Comparison of Rumen Degradation Characteristics of Lavender Straw and Lavender Straw Silage: Postprint

Authors: Wei Chen, You Wei, Tan Xiuwen, Jin Qing, Zhang Xianglun, Liu Guifen, Zhao Hongbo, Zhang Chen, Wan Fachun

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Abstract

This experiment was conducted to investigate the rumen degradation characteristics of lavender straw and lavender straw silage, and to compare the differences in their rumen degradation patterns. Four 1.5-year-old Liru bulls (Limousin × Luxi Yellow cattle) with an average body weight of (415$±$20) kg, fitted with permanent rumen fistulas, were used to evaluate the rumen degradation rates and parameters of dry matter (DM), organic matter (OM), crude protein (CP), and neutral detergent fiber (NDF) in lavender straw and lavender straw silage using the nylon bag technique. The results showed that silage treatment significantly reduced the OM content of lavender straw ($P<0.05$), significantly increased the ether extract (EE) content ($P<0.05$), and tended to increase the CP content ($P=0.07$) and decrease the NDF content ($P=0.08$), while having no significant effect on acid detergent fiber (ADF) content ($P>0.05$). Silage treatment significantly increased the 72 h rumen degradation rates of DM, OM, and NDF in lavender straw ($P<0.05$), but had no significant effect on the 72 h rumen degradation rate of CP ($P>0.05$). The effective degradation rates of DM, OM, CP, and NDF in lavender straw silage were all significantly higher than those in lavender straw ($P<0.05$). Silage treatment had no significant effect on the proportion of the rapidly degradable fraction (a) of DM and OM in lavender straw ($P>0.05$), but significantly increased the proportions of the slowly degradable fraction (b) and potentially degradable fraction (a+b) of DM and OM ($P<0.05$), and tended to increase the degradation rate (c) of the slowly degradable fraction of DM ($P=0.06$). There were no significant differences in the proportions of rapidly degradable fraction, slowly degradable fraction, and potentially degradable fraction of CP between lavender straw and lavender straw silage ($P>0.05$), while the degradation rate of the slowly degradable fraction of CP in lavender straw silage tended to increase ($P=0.06$). Silage treatment

significantly increased the proportion of rapidly degradable fraction, the proportion of potentially degradable fraction, and the degradation rate of the slowly degradable fraction of NDF in lavender straw (P<0.05), and tended to increase the proportion of slowly degradable fraction of NDF (P=0.08). These results indicate that silage treatment can improve the quality of lavender straw and enhance the utilization efficiency of lavender straw by beef cattle, providing a theoretical reference for the further development and utilization of lavender straw resources.

Full Text

Comparison on Rule of Rumen Degradation between Lavender Straw and Lavender Straw Silage

WEI Chen[1,2,3]*, YOU Wei[1,2,3]*, TAN Xiuwen[1,2,3], JIN Qing[1,2,3], ZHANG Xianglun[1,2,3], LIU Guifen[1,2,3], ZHAO Hongbo[1,2,3], ZHANG Chen[3,4], WAN Fachun[1,2,3,4]**

[1]Institute of Animal Science and Veterinary Medicine, Shandong Academy of Agricultural Sciences, Jinan 250100, China
[2]Shandong Provincial Key Laboratory of Animal Disease Control and Breeding, Jinan 250100, China
[3]Shandong Provincial Test Center for Beef Cattle Productivity, Jinan 250100, China
[4]College of Life Sciences, Shandong Normal University, Jinan 250014, China

Abstract: This study investigated the rumen degradation characteristics of lavender straw and lavender straw silage, comparing differences in their rumen degradation patterns. Four 1.5-year-old Lilu bulls (Limousin × Luxi Yellow Cattle) fitted with permanent rumen fistulas and averaging (415$±$20) kg body weight were used to evaluate rumen degradability and degradation parameters of dry matter (DM), organic matter (OM), crude protein (CP), and neutral detergent fiber (NDF) using the nylon bag technique. Results showed that ensiling significantly decreased OM content (P<0.05) and significantly increased ether extract (EE) content (P<0.05) of lavender straw, with tendencies to increase CP content (P=0.07) and decrease NDF content (P=0.08), while having no significant effect on acid detergent fiber (ADF) content (P>0.05). Ensiling significantly increased 72-h rumen degradability of DM, OM, and NDF (P<0.05) but did not affect 72-h CP rumen degradability (P>0.05). The effective degradability of DM, OM, CP, and NDF was significantly higher in lavender straw silage than in lavender straw (P<0.05). Ensiling did not affect the rapidly degradable fraction (a) of DM and OM (P>0.05) but significantly increased the slowly degradable fraction (b) and available fraction (a+b) of DM and OM (P<0.05), with a tendency to increase the degradation rate (c) of the slowly degradable fraction of DM (P=0.06). No significant differences were observed between lavender straw and lavender straw silage in the rapidly degradable fraction, slowly degradable fraction, or available fraction of CP (P>0.05), though

the degradation rate of the slowly degradable fraction of CP tended to increase after ensiling (P=0.06). Ensiling significantly increased the rapidly degradable fraction, available fraction, and degradation rate of the slowly degradable fraction of NDF (P<0.05), with a tendency to increase the slowly degradable fraction of NDF (P=0.08). These findings indicate that ensiling can improve the feed quality of lavender straw and enhance its utilization efficiency by beef cattle, providing a theoretical basis for further development and utilization of lavender straw resources.

Keywords: lavender straw; silage; rumen; degradation pattern

Botanically, lavender (*Lavandula* spp.) belongs to the Lamiaceae family and is an annual or perennial herb or shrub [1]. Native to the Mediterranean coast, Europe, and Oceania, lavender was introduced to China from France in 1952 and is now cultivated primarily in Xinjiang, Shaanxi, Jiangsu, and Yunnan [2-3]. With the development of the lavender industry and tourism economy, lavender cultivation area in China has expanded continuously, exceeding 2,000 hectares in the Ili River Valley region of Xinjiang alone [4]. However, large quantities of lavender straw are discarded annually after essential oil extraction, resulting in resource waste. If lavender straw could be utilized as an unconventional feed resource to replace certain conventional feeds, it might alleviate the shortage of high-quality forage resources for ruminants. Silage is an effective method for preserving and improving the quality of roughage. Previous studies have demonstrated that ensiling can enhance the nutritional value and utilization efficiency of corn straw and rice straw in ruminants [5-7]. Li et al. [8] reported that mixed silage of lavender straw with wild hay or wheat straw improved the nutritional quality of lavender straw. Liu et al. [9] found that feeding fattening cattle with mixed silage of lavender straw and wild hay resulted in higher body weight gain compared to corn silage, suggesting its potential as a roughage for fattening cattle. However, limited research has evaluated the feed value of lavender straw and its silage, and the effects of ensiling on lavender straw feed quality require further investigation. Therefore, this study aimed to investigate the rumen degradation characteristics of lavender straw and lavender straw silage using the nylon bag technique, compare differences in their rumen degradation patterns, and provide a theoretical reference for further development and utilization of lavender straw resources.

1.1 Experimental Materials

Lavender straw after essential oil extraction was collected from Yining City in the Ili River Valley of Xinjiang Uygur Autonomous Region, with an initial moisture content of 65.37%. One portion was air-dried without further treatment, while another portion was chopped into 2–3 cm pieces, compacted, and sealed in silage bags for 60 days. The ensiled lavender straw had a pH of approximately 4, a strong characteristic odor, no mold, slight discoloration to light yellow,

well-preserved stem-leaf structure, and moderate fermentation quality.

1.2 Experimental Animals

Four 1.5-year-old Lilu bulls (Limousin × Luxi Yellow Cattle) with an average body weight of (415$±$20) kg and fitted with permanent rumen fistulas were used. The basal diet consisted of 55% corn silage, 15% Chinese wild rye, and 30% concentrate. The composition and nutrient levels of the concentrate are shown in Table 1 . The diet was formulated according to *Nutrient Requirements and Feeding Standards for Beef Cattle* [10]. Animals were fed twice daily at 07:00 and 17:00, with ad libitum access to feed, water, and mineral blocks.

1.3 Experimental Design and Methods

The nylon bag technique was employed in this study. Prior to the experiment, lavender straw and lavender straw silage samples were dried at 65°C and ground. One portion was passed through a 1-mm sieve for routine nutrient analysis, while another portion was passed through a 2-mm sieve, placed in ziplock bags, and stored in a clean, dry location. Nylon bags (8 cm × 12 cm) were made from nylon cloth with 40- m pore size, labeled, soaked and rinsed with tap water, and dried at 65°C to constant weight. Two grams of feed sample (DM basis) were weighed into each nylon bag. Two bags were attached to a plastic tube with rubber bands, with the upper end of the tube tied to a nylon rope fixed to the outer end of the rumen fistula. Two hours after morning feeding, the bags were placed in the ventral sac of the rumen through the fistula. Seven tubes (14 bags) were inserted into each cow' s rumen at one time, following the principle of "simultaneous insertion, sequential removal." Incubation times were 3, 6, 12, 24, 36, 48, and 72 h, with one tube removed at each time point. The loss rate of feed samples from nylon bags was determined by rinsing the bags and samples with running water for 5 min and measuring the weight loss after drying at 65°C to constant weight. Bags removed at each time point were rinsed with running water until the water became clear (generally 5 min). The rinsed bags were oven-dried at 65°C to constant weight (approximately 48 h), and the residues were ground and passed through a 1-mm sieve for determination of DM, OM, CP, and NDF content.

1.4 Chemical Analysis

DM, OM, ether extract (EE), and CP contents of feed samples and residues at different time points were determined according to AOAC (1990) [11]. NDF and acid detergent fiber (ADF) contents of feed samples and NDF content of residues at different time points were determined according to Van Soest et al. [12].

1.5 Data Calculation and Statistical Analysis

Degradation parameters of DM, OM, CP, and NDF were calculated using the exponential model proposed by Ørskov et al. [13]:

$$dp = a + b(1 - e^{-ct})$$

where dp is the degradability of a nutrient after incubation time t in the rumen; a is the rapidly degradable fraction; b is the slowly degradable fraction; and c is the degradation rate of the slowly degradable fraction.

Rumen effective degradability (ED) was calculated using the following equation:

$$ED = a + \frac{bc}{c + k}$$

where k is the rumen outflow rate, set at 0.02 h^{-1} according to Bhargava et al. [14].

Rumen degradable protein (RDP) and rumen undegradable protein (RUP) proportions were calculated according to NRC [15]:

$$RDP = A + B\left[\frac{k_d}{k_d + k}\right] \times 100$$

$$RUP = B\left[\frac{k}{k_d + k}\right] + C \times 100$$

where A is the rapidly degradable fraction of CP in the rumen; B is the potentially degradable fraction of CP in the rumen; k_d is the degradation rate of the potentially degradable fraction of CP; $C = 100 - (A + B)$; and k is the rumen outflow rate, set at 0.02 h^{-1} according to Bhargava et al. [14].

Values for rapidly degradable fraction (a), slowly degradable fraction (b), degradation rate of slowly degradable fraction (c), rapidly degradable fraction of CP (A), potentially degradable fraction of CP (B), and degradation rate of potentially degradable fraction of CP (k_d) were calculated using the Non-Linear procedure in SAS 9.1 [16]. Nutrient degradability at each time point was analyzed using the repeated measures procedure in the Mixed model of SAS 9.1. Degradation parameters and nutrient composition were compared using Bonferroni' s t-test, with significance set at $P<0.05$ and a trend indicated by $0.05 \leq P < 0.10$. Results are presented as means.

2.1 Routine Nutrient Composition

As shown in Table 2 , the OM content of lavender straw silage was 917.4 g/kg DM, significantly lower than that of lavender straw (941.4 g/kg DM) ($P<0.05$). The EE content of lavender straw silage was 53.4 g/kg DM, significantly higher than that of lavender straw (29.1 g/kg DM) ($P<0.05$). Ensiling tended to increase CP content ($P=0.07$) and decrease NDF content ($P=0.08$) of lavender straw but had no significant effect on ADF content ($P>0.05$).

2.2 Nutrient Degradability and Degradation Parameters

As shown in Table 3 , DM rumen degradability at 3, 6, 24, 36, 48, and 72 h was significantly higher in lavender straw silage than in lavender straw ($P<0.05$), with a tendency for increased DM degradability at 12 h ($P=0.07$). Ensiling did not affect the rapidly degradable fraction of DM ($P>0.05$) but significantly increased the slowly degradable fraction, available fraction, and ED of DM ($P<0.05$), with a tendency to increase the degradation rate of the slowly degradable fraction of DM ($P=0.06$).

As shown in Table 4 , OM degradability at all time points was significantly higher in lavender straw silage than in lavender straw ($P<0.05$). No significant differences were observed between lavender straw and lavender straw silage in the rapidly degradable fraction or degradation rate of the slowly degradable fraction of OM ($P>0.05$). However, the slowly degradable fraction and available fraction of OM were significantly higher in lavender straw silage ($P<0.05$), and the ED of OM in lavender straw silage (54.8%) was significantly higher than that in lavender straw (50.4%) ($P<0.05$).

As shown in Table 5 , ensiling significantly increased CP rumen degradability at 3, 12, 24, and 36 h ($P<0.05$) and tended to increase CP degradability at 6 h ($P=0.09$) but had no significant effect at 48 and 72 h ($P>0.05$). No significant differences were observed between lavender straw and lavender straw silage in the rapidly degradable fraction, slowly degradable fraction, or available fraction of CP ($P>0.05$). Ensiling significantly increased the ED of CP ($P<0.05$) and tended to increase the degradation rate of the slowly degradable fraction of CP ($P=0.06$). No significant differences were found in RDP and RUP proportions between lavender straw and lavender straw silage ($P>0.05$).

As shown in Table 6 , NDF rumen degradability at all time points was significantly higher in lavender straw silage than in lavender straw ($P<0.05$). The rapidly degradable fraction and degradation rate of the slowly degradable fraction of NDF were significantly higher in lavender straw silage ($P<0.05$). Ensiling significantly increased the available fraction of NDF ($P<0.05$), tended to increase the slowly degradable fraction of NDF ($P=0.08$), and increased NDF ED from 31.4% to 39.8% ($P<0.05$).

3.1 Routine Nutrient Composition

Plant straw is a low-nutritive-value feed with relatively high NDF and low CP content. In this study, lavender straw contained 565.0 g/kg DM NDF and 95.9 g/kg DM CP, similar to values reported by Li et al. [8] (575.7 g/kg DM NDF and 80.4 g/kg DM CP) but substantially different from those reported by Liu et al. [17] (636.0 g/kg DM NDF and 67.0 g/kg DM CP). The ADF content of lavender straw in this study was higher than that reported by Li et al. [8] (331.3 g/kg DM) but similar to that reported by Liu et al. [17] (400.0 g/kg DM). These discrepancies may be attributed to variations in environmental, soil, temperature, and humidity conditions at the production sites.

Silage is a process in which anaerobic microorganisms (primarily lactic acid bacteria) proliferate and ferment under anaerobic conditions, degrading carbohydrates to produce organic acids such as lactic acid, thereby reducing pH and inhibiting aerobic microbial activity for long-term feed preservation [18]. In this study, ensiling altered the nutrient composition of lavender straw, likely because microorganisms consumed some carbohydrates and produced microbial protein during fermentation, thereby reducing OM and NDF contents and increasing CP content. Compared with lavender straw, the significantly higher EE content in lavender straw silage may be related to the relatively reduced carbohydrate content and microbial synthesis during proliferation, consistent with results reported by Xia et al. [19] and Zhang et al. [20] for corn straw and corn straw silage.

3.2 Nutrient Degradability and Degradation Parameters

The DM degradability of lavender straw at 3 and 72 h was 25.9% and 60.7%, respectively, both higher than values reported by Liu et al. [17], possibly due to differences in nutrient composition of lavender straw itself and different rumen fermentation status in fistulated animals (cattle vs. sheep). Feed nutrients consist of rumen-available and unavailable fractions, with the available fraction comprising rapidly and slowly degradable fractions. Results indicated that ensiling increased DM rumen degradability of lavender straw, primarily by increasing the available and slowly degradable fractions and the degradation rate of the slowly degradable fraction, similar to findings reported by Zhang et al. [21] for rice straw silage. This suggests that ensiling improved the extent of rumen utilization of lavender straw.

In this study, OM rumen degradability of lavender straw was slightly higher than DM rumen degradability, primarily because inorganic matter in DM is not easily degraded. Ensiling increased OM rumen degradability of lavender straw by increasing the available and slowly degradable fractions. Liu et al. [7] reported that ensiling increased OM rumen degradability of rice straw but primarily by increasing the rapidly degradable fraction rather than the slowly degradable fraction, possibly due to differences in the composition and proportions of non-structural carbohydrates, structural carbohydrates, and CP among different

feed materials. The degradation characteristics of CP and NDF in this study revealed that the increased OM ED after ensiling resulted from improved ED of both CP and NDF.

The CP rumen degradability of lavender straw at 3 and 72 h was 25.0% and 80.4%, respectively, both substantially higher than values reported by Liu et al. [17], likely for reasons similar to those causing differences in DM rumen degradability between studies. Ensiling effectively increased CP rumen degradability of lavender straw before 36 h but had minimal effect after 48 h, indicating that ensiling facilitates early fermentation and degradation of CP. Based on CP degradation parameters, ensiling did not alter the available fraction of CP but accelerated fermentation rate in the rumen and increased CP ED. This may be related to structural and compositional changes in CP of lavender straw due to microbial fermentation during ensiling. Xia et al. [19] reported that CP rumen degradability of corn straw silage was significantly higher than that of corn straw during the first 72 h, with increased available fraction, rapidly degradable fraction, and CP ED. Differences between studies may stem from variations in CP structure of lavender straw vs. corn straw and different ensiling conditions.

Feed CP can be divided into RDP and RUP. RDP is degraded by rumen microorganisms into small peptides, free amino acids, and ammonia, some of which are resynthesized into microbial protein, while RUP passes directly through the rumen to the lower digestive tract for utilization [22]. The proportions of RDP and RUP are important for feed nutritional value evaluation and animal requirement determination. This study showed that ensiling had minimal effect on RDP and RUP proportions of lavender straw.

The degradation extent of NDF in the rumen is an important indicator for evaluating feed nutritional value. Ensiling increased NDF rumen degradability at all time points and ED of lavender straw, promoting NDF fermentation in the rumen and improving nutritional value, consistent with results reported by Xia et al. [19] for corn straw. Compared with lavender straw, lavender straw silage showed increased rapidly degradable fraction, slowly degradable fraction, and degradation rate of the slowly degradable fraction of NDF, possibly because ensiling effectively preserves the original nutrients, loosens cellulose structure, reduces lignification during storage, facilitates rumen microbial attachment, promotes rapid NDF degradation, and increases NDF rumen degradability [7,23]. Additionally, Liu et al. [17] reported that lavender straw contains plant phenolic acids such as vanillic acid, protocatechuic acid, ferulic acid, and coumaric acid, which can bind with carbohydrates or nitrogenous compounds in lavender straw and reduce nutrient degradation in the rumen. El-Waziry [24] demonstrated that ensiling effectively reduces phenolic compound content in plants and, using in vitro gas production techniques, proved that ensiling increased NDF disappearance of *Acacia* and *Atriplex* containing plant polyphenols. The improvement in feed value of lavender straw by ensiling in this study may also be related to degradation of plant phenolic acids during the ensiling process.

4 Conclusion

Ensiling treatment can improve the feed quality of lavender straw, increase rumen degradability of DM, OM, and NDF, and enhance CP effective degradability, thereby improving utilization efficiency of lavender straw by beef cattle.

References

[1] Editorial Committee of Flora of China, Chinese Academy of Sciences. *Flora of China* Vol. 65(2) [M]. Beijing: Science Press, 1997.
[2] CHEN Heping, ZHOU Hexin, HE Ruizhen, et al. Research status and countermeasures of lavender in Xinjiang [J]. *Agricultural Reclamation Science*, 2005, 27(5): 371-372.
[3] LIAO Zhenni. Study on introduction and heat-humidity tolerance of lavender in different regions [D]. Master' s thesis. Changsha: Hunan Agricultural University, 2014.
[4] Investigation Report on Lavender Industry Development in Yili Prefecture. Lavender—a characteristic industry of Yili Prefecture [R/OL]. Yili Newspaper. [2013-04-19]. http://cif.mofcom.gov.cn/site/html/yl/html/1106143/2013/4/19/1366348662954.html.
[5] QI Hongwei. Correlation analysis of dry matter degradability between corn straw and its silage [J]. *Jilin Animal Husbandry and Veterinary Medicine*, 2005(12): 13-14.
[6] TAO Lian, DIAO Qiyu. Effects of ensiling fermentation on quality and microbial community composition of corn straw [J]. *Acta Zoonutrimenta Sinica*, 2016, 28(1): 198-207.
[7] LIU Kaiyu, ZHANG Yonggen, XIN Hangshu, et al. Study on nutrient composition and rumen degradation characteristics of rice straw with different treatments [J]. *Chinese Journal of Animal Science*, 2014, 50(7): 57-61, 101.
[8] LI Jing, LIU Jianming, YANG Guangwei, et al. Evaluation of mixed silage effects of lavender straw with wild hay or wheat straw after essential oil extraction [J]. *China Feed*, 2017(12): 13-17.
[9] LIU Jianming, LI Jing, YANG Guangwei, et al. Observation on fattening cattle fed with two types of lavender straw mixed silage [J]. *Feed Review*, 2017(5): 25-28.
[10] FENG Yanglian. *Nutrient Requirements and Feeding Standards for Beef Cattle* [M]. Beijing: China Agricultural University Press, 2000.
[11] AOAC. *Official Methods of Analysis* [S]. 15th ed. Arlington, VA: Association of Official Analytical Chemists, 1990.
[12] VAN SOEST P J, ROBERTSON J B, LEWIS B A. Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition [J]. *Journal of Dairy Science*, 1991, 74(10): 3583-3597.
[13] ØRSKOV E R, MCDONALD I. The estimation of protein degradability in the rumen from incubation measurements weighted according to rate of passage [J]. *The Journal of Agricultural Science*, 1979, 92(2): 499-503.
[14] BHARGAVA P K, ØRSKOV E R. *Manual for the Use of Nylon Bag Technique in the Evaluation of Feedstuffs* [M]. Aberdeen, Scotland: Rowett

Research Institute, 1987.
[15] NRC. *Nutrient Requirements of Beef Cattle* [S]. 8th ed. Washington, D.C.: National Academy Press, 2016.
[16] SAS. *Statistical Analysis System, version 9.1* [Z]. Cary, NC: SAS Institute Inc., 2003.
[17] LIU Hua, YANG Hongjian, WANG Guoqing, et al. Evaluation of rumen degradation characteristics of lavender before and after essential oil extraction using nylon bag method [J]. *China Animal Husbandry and Veterinary Medicine*, 2013, 40(11): 71-74.
[18] KONG Xiangde. Principles and production techniques of straw silage [J]. *Modern Agricultural Science and Technology*, 2012(7): 323-324.
[19] XIA Ke, YAO Qing, LI Fuguo, et al. Rumen degradation patterns of common roughages for dairy cows [J]. *Acta Zoonutrimenta Sinica*, 2012, 24(4): 769-777.
[20] ZHANG Wenju, YAN Xianghua, GONG Yuesheng, et al. Effects of ensiling on nutritional value and rumen effective degradability of corn straw [J]. *China Herbivore Science*, 2003, 23(1): 8-9.
[21] ZHANG Peihua, WANG Jiaqi, HE Jianhua, et al. Effects of ensiling on rumen degradation characteristics of DM and NDF in rice straw [J]. *Pratacultural Science*, 2008, 25(6): 80-84.
[22] ZHAO Guangyong. Research progress on utilizable crude protein and utilizable amino acids in ruminant feeds [C]//Proceedings of the 8th Academic Conference of Animal Physiology and Biochemistry Branch and the 3rd National Symposium on Ruminant Nutrition, Physiology and Biochemistry. Changchun: Chinese Association of Animal Science and Veterinary Medicine, 2004: 213-217.
[23] WANG Han. Study on ensiling and hydrolysis methods of corn straw [D]. Master' s thesis. Tianjin: Tianjin University, 2011: 33-35.
[24] EL-WAZIRY A M. Nutritive value assessment of ensiling or mixing acacia and atriplex using in vitro gas production technique [J]. *Research Journal of Agriculture and Biological Sciences*, 2007, 3(6): 605-614.

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