogenic function of asparagus flavonoids stimulating GH production. The lack of significant differences in serum GH and INS contents among piglets may be because supplementation did not alter these hormone levels in sow milk.

3.4 Effects on Serum Immunoglobulin Contents

Immunoglobulins, which have antibody activity and are widely present in intracellular and secretory fluids, bind to pathogenic microorganisms to clear pathogens and reduce tissue damage. IgG, comprising approximately 75% of total immunoglobulins, plays a vital role in neutralizing bacteria, resisting viruses, and enhancing phagocytosis. Asparagus contains saponins, polysaccharides, and other compounds that enhance immune function. This study demonstrated that 0.50 kg/day fermented asparagus by-product significantly increased serum IgA and IgG contents in sows at farrowing, strengthening their defense against pathogenic microorganisms.

3.5 Effects on Serum Inflammatory Factor Contents

IL-1, IL-6, and TNF- are important cytokines. IL-1, produced mainly by macrophages, B lymphocytes, and NK cells, promotes antigen presentation and antibody formation. IL-6 stimulates B cell antibody production, induces T cell proliferation and differentiation, and acts as an inflammatory response trigger. TNF-, produced by monocytes and macrophages, is a key inflammatory mediator. Studies show that flavonoid supplementation reduces inflammatory responses and pro-inflammatory factor levels, benefiting health. Asparagus extracts enhance cellular immunity and NK cell activity, while asparagus flavonoids alleviate inflammatory reactions. This study found that groups B and C had significantly lower IL-6 content than controls at both farrowing and

weaning, and group C showed significantly lower TNF- content at weaning, demonstrating that fermented asparagus by-product supplementation reduces inflammatory factor levels in sows.

Conclusion

1. Supplementing sows with 0.50 kg/day fermented asparagus by-product significantly increased serum T-SOD activity at weaning, GH, IgA, and IgG contents at farrowing, and significantly decreased serum MDA and IL-6 contents at farrowing and weaning, as well as TNF- content at weaning.
2. Supplementing sows with 0.25 kg/day fermented asparagus by-product significantly increased serum T-SOD activity and decreased MDA content in 10-day-old piglets. Supplementing with 0.50 kg/day significantly decreased serum TNF- content in 10-day-old piglets.

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