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**Baumont R. (ed.), Carrère P. (ed.), Jouven M. (ed.), Lombardi G. (ed.), López-Francos A. (ed.), Martin B. (ed.), Peeters A. (ed.), Porqueddu C. (ed.).**
**Forage resources and ecosystem services provided by Mountain and Mediterranean grasslands and rangelands**

**Zaragoza : CIHEAM / INRA / FAO / VetAgro Sup Clermont-Ferrand / Montpellier SupAgro**
**Options Méditerranéennes : Série A. Séminaires Méditerranéens; n. 109**

**2014**
pages 405-409

# Reticuloruminal pH values in dairy cows during the transition period from barn to pasture feeding

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**Abstract.** The effect of the transition from barn to pasture feeding on the pattern of reticuloruminal pH values in 8 multiparous dairy cows was studied with a validated indwelling wireless data transmitting system over a period of 42 days. After 7 days of barn feeding (period 1), all of the animals were pastured with increasing grazing times from 2 to 7 h/d over 7 days (period 2). From day 15 to day 21 (period 3), the cows spent 7 hours/d on pasture. Beginning on day 22, the animals had 20 h/d access to pasture (day and night grazing; 7 day periods 4-6). Despite a mild transition period from barn feeding to pasture, significant effects on reticuloruminal pH values were observed. During the periods of feed transition from barn to pasture feeding, reticuloruminal pH values were lowered significantly. After the beginning of grazing, it took 28-35 days for the reticuloruminal pH value to recover to the level of barn feeding.

**Keywords.** Rumen acidosis – Indwelling pH measurement – Dairy cattle – Feed transition.

***Variations du pH du* reticulo-rumen *au cours de la période de transition alimentaire lors de la mise à l'herbe des vaches laitières***

***Résumé.*** *L'effet de la mise à l'herbe sur les variations du pH dans le* reticulo-rumen *a été étudié sur 8 vaches laitières multipares pendant une période de 42 jours, grâce à un système de mesures du pH à demeure avec transmission sans fil des données. Les 7 jours d'alimentation à l'étable (période 1), ont été suivis de 7 jours d'une mise à l'herbe progressive avec 2 à 7 h/j passées au pâturage (période 2). Du 15ème au 21ème jour (période 3), les vaches ont passé 7 h/j au pâturage. Le 22ème jour, les bêtes avaient accès à l'herbe 20 h/j (pâturage jour et nuit, périodes 4 à 6, de 7 jours chacune). Malgré une mise à l'herbe progressive, des effets significatifs ont été observés sur les valeurs du pH dans le* reticulo-rumen. *Les valeurs de pH étaient significativement plus basses et les écarts à court-terme de la concentration en ions* $H_30^+$ *plus élevés pendant la période de transition alimentaire. Il a fallu 28 à 35 jours à compter du premier jour de la mise à l'herbe pour que le pH du* reticulo-rumen *retrouve le niveau du début de l'expérience à l'étable.*

***Mots-clés.*** *Acidose ruminale – Mesure du pH à demeure – Vache laitière – Transition alimentaire.*

## I – Introduction

Sub-acute rumen acidosis (SARA), is a widespread problem not only in indoor fed dairy cows (Duffield *et al.*, 2004) but also in grazing dairy cattle (Bramley *et al.*, 2008; O'Grady *et al.*, 2008). SARA is difficult to diagnose in the field. The examination of rumen fluid is the most meaningful criterion for evaluating fermentation conditions, and determination of the ruminal pH value is the definitive test for SARA (Krause and Oetzel, 2006). In the present study, a novel indwelling pH sensor was used to continuously monitor reticuloruminal pH during feed transition from barn to pasture feeding.

## II – Materials, animals and methods

The data of the present study were collected at the experimental organic dairy farm of the Agricultural Research and Education Centre Raumberg-Gumpenstein, Trautenfels, Austria (680 m altitude, 7°C average annual temperature, 1,014 mm (±63) precipitation per year; latitude: 47° 31‘ 03“ N; longitude: 14° 04‘ 26“ E). The trial was performed with 4 multiparous lactating Holstein Friesian cows and 4 multiparous lactating Brown Swiss cows (milk yield 26.5 kg/d ± 4.0 kg; parity 3.25 ± 1.4; DIM 110 ± 37; BW 556 kg ± 55.3). The pH measurement and wireless data transmitting units (pH bolus) were given orally to each cow on March 21st 2012, and after one week of barn feeding (period 1), the grazing period began on March 28th. A gradual transition from barn to pasture feeding was arranged. During trial days 8 to 14, the time cows spent on pasture increased constantly from 2 to 7 h/d (period 2). From day 15 to day 21 (period 3), the cows spent 7 hours/d on pasture. Beginning on day 22, the animals had 20 h/d access to the pasture (day and night grazing) and were brought to the barn twice daily for 2 hours each for milking and supplemental feeding. Feeding and milking times during all of the periods were 6:00 - 8:00 a.m. and 4:00 - 6:00 p.m., respectively. To investigate the animals' rumen adaptation during continuous grazing, the time span from day 22 to day 42 was sub-divided into another 3 weekly periods (periods 4-6). Rations fed in the barn were provided by Calan gates, and individual feed intake during barn feeding was measured twice daily (Table 1). Individual milk yield was recorded twice daily and samples for determination of milk composition were analysed three times a week. During the entire study period, all 8 cows received the same dietary treatment. On pasture, cows had free access to a continuously grazed (set stocking) sward, pasture intake was not measured. Sward height during the pasture period was measured weekly using a Filip's Folding Plate Pasture Meter; the mean sward height increased from 3.5 to 5.0 cm during periods 2-6. The botanical composition on the continuous grazed permanent grassland was dominated by *Poa pratensis* (21%), *Lolium perenne* (20%) and *Trifolium repens* (17%). Pooled feed samples were collected weekly for chemical analyses. The concentrate consisted of 30% maize grain, 56% barley, 10% oat and 4% of mineral supplementation. The average nutrient and energy content of the feed is shown in Table 2.

**Table 1. Daily dry matter intake of dietary components from barn feeding to pasture**

| Period | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Hay (kg DM/cow/d) | 4.25 | 3.81 | 3.66 | 2.57 | 1.24 | 1.12 |
| Grass silage (kg DM/cow/d) | 9.83 | 7.67 | 4.57 | 0 | 0 | 0 |
| Concentrate (kg DM/cow/d) | 2.90 | 2.70 | 2.65 | 1.12 | 0.90 | 0.62 |
| Time on pasture (hours/d) | 0 | 2-7 | 7 | 20 | 20 | 20 |

**Table 2. Average nutrient and energy content of feedstuffs**

| | Grass silage | Hay | Concentrate | Pasture |
|---|---|---|---|---|
| DM (g/kg FM) | 437 | 841 | 880 | 173 |
| CP (g/kg DM) | 145 | 113 | 116 | 201 |
| NDF (g/kg DM) | 479 | 521 | 175 | 407 |
| ADF (g/kg DM) | 319 | 306 | 65 | 244 |
| NEL† (MJ/kg DM) | 5.8 | 5.4 | 7.7 | 6.8 |

† Net energy for lactation (GfE, 2001).

For continuous measurement of the reticuloruminal pH value, an indwelling wireless data transmitting system (SmaXtec Animal Care, Austria) was used (Gasteiner *et al.*, 2009). The measurement interval was 600 seconds. Due to its dimensions this indwelling system can orally be administered to an adult cow. The pH values are expressed as daily means (mean pH/d). Means of daily minima and maxima are denoted “min pH/d” and “max pH/d”. The time for which reticuloruminal pH value was below specific thresholds (pH < 6.0-5.8) is given as “min/d < pH”. Using reverse logarithmic calculus, the pH values were re-transformed into primary $H_3O^+$ ion concentrations. The maximum short-term fluctuation of the $H_3O^+$-ion concentrations is given for 2 and 12 hours ($1 \times 10^{-8}$). Experimental data (daily means per animal) were tested for adherence to the normal distribution and for homoscedasticity using analysis of variance via visual testing of the fit diagnostics in SAS 9.2 (SAS Institute, 2002). The statistical analyses were implemented with PROC mixed of SAS 9.2 (SAS, 2002). The model contained breed (HF, BS), period (1-6) and day of period (1-7) as fixed effects (DDFM = Kenward-Roger). The day within the period was included as a repeated measurement for the subject animal. The results of this analysis were displayed as LS-means and residual standard error ($s_e$). P values < 0.05 were considered to be statistically significant. Tests of pairwise differences were performed using the Tukey-Kramer method.

## III – Results and discussion

Milk yield and milk protein content increased at the beginning of the grazing season (P<0.001), whereas milk fat content decreased numerically (Table 3). Despite a mild transition period from barn feeding to pasture, significant effects on reticuloruminal pH values were observed (Table 4). During barn feeding, the mean reticuloruminal pH value for all of the cows was 6.44 ± 0.14, and the pH values decreased significantly (P<0.001) during period 2 and 3 to 6.24 ± 0.17 and 6.21 ± 0.19, respectively. During periods 4, 5 and 6, the reticuloruminal pH values increased again (pH 6.30 ± 0.22; pH 6.33 ± 0.17; pH 6.37 ± 0.16). Even though average min. pH/d were constantly above 5.8 minima of single animals (nadir) were below this threshold and min/d pH<5.8 ranged from 6 (period 1) to 85 min/d (period 3). The lowest pH value (nadir) decreased from pH 6.0 (period 1) to below pH 5.5 (periods 2, 3 and 4) and rose to pH 5.7 and pH 5.8 over periods 5 and 6 (Fig.1). Short-term deviations in the $H_3O^+$ -ion concentration were highest during period 4.

**Table 3. Daily milk yield and milk composition**

| Period | 1 | 2 | 3 | 4 | 5 | 6 | $s_e$ | P-value |
|---|---|---|---|---|---|---|---|---|
| Milk (kg) | $25.2^{b}$ | $25.5^{b}$ | $26.5^{a}$ | $27.0^{a}$ | $26.5^{a}$ | $26.0^{ab}$ | 1.72 | <0.001 |
| Milk protein (%) | $2.78^{c}$ | $2.84^{bc}$ | $3.00^{ab}$ | $3.21^{a}$ | $3.26^{a}$ | $3.26^{a}$ | 0.13 | <0.001 |
| Milk fat (%) | 3.82 | 3.75 | 3.97 | 3.58 | 3.57 | 3.58 | 0.47 | 0.799 |

**Table 4. Reticuloruminal pH values, time (minutes/day) of pH values below specific thresholds and maximum short-term fluctuation of $H_3O^+$-ion concentration ($x10^{-8}$) during 2 and 12 hours per day**

| Period | 1 | 2 | 3 | 4 | 5 | 6 | $s_e$ | P-value |
|---|---|---|---|---|---|---|---|---|
| Mean pH/d | $6.44^{a}$ | $6.24^{cd}$ | $6.21^{d}$ | $6.30^{bc}$ | $6.33^{b}$ | $6.36^{b}$ | 0.11 | <0.001 |
| Min. pH/d | $6.09^{a}$ | $5.89^{cd}$ | $5.84^{d}$ | $5.86^{d}$ | $5.95^{bc}$ | $6.02^{ab}$ | 0.15 | <0.001 |
| Max. pH/d | $6.77^{a}$ | $6.64^{b}$ | $6.64^{b}$ | $6.76^{a}$ | $6.73^{a}$ | $6.74^{a}$ | 0.15 | <0.001 |
| Min/d pH<5.8 | $6^{c}$ | $43^{ab}$ | $85^{a}$ | $38^{ab}$ | $13^{b}$ | $9^{b}$ | 91 | <0.001 |
| Min/d pH<6.0 | $28^{b}$ | $273^{a}$ | $333^{a}$ | $226^{a}$ | $100^{b}$ | $89^{b}$ | 198 | <0.001 |
| Max. fluct. $H_3O^+$-ion 2 h | $65^{b}$ | $91^{ab}$ | $101^{ab}$ | $113^{a}$ | $83^{ab}$ | $66^{b}$ | 67 | 0.003 |
| Max. fluct. $H_3O^+$-ion 12 h | $75^{b}$ | $114^{ab}$ | $132^{a}$ | $140^{a}$ | $100^{ab}$ | $83^{b}$ | 71 | <0.001 |

There have been few studies investigating the ruminal effects of the transition from dry diets to fresh vegetative pastures. Lippke *et al.* (2000) showed that ruminal acetate:propionate (A:P) ratios were variable during the first week that beef steers were placed in a wheat pasture, and they suggested rumen acidosis as a possible cause for poor performance during the early grazing period. In the present study, the mean reticuloruminal pH value significantly decreased in all 8 cows ($P<0.001$) from period 1 to period 3. The mean reticuloruminal pH values steadily increased during periods 4-6, which can be interpreted as an effect of the rumen's microbial adaptation to grazing conditions. Gasteiner *et al.* (2012) demonstrated that the additional feeding of concentrate decreased reticuloruminal pH values in grazing dairy cows significantly and that these cows were at high risk for SARA. In the present study, the amount of additional feed (hay, grass silage and concentrate) was reduced significantly during pasture periods. It can be concluded that the feed transition to grazing may be less harmful for dairy cows when the additional feeding of concentrates is less than 2.5 kg/cow/d. However, in this study, no clinical health problems in any animals were observed.

Information on the daily mean reticuloruminal pH values may not adequately represent the highly variable characteristics of this trait (DeVeth and Kolver, 2001). While the daily mean reticuloruminal pH value could remain relatively high, the daily fluctuations of reticuloruminal pH value might lead to the nadir being < 5.8 for more than 180 minutes, which is often considered to represent SARA. Gozho *et al.* (2005) addressed the issue of the duration of SARA. They defined SARA as a rumen pH threshold of between 5.2 and 5.6 for > 176 min/d. Data from Alzahal *et al*. (2007) suggest that a period of ruminal pH lasting longer than 283 and 473 min/d below 5.6 or 5.8, respectively, indicates SARA. In the present study, the times the reticuloruminal pH value during periods 1-6 was below 5.8 were 6, 43, 85, 38, 13 and 9 min/d, respectively. Based on the SARA definition of Alzahal *et al*. (2007), it can be concluded that pH values were higher in this study and that the animals were not at risk of SARA. According to the definition of Nordlund and Garrett (1994), who recommended a pH of 5.5 as the cut-off point between normal and abnormal, the cows in the present study were at risk of SARA during phases 2, 3 and 4 (Fig. 1).

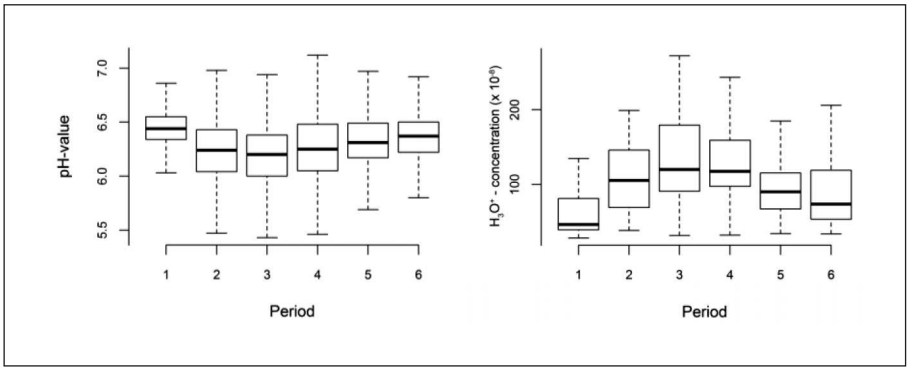


**Fig. 1. Box-whisker plots of the reticuloruminal pH values (left) and short-term fluctuation of $H_3O^+$-Ion concentration (x$10^{-8}$) during 12 hours per day (right).**

## IV – Conclusion

The animals in present trial showed significantly lowered reticuloruminal pH values and higher short-term deviations in the $H_3O^+$-ion-concentration during the periods of feed transition from barn to pasture feeding. After the beginning of grazing, it took 28-35 days for the reticuloruminal pH value to recover to the stage of barn feeding. In literature different definitions for pH-thresholds on SARA can be found. Depending on the applied definition of SARA cows in present study where at a beginning risk on SARA or not. The indwelling pH measurement and data transmitting system is a helpful and proper tool for long-term and continuous measurement of reticuloruminal pH value in grazing cows.

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