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ORIGINAL ARTICLE

Blood gas analyses, ruminal and blood pH, urine and faecal pH in dairy cows during subacute ruminal acidosis

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Abstract The aim of this study was to investigate the variations of some physiological parameters in dairy cows during subacute ruminal acidosis (SARA), a common important disorder of dairy cows that occurs in early lactation. pH changes in ruminal fluid collected by rumenocentesis were measured at ten farms stationed in different zones in the north of Italy. Additionally, the following parameters were measured: blood pH, faecal pH, urine pH, partial pressure of carbon dioxide oxygen, partial pressure of oxygen, bicarbonate level, base excess of extracellular fluid and oxygen content. Herds were divided into two groups according to their average ruminal pH: group A included farms with average ruminal pH>5.8 (normal) and group B farms with average ruminal pH<5.8 (acidosis). Unpaired Student's *t* test was used to reveal statistical significances between the two groups. Ruminal pH changes due to pathogenesis can be diagnostic for SARA.

Keywords Blood pH · Faecal pH · Urine pH · Ruminal pH · Subacute ruminal acidosis · Dairy cows

Abbreviations

SARA	subacute ruminal acidosis
pCO_2	partial pressure of carbon dioxide oxygen
pO_2	partial pressure of oxygen
HCO_3^-	bicarbonate level
Be_{ecf}	base excess of extracellular fluid
O_2ct	oxygen content

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Introduction

Ruminal acidosis is a bovine disease that affects feedlot and dairy cattle. It presents in different forms, from peracute life-threatening forms to chronic illnesses, which are difficult to detect. This article focuses on subacute ruminal acidosis (SARA) in dairy cows. The condition has come under increased scrutiny recently with the understanding of its detrimental effect on dairy production (Ramakrishnan et al. 2003; Oetzel 2004; Bramley et al. 2005). Considerable study has been directed to deliver a uniform definition and a viable diagnostic scheme for SARA, which has been confounded by the large variation in description of non-acute forms of ruminal acidosis (Oetzel 2000; Garrett et al. 1999).

Sub-clinical subacute ruminal acidosis was first mentioned by Dirksen (1965); he described the condition as

chronic latent and claimed that it is more frequent than its acute clinical manifestation. The sub-clinical form should be considered a herd or stock rather than a husbandry issue, in contrast to acute lactic rumen acidosis.

SARA is probably a sequel to non-adaptation of the ruminal environment to the uptake of diets high in concentrate (Kleen et al. 2003).

It has been demonstrated that ruminants will naturally select feeds varying in composition and physical form to compensate for nutritional deficiencies and metabolic disorders (Cooper et al. 1996; Keunen et al. 2003).

Diets rich in fermentable carbohydrates are used to stimulate high production in dairy cows in order to meet the increasing demands for nutrients during early lactation (Cottee et al. 2004). These diets decrease ruminal pH because of increased concentrations of fatty acids and lactic acid (Underwood 1992). Therefore, the diagnosis of SARA in a herd or group may be possible by randomly sub-sampling the herd and measuring ruminal pH. Subacute ruminal acidosis occurs when ruminal pH is between pH 5.2 and 5.8 (Cooper and Klopfenstein 1996). It is characterized by decreased or variable dry matter intake, decreased efficiency of milk production, reduced milk fat test, unexplained diarrhea and poor body condition despite adequate energy intake (Nocek 1997).

In early-lactation dairy cows, SARA is usually associated with the use of diets with high levels of rapidly fermentable carbohydrates and/or marginal (often deficient) levels of physically effective fiber (Oetzel 2003).

In mid-lactation, the development of SARA is linked to husbandry factors such as feeding frequency and processing of feed (Kleen et al. 2003).

Krause and Oetzel (2005) attempted unsuccessfully to induce subacute ruminal acidosis in lactating dairy cows. Other authors have studied the effect of time delay and storage temperature on blood gases of bovine venous blood (Gokce et al. 2004) and day/night pattern of arterial blood gases in the cow (Piccione et al. 2004).

On the basis of previous works, we examined ruminal pH, blood pH, urine pH, faecal pH and blood gas during subacute ruminal acidosis in lactating dairy cows with the aim of identifying any relationships between ruminal pH and physiological parameters of SARA.

Materials and methods

The study was carried out within ten intensive Italian dairy herds, located in different areas in the north of Italy. This arrangement was ratified by the Department of Veterinary Clinical Science of Padua and was planned with breeders to coincide with recording of the execution of rumenocentesis techniques.

The time of sampling was between 4 and 6 h after food ration distribution. In each dairy herd, 12 cows with absence of external clinical signs of disease were randomly selected for rumen fluid collection by rumenocentesis.

A 10×10-cm area in the left flank 20 cm caudal to the last rib and at the level of the top of the keep joint was prepared by disinfection with ethanol and iodine. The cows were restrained by means of a tail grip and a needle was introduced into the rumen. Ruminal fluid was collected by gentle aspiration with a 20-ml syringe and the ruminal pH was immediately determined using a portable pH meter (Nordlund and Garrett 1994). Cows were manually stimulated to urinate and the samples of urine were collected in a 30-ml container. Within 30 min of collection, pH was measured and a 10-ml aliquot was stored at −17°C to await laboratory analysis. Some dairy cows (approximately 20%) did not urinate.

A sample of faeces was captured from the rectum into suitable containers and pH was measured immediately after the collection.

Haemo-gas analysis was carried out by means of a SYNTHESIS 15 supplied by Instrumentation Laboratories.

Average values obtained were used for statistical analysis. The statistical significance values were calculated using Student's *t* test for unpaired data, between group A (farms with ruminal pH>5.8) and group B (farms with ruminal pH<5.8).

Results

The average values of ruminal pH and their standard error of the means are presented in Table 1.

Normal rumen pH condition was detected in six herds (1, 3, 4, 6, 7, 8) and the presence of SARA was detected in four herds (2, 5, 9, 10). On this basis, the farms were divided into two groups. The first group (group A) was composed of farms with ruminal pH>5.8, and the second group (group B) was composed of farms with ruminal

Table 1 Average values of ruminal pH together with standard errors in ten Italian herds

Experimental farms	Ruminal pH
Farm 1	6.01±0.08
Farm 2	5.73±0.07
Farm 3	6.30±0.06
Farm 4	5.80±0.06
Farm 5	5.77±0.04
Farm 6	6.04±0.09
Farm 7	5.85±0.09
Farm 8	5.82±0.07
Farm 9	5.59±0.11
Farm 10	5.73±0.04

Table 2 Average values of some blood gas, blood pH, faecal pH and urine pH, expressed in their conventional units together with standard errors in ten Italian herds

Parameters	Experimental farms									
	Farm 1	Farm 2	Farm 3	Farm 4	Farm 5	Farm 6	Farm 7	Farm 8	Farm 9	Farm 10
pCO_2 (mmHg)	44.07±1.37	46.09±1.00	4.87±0.83	45.5±0.83	50.09±0.97	40.9±1.76	44.6±0.89	45.95±1.13	53.5±0.97	50.69±1.44
pO_2 (mmHg)	39.50±1.37	37.16±0.99	35.91±1.31	38.7±1.14	33.66±1.48	45.5±6.18	38.5±1.49	40.25±0.74	38.9±1.32	36.61±1.16
HCO_3^- (mmol/l)	29.40±1.02	31.47±0.79	29.09±0.94	31.1±0.54	34.85±0.40	28.2±1.19	30.4±0.56	30.75±0.63	32±0.39	31.33±0.80
Be_{ecf} (mmol/l)	5.08±0.91	7.06±0.84	5.43±0.66	6.68±0.59	10.61±0.46	4.61±0.76	5.99±0.61	6.21±0.62	6.69±0.39	6.28±0.87
O_2ct (ml/dl)	12.05±0.46	10.81±0.43	10.03±0.42	10.30±1.10	9.45±0.63	12.21±0.6	11.14±0.50	10.54±0.30	10.15±0.50	10.33±0.43
Blood pH	7.42±0.003	7.43±0.006	7.42±0.004	7.4±0.006	7.44±0.008	7.4±0.009	7.4±0.006	7.43±0.004	7.3±0.005	7.39±0.005
Faeces pH	6.38±0.04	6.21±0.05	6.46±0.05	6.64±0.06	6.73±0.09	6.78±0.06	6.82±0.09	6.82±0.06	6.55±0.07	6.61±0.05
Urine pH	8.12±0.12	8.46±0,06	8.32±0.03	8.38±0.03	8.47±0.05	8.41±0.05	8.12±0.15	8.43±0.04	8.25±0.02	8.22±0.03

pH<5.8. All other parameters were analysed as comparators between the two groups using unpaired *t* test. The average values of the parameters together with standard error of the means are presented in Table 2 and statistically significant differences are shown in Table 3.

There was a statistically significant difference between the two groups with regard to blood pH, faecal pH, partial pressure of carbon dioxide oxygen (pCO_2), partial pressure of oxygen (pO_2), bicarbonate level (HCO_3^-), base excess of extracellular fluid (Be_{ecf}) and oxygen content (O_2ct) associated with subacute ruminal acidosis in lactating dairy cows but no statistically significant differences in urine pH.

Discussion

Results from this study support the previous study by Gunes and Atalan (2005), indicating that, during SARA, blood pH decreases are an indicator of physiological problems. Faecal pH is lower than normal, usually slightly acid (Dirksen 1985); this change is evident from alteration in stool colour, which appears brighter and yellowish. This may be due to post-ruminal fermentation in the intestines because of a massive outflow of fermentable carbohydrates from the rumen (Oetzel 2000). Alternatively, high osmolarity could lead to soft faeces due to binding of fluid in the intestinal lumen (Garry 2002). Many impaired ruminal functions could lead to the alteration of faecal aspects.

In contrast to other authors (Rouche et al. 2005), this study showed no urine pH changes associated with SARA. This is probably explained by the fact that there were no diet modifications between the two groups as urine pH increases linearly and quadratically with increasing dietary cation–anion balance (Tucker et al. 1988).

Statistical differences between the groups were detected for blood gas values studied; in particular, HCO_3^-, Be_{ecf} and O_2ct values increase statistically with SARA. This is in contrast to some other authors who studied animals with additional pathology such as pneumonia where condition

Table 3 Average values of parameters considered together with standard errors and statistical significances in dairy cows between groups A and B

Parameters	Group A	Group B	*P* value
pCO_2 (mmHg)	44.33±0.51	50.11±0.68	0.0001
pO_2 (mmHg)	39.76±1.15	36.60±0.67	0.03
HCO_3^- (mmol/l)	29.81±0.35	32.39±0.38	0.0001
Be_{ecf} (mmol/l)	5.65±0.29	7.66±0.41	0.0001
O_2ct (ml/dl)	11.05±0.25	10.21±0.26	0.02
Blood pH	7.42±0.002	7.41±0.004	0.001
Faeces pH	6.65±0.03	6.50±0.04	0.008
Urine pH	8.30±0.03	8.33±0.02	>0.05

combination may have altered the acidotic response due to differing pathogeneses (Gokce et al. 2004).

In this, pCO_2 was significantly different in the pathological stages of SARA which suggests a relatively acute respiratory acidosis or, more probably, a subacute ruminal acidosis. Contrastingly, pO_2 decreased statistically during SARA and it is possible that the pathology could cause increased vascular O_2 consumption. In this situation, a decrease in pO_2 values may be attributed to an increase in anaerobic metabolism and O_2 consumption (Gokce et al. 2004).

This study has demonstrated that there is a correlation between ruminal pH and many of the physiological parameters associated with SARA. Thus, variations of ruminal pH are useful for the diagnosis of SARA in dairy cows and indicative of the physiological changes that occur as part of the pathogenesis of the condition.

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