

Effects of Yeast Culture on Production Performance, Nutrient Apparent Digestibility, and Serum Indices of Dairy Cows in Mid-to-Late Lactation: Postprint

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Abstract

This experiment aimed to investigate the effects of yeast culture (YC) on production performance, nutrient apparent digestibility, and serum indices of dairy cows in mid-to-late lactation. Forty-eight healthy Holstein dairy cows in mid-to-late lactation were selected and randomly allocated to control, Experiment Group I, Experiment Group II, and Experiment Group III groups according to the principle of similar parity, milk yield [(36.49±1.50) kg], and days in milk [(175±6) d], with 12 replicates per group and one cow per replicate. The control group was supplemented with 500 g/(d·head) flaked corn on top of the basal diet, while Experiment Group I, Experiment Group II, and Experiment Group III were supplemented with 500 g/(d·head) yeast culture 1, 500 g/(d·head) yeast culture 2, and 100 g/(d·head) yeast culture 3 on top of the basal diet, respectively. The experimental period lasted 45 days, consisting of a 15-day preliminary period and a 30-day formal experimental period. The results showed: 1) Compared with the control group, dry matter intake of Experiment Group I was significantly increased by 0.82 kg/d (P 0.05), and milk yield was significantly increased by 1.18 kg/d (P 0.05); dry matter intake of Experiment Group II and Experiment Group III was increased by 0.58 and 0.66 kg/d, respectively, and milk yield was increased by 0.79 and 0.65 kg/d, respectively, but the differences were not significant (P 0.05). The milk fat percentage in milk composition of Experiment Group I was significantly higher than that of the control group and Experiment Group II by 5.12% and 4.83%, respectively (P 0.05); compared with the control group, milk fat percentage of Experiment Group II and Experiment Group III was increased by 0.26% and 2.70%, respectively, but the differences were not significant (P 0.05). 2) The apparent digestibility of dry matter and neutral detergent fiber in Experiment Group I was significantly

increased by 5.47% and 3.05% compared with the control group (P 0.05); the apparent digestibility of dry matter and neutral detergent fiber in Experiment Group II and Experiment Group III was increased by 3.71% and 1.84%, and 1.36% and 0.96% compared with the control group, respectively, but the differences were not significant (P 0.05). 3) Serum globulin content in Experiment Groups I and III was significantly higher than that of the control group on day 0 (P 0.05); serum globulin content in Experiment Group III was significantly higher than that of the control group on day 15 and for the overall average (P 0.05). 4) Compared with the control group, serum malondialdehyde content in Experiment Group I was significantly decreased on day 30 and for the overall average (P 0.05); serum glutathione peroxidase activity in Experiment Group I was significantly higher than that of the control group on day 15 and for the overall average (P 0.05). 5) Compared with the control group, gross profit in Experiment Group I was increased by 0.68 yuan/(d · head), while that in the other groups decreased. Comprehensive analysis indicated that dietary supplementation of yeast culture could improve production performance, enhance nutrient apparent digestibility, exert no negative effects on serum biochemical indices, simultaneously enhance serum antioxidant capacity, and improve economic benefits in dairy cows during mid-to-late lactation, with supplementation of 500 g/(d · head) yeast culture 1 demonstrating superior effects.

Full Text

Abstract

This experiment was conducted to investigate the effects of yeast culture (YC) on performance, nutrient apparent digestibility, and serum indexes of dairy cows in mid- and late lactation. Forty-eight healthy Holstein dairy cows in mid- and late lactation were randomly divided into four groups with 12 replicates per group and one cow per replicate, based on similar parity, milk yield [(36.49±1.50) kg], and days in milk [(175±6) d]. The control group received a basal diet supplemented with 500 g/(d · head) of flaked corn, while test groups I, II, and III received the basal diet supplemented with 500 g/(d · head) of yeast culture 1, 500 g/(d · head) of yeast culture 2, and 100 g/(d · head) of yeast culture 3, respectively. The experimental period lasted 45 days, including a 15-day preliminary period and a 30-day formal period. The results showed that: (1) Compared with the control group, dry matter intake (DMI) in test group I significantly increased by 0.82 kg/d (P<0.05), and milk yield significantly increased by 1.18 kg/d (P<0.05). DMI in test groups II and III increased by 0.58 and 0.66 kg/d, respectively, and milk yield increased by 0.79 and 0.65 kg/d, respectively, but these differences were not significant (P>0.05). Milk fat percentage in test group I was significantly higher than that in the control group and test group II by 5.12% and 4.83%, respectively (P<0.05). Compared with the control group, milk fat percentage in test groups II and III increased by 0.26% and 2.70%, respectively, but the differences were not significant (P>0.05). (2) Apparent digestibility of dry matter and neutral detergent fiber (NDF) in test group I

was significantly higher than that in the control group by 5.47% and 3.05%, respectively ($P < 0.05$). Test groups II and III showed increases in dry matter and NDF apparent digestibility of 3.71% and 1.84%, and 1.36% and 0.96%, respectively, compared with the control group, but these differences were not significant ($P > 0.05$). (3) Serum globulin content in test groups I and III was significantly higher than that in the control group on day 0 ($P < 0.05$). Serum globulin content in test group III on day 15 and the overall average were significantly higher than those in the control group ($P < 0.05$). (4) Compared with the control group, serum malondialdehyde (MDA) content in test group I on day 30 and the overall average were significantly lower ($P < 0.05$). Serum glutathione peroxidase (GSH-Px) activity in test group I on day 15 and the overall average were significantly higher than those in the control group ($P < 0.05$). (5) Gross profit in test group I increased by 0.68 RMB/(d · head) compared with the control group, while other groups showed decreased profits. In conclusion, dietary supplementation with yeast culture can improve performance and nutrient apparent digestibility in mid- and late lactation dairy cows without negatively affecting serum biochemical indexes, while enhancing serum antioxidant capacity and improving economic benefits. The supplementation of 500 g/(d · head) of yeast culture 1 showed the best effects.

Keywords: yeast culture; lactating dairy cow; performance; apparent digestibility; serum biochemical index; antioxidant index

Introduction

Milk production in dairy cows peaks during early lactation, accounting for 40-50% of total lactation yield, making this phase a primary focus for producers. However, after entering mid-lactation, milk yield declines at a rate of 6-7% per month, while body weight loss from early lactation begins to recover or ceases. Consequently, the rate of milk yield decline during mid- and late lactation significantly impacts overall production performance and economic efficiency. Therefore, it is essential to ensure adequate feed intake while improving diet digestibility to maintain cow health, stabilize and increase milk production, and guarantee profitability.

Yeast culture is a microecological preparation formed by the full fermentation of yeast under anaerobic conditions on a specialized medium. It primarily consists of fermented modified medium, yeast metabolites, and residual yeast cells, and is rich in nutrients including digestive enzymes, minerals, vitamins, growth-promoting factors, amino acids, and oligosaccharides, as well as some unknown factors that provide essential nutrition for rumen microbial growth, thereby regulating nutrient digestion.

Previous studies have demonstrated positive effects of yeast culture supplementation. Liu et al. reported that adding 400 g/(d · head) of a dual-strain culture to mid-lactation cows increased milk yield by 6.84% and decreased somatic cell count by 29.78%. Wang et al. found that supplementing 400 g/(d · head) of com-

pound yeast culture to mid-lactation cows increased milk yield by 1.07 kg/(d · head), reduced somatic cell count by 10%, and increased milk fat percentage by 0.08%. Chen et al. showed that adding 30 g/(d · head) of yeast culture improved apparent digestibility of crude protein and dry matter while enhancing antioxidant capacity in growing Jinjiang yellow cattle. Kou et al. reported that supplementing 20 g/kg yeast culture to cashmere goat kids significantly improved apparent digestibility of neutral detergent fiber and crude protein.

Although numerous studies on yeast culture in animals have been reported worldwide, research in dairy cows has primarily focused on improving performance during peak and mid-lactation, with limited reports on its effects on nutrient apparent digestibility during mid- and late lactation. Therefore, this study selected several common yeast cultures for feeding trials to investigate their effects on production performance, nutrient digestibility, serum biochemical indexes, and serum antioxidant indexes in mid- and late lactation dairy cows, providing a comprehensive evaluation of yeast culture application value and theoretical basis for its rational use in dairy production.

Materials and Methods

1.1 Experimental Materials

The three yeast cultures used were: Yeast Culture 1 (YC-1) produced mainly from agricultural by-products, containing *Bacillus subtilis*, modified medium, yeast cells and metabolites, with 22% crude protein, 1% mannose, 6% small peptides, and 3.2×10^8 CFU/g *B. subtilis*. Yeast Culture 2 (YC-2) was primarily produced from distiller's grains, containing modified medium, *B. subtilis*, residual live yeast and other probiotics, with 17% crude protein, 3.21% acid-soluble protein, 2.8×10^8 CFU/g *B. subtilis*, 4.5×10^8 CFU/g residual live yeast, and 1.2% mannose. Yeast Culture 3 (YC-3) was mainly produced from corn, consisting of modified medium, yeast cells and metabolites, with 18.5% crude protein, 2.15% mannan oligosaccharides, 5% mannan, and 9.2% small peptides.

1.2 Experimental Design

The experiment employed a single-factor randomized design. Forty-eight healthy lactating Holstein cows were randomly divided into four groups (12 replicates per group, one cow per replicate) based on similar parity, milk yield, and days in milk. According to product recommendations and energy equivalence principles, the control group received 500 g/(d · head) of flaked corn added to the basal diet, while test groups I, II, and III received 500 g/(d · head) of YC-1, 500 g/(d · head) of YC-2, and 100 g/(d · head) of YC-3, respectively. The 45-day trial included a 15-day preliminary period and a 30-day formal period. All cows were housed in the same barn and fed by the same person. Total mixed ration (TMR) was fed twice daily at 07:00 and 17:00. Pre-weighed yeast cultures were sprinkled onto TMR at 07:00 each day and thoroughly mixed before feeding. Cows were kept in free-stall housing with ad libitum water access. Feed intake, rumination,

behavior, feces/urine, and mastitis occurrence were monitored and recorded.

1.3 Basal Diet

The composition and nutrient levels of the basal diet are shown in Table 1. The commercial concentrate was provided by Beijing Capital Agribusiness Group, with other yeast cultures excluded. Each kilogram of diet contained: VA 4,300 IU, VD 1,300 IU, VE 26 IU, Mn (as manganese sulfate) 17 mg, Zn (as zinc sulfate) 65 mg, I (as potassium iodide) 0.45 mg, and Se (as sodium selenite) 0.3 mg. Net energy for lactation (NEL) was a calculated value, while other nutrient levels were measured values.

1.4 Measurements

1.4.1 Milk Yield, Dry Matter Intake, and Diet Sampling During the formal period, cows were milked three times daily (08:00, 13:00, 18:00) using a DeLaval parallel milking system with Apollo software recording milk yield. Individual cow feed intake and refusals were recorded using automatic feeding troughs. Diet samples were collected every 14 days using the quartering method, dried at 65°C, equilibrated, and prepared as air-dried samples for storage. Dry matter content was determined according to Zhang (2007), followed by analysis of crude protein, ether extract, neutral detergent fiber (NDF), and acid detergent fiber (ADF) on a dry matter basis. Crude protein was measured by the Kjeldahl method, ether extract by Soxhlet extraction, and NDF/ADF by the Van Soest detergent fiber method.

1.4.2 Milk Composition Analysis On days 1, 15, and 30 of the formal period, milk samples were collected and mixed in a 4:3:3 ratio (morning:afternoon:evening). A 50 mL subsample was preserved with potassium dichromate and immediately sent to Beijing Dairy Cattle Center for analysis using a MilkoScan 605 (Foss Electric, Denmark) to determine milk protein percentage, milk fat percentage, lactose percentage, milk urea nitrogen content, and somatic cell count.

1.4.3 Apparent Nutrient Digestibility Seven cows per group were randomly selected for fecal collection via rectal sampling on days 28, 29, and 30 of the formal period. Samples were collected 12 times total: at 03:00, 08:00, 13:00, and 18:00 on day 28; at 04:00, 09:00, 14:00, and 19:00 on day 29; and at 05:00, 10:00, 15:00, and 20:00 on day 30. Approximately 200-400 g of feces was collected per cow per sampling. Feces from each cow were thoroughly mixed, and about 200 g was subsampled and treated with 10% tartaric acid (1/4 of fecal weight) for nitrogen fixation, then dried to prepare air-dried samples for nutrient and acid-insoluble ash (AIA) analysis. Apparent digestibility was calculated using AIA as an internal marker according to Sun et al. (2017):

$$\text{Apparent digestibility (\%)} = 100 \times [1 - (\text{Ad} \times \text{Nf}) / (\text{Af} \times \text{Nd})] \times 100$$

where Ad and Af are AIA content (g/kg) in diet and feces, respectively, and Nd and Nf are nutrient content (g/kg) in diet and feces, respectively.

1.4.4 Blood Sampling and Analysis On day 0 (one day before formal period) and days 15 and 30, six cows per group were randomly selected for tail vein blood collection (10 mL) using vacuum tubes before morning feeding. Blood samples were centrifuged at $1,500\times g$ for 20 min at 4°C , and serum was collected and stored at -20°C . Serum biochemical indexes including glucose (GLU), total protein (TP), albumin (ALB), urea nitrogen (UN), and alanine aminotransferase (ALT) activity were measured by colorimetric methods at Beijing LabTech Technology Development Co., Ltd. Antioxidant indexes including superoxide dismutase (SOD), malondialdehyde (MDA), and glutathione peroxidase (GSH-Px) were measured using assay kits (Nanjing Jiancheng Bioengineering Institute).

1.4.5 Economic Analysis Economic profit was calculated based on milk yield, milk protein percentage, and DMI. Milk yield was converted to 4% fat-corrected milk (FCM) using current milk prices, and diet dry matter cost was based on farm prices. The 4% FCM yield was calculated as: $4\% \text{ FCM} = M(0.4 + 0.15F)$, where M is milk yield and F is milk fat percentage. Gross profit was calculated as: $\text{Gross profit} = AB - CD - E - Q$, where A is 4% FCM yield, B is milk price (3 RMB/kg in this trial), C is diet cost per kg DMI (3.2 RMB/kg), D is DMI, E is cost of 500 g flaked corn ($1.29 \text{ RMB}/(\text{d} \cdot \text{head})$), and Q is yeast culture cost (4, 4, and 5 RMB/ $(\text{d} \cdot \text{head})$ for YC-1, YC-2, and YC-3, respectively).

1.5 Statistical Analysis

Data were initially processed using Excel 2007 and analyzed using SPSS 17.0 software via one-way ANOVA. Duncan's multiple comparison test was used for significance testing. Results are expressed as mean \pm standard deviation, with $P < 0.05$ indicating significant difference.

Results

2.1 Effects of Different Yeast Cultures on DMI, Milk Yield, and Milk Composition

As shown in Table 2, DMI in test group I was significantly higher than that in the control group by 0.82 kg/d ($P < 0.05$), and milk yield significantly increased by 1.18 kg/d ($P < 0.05$). DMI in test groups II and III increased by 0.58 and 0.66 kg/d, respectively, and milk yield increased by 0.79 and 0.65 kg/d, respectively, but these differences were not significant ($P > 0.05$). Milk fat percentage in test group I was significantly higher than that in the control group and test group II by 5.12% and 4.83%, respectively ($P < 0.05$). Compared with the control group, milk fat percentage in test groups II and III increased by 0.26% and

2.70%, respectively, but differences were not significant ($P>0.05$). Milk protein percentage, lactose percentage, and milk fat percentage were all higher in test groups than in the control group, while somatic cell count was lower, but no significant differences were observed among groups ($P>0.05$).

2.2 Effects of Different Yeast Cultures on Nutrient Apparent Digestibility

As shown in Table 3, apparent digestibility of dry matter and NDF in test group I was significantly higher than that in the control group by 5.47% and 3.05%, respectively ($P<0.05$). Test groups II and III showed increases in dry matter and NDF apparent digestibility of 3.71% and 1.84%, and 1.36% and 0.96%, respectively, compared with the control group, but these differences were not significant ($P>0.05$). Apparent digestibility of crude protein, ether extract, and ADF was higher in all test groups than in the control group, but differences were not significant ($P>0.05$).

2.3 Effects of Different Yeast Cultures on Serum Biochemical Indexes

As shown in Table 4, overall patterns in serum biochemical indexes were not clearly consistent. For serum globulin content, test groups I and III were significantly higher than the control group on day 0 ($P<0.05$). Test group III showed significantly higher serum globulin content than the control group on day 15 and for the overall average ($P<0.05$).

2.4 Effects of Different Yeast Cultures on Serum Antioxidant Indexes

As shown in Table 5, average serum SOD activity was higher in all test groups than in the control group, but differences were not significant ($P>0.05$). Serum MDA content in test group I on day 30 and for the overall average was significantly lower than that in the control group ($P<0.05$), with no significant differences at other time points ($P>0.05$). Serum GSH-Px activity in test group I on day 15 and for the overall average was significantly higher than that in the control group ($P<0.05$), with no significant differences at other time points ($P>0.05$).

2.5 Economic Analysis

As shown in Table 6, gross profit in test group I was 0.68 RMB/(d·head) higher than that in the control group, while test groups II and III were 2.55 and 2.37 RMB/(d·head) lower than the control group, respectively.

Discussion

3.1 Effects of Different Yeast Cultures on Performance of Mid- and Late Lactation Dairy Cows

Dairy cow performance is critical to economic efficiency in dairy farming, making nutritional regulation an important approach to improve profitability. Wang et al. found that supplementing 3% yeast culture to mid-lactation cows significantly increased DMI by 0.59 kg/d and milk yield by 1.42 kg/d, while increasing milk fat percentage by 2.57% and milk protein percentage by 2.67%. Wang et al. reported that supplementing compound yeast culture to mid- and late-lactation cows (135-205 d) improved DMI and significantly increased milk yield by 10.05%, milk fat and protein percentages, and reduced somatic cell count. Yao et al. observed that adding 250 g/(d · head) yeast culture to mid- and late-lactation cows significantly increased milk yield by 14.61% and milk fat percentage by 5.81%. However, Liu et al. found that adding 1, 2, or 4 kg/t yeast culture to late-lactation cows had no effect on milk fat percentage, milk protein percentage, or total milk solids.

In the current study, YC-1 supplementation significantly improved DMI and milk yield, while YC-2 and YC-3 also increased DMI and milk yield. The increased DMI may be attributed to aromatic compounds in yeast culture improving diet palatability, while increased cellulase activity in the rumen enhanced fiber degradation and utilization, reducing rumen fill and stimulating appetite. Increased feed intake and small peptides rich in yeast culture both contributed to improved milk yield. Milk fat percentage in test group I was significantly higher than that in the control group and test group II by 5.12% and 4.83%, respectively, which differs from some previous studies. These discrepancies may be due to differences in diet composition, lactation stage, yeast strains, culture medium, feeding duration, and feeding methods.

3.2 Effects of Different Yeast Cultures on Nutrient Apparent Digestibility

Nutrient apparent digestibility is crucial for improving milk production performance and reflects diet digestibility and animal digestive capacity. Wiedmeier et al. reported that yeast culture supplementation significantly improved apparent digestibility of crude protein, hemicellulose, and dry matter in heifers. Zhang found that adding 1.5% and 3.0% yeast culture to sheep diets did not significantly affect whole-tract digestibility of dry matter, organic matter, crude protein, crude fiber, NDF, or ADF. Tang reported that adding 29 g/kg dried yeast culture to late-gestation sows and piglets significantly improved feed conversion and promoted intestinal development.

In this study, YC-1 significantly improved apparent digestibility of dry matter and NDF compared with the control group, which differs from some previous findings. These variations may be attributed to differences among animal species, yeast culture types, and supplementation levels. Probiotics in yeast

culture can promote microbial secretion of amylase, lipase, and cellulase in the rumen, enhancing degradation of starch, fat, and carbohydrates, thereby improving digestibility of dry matter and fiber.

3.3 Effects of Different Yeast Cultures on Serum Biochemical Indexes

Serum biochemical indexes are important parameters for assessing physiological function and reflect metabolic and health status. Serum glucose content reflects the balance of glucose absorption, transport, and metabolism. Serum total protein, albumin, and urea nitrogen contents reflect protein absorption, synthesis, and decomposition. Normal serum total protein in dairy cows ranges from 62-82 g/L, and albumin from 28-39 g/L. Serum globulin has immune activity and reflects immune status. Blood urea nitrogen, derived from tissue protein catabolism and rumen ammonia absorption, is excreted by kidneys and reflects protein metabolism, serving as an important diagnostic indicator. Alanine aminotransferase is an important amino acid transferase in animal cells, and its activity reflects heart and liver function.

Xiao reported that yeast culture supplementation significantly increased serum total protein in broilers. The current results are consistent with Wang et al., showing no significant differences in serum glucose, total protein, albumin, urea nitrogen, or ALT activity among groups. For serum globulin, groups supplemented with YC-1 and YC-3 were significantly higher than the control group on day 0; YC-3 remained significantly higher on day 15 and for the overall average. Mannan and β -glucan in yeast culture can stimulate and activate intestinal mucosal immune function, promoting globulin secretion and enhancing immunity. All test groups showed higher ALT activity than the control group, indicating that yeast cultures do not damage heart or liver function and may promote amino acid metabolism and interconversion of proteins, fats, and carbohydrates. Serum glucose, total protein, albumin, and urea nitrogen remained within normal ranges without significant differences, suggesting that yeast culture does not negatively affect energy metabolism or protein synthesis and degradation.

3.4 Effects of Different Yeast Cultures on Antioxidant Indexes

Serum SOD, GSH-Px activities, and MDA content are important indicators of antioxidant capacity. Wang et al. found that 3% yeast culture supplementation in mid-lactation cows significantly increased blood SOD activity and total antioxidant capacity (T-AOC), with some effects on MDA and GSH-Px. Zhang et al. reported that 2% yeast culture significantly reduced reactive oxygen species and MDA content while increasing SOD, GSH-Px activities, and T-AOC in cashmere goats. Cheng found that 60 g/d yeast culture significantly decreased plasma MDA and increased SOD and GSH-Px activities in mid-lactation cows.

In this study, YC-1 significantly reduced serum MDA content on day 30 and for the overall average, and significantly increased serum GSH-Px activity on day 15 and for the overall average compared with the control group. YC-3 also sig-

nificantly increased overall average GSH-Px activity. These results align with previous studies. Diet can substantially influence antioxidant status, making it feasible to enhance antioxidant capacity through dietary manipulation. Yeast culture is rich in various nutrients including vitamins, minerals (selenium, zinc, iron), nucleotides, amino acids, oligosaccharides, enzymes (SOD), glutathione (GSH), and unknown factors that enhance antioxidant capacity. Studies indicate that yeast culture is rich in GSH, which increases dietary and animal GSH content. GSH-Px uses GSH as a reducing agent to reduce hydrogen peroxide, organic hydroperoxides, and lipid hydroperoxides, protecting cells from oxidative damage. These bioactive nutrients work through various metabolic pathways to enhance overall antioxidant capacity.

Conclusion

Dietary supplementation with yeast culture can improve production performance and nutrient apparent digestibility in mid- and late-lactation dairy cows without negatively affecting serum biochemical indexes, while enhancing antioxidant capacity and improving economic benefits. Supplementation with 500 g/(d · head) of YC-1 demonstrated the best effects.

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