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Effect of fiber content of roughage on energy cost of eating and rumination in Holstein cows

Tomoyuki Suzuki[a,*], Yuko Kamiya[a], Masahito Tanaka[a], Ikuo Hattori[a], Takeo Sakaigaichi[b], Takayoshi Terauchi[b], Itoko Nonaka[a], Fuminori Terada[c]

[a] *Livestock and Grassland Research Division, NARO Kyushu Okinawa Agricultural Research Center, 2421 Suya, Koushi, Kumamoto 861-1192, Japan*
[b] *Crop and Agribusiness Research Division, NARO Kyushu Okinawa Agricultural Research Center, 1742-1 Anno, Nishinoomote, Kagoshima 891-3102, Japan*
[c] *NARO Institute of Livestock and Grassland Science, 2 Ikenodai, Tsukuba, Ibaraki 305-0901, Japan*

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The effect of the fiber content of roughage on energy cost of chewing was determined by indirect calorimetry. Four Holstein non lactating cows [779 ± 71 kg body weight (BW)] were used in a cross over design with 14-day periods. Two cows were fed sugarcane silage as high fiber roughage (HF) and the other two cows were fed oaten hay as low fiber roughage (LF), along with soybean meal [0.5 g/kg BW on a dry matter (DM) basis]. The aNDFom and peNDF contents were different (718 vs. 542 g/kg DM and 554 vs. 402 g/kg DM, respectively), whereas the physical effectiveness factors (pef) was similar between sugarcane silage and oaten hay (771 vs. 741 g/kg DM). The study was performed in open circuit respiration chambers over a 14-day period, consisting of a 9-day adaptation and a 5-day energy balance measurements. Energy cost of chewing per minute was determined using a multiple linear regression model, with heat production per 10 min as the dependent variable and duration of activities per 10 min as independent variables. DM intake (DMI) of roughage in HF was lower than that in LF (5.46 vs. 9.79 kg/day; P=0.006), whereas duration in total chewing (Eating + rumination) was higher for HF than for LF (120 vs. 77 min/kg DMI; P=0.006). Energy cost of rumination per unit DMI tended to be higher for HF than for LF (0.71 vs. 0.48 MJ/kg DMI, P=0.062), whereas energy cost of each eating and rumination per unit time was similar between treatments (17.7 vs. 18.4 J/min/kg BW for eating, P=0.272; 12.0 vs. 12.7 J/min/kg BW for rumination, P=0.285). Energy cost of total chewing per unit metabolizable energy (ME) was higher for HF than that for LF (14.3 vs. 9.0 MJ/100 MJ ME, P=0.009). These results indicate that fiber content in roughage possibly affects energy cost of chewing per DMI and consequently results in loss of ME available for production.

Abbreviations: ADFom, acid detergent fiber expressed exclusive of residual ash; aNDFom, neutral detergent fiber assayed with α-amylase and expressed exclusive of residual ash; BW, body weight; CP, crude protein; DEI, digestible energy intake; DM, dry matter; DMI, DM intake; GE, gross energy; HF, high fiber roughage; HP, heat production; LF, low fiber roughage; Lignin(sa), lignin determined by solubilization of cellulose with sulfuric acid; ME, metabolizable energy; MEI, ME intake; peNDF, physically effective NDF; pef, physical effectiveness factors.

* Corresponding author at: Present address: Japan International Research Center for Agricultural Sciences, 1-1 Ohwashi, Tsukuba, Ibaraki, 305-8686, Japan. Tel.: +81 29 838 6313: fax: +81 29 838 6316.
E-mail address: suzukito@affrc.go.jp (T. Suzuki).

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1. Introduction

In ruminants, the physical properties of feed affect intake and chewing activity as well as salivary secretion that have a buffering effect in the rumen. Lack of physical properties, such as short particles or low fibrousness, results in rumen acidosis, inhibition of milk fat synthesis, and disorders in cows. Fiber content (Waldo, 1986; Mertens, 1997), roughage value index (Sudweeks et al., 1981), or physically effective neutral detergent fiber (peNDF; Mertens, 1997) are generally used to evaluate the physical properties of feed. It is known that the energy cost of eating is affected by acid detergent fiber (ADF) or acid detergent lignin (ADL) content (Lachica et al., 1997) and by roughage species (Adam et al., 1984; Lachica et al., 1997; Susenbeth et al., 2004). Thus, the energy cost of chewing might also be available as an index of the physical properties of feed.

Susenbeth et al. (1998, 2004) reported that the proportion of energy cost of chewing to metabolizable energy intake (MEI) differed with the roughage species, and it was in the range of 6–9 MJ/100 MJ MEI for eating, and estimated at 2–5 MJ/100 MJ MEI for rumination. Therefore, ME loss caused by chewing has some effect on animal productivity. There is very little information on energy cost of rumination compared to that during eating, especially in cattle (Susenbeth et al., 1998). The most of studies determined the energy cost of chewing as the difference between heat production (HP) during chewing and HP during no chewing using indirect calorimetry. Eating generally occurs at feeding in a standing position, but rumination occurs either in standing or lying throughout the day. Energy cost also depends on the position of the cow, and HP while standing is 1.19 times as high as that while lying (Susenbeth et al., 2004). The lack of data on rumination is primarily due to the difficulty in controlling the rumination and the position of an animal. Suzuki et al. (2012) suggested calculation of HP with respective activities using multiple linear regression model including HP per unit time as dependent variable, and duration of eating, rumination and standing per unit time as independent valuables. There is a possibility to evaluate the effect of feed on energy cost of chewing using this multiple regression model.

The objective of this study was to investigate the effect of fiber content, which is one of the factors affecting physical properties, on energy cost of chewing in cows fed roughage with high fiber (HF) content (sugarcane silage) or low fiber (LF) content (oaten hay), by using multiple regression model.

2. Materials and methods

2.1. Feed preparation

Sugarcane (KRFo93-1) developed for animal feed (Suzuki et al., 2010) and oaten hay were used in this study. The sugarcane was harvested at 4 months after regrowth and chopped at a theoretically cutting length of 9 mm (MCH2830; IHI STAR Machinery Co. Ltd., Hokkaido, Japan). It was baled using a round bailer (TSB1000; IHI STAR Machinery Co. Ltd.), wrapped (MWM1060 W; IHI STAR Machinery Co. Ltd.), and stored for about 4 months until the animal trial. Oaten hay was chopped at a theoretically cutting length of 50 mm using a chopping machine (KEIYO Machinery Co. Ltd., Chiba, Japan).

2.2. Animals and experimental design

Four non lactating Holstein cows averaging 779 ± 71 kg in body weight (BW) and fitted with ruminal canula were randomly divided into two groups in a cross over design. Two cows were fed the sugarcane silage as HF roughage, and the other two cows were fed the oaten hay as LF roughage. Each experimental period consisted of 14 days, with the first 9 days for feed adaptation and the last 5 days for the energy and nutrient balance measurements. Experimental cows were housed individually in open circuit respiration chambers (Suzuki et al., 2012) throughout the experiments, whereas the doors of chambers were kept open during 9 day of adaptation period. The cows were fed roughage at 1.1 times of the previous day's intake, and were also fed soybean meal at 0.5 g/kg BW on a dry matter (DM) basis. One third of the daily feed was provided at 11:00 h and the remainder at 18:00 h. Water and mineral salt block (E100TZ; Nippon Zenyaku Kogyo Co. Ltd., Fukushima, Japan) were freely accessed. This experiment was approved by the Animal Care Committee of the NARO Kyushu Okinawa Agricultural Research Center (KARC).

2.3. Sample and data collection

The amount of orts was recorded at 10:30 h. During the balance measurements, orts, urine, and feces were collected and weighed at 10:30 h, and their constant aliquot were combined into one sample at each period. Portions of the feed samples were kept in a refrigerator at 5 °C, and the remaining portions and orts and fecal samples were dried in a 55 °C forced air oven for 72 h and then ground in a mill (1 mm; P-15; FRITSCH, Idar-Oberstein, Germany) for chemical analysis. A filtered extract of sugarcane silage was prepared from a mixture of sugarcane silage (25 g) and distilled water (100 mL) that was stored at 5 °C overnight. The extract was kept at −20 °C until analysis of fermentation quality.

Body weights of experimental cows were measured at 10:30 h on days 9 and 14. Ruminal liquor was collected at 11:00 h of day 14 and was filtered immediately through 8 layers of gauze. The pH of the filtered ruminal liquor was determined immediately using a pH meter (PH82; Yokogawa Electric Co., Tokyo, Japan). The ruminal liquor was centrifuged (1940 × *g*, 15 min, 4 °C) and then kept at −20 °C for further analysis.