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Effects of Rumen-protected Glucose Supplementation on Growth Performance, Body Measurements and Plasma Biochemical Indices of Fattening Chinese Simmental Bulls

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ABSTRACT

Background: The objective of the study was to investigate the effects of rumen-protected glucose (RPG) supplementation on growth performance, body measurements and plasma biochemical indices of Simmental bulls in Northeast China during the fattening period.

Methods: A 90 d feedlot study was conducted using thirty Simmental bulls (body weight= 444.3±26.9 kg). Bulls were randomly allocated into three groups to receive a basal total mixed ration (TMR) supplemented daily with 0 g RPG (control, Con), 100 g RPG (RPG100) or 300 g RPG (RPG300) per bull. Growth performance, body measurements and plasma biochemical indices were evaluated.

Result: The greater ADG (P<0.05) and lower feed efficiency value (P<0.01) were found for bulls fed RPG compared to CON diet. Bulls fed RPG had increased body height and chest girth growth compared with CON diet (P<0.05). The plasma glucose (GLC) concentration was higher for bulls fed RPG300 diet than CON and RPG100 diets (P<0.01). Nonestesterified fatty acid (NEFA) concentration was lower for RPG compared with CON treatment (P<0.05). Our analysis suggests that a daily supplement of 300 g RPG is an effective way to increase the body's total GLC provision and thus improve the growth performance of Simmental bulls during the fattening period.

Key words: Body measurements, Chinese Simmental bulls, Growth performance, Plasma biochemical indices, Rumen-protected glucose.

INTRODUCTION

The Simmental breed is one of the most popular beef breeds raised in many regions especially in the Northeast region of China. Simmental bulls reared by farmers are typically fed high energy diets to enhance growth performance during the fattening period. Generally, feeding cereal grains is one way to raise net energy supply because the dietary starch can be utilized in the rumen and the small intestine. The resulting volatile fatty acids from rumen fermentation and glucose (GLC) from small intestinal absorption contributes significantly to the animal's energy supply. Maximum starch utilization can be achieved by optimizing fermentation of starch in the rumen to produce propionate (a gluconeogenic precursor) and maximizing starch digestion and absorption in the small intestine (Park *et al.*, 2018).

However, due to the rumen physiology, the use of a rumen-unprotected GLC source is rapidly fermented in the rumen and limits the amount of GLC absorbed in the alimentary tract (Branco *et al.*, 1999; Wang *et al.*, 2020). Efficiency of conversion of starch energy into tissue energy is improved when starch is digested in the small intestine rather than fermented in the rumen (Harmon, 1992). Increasing digestion of rumen-protected starch in the small intestine can help increase the GLC supply. A considerable amount of GLC is absorbed from the small intestine when high-starch diets are fed, especially during the beef cattle fattening period. Ørskov (1986) reported that up to 42% of dietary starch may escape ruminal fermentation and reach the small intestine. Harmon and McLeod(2001) reported that starch digestion is more efficient in the small intestine than during fermentation in the rumen: the total energetic efficiency of rumen-fermented starch was about 73% that of small intestine-digested starch.

In order to enhance direct absorption of GLC from the gastrointestinal tract, it is feasible to selectively supplement carbohydrate resources in diets that can bypass the rumen without easily being fermented. For example, some cereal grains like sorghum and some corn hybrids contain starch which partially escapes the rumen and can be digested in

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the duodenum (Hindle *et al.*, 2005), thereby increasing the absorption of GLC. More directly, rumen-protected glucose (RPG) coated with fat has been developed to enhance the absorption of GLC from the gastrointestinal tract of ruminants.

Nevertheless, the studies on RPG in ruminants have mainly focused on postpartum dairy cows and little information is available to show the effect of RPG on feedlot performance of beef cattle during the fattening period. We hypothesized that feeding RPG may be an alternative strategy to increasing the energy supply for fattening beef cattle. Thus, the current study was carried out to investigate the effects of RPG on growth performance, body measurements and plasma biochemical indices of Simmental bulls during the fattening period.

MATERIALS AND METHODS

Bulls, feeds and management

The animal care and experimental procedures were conducted according to procedures approved by the Animal Welfare and Ethics Committee of Heilongjiang Bayi Agriculture University. Animal care and handling followed the guidelines by the regulations for the Administration of Affairs Concerning Experimental Animals (The State Science and Technology Commission of China, 1988). The experiment was carried out at the experimental farm of Heilongjiang Academy of Land Reclamation Sciences from August 3rd to November 1st, 2020. Thirty Simmental bulls (13-14 mo of age) with initial body weight of (444.3±26.9 kg) were selected and randomly divided into three groups in such a way that each group contained ten bulls. The bulls in each group were fed a basal total mixed ration (TMR) supplemented with either 0 g RPG (control, Con), 100 g RPG (RPG100), or 300 g RPG(RPG300) per bull per day.

Ingredient and nutrient levels of basal total mixed ration are shown in Table 1. The RPG used in this study was manufactured by a patented technique. It was prepared with 45% GLC as the core material with 50% fat as a coating and 5% water. The product is granular, with a particle diameter of 0.6-0.85 mm. Considering the possible additional effect on growth performance caused by increased RPG intake, the control group was supplemented with 135 g GLC and 150 g coating fat per bull daily. RPG100 group was supplemented with 90 g GLC and 100 g coating fat per bull daily. Thus, the same amount of GLC and coating fat were offered to bulls across the three different treatments (Table 2).

The RPG, GLC and coating-fat were equally distributed over two feeding by top-dressing on the TMR at each feeding. Bulls were housed in individual stalls and consumed feed ad libitum, with equal portions of fresh feed given twice daily at 0600 and 1430 h. Orts were collected and weighed prior to each feeding. Fresh and clean water was available at all times. Bulls were given 7 days for adaption prior to start of experimental period. No abnormal behavior were observed during the adaptation period. The experimental period lasted 90 days after the adaptation period.

Growth performance

Bulls were weighed before the morning feeding for three consecutive days at the 0d and 90d of the experiment to calculate the initial body weight, final body weight and average daily gain (ADG). Feed consumption was recorded daily. Feed efficiency was determined by dividing feed consumption by ADG. Body measurements including body height, body length, withers height and chest girth were taken at the beginning and end of the trial according to the study made by Li *et al.* (2019).

Plasma biochemical indices

At the end of the experiment, blood samples (about 10 mL) were collected from the jugular vein at approximately 3 h post morning feeding for three consecutive days. Blood samples were collected into heparinized vacuum tubes and plasma was obtained by centrifuging at 3000 × g for 15 min; it was then stored (-20°C) until analysis. Plasma biochemical indices including GLC, NEFA, triglycerides (TG), total protein (TP) and β-hydroxybutyric acid (BHBA) were measured on an automatic hematology analyzer (iChem-340, Kubeier Instruments Co., Ltd, China) by using commercial kits (BSBE Biotechnology Co., Ltd., Beijing, China).

Table 1: Ingredient and nutrient levels of the basal diet (DM basis, %).

Ingredient	Content	Nutrient levels	Content
Leymus chinensis	40.00	NEm (Mcal/kg)[2]	1.44
Steam flaked corn	16.80	NEg (Mcal/kg)[3]	0.88
Corn germ meal	13.56	DM[4]	89.33
DDGS[1]	18.84	CP[5]	12.33
Extruded urea	2.4	EE[6]	2.71
Sodium bicarbonate	2.4	NDF[7]	38.07
Limestone	2.4	ADF[8]	21.33
Sugarcane molasses	1.8	Ash	6.23
NaCl	0.6	Ca[9]	0.73
Premix[11]	1.2	P[10]	0.28

1: DDGS: Distillers dried grains with solubles; 2: NEm: Net energy for maintenance; 3: NEg: Net energy for gain; 4: DM: Dry matter; 5: CP: Crude protein; 6: EE: Ether extract; 7: NDF: Neutral detergent fiber; 8: ADF: Acid detergent fibrr; 9: Ca: Calcium; 10: P: Phosphorus; 11: The premix provided the following per kilogram of the diet: Vitamin A: 11,000IU; Vitamin D: 3,000IU, Vitamin E: 80 mg, Fe: 60.74 mg, Zn: 146.55 mg, Mn: 51.04 mg, Cu:15.12 mg, I:1.22 mg, Se: 0.53 mg, Co: 0.41 mg, Cr: 0.56 mg.

Table 2: RPG, GLC and coating-fat supplementation of different treatment groups.

	CON	RPG100	RPG300
RPG (g/head·d)	0	100[1]	300[2]
GLC (g/head·d)	135	90	0
Coating -fat (g/head·d)	150	100	0
Total GLC (g/head·d)	135	135	135
Total Coating-fat (g/head·d)	150	150	150

[1]100 g RPG containing: 45 g GLC and 50 g coating fat.
[2] 300 g RPG containing: 135 g GLC and 150 g coating fat.

Statistical analysis

All data were statistically analysed by PROC MIXED of SAS version 9.4 (SAS Institute Inc., Cary, NC, USA). The statistical model was

$$Y_{ij} = \mu + D_i + B_j + \varepsilon_{ij}$$

Where

Y_{ij} is the observed variable, μ is the overall mean, D_i is the fixed effect of diet treatment, B_j is the random effect of bulls and ε_{ij} denotes the residual error. Significance was declared for $P<0.05$ and trends were reported at $0.05<P<0.10$. When a significant effect of treatment was detected ($P<0.05$), differences between the means were tested using the Bonferroni multiple comparison test.

RESULTS AND DISCUSSION

Growth performance

The results of growth performance of bulls are shown in Table 3, Fig 1 and 2. The initial BW, final BW, DMI were not different among dietary treatments. Bulls fed RPG300 had greater ADG than bulls fed CON and RPG100 diets ($P<0.05$). Compared with bulls fed CON, Bulls offered RPG improved feed efficiency due to a lower value of feed efficiency ($P<0.01$).

Feed intake and utilization involve a complex of biological processes and pathways (Arthur and Herd, 2005) and DMI is often highly correlated with body weight and level of production. In the present study, DMI was not different among treatments in the different phases. However, DMI appeared to decrease numerically with increasing RPG level during the late fattening phase. It appears that higher glucose availability to small intestine may improve the energy supply and possibly decrease DMI. Knowlton *et al.* (1998) found a 40 g/kg decrease of DMI with 1500 g/d of starch infusion in early lactation dairy cows. Larsen and Kristensen (2009) reported that a continuous abomasal GLC infusion led to a 6.2 kg/d decline of DMI in early lactation of dairy cows. Li *et al.*(2019) showed there was a numeric decrease of 0.6 kg for transition dairy cows supplemented with 200 g/d RPG. However, most of the research has focused on dairy cows and limited studies could be found on beef cattle. So, further research is needed to explore the impacts of RPG on intestinal GLC absorption and feed intake regulation in beef cattle.

Simmental beef cattle are welcomed by Chinese farmers mainly because they usually have excellent growth rate and are more efficient under intensive feeding conditions. The bulls in this trial presented a satisfactory daily gain exceeding 1.43 kg/d. A survey conducted by Gallo *et al.* (2014) over nearly a 10-year period in Italian feedlots showed the ADG of imported Simmental bulls from Eastern European countries (32 batches of cattle with a total of approximately 2000 head) was 1.30 kg/d. Sami *et al.* (2004) reported an ADG of 1.39 kg/d for German Simmental bulls (approximately 15 months old) and was affected by feeding intensity. Spanghero *et al.* (2017) found that Italian Simmental bulls (14 months old) gained 1.25-1.37 kg/d when

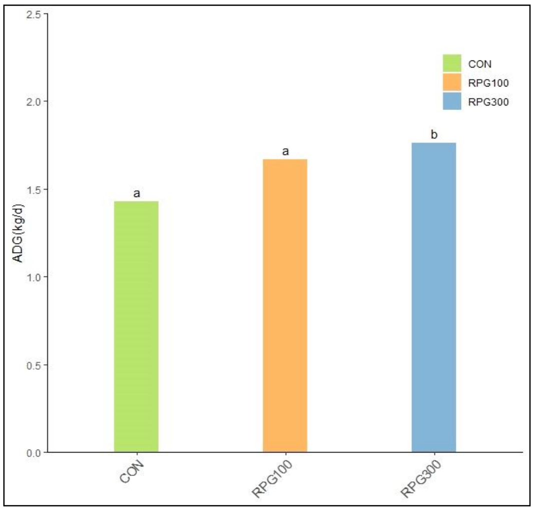

Fig 1: Average daily gain (ADG) of different RPG supplementation treatments.

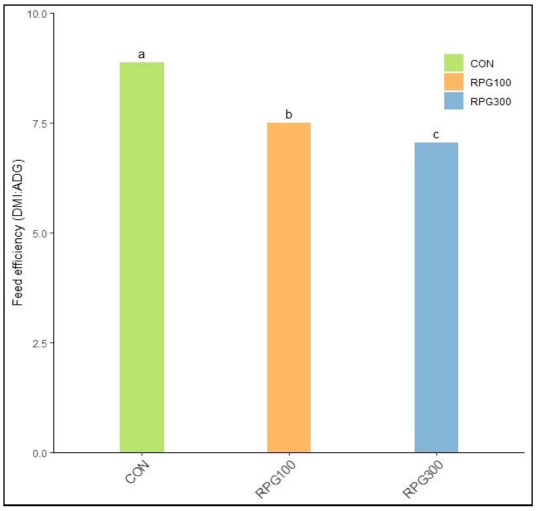

Fig 2: Feed efficiency (DMI:ADG) of different RPG supplementation treatments.

Table 3: Effects of different RPG supplementation on growth performance of Simmental Bulls.

Item	CON	RPG100	RPG300	SEM	*P* value
Initial BW (kg)	446.2	441.0	446.1	29.4	0.980
Final BW (kg)	574.6	591.0	604.6	19.6	0.630
DMI (kg/d)	12.6	12.5	12.4	0.06	0.621
ADG (kg/d)	1.43[a]	1.67[a]	1.76[b]	0.14	0.048
Feed efficiency (DMI:ADG)	8.87[a]	7.49[b]	7.05[c]	0.05	<0.01

[a,b]Mean values within a row with different superscript letter differ significantly ($P<0.05$).

fed a diet similar to the current study control diet. In the current study, the ADG of bulls fed RPG300 was higher than the bulls in the control and RPG100 group (1.76 vs 1.43 and 1.67 kg/d). Compared with the above-mentioned research, Simmental bulls fed RPG in this trial achieved a higher ADG at a similar age in a comparable BW. The feed efficiency of bulls fed RPG300 and RPG100 were better than those fed CON diets (7.05 and 7.49 vs 8.87, respectively). The efficiency data were similar to that obtained by Sami *et al*. (2004), but not higher than the results observed by Spanghero *et al*.(2017).

ADG and feed efficiency were positively affected by high dietary energy content (Sami *et al*., 2004). Unlike starch, glucose is readily absorbed in the small intestine (Krehbiel *et al*., 1996; Rodriguez *et al*., 2004). Rodriguez *et al*.(2004) showed that glucose is more efficiently used by the fattening animal when it is directly absorbed in the small intestine thereby increasing energy deposition efficiency. Our results indicate that increasing the small intestinal GLC supply is a strategy to improve ADG and feed efficiency of finishing beef cattle.

Body measurements

The results of body measurements of bulls are shown in Table 4. Body measurements including withers height, body length, hip height and chest girth were not different at the beginning and the end of the experiment. Greater withers height and chest girth growth were observed for bulls fed RPG100 or RPG300 than those fed CON diet (*P<0.05*). Bulls fed RPG300 had the highest numerical values for body height and chest girth growth.

Body measurements usually reflect body growth and development, which can be used to estimate liveweight (Chaturvedani *et al*., 2017; Kumar *et al*., 2018). A tendency of the body to become longer and deeper as animals grow is well known. Withers height and body length are mainly determined by the composition of the bones, which are an early maturing part of the body. In the present study, withers height and body length were in the normal range which in agree with the research reported by Albertí *et al*. (2008) and no significant differences were detected among the three groups at the beginning and end of the experiment. However, bulls assigned to RPG treatment groups achieved a greater growth for withers height than CON diet. The result indicated that feeding RPG appear to have a positive effect on withers height growth. Chest girth typically has a high correlation with body weight in many breeds of cattle (Heinrichs *et al*., 2007). The increasing RPG level contributed to a greater chest girth growth in the present study and this result fully corresponds with the higher ADG obtained by the bulls fed RPG. Moreover, chest girth is a relatively late maturing part of the body and mainly determined by muscle and fat deposition. Therefore, increasing RPG supply may improve protein and fat deposition of bulls.

Plasma biochemical indices

Plasma biochemical indices of different treatments are presented in Table 5, Fig 3 and 4. Plasma biochemical indices including TG, TP and BHBA concentrations were not affected by different diet treatments. GLC concentration was significantly higher for bulls fed RPG300 compared with CON and RPG100 diets (*P<0.01*). NEFA concentration was lower for the RPG treatments compared with the CON treatment (*P<0.05*).

GLC, NEFA and BHBA are the most common metabolites used to assess the energy status of beef cattle and cows (Khune *et al*., 2019; Selvaraj *et al*., 2019). Glucose values observed among the different treatment groups were 79.38-90.36 mg/dL, these concentrations are within expected normal ranges. Previous studies have reported plasma glucose levels ranging from 69.9 to 101.1 mg/dL in finishing feedlot steers (Kolath *et al*., 2006; Kang *et al*., 2020; Warner *et al*., 2020). Blood plasma GLC concentration was higher for bulls fed RPG300 compared with CON and RPG100 diets. Due to the extensive rumen fermentation of dietary carbohydrates, VFA and not glucose are the main digestion end products absorbed across the gut in ruminants (Harmon and Swanson, 2020) and there

Table 4: Effects of different RPG supplementation on body measurements of Simmental bulls.

Item	CON	RPG100	RPG300	SEM	*P* value
Initial					
Withers height (cm)	127.3	124.8	122.0	2.48	0.368
Body length (cm)	141.1	144.0	142.0	2.58	0.715
Hip height (cm)	132.1	129.8	129.7	1.36	0.382
Chest girth (cm)	172.8	176.8	168.7	3.90	0.320
Final					
Withers height (cm)	134.3	132.0	132.5	2.44	0.795
Body length (cm)	148.6	151.7	152.7	1.97	0.328
Hip height (cm)	140.3	137.4	137.5	1.12	0.135
Chest girth (cm)	189.3	193.5	192.0	3.62	0.651
Growth					
Withers height (cm)	7.0	7.3	10.5	0.85	0.030
Body length (cm)	7.5	7.7	10.7	1.22	0.214
Hip height (cm)	8.2	7.6	7.8	0.89	0.890
Chest girth (cm)	16.5	16.8	23.3	1.85	0.049

Table 5: Effects of different RPG supplementation on plasma biochemical indices of Simmental bulls.

Item	CON	RPG100	RPG300	SEM	*P* value
GLC (mg/dL)	80.46[a]	79.38[a]	90.36[b]	0.096	0.003
NEFA (mmol/L)	1.77[a]	1.49[b]	1.46[b]	0.064	0.015
TG (mmol/L)	0.21	0.21	0.27	0.031	0.275
TP (g/L)	87.79	88.43	89.51	2.030	0.835
BHBA (mmol/L)	2.00	1.96	1.96	0.062	0.853

[ab]Mean values within a row with different superscript letter differ significantly (*P<0.05*).

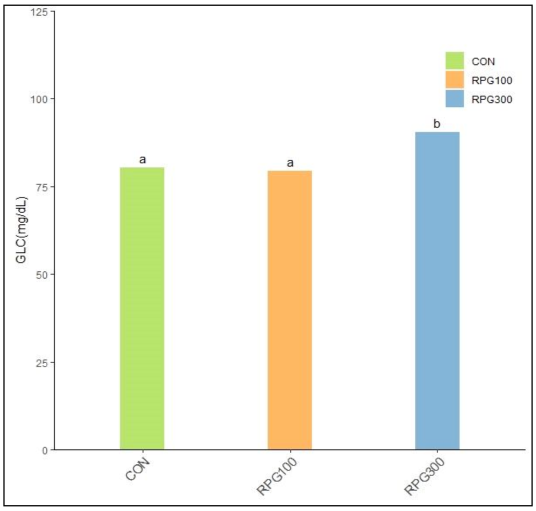

Fig 3: Glucose (GLC) of different RPG supplementation treatments.

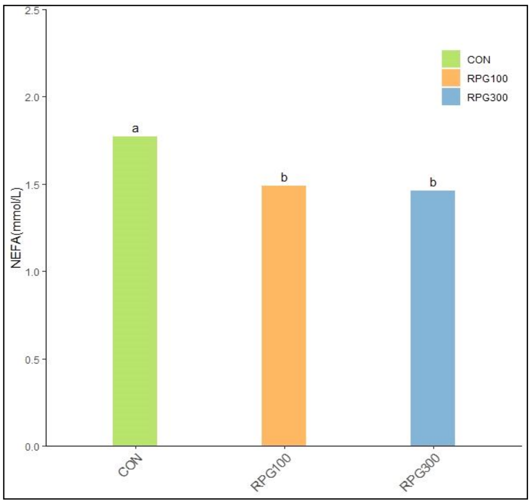

Fig 4: Nonestesterified fatty acid (NEFA) of different RPG supplementation treatments.

are limitations in the amount of starch that is then digested in the small intestine. The results suggest that additional GLC supplied to small intestine can be more directly absorbed into bloodstream, which contribute to increasing plasma GLC concentration.

NEFA is considered as important clinical indicator which reflect body fat catabolism in response to negative energy balance or stress conditions. NEFA concentrations are commonly used in assessing energy status of dairy cows (Adewuyi *et al.*, 2005; Leroy *et al.*, 2011). Elevated NEFA levels indicate that dietary energy intake is insufficient for the cattle's production and that body fat is being mobilized to supply the energy deficit. Chimonyo *et al.*(2000) reported increasing NEFA levels in undernourished cows that were used for draught power. High circulatory NEFA can be transported to the liver which resulted in either elevated ketones or fat production by the liver(Herdt, 2000; Grummer, 2008). In this study, a decrease in the plasma NEFA concentration was found with RPG supplementation. The results showed that RPG supplementation in the diet can exert positive effects on the efficiency of energy utilization of Simmental bulls.

CONCLUSION

The key findings of this research indicate that supplementation with RPG for fattening Simmental bulls improved ADG, withers height and chest girth growth; increased plasma GLC and lowered plasma NEFA concentration. We conclude that a daily supplement of 300g RPG is an effective way to increase the body's total GLC provision and thus improve the growth performance of beef cattle during the fattening period.

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