Effects of Yeast Polysaccharides on Growth Performance, Digestion and Metabolism, and Serum Biochemical Parameters in Suckling Calves (Postprint)

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Abstract

This experiment was conducted to investigate the effects of dietary supplementation with different doses of yeast polysaccharide on growth performance, digestion and metabolism, and serum biochemical indices in suckling calves. Fifty-six healthy Chinese Holstein calves with similar birth weight were selected and randomly allocated into 4 groups with 14 calves per group. Group I (control) was fed a basal diet, while groups II, III, and IV were supplemented with 1, 2, and 3 g/(head · d) of yeast polysaccharide in the basal diet, respectively. The experimental period lasted 60 days. The results showed: 1) The average daily gain of calves in group III was significantly higher than that in group I ($P<0.05$); dry matter intake at each stage showed no significant differences among groups ($P>0.05$), with group III being the highest; supplementation with yeast polysaccharide had no significant effect on body height, body length, chest circumference, and cannon circumference of calves ($P>0.05$). 2) The apparent digestibility of dry matter, crude protein, crude fat, neutral detergent fiber, and acid detergent fiber in calves of group III was significantly higher than that in group I ($P<0.05$). 3) The diarrhea rate and diarrhea frequency of calves in groups II, III, and IV were lower than those in group I. 4) Serum TP content in calves of groups III and IV was significantly higher than that in group I ($P<0.05$); serum glucose, albumin, and urea nitrogen contents showed no significant differences among groups ($P>0.05$). Serum alkaline phosphatase, lysozyme activity, and total antioxidant capacity in calves of group III were significantly higher than those in group I ($P<0.05$), while serum malondialdehyde content in calves of group III was significantly lower than that in group I ($P<0.05$). Comprehensive analysis indicated that dietary supplementation with yeast polysaccharide in suckling calves could promote growth and development and nutrient digestion

and absorption, and reduce diarrhea rate. Under the conditions of this experiment, the appropriate supplementation level of yeast polysaccharide in the diet of suckling calves was 2 g/(head · d).

Full Text

Effects of Yeast Polysaccharide on Growth Performance, Digestion Metabolism and Serum Biochemical Indices of Sucking Calves

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Abstract: This experiment was designed to investigate the effects of dietary supplementation with different dosages of yeast polysaccharide on growth performance, digestion metabolism, and serum biochemical indices of suckling calves. Fifty-six healthy Holstein calves with similar birth weight were selected and randomly divided into 4 groups with 14 calves per group. Group I (control) was fed a basal diet, while groups II, III, and IV were fed the basal diet supplemented with 1, 2, and 3 g/(head · d) of yeast polysaccharide, respectively. The experimental period lasted 60 days. The results showed: (1) The average daily gain of calves in group III was significantly higher than that in group I ($P<0.05$). Dry matter intake did not differ significantly among groups at any stage ($P>0.05$), though it was highest in group III. Yeast polysaccharide supplementation had no significant effect on body height, body length, heart girth, or cannon circumference ($P>0.05$). (2) The apparent digestibility of dry matter, crude protein, ether extract, neutral detergent fiber, and acid detergent fiber in group III was significantly higher than in group I ($P<0.05$). (3) The diarrhea rate and diarrhea frequency in groups II, III, and IV were all lower than in group I. (4) Serum total protein content in groups III and IV was significantly higher than in group I ($P<0.05$), while serum glucose, albumin, and urea nitrogen contents did not differ significantly among groups ($P>0.05$). Serum alkaline phosphatase activity, lysozyme activity, and total antioxidant capacity in group III were significantly higher than in group I ($P<0.05$), while serum malondialdehyde content in group III was significantly lower than in group I ($P<0.05$). In conclusion, dietary supplementation with yeast polysaccharide can promote growth and nutrient digestion and absorption while reducing diarrhea rate in suckling calves. Under the conditions of this experiment, the

appropriate supplementation level of yeast polysaccharide in suckling calf diets is 2 g/(head · d).

Keywords: yeast polysaccharide; suckling calves; growth performance; apparent digestibility; serum biochemical indices

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Yeast polysaccharide (YP), the main component of yeast cell walls, is a macromolecular polysaccharide complex extracted from yeast cell walls. It consists of an outer layer of mannan (approximately 25% content), a middle layer of proteinaceous substances, and an inner layer of glucan (approximately 25% content) [?]. Yeast polysaccharide enhances animal performance by regulating intestinal microflora, reducing gastrointestinal diseases, promoting nutrient digestion and absorption, and improving overall resistance. Since suckling calves have low immunity and are susceptible to various diseases such as diarrhea when facing environmental stressors, enhancing their immunity is crucial for promoting growth performance. As a natural, non-toxic growth-promoting biological agent, investigating the effects of yeast polysaccharide on the growth, development, and metabolism of suckling calves is of significant importance.

Numerous studies have demonstrated that yeast polysaccharide can improve antioxidant capacity and growth performance in poultry [?, ?, ?], reduce diarrhea rates in piglets, and increase daily weight gain, serum immunoglobulin content, and overall growth performance [?, ?, ?]. Research also indicates that yeast polysaccharide can enhance energy metabolism in heifers under immune challenge [?], increase dry matter intake (DMI) and daily weight gain in steers during stress periods [?, ?], and improve milk yield and protein percentage in lactating cows [?, ?]. While the effects of mannan or -glucan as single components on suckling calves have been reported, the effects of yeast polysaccharide as a whole on suckling calves remain unreported. Therefore, this experiment aimed to investigate the effects of different dietary supplementation levels of yeast polysaccharide on growth performance, digestion metabolism, and related serum biochemical indices in suckling calves and to determine its optimal supplementation level.

1.1 Experimental Materials

Yeast polysaccharide was purchased from Hubei Angel Yeast Co., Ltd., containing 20.0%-30.0% -glucan, 20.0%-30.0% -mannan peptide, 30.0% peptides and proteins, 2.0% chitin, and >50% purity.

1.2 Experimental Design

Fifty-six healthy Chinese Holstein calves with similar birth weight [(45.00±5.29) kg] were selected and randomly divided into 4 groups with 14 calves each. There were no significant differences in average birth weight among groups ($P>0.05$). Group I received the basal diet, while groups II, III, and IV received the basal diet supplemented with 1, 2, and 3 g/(head · d) of yeast polysaccharide, respectively. The experimental period lasted 60 days.

1.3 Management

Calves were fed 4 L of colostrum within 1 hour after birth and then housed individually in calf hutches with free access to water. During the experiment, each calf was fed 4 kg of milk daily. Calf starter was introduced at 7 days of age, and alfalfa hay was offered ad libitum starting at 45 days of age. Yeast polysaccharide was added to milk from days 1–6 and to calf starter from days 7–60. The composition and nutrient levels of the starter are shown in Table 1 , and the nutrient levels of fresh milk and alfalfa are shown in Table 2 .

1.4 Sample Collection and Processing

1.4.1 Diet and Fecal Sample Collection and Processing Diet samples of starter and alfalfa hay were collected using the quartering method, dried at 65 °C for 48 hours to produce air-dried samples, and stored in sealed bags for nutrient analysis. Fecal samples were collected continuously for 3 days before the experiment ended, with 600 g collected per calf per day and divided into two equal portions. One portion was directly sealed to prepare air-dried samples for determination of ether extract (EE), calcium (Ca), phosphorus (P), neutral detergent fiber (NDF), and acid detergent fiber (ADF) contents. The other portion was treated with 20 mL of 10% H SO per 100 g of fresh feces and stored at -20 °C for crude protein (CP) determination.

1.4.2 Blood Sample Collection and Processing On the final day of the experiment before morning feeding, 30 mL of blood was collected from the jugular vein using procoagulant vacuum tubes. Blood samples were incubated in a 37 °C water bath for 30 minutes, then centrifuged at 1,240×g for 15 minutes to separate serum, which was stored at -20 °C until analysis.

1.5 Measurement Indicators and Methods

1.5.1 Body Weight and Body Measurements Birth weight was measured at calving, and final weight was measured on the morning of day 60 to calculate average daily gain (ADG) from days 1–60. Body height, body length, heart girth, and cannon circumference were also measured. Body height was measured as the vertical distance from the highest point of the withers to the ground using a measuring stick. Body length was measured as the distance from the front of the shoulder joint to the ischial tuberosity using a rigid ruler. Heart girth was measured as the vertical circumference at the posterior angle of the scapula using a tape measure, with tension allowing insertion of the index and middle fingers. Cannon circumference was measured as the horizontal circumference at the thinnest point of the upper 1/3 of the metacarpus using a tape measure.

1.5.2 Dry Matter Intake Determination During the experiment, the daily amount and residual quantity of starter and alfalfa hay offered to each calf were recorded. Samples of pellet feed and alfalfa hay (300–500 g) were collected from each group, dried at 105 °C to constant weight, and used to calculate dry matter content. At the end of the experiment, DMI for each group was calculated.

1.5.3 Diarrhea Rate Determination Calves were observed daily for defecation status, and diarrhea was assessed using fecal scoring criteria [?, ?]. A day with a fecal score 2 was recorded as one diarrhea day. Each diarrhea day per calf was counted as one diarrhea incident. Diarrhea rate and frequency were calculated as follows:

Diarrhea rate (%) = (Number of calves with diarrhea / Total number of calves) × 100
Diarrhea frequency (%) = [Σ(Number of calves with diarrhea × Diarrhea days) / (Total number of calves × Experimental days)] × 100

1.5.4 Nutrient Apparent Digestibility Determination Diet and fecal DM content was determined using the method of Zhang [?]. EE, Ca, and P contents were determined according to GB/T 6436-2002 [?], GB/T 6437-2002 [?], and GB/T 6437-2002 [?], respectively. CP content was determined using a FOSS automatic protein analyzer according to GB/T 6432-94 [?]. NDF and ADF contents were determined using an ANKOM-A2000i automatic fiber analyzer (USA) according to GB/T 20806-2006 [?] and NY/T 1459-2007 [?], respectively.

Nutrient apparent digestibility was calculated using the acid-insoluble ash method (endogenous indicator method) with the following formula:

Nutrient apparent digestibility (%) = [(a/c - b/d) / (a/c)] × 100

Where: a = nutrient content in diet (%); b = nutrient content in feces (%); c = indicator content in diet (%); d = indicator content in feces (%).

1.5.5 Serum Biochemical Indicators Determination Serum glucose (GLU), urea nitrogen (UN), total protein (TP), albumin (ALB) contents, and alkaline phosphatase (ALP) activity were measured using kits from Beijing Beijian Company (batch numbers: 20170407, 20170201, 20170201, 20170201, 20170302). Serum malondialdehyde (MDA) content and total antioxidant capacity (T-AOC) were measured using kits from Nanjing Jiancheng Bioengineering Institute (batch numbers: 20170410, 20170410) with a GF-D200 semi-automatic biochemical analyzer (Shandong Gaomi Rainbow). Serum lysozyme (LZM) activity was measured using a kit from Shanghai Huole Biotechnology Co., Ltd. (batch number: 20170428) with a THERMO Multiskan Ascent automatic microplate reader (USA).

1.6 Statistical Analysis

Experimental data were analyzed using one-way ANOVA with SPSS 19.0 software, and Duncan's multiple comparison test was used for post-hoc comparisons. Results are expressed as mean ± standard deviation, with P<0.05 considered significant and P<0.01 considered highly significant.

2.1.1 Effects of Yeast Polysaccharide on Body Weight of Suckling Calves

As shown in Table 3 , there were no significant differences in birth weight or final weight among groups (P>0.05). The ADG of calves in group III was significantly higher than that in group I (P<0.05), while no significant differences were observed among groups I, II, and IV (P>0.05).

2.1.2 Effects of Yeast Polysaccharide on DMI of Suckling Calves

As shown in Table 4 , there were no significant differences in DMI among groups at any stage (P>0.05). However, DMI from starter and alfalfa in groups II, III, and IV was higher than in group I, with group III showing the highest DMI overall.

2.1.3 Effects of Yeast Polysaccharide on Body Measurements of Suckling Calves

As shown in Table 5 , dietary supplementation with yeast polysaccharide had no significant effect on body height, body length, heart girth, or cannon circumference (P>0.05), though groups II and III showed an increasing trend compared to group I.

2.2 Effects of Yeast Polysaccharide on Nutrient Apparent Digestibility of Suckling Calves

As shown in Table 6 , the apparent digestibility of DM and CP in groups II, III, and IV was higher than in group I, with group III showing significant improvements of 8.66% and 9.97% compared to group I (P<0.05). The apparent digestibility of EE in groups III and IV was significantly higher than in group I, increasing by 7.75% and 8.84%, respectively (P<0.05). The apparent digestibility of NDF and ADF in group III was significantly higher than in group I, increasing by 15.88% (P<0.05) and 16.43% (P<0.01), respectively. Although no significant differences were observed in Ca and P digestibility among groups (P>0.05), group III showed the highest values.

2.3 Effects of Yeast Polysaccharide on Diarrhea Rate of Suckling Calves

As shown in Table 7 , the diarrhea rate and diarrhea frequency in groups II, III, and IV were lower than in group I, with reductions of 24.93%, 50.00%, and

24.93% in diarrhea rate, and 42.86%, 61.90%, and 49.21% in diarrhea frequency, respectively. Group III exhibited the lowest diarrhea rate and frequency.

2.4.1 Effects of Yeast Polysaccharide on Serum Metabolites of Suckling Calves

As shown in Table 8 , serum TP content in groups III and IV was significantly higher than in group I ($P<0.05$), with a 4.12% increase in group III compared to group I. No significant differences were observed among groups in serum GLU, ALB, or UN contents ($P>0.05$).

2.4.2 Effects of Yeast Polysaccharide on Serum Enzyme Activity of Suckling Calves

As shown in Table 9 , serum ALP activity in groups II and III was significantly higher than in group I, increasing by 7.84% and 17.24%, respectively ($P<0.01$). Serum LZM activity in groups III and IV was significantly higher than in group I ($P<0.05$), increasing by 6.79% and 6.20%, respectively.

2.4.3 Effects of Yeast Polysaccharide on Serum Antioxidant Indices of Suckling Calves

As shown in Table 10 , serum T-AOC in group III was significantly higher than in group I, increasing by 17.41% ($P<0.05$). Serum MDA content in groups II and III was significantly lower than in group I, decreasing by 11.04% in both groups ($P<0.05$), with no significant difference between groups II and III ($P>0.05$).

3.1 Effects of Yeast Polysaccharide on Growth Performance of Suckling Calves

Baldwin et al. [?] reported that because the rumen is not fully developed during the suckling period, young calves have digestive functions similar to young monogastric animals. Xu et al. [?] found that adding 0.1% yeast cell wall polysaccharide to piglet diets increased daily weight gain. In weaned piglets, supplementation with 250 mg/kg yeast cell wall increased feed intake and daily weight gain, but levels exceeding 250 mg/kg reduced growth performance [?]. Studies have reported that adding mannan oligosaccharide to calf milk had no significant effect on ADG [?], while supplementation with 75 mg/kg -glucan in early-weaned calf diets significantly increased ADG [?]. In this experiment, calves receiving yeast polysaccharide showed higher ADG and DMI than the control group, with the highest values observed in calves receiving 2 g/(head · d). This may be attributed to the combined action of mannan oligosaccharide and -glucan in yeast polysaccharide, which increased feeding frequency and promoted intestinal digestion and absorption capacity, thereby improving feed intake and daily weight gain.

3.2 Effects of Yeast Polysaccharide on Nutrient Apparent Digestibility of Suckling Calves

Few reports have addressed the effects of yeast polysaccharide on nutrient digestibility. However, studies have shown that mannan oligosaccharide can increase villus length/crypt depth in pigs, expand intestinal absorption surface area, reduce Escherichia coli populations [?, ?], promote mucosal layer growth, accelerate intestinal mucosal cell recovery [?], and enhance nutrient digestion and absorption, thereby improving digestibility. Nochta et al. [?] reported that adding 2 or 4 g/kg mannan oligosaccharide to piglet diets significantly improved CP and crude fiber digestibility in the ileum, while 1 g/kg significantly increased Ca and P digestibility, and 2 g/kg increased DM digestibility compared to the control. Zhou [?] reported that supplementation with 75 mg/kg yeast -glucan significantly improved DM, CP, EE, and P digestibility in calves. Lei et al. [?] found that yeast cell wall improved apparent digestibility of ADF and total P in beef cattle. The results of this experiment are consistent with previous reports, showing that nutrient apparent digestibility was higher in yeast polysaccharide-supplemented groups than in the control group, with group III exhibiting significantly higher DM, CP, NDF, and ADF digestibility than other groups. This indicates that appropriate supplementation with yeast polysaccharide in suckling calf diets can promote nutrient absorption and utilization.

3.3 Effects of Yeast Polysaccharide on Diarrhea Rate of Suckling Calves

Diarrhea is a major factor affecting calf health and growth. The establishment of immune function in calves occurs approximately after 3 weeks of age [?]. Calf diarrhea not only increases mortality but also affects future calving and milk production [?]. Therefore, enhancing calf immunity and reducing disease risk during early suckling is essential. Kara et al. [?] found that adding mannan oligosaccharide to calf milk had no significant effect on diarrhea rate. Ghosh et al. [?] reported that mannan olysaccharide supplementation in crossbred beef cattle diets significantly reduced diarrhea severity. Zhao et al. [?] found that mannan oligosaccharide in weaned pig diets significantly reduced diarrhea rate and positively affected growth performance and nutrient digestion. Wang et al. [?] reported that 50 mg/kg yeast -glucan significantly reduced diarrhea frequency in weaned piglets, but higher doses increased diarrhea frequency. Gao and Zhao [?] found that yeast cell wall hydrolysate reduced piglet diarrhea rate, maintained intestinal microecological balance, and inhibited harmful bacteria proliferation. However, Xu et al. [?] reported that 0.15% yeast cell wall polysaccharide aggravated diarrhea in weaned piglets, possibly due to high-dose supplementation of fully broken yeast cell wall polysaccharide causing illness and affecting healthy growth.

In this experiment, yeast polysaccharide supplementation reduced calf diarrhea rate, with the lowest rate observed in calves receiving 2 g/(head·d), likely due to enhanced disease resistance and immunity. The increased diarrhea rate at higher supplementation levels may result from excessive microbial fermentation in the posterior digestive tract, particularly non-specific growth of bacteria such as E. coli, causing indigestion, diarrhea, gastrointestinal mucosal damage, reduced nutrient absorption, and growth inhibition [?].

3.4.1 Effects of Yeast Polysaccharide on Serum Metabolites of Suckling Calves

Serum glucose content is the primary energy source for maintenance and growth in most animals, reflecting the dynamic balance between glycogen synthesis and breakdown [?]. In this experiment, yeast polysaccharide supplementation had no significant effect on serum GLU content, possibly due to calves' ability to maintain glucose homeostasis.

Serum total protein content reflects overall protein synthesis metabolism in the body. Elevated serum TP content is beneficial for improving metabolic status and immunity, promoting healthy animal growth [?]. In this experiment, calves receiving 2 g/(head · d) yeast polysaccharide had the highest serum TP content, indicating that supplementation enhanced resistance and promoted healthy growth.

Albumin is the main regulator of blood osmotic pressure. Although no significant differences were observed in serum ALB content among groups, calves receiving 2 g/(head · d) yeast polysaccharide had the lowest ALB content, suggesting that this supplementation level could maintain plasma osmotic pressure and preserve liver function and immune regulation.

Serum urea nitrogen content reflects protein metabolism status in animals. Reduced serum UN content indicates improved nitrogen utilization. In this experiment, no significant differences in serum UN content were observed among groups, indicating that the supplementation levels used did not affect nitrogen metabolism.

3.4.2 Effects of Yeast Polysaccharide on Serum Enzyme Activity of Suckling Calves

Alkaline phosphatase and lysozyme are lysosomal enzymes in phagocytic cells that play important roles in phagocytic and bactericidal capabilities. ALP activity reflects growth rate and performance, while LZM, primarily secreted by macrophages, plays a crucial role in defense by dissolving bacterial cells, rapidly clearing mucosa, and enhancing anti-infection capacity. Wang et al. [?] reported that yeast cell wall improved non-specific immunity and increased serum ALP activity in piglets. This experiment showed that supplementation with 1 or 2 g/(head · d) yeast polysaccharide significantly increased serum ALP activity compared to the control group, while 2 or 3 g/(head · d) significantly increased serum LZM activity. Thus, appropriate yeast polysaccharide supplementation in suckling calf diets can enhance non-specific immunity and anti-infection capacity.

3.4.3 Effects of Yeast Polysaccharide on Serum Antioxidant Indices of Suckling Calves

The antioxidant defense system is a complete and complex system formed during animal evolution. Total antioxidant capacity is the main system antagonizing oxygen free radicals and a comprehensive indicator of antioxidant capacity, with its level reflecting the resistance of enzymatic and non-enzymatic antioxidant systems to oxidative stress [?]. Malondialdehyde is a decomposition product of lipid peroxidation, and its content reflects oxygen free radical levels and the intensity and rate of lipid peroxidation; elevated content indicates weakened antioxidant function. Huang et al. [?] reported that 1 kg/t yeast cell wall polysaccharide in ROSS broiler diets promoted immune organ development and enhanced liver antioxidant capacity. Li [?] found that -mannanase significantly increased serum T-AOC and reduced serum MDA content in weaned piglets, thereby improving antioxidant capacity. In this experiment, yeast polysaccharide supplementation increased serum T-AOC and reduced MDA content, with the 2 g/(head · d) group showing the best results. This suggests that exogenous yeast polysaccharide can scavenge oxygen free radicals by increasing antioxidant enzyme activity, preventing reactive oxygen species damage, and maintaining health, though the specific mechanism requires further investigation.

4 Conclusion

Dietary supplementation with yeast polysaccharide in suckling calves can promote growth and nutrient digestion and absorption while reducing diarrhea rate. Under the conditions of this experiment, the optimal supplementation level of yeast polysaccharide for suckling calves is 2 g/(head · d).

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