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Rumen fermentation pattern of dairy heifers fed restricted amounts of low, medium, and high concentrate diets without and with yeast culture☆

G.J. Lascano, A.J. Heinrichs *

Department of Dairy and Animal Science The Pennsylvania State University 324 Henning Building University Park, PA 16802, United States

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Restricted feeding and high concentrate diets are potential strategies for growing dairy heifers. Ruminal manipulation with additives such as *Saccharomyces cerevisiae* yeast culture (YC) has been shown to alter digestibility when added to this type of diet. An experiment was conducted to investigate the ruminal fermentation and in situ digestibility of diets with 3 different levels of forage to concentrate (F:C) fed at restricted intake without and with YC addition. Three cannulated post-pubertal Holstein heifers (age 18.0 ± 1.2 months; body weight 449.6 ± 19.7 kg) were fed diets consisting of corn silage as the sole forage source in a 3 period (35-day) Latin square design. Heifers were fed diets for 21 days with no YC addition, followed by 14 days where YC was added to the diet (1 g/kg as fed basis). Low (LC), medium (MC), and high (HC) concentrate diets (20, 40, and 60% concentrate) were fed once daily on a restricted basis to provide 0.22 Mcal ME/kg empty $BW^{0.75}$. Rumen fluid was sampled on days 18 and 32 of each period, and rumen contents were evacuated on days 21 and 35 of each period. An in situ study was done on days 14 to 17 and on days 28 to 31. Mean ruminal pH was not different between dietary treatments and no YC effect was detected. Mean total volatile fatty acids (VFA) and ruminal ammonia-nitrogen (NH_3-N) concentration was also not different among diets with different F:C. Molar proportions of acetate were decreased, and propionate were increased; while the acetate-to-propionate ratio was decreased as the concentrate level increased from LC to HC. Total VFA, propionate, and acetate as well as isoacids concentration increased, yet NH_3-N concentration decreased with YC addition in all diets. From these results we conclude that feeding HC diets in restricted amounts had minimal effects on rumen fermentation rate between different F:C diets. The addition of YC modified NH_3-N and volatile fatty acid concentrations in the rumen in all 3 diets in this study, presumably through alterations in end-product production and utilization.

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1. Introduction

One of the most useful measures of animal performance across species is feed efficiency, a direct marker of the animal's ability to be more productive. Improving the efficiency to convert units of feed to units of growth means less feed is required to raise more livestock in a given amount of time (Loerch, 1990; Hoffman et al., 2007). Another marker of animal performance is average daily gain (ADG; Gerrard and Grant, 2003). Research suggests that a prepubertal ADG of approximately 800 g/d is appropriate for large breed dairy heifers to maximize first lactation milk yields (Zanton and Heinrichs, 2005). Adequate body size is also necessary, and an age at first calving between 23 and 24 months results in profitable milk production (Pirlo et al., 2000). Since feed costs contribute the most to raising heifers, it is logical to expect that improving feed efficiency could decrease the cost for raising dairy heifers, provided ADG is adequate.

A typical dairy heifer is fed a ration primarily derived from forages as opposed to concentrates. However, there is a large inefficiency associated with this method of feeding due to lower digestibility of most forages, greater metabolic protein

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* Corresponding author. Tel.: +1 814 863 3916; fax: +1 814 865 7442.
E-mail address: ajh@psu.edu (A.J. Heinrichs).

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and energy requirements associated with digesting forage (Reynolds et al., 1991), and higher feed costs per unit of energy as compared to concentrates (Zanton and Heinrichs, 2007). The potential therefore exists to replace a significant proportion of the ration forage dry matter (DM) with concentrate DM, reducing some inefficiency associated with raising dairy heifers while maintaining ADG. Experiments have recently been conducted to evaluate heifer growth characteristics and nutrient utilization when fed differing forage to concentrate ratios (F:C) at restricted intakes to achieve similar ADG (Hoffman et al., 2007; Zanton and Heinrichs, 2007). In areas with limited land resources, corn silage is often the forage of choice due to its high DM yield potential per hectare. However, when limit-feeding high energy forages and diets based on corn silage, rumen fermentation and growth of the animal may be challenged.

Yeast culture (YC) has been used as an additive to ruminant diets since 1924, with various results reported in the literature. Results following addition of YC based on *Saccharomyces cerevisiae* to the diet include improved productivity in both lactating and growing animals. Though increases in productivity are generally variable, rumen fermentation rate and patterns seem to be involved in this response (Carro et al., 1992). The mode of action of YC products has not been completely described, but many hypotheses are related to changes in rumen fermentation rate and patterns. Volatile fatty acid (VFA) production, neutral detergent fiber (NDF) digestibility and disappearance, organic matter digestibility, and bacterial and protozoal populations have been enhanced by yeast supplementation (Lascano and Heinrichs, 2007). Decreases in lactic acid concentration and the lag time of DM degradation as well as stabilization of rumen pH are other observed effects (Wallace, 1996). Overall, the rumen environment typically benefits, which leads to an improved metabolic performance of the animal.

Research indicates that including live or dead YC products in adult and young ruminant diets can alter the rumen environment; however, different responses have been found depending on the diet used (Lascano and Heinrichs, 2007). In lactating dairy cows, YC has been shown to increase the nutritional value of high concentrate diets (Arambel and Kent, 1990). Therefore, the purpose of this study was to investigate the effect of YC in the rumen environment when added to limit-fed, high concentrate diets based on corn silage offered to dairy heifers.

2. Materials and methods

2.1. Animal, housing and diet

Three Holstein dairy heifers, each previously fitted with a 10.6 cm rumen cannula (Bar Diamond, Parma, ID,USA) under anesthesia, were housed in a mechanically ventilated and environmentally controlled tie stall barn. Animal care procedures followed the Pennsylvania State University Institutional Animal Care and Use Committee approval. Total mixed rations (TMR) contained corn silage as the sole forage source, ground corn, soybean meal and heat treated soybean meal (Table 1). Animals were fed once daily at 1000 h and no refusals were observed during the trial. Rations were mixed daily in a rotary mixer (Calan Super Data Ranger; American Calan, Northwood, NH, USA) for approximately 5 min. Three F:C were formulated and mixed to provide 80:20, 60:40, and 40:60, designated low (LC), medium (MC), and high (HC) concentrate, respectively. Yeast culture product (YC, Yea-Sacc® 1026, Alltech, Inc., Nicholasville, KY, USA) was added at a rate of 1 g/kg/d as fed basis. This dose was selected to have a constant inclusion level of YC across treatments with different intakes. Research shows that when the amount of YC is constant regardless of the intake, the YC effect in animals with higher feed consumption tends to disappear (Lascano and Heinrichs, 2007; Robinson and Erasmus, 2007). Feed ingredients and TMR samples were collected daily and composited for every period, dried in a forced air oven (55 °C) immediately after collection, and stored for further analysis. Health conditions of experimental animals were monitored twice daily at 0830 and 2030 h. Heifers had free choice access to water and were released 1 h post-feeding for approximately 1 h daily to a paved exercise lot, except on intensive sampling days. Heifers were kept for 30 d before starting the experiment to adapt to the tie stall facility and experimental diets. Animals at 18.0 ± 1.2 months of age with 449.6 ± 19.7 kg body weight (BW) were randomly assigned to 1 of 3 treatments in a 3 × 3 Latin square design. Each of the 3

Table 1
Ingredient and nutrient composition of high concentrate (HC), medium concentrate (MC), and low concentrate (LC) rations fed to heifers.

	Treatment			
Composition	LC	MC	HC	SE
Ingredients (%DM)				
Corn silage[1]	80.00	60.00	40.00	.
Ground corn	5.67	29.60	47.70	.
Soybean meal (SBM)	9.47	9.94	9.00	.
Heat treated SBM	1.60	0.80	0.00	.
Sodium bicarbonate	0.35	0.35	0.35	.
High mineral mix[2]	0.00	1.23	2.95	.
Low mineral mix[3]	2.45	1.48	0.00	.
Nutrients[4]				
DM %	41.93^a	50.61^b	56.51^c	1.03
CP %	12.93^b	12.38^a	13.17^b	0.10
Soluble, % of CP	43.65^b	43.65^b	33.84^a	0.76
ADF %	20.45^c	17.93^b	12.97^a	0.19
NDF %	34.18^c	30.03^b	23.23^a	0.38
NFC %[5]	48.05^a	53.30^b	58.48^c	0.14
TDN %[6]	72.13^a	75.13^b	78.63^a	0.11
ME, Mcal/kg DM[7]	2.63^a	2.72^b	2.84^c	0.01
Ca %	0.38	0.37	0.36	0.02
P %	0.30	0.28	0.30	0.01
Mg %	0.20	0.22	0.23	0.01
K %	1.33^c	1.12^b	1.02^a	0.03

^{a,b,c} Means in the same row with different superscripts differ ($P<0.05$).
[1]Corn silage contained: 33.7% DM, 38.4% NDF, 23.9% ADF, 9.1% CP, 36.32% starch on DM basis.
[2]High mineral mix contained: 7.8% vitamin E, 2.6% vitamin ADE, 28.6% distillers corn with soluble vitamin D, 14.6% plain salt, 36.5% limestone, 2.6% magnesium oxide, 5.7% trace mineral premix, and 1.6% selenium premix on a DM basis.
[3]Low mineral mix contained: 7.4% vitamin E, 2.5% vitamin ADE, 28.6% distillers corn with soluble vitamin D, 13.9% plain salt, 34.8% limestone, 6.0% magnesium oxide, 5.5% trace mineral premix, and 1.5% selenium premix on a DM basis.
[4]$n = 6$ composite samples representing 42 samples per treatment taken daily throughout the collection periods.
[5]Non fibrous carbohydrates analyzed by Cumberland Valley Analytical Services Laboratory (Maugansville, MD, USA).
[6]Total digestible nutrients (calculated from ingredients).
[7]Estimated: metabolizable energy (ME) = TDN × 0.04409 × 0.82 (Lammers and Heinrichs, 2000).