Effects of Dietary Ginseng Residue Supplementation on Reproductive Performance and Plasma Physiological and Biochemical Parameters in Pregnant Sows (Postprint)

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Abstract

This experiment aimed to investigate the effects of dietary ginseng residue supplementation on reproductive performance and plasma physiological and biochemical indices in pregnant sows. Ninety-six sows (Landrace × Yorkshire) with similar body condition and 2–4 parities were selected and randomly divided into 4 groups using a single-factor experimental design, with 24 replicates per group and 1 sow per replicate. The control group was fed a basal diet, while experimental groups I, II, and III were fed test diets supplemented with 1%, 3%, and 5% ginseng residue in the basal diet, respectively. The formal trial began on day 60 of gestation and continued until the sows completed farrowing. The results showed that: compared with the control group, dietary supplementation with 3% and 5% ginseng residue significantly increased individual piglet birth weight ($P<0.05$) and extremely significantly increased litter birth weight ($P<0.01$). Compared with the 1% ginseng residue group, dietary supplementation with 3% and 5% ginseng residue extremely significantly or significantly increased litter birth weight ($P<0.01$ or $P<0.05$). Compared with the control group, dietary supplementation with 5% ginseng residue significantly increased the total number of piglets born per litter and the number of piglets born alive per litter ($P<0.05$), while supplementation with 1% and 3% ginseng residue had no significant effect on these parameters ($P>0.05$). Compared with the control group, dietary supplementation with 5% ginseng residue extremely significantly decreased plasma glucose levels in sows ($P<0.01$); plasma triglyceride levels in the 3% ginseng residue group were extremely significantly lower than those in the other groups ($P<0.01$), and plasma triglyceride levels in the 5% ginseng residue group were significantly lower than those in the control group ($P<0.05$); plasma high-density lipoprotein cholesterol levels in the 3% and 5%

ginseng residue groups were extremely significantly higher than those in the control group and the 1% ginseng residue group (P<0.01). Plasma insulin-like growth factor-2 (IGF-2) levels in sows in all three experimental groups were extremely significantly higher than those in the control group (P<0.01), and the 3% and 5% ginseng residue groups were significantly higher than the 1% ginseng residue group (P<0.05). Dietary ginseng residue supplementation had no significant effect on plasma urea nitrogen, growth hormone (GH), and insulin-like growth factor binding protein-3 (IGFBP-3) levels in sows (P>0.05). These results indicate that dietary supplementation with 1% to 5% ginseng residue can increase plasma IGF-2 levels in pregnant sows, supplementation with 3% and 5% ginseng residue can decrease blood lipid levels, and supplementation with 5% ginseng residue can decrease blood glucose levels and improve reproductive performance.

Full Text

Effects of Dietary Ginseng Residue Supplementation on Reproductive Performance and Plasma Physiological and Biochemical Indexes of Gestation Sows

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Abstract

This experiment was conducted to investigate the effects of dietary ginseng residue supplementation on reproductive performance and plasma physiological and biochemical indexes of gestation sows. Ninety-six healthy gestation sows (Landrace × Large White) with similar body condition and 2 to 4 parities were randomly allocated into 4 groups using a single-factor experimental design, with 24 replicates per group and 1 sow per replicate. Sows in the control group were fed a basal diet, while those in experimental groups I, II, and III were fed the basal diet supplemented with 1%, 3%, and 5% ginseng residue, respectively. The trial period spanned from day 60 of gestation to parturition.

The results showed that, compared with the control group, dietary supplementation with 3% and 5% ginseng residue significantly increased individual piglet birth weight ($P < 0.05$) and extremely significantly increased litter birth weight ($P < 0.01$). Compared with the 1% ginseng residue group, supplementation with 3% and 5% ginseng residue extremely significantly or significantly increased litter birth weight ($P < 0.01$ or $P < 0.05$). Dietary supplementation with 5% ginseng residue significantly increased total litter size and live litter size compared with the control group ($P < 0.05$), whereas supplementation with 1% and

3% ginseng residue had no significant effects on these parameters ($P > 0.05$). Additionally, the 5% ginseng residue group exhibited an extremely significant reduction in plasma glucose level ($P < 0.01$). The plasma triglyceride level in the 3% ginseng residue group was extremely significantly lower than in all other groups ($P < 0.01$), while the 5% group was significantly lower than the control ($P < 0.05$). The plasma high-density lipoprotein cholesterol level in the 3% and 5% ginseng residue groups was extremely significantly higher than in the control and 1% groups ($P < 0.01$). All three experimental groups showed extremely significant increases in plasma insulin-like growth factor-2 (IGF-2) level compared with the control ($P < 0.01$), with the 3% and 5% groups being significantly higher than the 1% group ($P < 0.05$). Ginseng residue supplementation had no significant effects on plasma urea nitrogen, growth hormone (GH), or insulin-like growth factor binding protein-3 (IGFBP-3) levels ($P > 0.05$). In conclusion, dietary supplementation with 1% to 5% ginseng residue can increase plasma IGF-2 levels in gestation sows; supplementation with 3% and 5% ginseng residue can reduce blood lipid levels; and supplementation with 5% ginseng residue can decrease blood glucose levels while improving reproductive performance.

Keywords: ginseng residue; gestation sows; reproductive performance; plasma physiological and biochemical indexes

Introduction

Sow reproductive performance is a critical indicator of production efficiency in intensive pig farming. High embryonic/fetal mortality and intrauterine growth retardation (IUGR) during gestation have become issues of widespread concern. Research indicates that sows may lose 40% to 50% of embryos or fetuses during pregnancy, or experience severe IUGR. Nutritional interventions to improve uterine and placental function and enhance fetal survival and development represent effective strategies for improving sow reproductive capacity.

Ginseng contains dozens of bioactive components, including saponins, ginseng polysaccharides, volatile oils, polypeptides, amino acids, organic acids, alkaloids, flavonoids, and sterols. When ginseng powder is sieved through a 100-mesh screen and extracted with 70% to 75% ethanol under reflux, the resulting extract can be concentrated and dried to obtain ginseng extract, with ginsenosides as the main active components. The recovery rate of ginseng extract generally does not exceed 20%, leaving over 80% residual material containing ginseng polysaccharides, saponins, volatile oils, and other active components. This residual material, commonly called ginseng residue, is typically discarded as waste, causing not only significant resource waste but also serious environmental pollution. Currently, few studies have investigated the effects of ginseng residue on sow reproductive performance. This experiment was designed to examine the impact of ginseng residue on reproductive performance and plasma physiological and biochemical indexes of gestation sows, aiming to improve sow reproductive

performance while achieving efficient and comprehensive utilization of ginseng resources.

1.1 Experimental Material

The ginseng residue used in this experiment was provided by Ningbo Lihua Plant Extraction Technology Co., Ltd. Ginseng was pulverized to 100 mesh and extracted three times with 8 volumes of 75% ethanol under reflux for 2 hours each time. The extract was centrifuged, and the lower precipitate was vacuum-dried to remove residual ethanol, yielding dried ginseng residue with a moisture content of 8.7%.

1.2 Experimental Design

A corn-soybean meal basal diet was formulated according to NRC (1998) nutrient standards for gestating sows. Three experimental diets were prepared by adding 1%, 3%, and 5% ginseng residue to the basal diet. The composition and nutrient levels of the experimental diets are shown in . Ninety-six "Landrace × Large White"crossbred sows (parities 2 to 4) were selected and randomly divided into 4 groups using a single-factor design, with 24 replicates per group and 1 sow per replicate. The control group received the basal diet, while experimental groups I, II, and III received diets supplemented with 1%, 3%, and 5% ginseng residue, respectively. Feeding began on day 60 of gestation and continued until parturition.

1.3 Animal Management

Gestation sows were housed in individual gestation crates and fed an average of 2.6 kg daily in two equal meals at 06:30 and 16:30. Sows were moved to farrowing crates 7 days before expected parturition and managed according to the farm' s routine immunization and management protocols.

1.4 Measurements

1.4.1 Reproductive Performance Total litter size, live litter size, and individual piglet birth weight were recorded, and litter birth weight was calculated.

1.4.2 Plasma Collection and Preparation Before parturition, 10 mL of blood was collected from the ear marginal vein of each sow into heparin-pretreated tubes. Samples were left at 37 °C for 10 to 15 minutes, then centrifuged at 3,000 r/min for 5 minutes to collect plasma for physiological and biochemical analysis.

1.4.3 Plasma Index Analysis Plasma levels of urea nitrogen, triglycerides, glucose, high-density lipoprotein cholesterol, insulin-like growth factor-2 (IGF-2), insulin-like growth factor binding protein-3 (IGFBP-3), and growth hormone

(GH) were analyzed using kits from Nanjing Jiancheng Bioengineering Institute and an automatic microplate reader (BIOTEK Synergy H1) according to the manufacturer' s instructions.

1.5 Statistical Analysis

Data were initially processed using Excel 2007, followed by analysis of variance for unequal replicates using SPSS 16.0 software. Differences among treatments were tested using F-tests, and all data are expressed as mean ± standard deviation. $P < 0.05$ was considered statistically significant.

Results

2.1 Effects of Ginseng Residue on Reproductive Performance of Gestation Sows

As shown in , compared with the control group, dietary supplementation with 3% and 5% ginseng residue significantly increased individual piglet birth weight ($P < 0.05$), whereas 1% supplementation had no significant effect ($P > 0.05$). Supplementation with 3% and 5% ginseng residue extremely significantly increased litter birth weight compared with the control group ($P < 0.01$). Compared with the 1% ginseng residue group, 3% supplementation extremely significantly increased litter birth weight ($P < 0.01$), while 5% supplementation significantly increased it ($P < 0.05$). Dietary supplementation with 1% and 3% ginseng residue had no significant effects on total litter size or live litter size ($P > 0.05$), but 5% supplementation significantly increased both parameters ($P < 0.05$).

2.2 Effects of Ginseng Residue on Plasma Metabolism-Related Indicators

As shown in , dietary supplementation with 5% ginseng residue extremely significantly decreased plasma glucose level compared with the control group ($P < 0.01$). The plasma triglyceride level in the 3% ginseng residue group was extremely significantly lower than in all other groups ($P < 0.01$), while the 5% group was significantly lower than the control ($P < 0.05$). The plasma high-density lipoprotein cholesterol level in the 3% and 5% ginseng residue groups was extremely significantly higher than in the control and 1% groups ($P < 0.01$), with the 5% group being significantly higher than the 3% group ($P < 0.05$). No significant differences were observed in plasma urea nitrogen levels among groups ($P > 0.05$).

2.3 Effects of Ginseng Residue on Plasma Hormone Levels

As shown in , dietary supplementation with 1%, 3%, and 5% ginseng residue all extremely significantly increased plasma IGF-2 levels compared with the control group ($P < 0.01$), with the 3% and 5% groups being significantly higher than

the 1% group ($P < 0.05$). Ginseng residue supplementation had no significant effects on plasma IGFBP-3 or GH levels ($P > 0.05$).

Discussion

Ginseng is renowned as the "king of herbs" with traditional effects of "greatly replenishing vital energy, restoring pulse and securing collapse, tonifying spleen and lung, generating fluids, and calming the mind." Modern scientific research has revealed that ginseng possesses multiple pharmacological activities, including anti-fatigue, anti-stress, anti-depression, memory improvement, immune function modulation and enhancement, antioxidant, and anti-tumor effects. In 2012, China's Ministry of Health announced that ginseng (artificially cultivated) was approved as a new resource food, allowing its use in food production and processing.

Due to its high economic value, few studies have investigated ginseng application in livestock production. Li et al. added 0.02% to 0.08% ginseng to Guifei chicken diets and observed significantly reduced aspartate aminotransferase activity and significantly increased total amino acid and umami amino acid content in leg muscle. Active components such as ginseng polysaccharides and saponins exhibit antioxidant properties, improve animal immune function, and enhance vaccine immunogenicity. Ginseng compound polysaccharides have immunomodulatory effects on gestation sows and influence piglet growth and immune function through maternal effects. Supplementing basal diets with 400 mg/kg ginseng compound polysaccharides increased immunoglobulin A (IgA) and immunoglobulin G (IgG) levels in sow milk, improved piglet immunity, and promoted growth. Sun et al. added 200 to 400 mg/kg ginseng compound polysaccharides to basal diets and found significantly increased porcine circovirus antibody levels and glutathione peroxidase activity in piglet serum, indicating that ginseng polysaccharides enhance circovirus vaccine efficacy and improve piglet antioxidant capacity. Additionally, ginseng polysaccharides can block or inhibit porcine reproductive and respiratory syndrome virus infection of host cells.

Ginseng residue, a byproduct of ginseng extract preparation, represents a promising feed resource. The ginseng residue used in this study is the residual component after ethanol extraction of ginseng. Its main chemical difference from ginseng lies in ginsenoside content; ginseng residue contains almost no saponins, but its polysaccharide, volatile oil, and free amino acid contents are even higher than in ginseng. Yu et al. found that dietary supplementation with 25 to 50 mg/kg ginseng residue significantly improved daily weight gain and feed conversion ratio in Arbor Acres broilers. Song added 0.43% to 1.70% ginseng residue to diets for rabbits and mice and observed enhanced animal resistance and improved meat quality. Ming et al. added 0.5% to 1.0% ginseng byproduct to diets and reported significantly improved growth performance and carcass quality in growing-finishing pigs, with good economic benefits. This study investigated the effects of ginseng residue on gestation sow reproductive performance, demonstrating that dietary supplementation with

3% to 5% ginseng residue significantly increased piglet litter birth weight and individual birth weight, while 5% supplementation also significantly increased total litter size and live litter size. Although the experimental subjects differed from previous studies, the results are generally consistent, indicating that dietary supplementation with 5% ginseng residue can improve gestation sow reproductive performance.

IGF-2, also known as somatomedin A, is currently recognized as the most functionally complex and diverse growth factor. It promotes cell mitosis, accelerates embryonic development, stimulates central nervous system growth, and enhances muscle growth and fat deposition. Zhou et al. found that intrauterine growth retardation and postnatal growth catch-up are closely related to IGF-2. Yuan et al. reported that IGF-2 can stimulate in vitro differentiation of embryonic stem cells, thereby promoting fetal development and maturation. IGFBP-3 is an important carrier of insulin-like growth factors (IGFs) in blood, extending IGF half-life and regulating IGF biological activity. However, IGFBP-3 function is not only influenced by IGFs but also regulated by many other factors, although it is positively correlated with blood GH levels. This study showed that dietary supplementation with 1% to 5% ginseng residue increased sow plasma IGF-2 levels but had no significant effects on plasma IGFBP-3 and GH levels, suggesting that ginseng residue may stimulate embryonic development by increasing plasma IGF-2 levels, thereby improving litter size and birth weight. No previous studies have investigated the effects of ginseng residue on animal IGFs and IGFBPs. This study is the first to report that ginseng residue can significantly increase plasma IGF-2 levels in gestation sows without significantly affecting IGFBP-3 levels. The mechanisms through which IGF-2 exerts its biological activities require further investigation.

Seo et al. and Kim et al. reported that ginseng significantly reduces blood glucose and lipid levels in humans and animals. This study demonstrated that dietary supplementation with 3% to 5% ginseng residue significantly reduced plasma triglyceride levels and increased plasma high-density lipoprotein cholesterol levels in gestation sows, while 5% supplementation also significantly reduced plasma glucose levels. These findings suggest that ginseng residue can reduce blood lipid and glucose levels in gestation sows, consistent with previous research. Notably, this experiment used ginseng residue rather than ginseng itself. The main chemical difference between the two is ginsenoside content; ginseng residue contains almost no saponins, whereas ginseng is rich in them. The finding that ginseng residue also exhibits excellent lipid- and glucose-lowering effects suggests that these activities are not mediated by ginsenosides but possibly by other active components such as ginseng polysaccharides and volatile oils. Liu reported that ginseng polysaccharides can stimulate glucose transporter translocation to the cell membrane surface in adipocytes, promoting glucose metabolism and exerting glucose-regulating effects. Xue et al. noted that the main active components responsible for ginseng' s glucose-lowering effects may include ginseng polysaccharides, ginseng polypeptides, and ginsenosides, which may regulate glucose metabolism through multiple mechanisms

including direct stimulation of insulin secretion from pancreatic B cells, repair and enhancement of B cell viability, increased insulin sensitivity, and delayed intestinal glucose absorption. Liu et al. found that ginseng glycopeptides can reduce serum triglyceride and cholesterol levels in rats, demonstrating significant lipid-lowering effects. Ginsenosides and ginseng proteins also have lipid-lowering functions. The specific mechanisms of these active components require further investigation. Most studies on ginseng' s biological functions have focused on laboratory animals and humans, with limited research on livestock and poultry and almost no investigation of its mechanisms. To promote the application of ginseng processing byproducts such as ginseng residue in animal production, deeper mechanistic studies are needed.

Conclusions

1. Dietary supplementation with 3% and 5% ginseng residue significantly increased individual piglet birth weight and litter birth weight in gestation sows, while supplementation with 5% ginseng residue also significantly increased total litter size and live litter size.
2. Dietary supplementation with 3% and 5% ginseng residue significantly reduced plasma triglyceride levels and increased plasma high-density lipoprotein cholesterol levels in gestation sows. Supplementation with 5% ginseng residue also reduced plasma glucose levels, demonstrating lipid- and glucose-lowering effects.
3. Dietary supplementation with 1% to 5% ginseng residue increased plasma IGF-2 levels in gestation sows, exerting growth-promoting effects that benefit embryonic and fetal development.

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Note: Figure translations are in progress. See original paper for figures.