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Reticulo-ruminal pH and temperature relationship between dairy cow productivity and milk composition

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Abstract. The aim of the research was to establish interrelations between reticulo-ruminal pH and temperature, cows' productivity and milk composition (milk fat, protein, lactose, somatic cell count and electrical conductivity of milk) by using specific *SmaXtec* reticulo-ruminal boluses. In the research were included four different age dairy cows in early lactation period. The reticulo-ruminal pH and temperature was measured every 600 sec. over a 79 day period. The milk yield and quality was registered three times per day with automated data recording and management system *Afmilk*. Results showed that reticulo-ruminal temperature brightly demonstrates cow drinking behaviour and did not influence any of the investigated milk parameters. There was established a weak, statistically significant correlation between reticulo-ruminal pH and energetically corrected milk ($r = 0.19$; $P < 0.01$), milk protein level ($r = 0.35$) and a weak negative correlation between milk fat/protein ratio ($r = -0.22$; $P < 0.01$). No relation between reticulo-ruminal pH, milk somatic cell count and milk electroconductivity was observed. Reticulo-ruminal pH fluctuations were at individual ranges for each cow without affecting an individual milk fat/protein ratio despite all of them received the same ration. It seems that milk fat/protein ratio is primarily dependent on the feed composition and properties. In the study was included one cow whose reticulo-ruminal pH was decreased below 5.7 for 400 min. in a day, and it had not had any individual effect on milk fat/protein ratio. That fact indicates to an individual cow tolerance to subacute rumen acidosis.

Key words: reticulo-ruminal pH, reticulo-ruminal temperature, milk composition, productivity.

INTRODUCTION

Subacute rumen acidosis (SARA), when rumen pH becomes too low for long time is a widely spread problem for high yielding dairy cows. High amount of easily digestible carbohydrates are included in dairy cow feeding ration to reach maximal productivity. That kind of feeding balances with ruminant physiological possibility to maintain homeostasis in the rumen and health in general (Krause & Oetzel, 2006). Different pathologies could occur if a cow herd suffers from SARA. The most common problems are immunosuppression, diarrhoea, reduced body condition, laminitis, rumenitis, displacement of abomasum and low milk fat content (Krause & Oetzel, 2006; Enemark, 2007; Gasteiner et al., 2012; Aditya et al., 2016). Various attempts have been applied to diagnose SARA in dairy cattle herds because that condition refers not only to cow health and productivity, but also on cow welfare (Krause et al., 2006). The most popular methods are evaluation of cow chewing activity, fat amount in milk, fat/protein ratio, and incidence of laminitis and examination of rumen fluid. The rumen pH is an important parameter to estimate nutritional and metabolic status in dairy cows (Enemark, 2007; Danscher et al., 2015). Abdela (2016) suspects that rumeno-centhesis remains the most profitable tool to detect SARA in herd. Rumen fluid sample can also be acquired with an oral-ruminal probe or through a rumen fistula (Colman et al., 2010). Repeated sampling is necessary because the rumen pH is a fluctuating parameter. These methods can cause distress for the cows (Danscher et al., 2015). In recent years many companies have elaborated intra-ruminal boluses for non-invasive, long term investigation and monitoring reticulo-ruminal pH and temperature to monitor cow intra-ruminal metabolism (Gasteiner et al., 2012; Sato, 2016).

The aim of the research was to establish possible interrelations between reticulo-ruminal pH and temperature, cow productivity and milk composition (milk fat and protein level, somatic cell count and electrical conductivity of milk) by using specific *SmaXtec* reticulo-ruminal boluses.

MATERIALS AND METHODS

In the research were included four different age dairy cows in early lactation period from 10 to 34 days in lactation over a 79 day period (cow A, B, C, D respectively). All the test cows were kept in the same feeding group and were fed with total mixed ration (TMR). TMR was distributed twice a day at 7.00 a.m. and 14.30 p.m., and it was available *ad libitum*. All cows had free access to drinking water. Average cow body weight (~650 kg) and productivity (~30 kg) were taken as a basis to calculate feed ration. Feed composition was varied: grass and maize silage, barley flour, rapeseed cake, beet pulp, molasses, propylene glycol, 'Optigen', live yeast, macro/micro elements and vitamins. TMR was made from the mentioned components. Dairy cow ration contained 45.4% of dry matter. One kilogram of dry matter contained: crude protein − 16.2%; NDF − 36%; crude oils and fats − 3.7 g; 7.04 MJ; Ca − 7.1 g; P − 4.0 g; Mg − 3.0 g; K − 12.2 g; starch − 222 g and 68 g of sugars. Calculated daily ration for cow's 100 kg body weight was intended to 3.6 kg dry matter which corresponds 23.3 kg of dry matter for one cow.

The research was carried out in the spring-summer season. The specific intraruminal boluses were given orally to monitor reticulo-ruminal pH and temperature every 600 sec., or every 10 minutes over a 79 days period. The indwelling and wireless data transmitting system (*SmaXtec Animal Care GmbH, Graz*, Austria) was used. *SmaXtec* intra-ruminal boluses combine electronic, chemical and radio functionalities. The data of reticulo-ruminal pH and temperature were collected by means of an analogue to digital converter and stored in an external memory chip.

During the study cow ration changes occurred several times. Energetically corrected milk was calculated according to the formula prescribed by Agricultural Data Centre:

$$ECM = milk(kg)x\frac{(0.383xMF\%) + (0.242xMP\%) + 0.7832}{3.140} \quad (1)$$

where: ECM − energetically corrected milk, MF − milk fat and MP − milk protein.

Data statistical processing was performed with *SPSS* and *Microsoft Excel* was used for graphic figures. The Arithmetic Mean and the Standard Error were the indicators of descriptive statistics. The Pearson correlation coefficient was used for profiling the interrelations among the results obtained in the study.

The milk yield and quality was registered three times a day at 3:00 a.m., 11:00 a.m. and 17:00 p.m. with an automated data recording and management system *Afmilk*. All test cows were at first part of lactation (Table 1).

Table 1. Dairy cows parameters beginning of the research

Parameters / cows	A	B	C	D
Lactation starting day	10	14	31	34
Reticulo-ruminal pH	**6.03**	6.17	6.31	**6.45**
Reticulo-ruminal T °C	38.8	38.8	38.6	38.9
Milk fat%	3.99	3.93	3.69	3.82
Milk protein%	3.66	3.44	3.48	3.55
Milk lactose%	4.38	4.60	4.67	4.58
Milk fat/protein ratio	1.09	1.14	1.06	1.08
Energetically corrected milk, kg	31.1	36.6	33.2	28.3
Cows weight after calving, kg	560	611	649	710

An average ECM from cow was 28.3–36.6 kg in a day. The highest milk fat content was in cows A and B, but the highest milk protein amount was in cows A and D. Level of lactosis in milk was low in all test cows. Milk fat/protein ratio in milk was too low in all cows at the start of the study. Reticuloruminal temperature at the start of study was 38.6–38.9 °C. At the start of the study the lowest reticulo-ruminal pH was in cow A (6.03), but the highest it was in cow D (6.45). Body weight was different in the test cows (A 560 kg; B 611 kg; C 649 kg; D 710 kg). Cows with higher live weight are able to eat more dry matter compared with smaller cows (Rim et al., 2008).

RESULTS AND DISCUSSION

Results showed different individual range fluctuating of reticulo-ruminal pH for each cow despite the similar feeding. Mean pH reticulo-ruminal values overlapped occasionally between cow A and B, all the time between cow B and C, very often between C and D but rarely between A and D (A 6.0 ± 0.05; B 6.2 ± 0.04; C 6.3 ± 0.06; D 6.5 ± 0.05 respectively), (Fig 1).

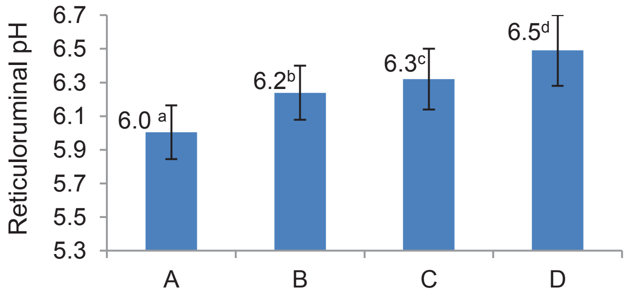


Figure 1. Test cow reticulo-ruminal pH in 79 days period under similar feeding.

Reticulo-ruminal pH was statistically different in all test cows. ($P < 0.05$). Fluctuation of reticulo-ruminal temperature brightly demonstrates cow drinking behaviour and it did not influence any of investigated milk parameters. We found out that cows had drunk 8.5 ± 3.23 times throughout the day. Presence of negative correlation between reticulo-ruminal pH and temperature was found in both healthy and from SARA suffering cows (Sato, 2016). In our study we established weak positive correlation between reticulo-ruminal pH and temperature in cow A (r = 0.15; $P < 0.001$), cow B (r = 0.20; $P < 0.001$), no correlation in cow C and a weak positive correlation in cow D (r = 0.22; $P < 0.001$). Higher ruminal temperature was observed in SARA cows (Wahrmund et al., 2012).

Water drinking was less frequent in night time, but more frequent in day time especially after meals and milking. It is very important not to disturb when the cow wants to drink in a routine round. We were able to evaluate different patterns of drinking and eating behaviour for each cow. Cow A had the lowest reticulo-ruminal pH during the study time (6.00 ± 0.006) and usually she had the most intensive feed intake in night time despite feed being distributed at 7:00 a.m. and 14:30 p.m. each day (Fig. 2).

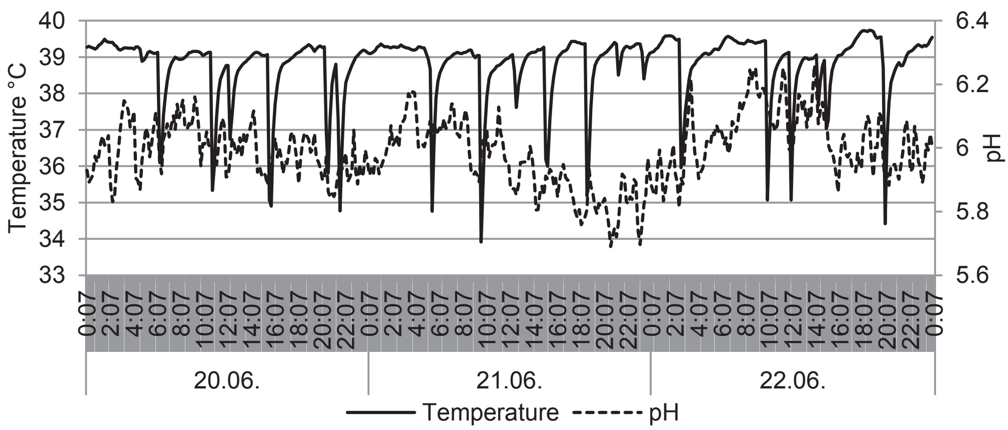


Figure 2. Cow 'A' drinking and eating pattern through three days.

This indicates the importance of feed pushing-up throughout the day to provide ad libitum access to the feed. It especially important if hierarchy problems exist in the herd (Soltysiak & Nagalski, 2010), concerning cow A it clearly seems so and this cow had the lowest body weight in comparison with other test cows. Feed must be offered to cows providing to consume small and frequent meals regularly all the time to avoid SARA (Krause & Oetzel, 2006). Increasing feeding frequency may reduce the risk of SARA and may also increase milk fat (Macmillan et al., 2016).

Cow D had the highest reticulo-ruminal pH during the study time (6.49 ± 0.006) with the most intensive feed intake at 7:00 a.m. when feed was distributed first time in a day. (Fig. 3.)

Cow D had the highest body weight. This cow drank water more frequently than cow A which had the lowest body weight (22 vs. 18 times respectively). These cows had different rumen pH patterns. It depends on eating behaviour throughout the day (Figs 2 & 3).

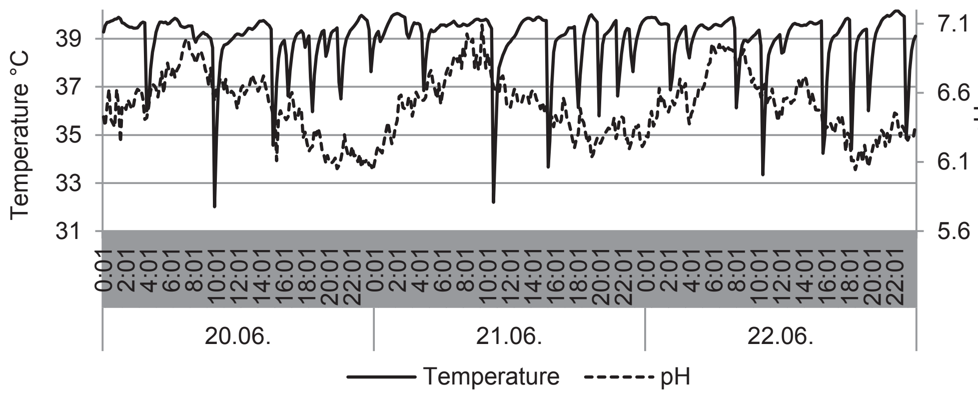


Figure 3. Cow 'D' drinking and eating pattern in a three day period.

All the evaluated parameters between cow A and D were statistically different ($P < 0.05$), except reticulo-ruminal temperature and milk fat content (Table 2). Cow D with the highest body weight had the highest productivity during the study time (average milk in a day 31.5 kg; milk fat 3.18%; milk protein 3.22%). The smallest cow A was a primiparous cow and it had the lowest productivity (average milk in a day 23.0 kg; milk fat 3.07%; milk protein 2.90%) which indicates a low dry matter intake. Both cows were in a lactation phase (45–69 d in lactation) when dry matter intake is important to maintain energy balance.

Table 2. Dairy cows A and D average parameters (20.06.–22.06. 2013)

Parameters / cows	A	D
Days of lactation	45 ± 0.6^a	69 ± 0.6^b
Reticulo-ruminal pH	6.01 ± 0.041^a	6.50 ± 0.015^b
Reticulo-ruminal T °C	38.8 ± 0.09	38.9 ± 0.03
Milk fat%	**3.07 ± 0.050**	3.18 ± 0.026
Milk protein%	**2.90 ± 0.066^a**	3.22 ± 0.055^b
Milk lactose%	4.72 ± 0.038^a	4.48 ± 0.007^b
Milk fat/protein ratio	1.06 ± 0.006^a	0.99 ± 0.021^b
Energetically corrected milk, kg	**23.0 ± 0.33^a**	31.5 ± 0.07^b

^{a,b} – productivity indicators across the tested cows are essentially different; $P < 0.05$.

Milk fat and protein level and fat/protein ratio was not significantly different just between cow B and C, but in cows A and D these parameters were higher ($P < 0.05$). Milk yield was the lowest for cow A (26.1 ± 0.32 kg day^{-1}), which had the lowest reticulo-ruminal pH, it was significantly lower than cow D (29.4 ± 0.34 kg day^{-1}), which had the highest reticulo-ruminal pH. The highest milk yield was in cows B and C, 39.2 ± 0.29 and 31.2 ± 0.31 kg per day, respectively (Table 3). In our study reticulo-ruminal pH and temperature was not an important and statistically significant parameter on the whole productivity for healthy cows.

Table 3. Dairy cows average parameters of the research period

Parameters / cows	A	B	C	D
Average days of lactation	49 ± 2.6[a]	53 ± 2.6[a]	70 ± 2.6[b]	73 ± 2.6[b]
Reticulo-ruminal pH	6.00 ± 0.006[a]	6.24± 0.005[b]	6.32 ± 0.007[c]	6.49 ± 0.006[d]
Reticulo-ruminal T °C	39.0 ± 1.04	39.1 ± 1.34	39.1 ± 1.29	39.0 ± 1.04
Energetically corrected milk, kg	26.1 ± 0.32[a]	39.2 ± 0.29[b]	31.2 ± 0.31[c]	29.4 ± 0.34[d]
Milk fat%	3.39 ± 0.038[a]	3.16 ± 0.027[b]	3.28 ± 0.025[c]	3.44 ± 0.025[a]
Milk protein%	3.11 ± 0.022[a]	3.27 ± 0.023[b]	3.34 ± 0.015[c]	3.30 ± 0.020[abc]
Milk lactose%	4.76 ± 0.016[a]	4.66 ± 0.013[b]	4.82± 0.017[c]	4.79 ± 0.016[ac]
Milk fat/protein ratio	1.09 ± 0.012[a]	0.97 ± 0.010[bc]	0.98 ± 0.008[bc]	1.05 ± 0.010[d]

a,b,c,d – productivity indicators across the tested cows are essentially different; $P < 0.05$.

The results show a weak, statistically significant correlation between reticulo-ruminal pH and energetically corrected milk ($r = 0.19$; $P < 0.01$), milk protein level ($r = 0.35$; $P < 0.01$) and weak negative correlation between milk fat/protein ratio ($r = -0.22$; $P < 0.01$) for all cows together. Statistically significant correlation was not established among reticulo-ruminal pH and any of investigated parameters in cow A except reticulo-ruminal temperature with milk fat ($r = 0.32$; $P < 0.05$) and milk fat/protein ratio ($r = 0.29$; $P < 0.05$). In cow B reticulo-ruminal pH negatively correlated with milk fat ($r = -0.37$; $P < 0.05$), milk fat/protein ratio ($r = -0.35$; $P < 0.05$) and a positive correlation was found with productivity kg ($r = 0.26$; $P < 0.05$). No correlations were found regarding reticulo-ruminal temperature and investigated parameters in cow B. Similar correlations were found in cow C – reticulo-ruminal pH with milk fat ($r = -0.26$; $P < 0.05$), milk fat/protein ratio ($r = -0.29$; $P < 0.05$) and productivity kg ($r = 0.24$; $P < 0.05$). In cow D, which had the highest reticulo-ruminal pH we did not find any correlation among reticulo-ruminal pH and the investigated parameters, but a weak positive correlation was established between reticulo-ruminal temperature and productivity kg ($r = 0.28$; $P < 0.05$), and energetically corrected milk ($r = 0.31$; $P < 0.05$).

Daily milk yield did not drop if reticulo-ruminal pH was lower or even if a cow suffered from SARA (Danscher et al., 2015). No relation between reticulo-ruminal pH, milk somatic cell count, and milk electro conductivity was observed.

Cow A with the lowest reticulo-ruminal pH did not have the lowest milk fat/protein ratio. Milk fat/protein ratio is primarily dependent on the feed composition, properties (Esmaeili et al., 2016) and feeding management (Fig. 3).

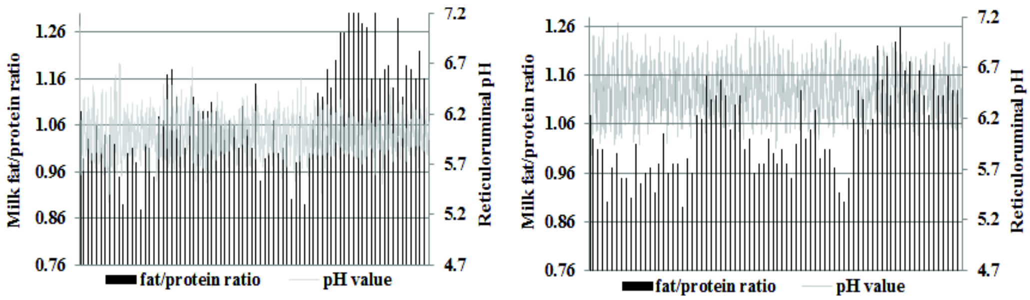
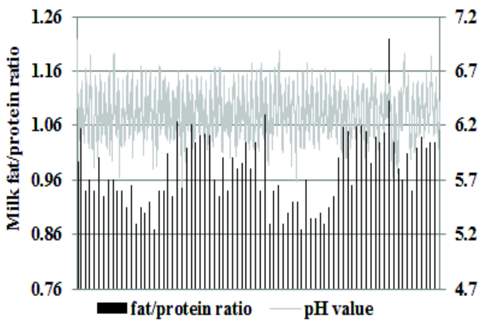


Figure 4. Milk fat/protein ratio in connection with daily reticulo-ruminal pH in cow A and D.

All the investigated cows had a decreased milk fat/protein ratio level most of the test days and it proves that the energy amount in feed is too low (Bergk & Swalve, 2011). It could be one of the evidence parameter of sub-acute rumen acidosis (Rossow, 2003). Milk fat/protein ratio fluctuations from 0.81 up to 1.38 were fixed throughout the study. Appropriate milk fat/protein ratio was fixed just for several days during the study time (Figs 3, 4.).



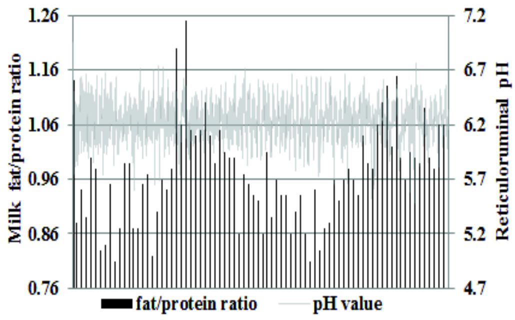


Figure 5. Milk fat/protein ratio in connection with daily reticulo-ruminal pH in cow C and B.

Production traits for 305 days of lactation were established (Table 4). These parameters did not show significant changes regarding milk yield in all cows.

Table 4. Cow productivity through 305 lactation days

Parameters / cows	A	B	C	D
Energetically corrected milk, kg	7,117.7	9,903.2	8,474.4	7,649.0
Milk fat%	4.40	3.61	3.68	3.30
Milk protein%	3.46	3.02	3.30	3.14
Milk fat/protein, kg	531.7	712.7	621.3	551.7

The highest productivity calculated to 100 kg of body weight was in the cow B (1,620.8 kg), then followed cow C (1,305.8 kg), cow A (1,271.0 kg) and cow D (1,077.3). Despite cow A had significantly lower reticulo-rumen pH (6.0) it produced the most amount of ECM calculated on 100 kg of body weight in 305 lactation days. In cow D which had the highest reticulo-rumen pH (6.5) 305 day's ECM production was the lowest. It demonstrates insufficiency regarding to energy in feed appropriate for cow with larger body weight. We did not find any correlation between this calculated productivity and reticulo-ruminal pH and temperature.

Ruminal fermentation changes during SARA are due to a combination of pH and diet effects, so this process could be named as a 'high-concentrate syndrome' (Calsamiglia et al., 2012), because milk fat level and milk fat/protein ratio could not be the main indicators to diagnose SARA in cow herd. No relation between reticulo-ruminal pH, milk somatic cell count and milk electroconductivity was observed.

CONCLUSIONS

Monitoring of the reticulo-ruminal temperature brightly reflects the cows feed and water intake habits. Reticulo-ruminal pH varieties could be in individual ranges for each cow without affecting an individual milk fat/protein ratio despite all of them receiving the same ration. The milk fat/protein ratio and reticulo-ruminal pH did not correlate with milk yield in cows with physiological reticulo-ruminal pH values. It seems that milk fat/protein ratio is primarily dependent on the feed composition and properties, as it was below 0.9 in presence to high and optimal reticulo-ruminal pH. The study included one cow (A) whose reticulo-ruminal pH was decreased below 5.7 for 400 min. in a day, and it did not have any individual effect on milk fat/protein ratio. That fact indicates to an individual cow tolerance to SARA. There weren't found out convincing interrelations between reticulo-ruminal pH and temperature, cow productivity and milk composition to diagnose early consequences of too low reticulo-ruminal pH using *SmaXtec* reticulo-ruminal boluses.

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