Effects of Selenium- and Germanium-Enriched Yeast Culture on Growth Performance, Muscle Fatty Acids, and Amino Acid Content in Yanbian Cattle (Postprint)

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Abstract

This experiment aimed to investigate the effects of selenium-enriched and germanium yeast culture on growth performance, muscle fatty acid, and amino acid content in Yanbian cattle. Twenty 30-month-old Yanbian cattle bulls with good growth and development, weighing (351$±$20) kg, were selected and randomly divided into 4 groups (5 head per group). The control group was fed a basal diet, while experimental groups I, II, and III were fed experimental diets supplemented with 0.1%, 0.2%, and 0.3% selenium-enriched and germanium yeast culture in the basal diet, respectively. The experimental period was 90 d. The results showed that, compared with the control group: 1) The average daily gain of the experimental groups all increased, but the changes were not significant (P>0.05); the feed conversion ratio of experimental groups I and II improved by 18.93% (P<0.05) and 22.85% (P<0.05), respectively. 2) The linoleic acid content in muscle of experimental groups I, II, and III increased by 9.21% (P<0.05), 11.26% (P<0.05), and 17.06% (P<0.01), respectively; there was no significant difference in other fatty acid contents in muscle among groups (P>0.05). 3) The lysine content in muscle of experimental group III increased by 3.81% (P<0.05); the alanine content in muscle of experimental groups II and III increased by 7.81% (P<0.05) and 7.56% (P<0.05), respectively; the glutamic acid content in muscle of experimental group II increased by 4.98% (P<0.05); there was no significant difference in other amino acid contents in muscle among groups (P>0.05). In conclusion, dietary supplementation with selenium-enriched and germanium yeast culture can improve feed conversion ratio, increase muscle linoleic acid content, decrease the saturated fatty acid/unsaturated fatty acid ratio, increase the content of flavor amino acids (lysine, alanine, and glutamic acid) in muscle, and improve beef flavor. It is recommended to add 0.2% selenium-enriched and germanium yeast culture to the diet of Yanbian cattle.

Full Text

Effects of Yeast Culture with Selenium and Germanium on Growth Performance, Fatty Acid and Amino Acid Contents in Muscle of Yanbian Yellow Cattle

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Abstract: This study investigated the effects of yeast culture enriched with selenium and germanium on growth performance, fatty acid composition, and amino acid content in muscle of Yanbian yellow cattle. Twenty healthy 30-month-old Yanbian yellow cattle bulls weighing (351$±$20) kg were randomly allocated into four groups (n=5 per group). The control group received a basal diet, while experimental groups I, II, and III received the basal diet supplemented with 0.1%, 0.2%, and 0.3% selenium- and germanium-enriched yeast culture, respectively. The trial lasted 90 days. Compared with the control group: (1) average daily gain in all treatment groups increased, but differences were not significant (P>0.05); feed conversion ratio in groups I and II improved by 18.93% (P<0.05) and 22.85% (P<0.05), respectively. (2) Muscle linoleic acid content in groups I, II, and III increased by 9.21% (P<0.05), 11.26% (P<0.05), and 17.06% (P<0.01), respectively; no significant differences were observed in other fatty acids among groups (P>0.05). (3) Muscle lysine content in group III increased by 3.81% (P<0.05); alanine content in groups II and III increased by 7.81% (P<0.05) and 7.56% (P<0.05), respectively; glutamic acid content in group II increased by 4.98% (P<0.05); no significant differences were found in other amino acids among groups (P>0.05). In conclusion, dietary supplementation with selenium- and germanium-enriched yeast culture can improve feed conversion ratio, increase muscle linoleic acid content, decrease the saturated/unsaturated fatty acid ratio, elevate flavor amino acids (lysine, alanine, and glutamic acid) content, and enhance beef flavor in Yanbian yellow cattle. A supplemental level of 0.2% is recommended.

Keywords: selenium- and germanium-enriched yeast culture; Yanbian yellow cattle; growth performance; fatty acid; amino acid

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Introduction

With rising consumption levels, consumer attitudes toward beef consumption have undergone significant transformation, with safe, green, and high-quality beef becoming the primary focus of research [1]. Studies have demonstrated that herbal preparations, saponins, bioactive peptides, and microecological agents can significantly improve livestock product quality [2]. Yeast culture (YC) is a microecological preparation produced through anaerobic fermentation of yeast using specific culture media [3]. Yeast culture can enhance cattle production

performance and meat quality. Geng et al. [4] reported that supplementing Simmental cattle diets with 50 g/(d · head) yeast culture improved beef tenderness and flavor. Zhang [5] found that adding 20 mg/kg negative-ion selenium and germanium herbal compound preparation to Yanbian yellow cattle diets increased muscle protein and unsaturated fatty acid content. Inorganic trace elements can be transformed into organic forms through biological enrichment, thereby improving their bioavailability. Research has shown that selenium- and germanium-enriched yeast culture in Yanbian yellow cattle diets can enhance the umami taste of beef from the loin and round [6]. Germanium can regulate lipid metabolism in poultry and significantly inhibit cholesterol metabolism in eggs [7]. Currently, selenium-enriched yeast is primarily used to improve product quality in poultry and monogastric animals, with limited reports in ruminants. Moreover, most studies have investigated selenium and germanium independently, with few reports on their combined effects in animal production, except for basic research on compound trace element yeast [8]. This study utilized yeast to enrich selenium and germanium, investigating the effects of selenium- and germanium-enriched yeast culture on growth performance, muscle fatty acids, and amino acids in Yanbian yellow cattle to provide a theoretical basis for improving beef quality.

Materials and Methods

1.1 Experimental Material

The selenium- and germanium-enriched yeast culture was provided by the Animal Nutrition and Feed Science Laboratory of the Agricultural College of Yanbian University. The fermentation conditions were: pH 7.0, culture time 60 h, inoculum size 10%, temperature 30.2 °C, rice bran addition 144 g/L, liquid volume 350 mL/L, sodium selenite (Na_2SeO_3) addition 10 mg/L, and germanium oxide (GeO_2) addition 120 mg/L. The final product was obtained through repeated filtration, drying (65 °C), and crushing (150 mesh). UV spectrophotometry determined the organic selenium content at 2.27 mg/kg and organic germanium content at 9.80 mg/kg [9].

1.2 Experimental Design and Animals

The experimental animals were sourced from the Xuchun Beef Cattle Demonstration Base in Hunchun City, Jilin Province. Twenty healthy 30-month-old Yanbian yellow cattle bulls weighing (351$±$20) kg were randomly divided into four groups (n=5 per group) with no significant differences in body weight within or among groups (P>0.05). The control group received a basal diet, while experimental groups I, II, and III received the basal diet supplemented with 0.1%, 0.2%, and 0.3% selenium- and germanium-enriched yeast culture, respectively. The composition and nutrient levels of the basal diet are shown in Table 1 . Cattle were fed twice daily at 04:30 and 16:30, with ad libitum access to water. Regular disinfection and disease prevention measures were implemented throughout the 90-day trial period.

1.3 Measurement Indicators

1.3.1 Growth Performance Average daily feed intake (ADFI) was calculated by accurately recording daily feed consumption and refusals for each animal (dry matter basis). Average daily gain (ADG, kg) = (final body weight - initial body weight) / trial days. Feed conversion ratio (FCR, %) = 100 × ADG / ADFI.

1.3.2 Muscle Fatty Acid Content Three cattle per group were selected, and 100 g of longissimus dorsi muscle between the 12th and 13th ribs was sampled for fatty acid analysis. Sample preparation followed GB/T 22223-2008. Analysis was performed using a gas chromatograph (7890AGC, Agilent, USA) with nitrogen as carrier gas (>99.999% purity, purchased from Changchun Zhongchen Gas Co., Ltd., Jilin Province), hydrogen generated by a high-purity hydrogen generator (SGH-300, Beijing Dongfang Jinghuayuan Technology Co., Ltd.), and high-purity air (>99.999% purity, purchased from Changchun Juyang Gas Technology Co., Ltd., Jilin Province). The standard was a mixed fatty acid methyl ester standard containing 37 components (C4-C24, Sigma, LB74422). The chromatographic column was a Supelco SP-2560 (100 m × 250 m, 0.2 m) with a flame ionization detector. Temperature program: initial 130 °C held for 3 min, ramped at 4 °C/min to 240 °C over 5 min, held for 35 min, total run time 50 min; injector temperature 2400 °C; detector temperature 250 °C.

1.3.3 Muscle Amino Acid Content A 200 g longissimus dorsi sample was prepared according to GB/T 14965-99. Analysis was performed using a high-performance liquid chromatograph (2010A HT, Shimadzu, Japan). Protein hydrolysis tubes were purchased from Fisher. The 17 amino acid standards were from Sigma (SLBC0408V). PITC was from Dikma (USA, chromatographic grade), acetonitrile from Tedia (USA, chromatographic grade), and other reagents were domestic analytical grade. The column was a Shim-Pack VP-ODS (250 mm × 4.6 mm, 5 m) at 38 °C; detection wavelength 254 nm; injection volume 1 L. Mobile phase A: phosphate buffer; mobile phase B: acetonitrile solution. Linear gradient elution: 0 min, 0% B; 5 min, 10% B; 30 min, 40% B; 30.01 min, 70% B; 36 min, 70% B; 45 min, STOP. Flow rate: 1.0 mL/min.

1.4 Statistical Analysis

Data were processed using Excel 2016 and analyzed by one-way ANOVA using SPSS 20.0.

Results

2.1 Effects on Growth Performance

As shown in Table 2 , compared with the control group, average daily gain in all treatment groups increased but differences were not significant (P>0.05).

Feed conversion ratio in groups I and II was significantly improved ($P<0.05$), with no significant difference between these two groups ($P>0.05$). Average daily feed intake showed an upward trend in all treatment groups but did not differ significantly among groups ($P>0.05$).

2.2 Effects on Muscle Fatty Acid Content

As shown in Table 3 , compared with the control group, muscle linoleic acid content in groups I, II, and III increased by 9.21% ($P<0.05$), 11.26% ($P<0.05$), and 17.06% ($P<0.01$), respectively. The saturated/unsaturated fatty acid ratio decreased with increasing supplementation levels, with significant differences observed in groups II and III compared with the control ($P<0.05$). Stearic and palmitic acid contents were slightly lower, while oleic and linolenic acid contents were slightly higher in treatment groups, but these differences were not significant ($P>0.05$). These results indicate that selenium- and germanium-enriched yeast culture can significantly increase muscle linoleic acid content and decrease the saturated/unsaturated fatty acid ratio.

2.3 Effects on Muscle Amino Acid Content

As shown in Table 4 , compared with the control group, lysine content in group III increased by 3.81% ($P<0.05$); alanine content in groups II and III increased by 7.81% ($P<0.05$) and 7.56% ($P<0.05$), respectively; glutamic acid content in group II increased by 4.98% ($P<0.05$). No significant differences were observed among treatment groups for lysine, alanine, or glutamic acid ($P>0.05$), and other amino acids did not differ significantly among groups ($P>0.05$). These results suggest that selenium- and germanium-enriched yeast culture can significantly increase the contents of lysine, alanine, and glutamic acid in muscle.

Discussion

3.1 Effects on Growth Performance

Yeast and lactic acid bacteria are beneficial rumen microorganisms that play crucial roles in maintaining rumen microbial homeostasis in ruminants. Yeast can regulate microbial community structure, enhance lactic acid bacteria activity, and stabilize rumen pH. Selenium-enriched yeast is a common selenium supplement that converts selenium into highly bioactive L-(+)-selenomethionine, facilitating animal absorption and utilization. In this study, different supplementation levels of selenium- and germanium-enriched yeast culture improved average daily gain and feed conversion ratio in Yanbian yellow cattle. All treatment groups showed increased average daily gain without significant intergroup differences. At 0.1% supplementation, feed conversion ratio differed significantly from the control, with better weight gain than at 0.3% supplementation. At 0.2% supplementation, feed conversion ratio improved by 22.85% compared with the control. Average daily feed intake was higher in all treatment groups than in the control, but differences were not significant. Bontempo et al. [10] reported

that live yeast supplementation improved cattle growth performance. Wichtel et al. [11] found that selenium supplementation in 5-month-old dairy calves increased average daily gain. However, Chorfi et al. [12] and Gunter et al. [13] reported no significant effects of selenium-enriched yeast culture or selenium on cattle growth performance. Germanium can increase blood triiodothyronine (T3) and thyroxine (T4) levels, promoting animal growth [14]. Wu et al. [15] found that combined supplementation of selenium (0.15 mg/kg) and germanium (5 mg/kg) with vitamin E yielded optimal results in broiler chickens. Wu et al. [16] reported that germanium-enriched yeast culture improved average daily gain and reduced feed-to-gain ratio in mice. Bai et al. [17] demonstrated that germanium-enriched yeast culture enhanced average daily gain and feed conversion ratio in piglets. Limited research exists on germanium-enriched yeast culture in ruminant production, and its specific mechanisms require further investigation. Differences between our results and previous studies may be related to the combined effects of selenium and germanium. Most current research has examined selenium or germanium yeast culture independently, with no studies on their combined effects.

3.2 Effects on Muscle Fatty Acid Content

Fatty acid content and composition are important indicators of beef quality. Fatty acids are classified as saturated or unsaturated. High saturated fatty acid intake increases the risk of arteriosclerosis [18], while unsaturated fatty acids have anticancer, lipid-lowering, and cardiovascular disease prevention effects. Linoleic and linolenic acids are essential fatty acids for humans and significantly influence beef flavor [19]. Selenium has been shown to regulate fatty acid metabolism in animals [20]. Czauderna et al. [21] reported that selenium-enriched yeast culture increased conjugated linoleic acid content in mouse muscle. Supplementation with selenium-enriched yeast culture also increased unsaturated fatty acid content in cow milk [22]. Limited research exists on germanium' s effects on muscle fatty acid content, but studies on germanium-enriched Ganoderma lucidum showed higher polyunsaturated fatty acid content compared with regular Ganoderma [23]. In this study, selenium- and germanium-enriched yeast culture increased muscle linoleic acid content and decreased the saturated/unsaturated fatty acid ratio.

3.3 Effects on Muscle Amino Acid Content

Of the 22 amino acids required daily by humans, eight must be obtained from food sources. Beef contains these eight essential amino acids with high bioavailability, making it an excellent dietary source. To enhance beef flavor, fermented straw, total mixed rations, and feed additives have been applied in beef cattle production [24-25]. However, muscle amino acid content varies with breed, sex, diet, and rearing environment. In this study, selenium- and germanium-enriched yeast culture increased flavor amino acids (lysine, alanine, and glutamic acid) content, improving beef flavor. Shen [26] used electronic nose and tongue anal-

ysis to demonstrate that selenium- and germanium-enriched yeast culture enhanced umami taste and aftertaste in Yanbian yellow beef. Fu [27] found that 0.35 mg/kg selenium supplementation in Tan sheep diets increased proline and lysine contents, improving mutton flavor. Currently, no reports exist on germanium' s effects on amino acid content in cattle muscle, and the underlying mechanisms require further investigation.

Conclusions

1. Dietary supplementation with selenium- and germanium-enriched yeast culture can increase muscle linoleic acid content and decrease the saturated/unsaturated fatty acid ratio in Yanbian yellow cattle.
2. Dietary supplementation with selenium- and germanium-enriched yeast culture can increase flavor amino acids (lysine, alanine, and glutamic acid) content and improve beef flavor in Yanbian yellow cattle.
3. Considering all measured parameters and feed costs, a supplemental level of 0.2% selenium- and germanium-enriched yeast culture is recommended for Yanbian yellow cattle diets.

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