Including ramie (*Boehmeria nivea* L. Gaud) in the diet of dairy cows: effects on production performance, milk composition, rumen fermentation, and nutrient digestion

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**ABSTRACT**

This experiment was conducted to examine the effects of substituting mixed silage (fresh ramie: dry rice straw = 80: 20; kg: kg) composed of fresh forage ramie, also known as ‘China grass’, *Boehmeria nivea* L. Gaud (a nettle native to Asia) and rice straw for corn silage and alfalfa hay on the production performance, milk components, rumen fermentation parameters, and nutrient digestion in dairy cows. Thirty multiparous Chinese Holstein cows (629 ± 59.2 kg of BW, 25 ± 4.7 kg of milk yield, and 100 ± 18 DIM; mean ± SD) were randomly divided into three groups. The experimental treatments containing three diets, each consisting of differing proportions of mixed silage (0%, 10%, and 20%, designated as CON, MS1, and MS2, respectively) as a substitution for corn silage and alfalfa hay. There were no effects of mixed silage diets on dry matter intake (DMI), 3.5% fat-corrected milk (FCM) yield, milk protein percentage, milk somatic cell count, and milk urea nitrogen (MUN), but linearly increased total solids (\(p = .03\)) and milk fat percentage (\(p = .001\)) in cows fed the MS1 and MS2 diets. Feeding mixed silage diets linearly reduced milk yield (\(p = .01\)) and milk lactose percentage (\(p = .01\)), and had linearly increased rumen pH values (\(p = .01\)). There were no observable differences in other rumen fermentation parameters between the mixed silage and control diets. Mixed silage diets exhibited increased DM digestibility (linearly, \(p = .04\); quadratically, \(p = .017\)) and linearly decreased crude protein digestibility (\(p = .05\)), but we observed no differences in the apparent total-tract digestibility of EE, NDF, and ADF between the control and mixed silage diets. In conclusion, using ramie and rice straw mixed silage proved beneficial by increasing milk fat percentage, milk solids, and DM digestibility, ramie could be used as a potential forage resource in dairy cow diets.

**HIGHLIGHTS**

- We tested the effects of substituting alfalfa hay and corn silage with mixed silage composed of fresh forage ramie and rice straw on dairy cows
- Mixed silage diets had no effect on dry matter intake (DMI)
- Mixed silage diets reduced milk yield and milk lactose percentage

**Introduction**

Ramie (*Boehmeria nivea* L. Gaud) is mainly grown as a fibre crop around the world, but can also be used as a suitable feed for domestic livestock (Dai et al. 2019). Ramie not only has a high biomass, but also has high content of main nutrients, as crude protein, carbohydrates and minerals which is an unconventional quality in forage (Liu et al. 2012; Wu et al. 2017). Kipriotis et al. (2015) reported the nutritional value of ramie as: 22% crude protein, 1.02% lysine, and 4.07% calcium on a dry matter basis, making it nutritionally similar with alfalfa. De Toledo et al. (2008) found that ramie was a suitable replacement for alfalfa, and suggested that ramie may improve growth performance of growing rabbits. Similarly, Tang et al. (2019) reported that ramie had no negative effects on the performance of black goats when replaced for alfalfa hay.

Rice is the major crop cultivated in southern China, with billions of tons of rice coproducts produced each year, especially straw. However, a large majority of this...
straw is left unused or burned after harvest due to its low economic value, leading to serious environmental problems (Li et al. 2017). High temperatures and humidity are not suitable for alfalfa growing and some other forage drying, which poses a major issue with its use as an agricultural feed in southern China. The mixed silage of fresh ramie and rice straw can not only adjust the water content of silage, but also improve the utilisation rate of straw. In addition, our preliminary experiment showed that the quality of silage was better when fresh ramie and rice straw were mixed in a proportion of 80: 20 (kg: kg) (Chen et al. 2019). We hypothesised that mixed silage of fresh ramie in combination with rice straw will be used as a partial substitute for corn silage and alfalfa hay in the diet of dairy cows, and has no the negative impacts on production performance, rumen fermentation, and nutrient digestion of dairy cows. Therefore, the objective of the current study was to evaluate if there were any negative or positive effects on production and components of milk, rumen fermentation and nutrient digestion when replacing corn silage and alfalfa hay with a mixture of fresh ramie and rice straw in mixed silage.

Materials and methods

All experimental procedures and animal protocol were approved by the Animal Care and Use Committee, Institute of Bast Fibre Crops, Chinese Academy of Agricultural Sciences, Changsha, China.

Preparation of silage

Fresh ramie (Zhongsizhu 1\textsuperscript{a}) with a height of 1.5 m was machine-harvested and smashed (to around 2–3 cm in length) using a straw cutter (RC500 Chaffcutter, Qufu Ruicheng Agricultural Machinery Co., LTD, Shandong, China). The ramie was then mixed with dry rice straw (about 2–3 cm in length and air dried) at a ratio of 80:20 (fresh ramie: dry rice straw; kg: kg) according to the results (crude protein: 7.96%, ether extract: 2.27%, neutral detergent fibre: 49.89%, acid detergent fibre: 36.12%, and gross energy: 16.12 MJ/kg; DM basis) of our previous silage tests (Chen et al. 2019), packed by an automatic silage wrapping machine (model TSW2020C, Shanghai Shidaer Modern Agricultural Machinery Co., LTD), and stored for 60 days, until it was used to formulate the total mixed ration (TMR) used in this experiment.

Animal and experimental design

Thirty multiparous Chinese Holstein dairy cows (third parity, 629 ± 59.2 kg of BW, 25 ± 4.7 kg of milk yield, and 100 ± 18 DIM; mean ± SD) were randomly divided into three treatment groups with ten cows per group. The cows were fed a TMR formulated according to the guidelines of NRC (2001). The treatments were as follows: (1) control diet (no mixed silage; CON); (2) diet in which 10% of total alfalfa and corn silage was replaced by mixed silage (MS1 diet) and (3) diet in which 20% of total alfalfa and corn silage was replaced by mixed silage (MS2 diet). Dietary ingredients and nutrient compositions of each treatment are shown in Table 1. The cows were kept in a tethered stall with neck straps and individual troughs with free access to diets. Diets were offered ad libitum twice daily (at 05:30–06:00 and 17:30–18:00) to ensure at least 5% refusal. Cows had free access to the clean water throughout the whole study. The experimental period lasted 70 d with 10 d of acclimation prior to its start.

Sampling and measurements

Milk yield was recorded through the experimental period. On day 68, 69, and 70, milk samples were collected twice daily (0600 h and 1630 h) from each cow during each milking, and then mixed and composited.
proporionally based on the yield at each milking. All samples were immediately cooled after collecting, and then within 48 h were transported to the laboratory, where they were analysed to determine the milk protein percentage, milk lactose percentage, milk fat percentage, milk somatic cell count, milk urea nitrogen (MUN), and total dry matter (DM) of each sample using an automated analyser (Foss Mikkro-FT120, FOSS instruments Co., Ltd., Denmark). The yields of 3.5% FCM were calculated according to the following NRC (2001) equations:

\[ FCM = 0.432 \times \text{milk yield} + 16.23 \times \text{fat yield} \]

Amounts of diet offered and refused were weighed and recorded daily during the experiment to measure the dry matter intake (DMI) for each animal. Samples of TMR and refusal were collected daily throughout the dry matter intake (DMI) for each animal. Samples were subsequently placed on dry ice immediately and stored at \(-20{\degree}C\). Faecal samples were collected directly from the rectum for 3 consecutive days (last 3 days of the experimental period) every 8 h, and approximately 500 g was immediately frozen at \(-20{\degree}C\). Then, the samples from the same cow were mixed to estimate daily nutrient excretion. All samples were dried in a forced-air oven (Model DHG-9005, Shanghai Yiheng Scientific Instruments Co. LTD, Shanghai, China) at 65°C for 72 h, ground in a mill (Model FW-400A, Beijing Zhongxing Weiye Scientific Instruments Co. LTD, Beijing, China), and put into plastic pockets while awaiting analysis. All samples were analysed for dry matter (DM) by drying in a forced-air oven at 105°C for 2 h (Method 930.15), crude protein (CP) (Method 990.03), ether extract (EE) (Method 920.39), acid detergent fibre (ADF) (Method 973.18), neutral detergent fibre (NDF) (Method 2002.04) according to AOAC (2007). The indigestible ADF (iADF) was used as an internal marker to evaluate total-tract digestibility of DM, CP, EE, NDF, and ADF, calculated using the equations of Silva et al. (2018).

Rumen fluid was collected using a sampler that was inserted via the mouth into the rumen before morning feeding. An approximately 50 mL sample of the rumen contents was obtained for each animal. The pH of the rumen fluid was measured immediately after sampling using a pH metre (Model S210 Seven Compact™ pH; Mettler-Toledo Instruments Ltd., Shanghai, China). The samples were subsequently placed on dry ice immediately and stored at \(-20{\degree}C\). Samples used in volatile fatty acid (VFA) and ammonia N (NH₃-N) assays were analysed using gas chromatography (GC7890A, Agilent, USA) and a spectrophotometer (UV-2600, Shimadzu Instrument Co., LTD, Suzhou, China), respectively, according to Wu et al. (2013).

Statistical analysis

Feed intake and milk yield of each cow during the whole experimental period (except adaptation period) were averaged and statistically analysed. Statistical data analysis was performed using the MIXED procedure of SAS (Version 9.2) based on completely randomised design. The statistical model was listed as the following:

\[ \gamma = \mu + \alpha + \beta + \delta \]

where \(\gamma\) is the observed value, \(\mu\) is the overall mean, \(\alpha\) is the effect of mixed silage level, \(\beta\) is the random effect of dairy cows, and \(\delta\) is the random error. The orthogonal polynomial contrasts were conducted to analyse the linear and quadratic effects of the level of mixed silage. Least square means were expressed in tables, and significance was declared when \(p\) values \(\leq .05\) and trends at \(.10 > p > .05\).

Results and discussion

The mixed silage diets had no effect on DMI, 3.5% FCM yield, milk protein percentage, MUN, and milk somatic cell count \((p > .05)\). Cows fed the mixed silage diets had linearly reduced milk yields \((p = .01)\) and milk lactose percentages \((p = .01)\) relative to the control group, while under both diets total solids \((p = .03)\) and milk fat percentage linearly increased relative to the control group \((linear, p < .01; \quad quadratic, p = .08)\) (increases in milk fat percentage relative to the control group: MS1 61.24% and MS2 61.24%) (Table 2).

The mixed silage treatment did not affect ruminal NH₃-N or VFA, nor the molar proportions of acetate and propionate in the VFA \((p > .05)\) (Table 3). Mixed silage increased the ratio of acetate: propionate \((p > .05)\). The mixed silage diet (MS2) caused significantly linear increases in the rumen fluid pH relative to the control group \((p = .01)\).

Dairy cows fed the mixed silage diets exhibited significantly increased DM digestibility \((MS1: 13.16\% \quad and \quad MS2: 8.55\%)\) \((linear, p = .04; \quad quadratic, p = .02)\) relative to the control group (Table 4). Mixed silage diets did not affect the apparent total-tract digestibility of EE, NDF, and ADF \((p > .05)\), while CP digestibility linearly \((p = .05)\) was lower in cows fed the MS1 and MS2 diets relative to cows in the control group.

Roughage is a very important component of dairy cow feed, affecting both performance and milk quality as well as other economically important animal traits. Numerous studies have reported that ramie is rich in protein, especially in the leaves, and have compared
its nutritive value with that of alfalfa (ContÔ et al. 2011; Peng et al. 2016). Dai et al. (2019) reported that substituting fresh ramie for alfalfa in the diets of dairy cows had no significant effects on milk yield, milk fat percentage, and milk lactose percentage, but reduced DMI. Similarly, Gabbi et al. (2004) evaluated the effects of increasing proportions of dietary ramie hay on feed intake in rabbits, and found that as the proportion of ramie hay in the diet increased, feed intake decreased. The findings of these two studies are not consistent with our results. There are some potential reasons for this, including differences in the type of ramie used (hay, fresh ramie, or mixed silage) and differences between study species. It is generally known, dietary fibre sources and NDF content have effects on milk fat percentage. Studies showed that as dietary NDF increased, fat percentage increased, but milk yield decreased (Beauchemin et al. 1994). Rojo et al. (2015) found that greater concentration of acetic acid in the ruminal fluid of dairy goats is the main reason for greater milk fat content. The content of NDF in experimental diets was similar. So, in current study, the forage source had effects on milk fat percentage, but not 3.5% FCM. Similarly, Kahyani et al. (2019) found that fed dairy cows with diets of similar proportions of diet fibre had no effects on 3.5% FCM.

Ki et al. (2009) reported that the pH value of whole corn silage was lower than that of whole rice silage, a difference likely due to the higher soluble carbohydrate content of maize relative to rice. In this study, rumen NH$_3$-N concentration was not affected by mixed silage diets, suggesting that dietary protein degradability between cows fed alfalfa- and ramie-based diets. Tang et al. (2019) found that the concentration of TVFA and the VFA profile of black goats were unaffected by the replacement of alfalfa by ramie, and also noted increases in the ratio of acetate: propionate in the rumen fluid, findings consistent with those reported here.

Li et al. (2018), in their study of growing pigs, found that ramie-based diets (containing 15% or 30% ramie) had no effect on NDF or ADF digestibility, significantly decreased digestibility of CP and DM, but significantly increased digestibility of EE relative to a control. In addition, Tang et al. (2019) reported no differences in DM digestibility, and significantly lower digestibility of CP, NDF, and ADF in their study of black goats. The above results are not completely consistent with those reported here, potentially due to
variation in the type and amount of ramie added to the diets and differences between study species.

Conclusions

The inclusion of the ramie and rice straw mixed silage in dairy cow diets could improve the quality of the milk by increasing milk fat percentage and milk solids. And mixed silage had a beneficial effect of ruminal pH and DM digestibility, with no with noticeable variation in rumen fermentation and total-tract digestibility of nutrients. Therefore, ramie and rice straw mixed silage not only could be used as a source of forage in dairy cow diets, but also improve the utilisation of rice straw.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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Disclosures

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